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Radioactive Effluents from Nuclear Power Plants

Annual Report 2012

Office of Nuclear Reactor Regulation

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ABSTRACT

There are 104 commercial nuclear power plants (NPPs) licensed to operate on 65 sites in the United States (U.S.) regulated by the Nuclear Regulatory Commission (NRC). Each year, each power reactor sends a report to the NRC that identifies the radioactive liquid and gaseous effluents discharged from the facility. In 2012, these effluent reports comprised about 10,000 pages of information, which described the radioactive materials discharged, as well as the resulting radiation doses to the general public. This report summarizes that information and presents the information in a format intended for both nuclear professionals and the general public.

The reader can use this report to quickly characterize the radioactive discharges from any U.S. NPP in 2012. The radioactive effluents from one reactor can be compared with other reactors. The results can also be compared with typical (or median) effluents for the industry, including short-term trends and long-term trends.

Reference information is included so the reader can compare the doses from NPP effluents with the doses the general public receives from other sources of radiation, such as medical procedures, industrial devices, and natural materials in the environment.

Although all operating NPPs released some radioactive materials in 2012, all effluents discharged were within the NRC's and the Environmental Protection Agency's (EPA's) public dose limits, and NRC "as low as is reasonably achievable" (ALARA) criteria. Additionally, the doses from radioactive effluents were much less than the doses from other sources of natural radiation that are commonly considered safe. This indicates radioactive effluents from NPPs in 2012 had no significant impact on the health and safety of the public or the environment.

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ABBREVIATIONS AND ACRONYMS

ALARA	as low as is reasonably achievable
ARERR	Annual Radioactive Effluent Release Report
Bq	becquerel
BWR	boiling-water reactor
C-14	carbon-14
CFR	Code of Federal Regulations
Ci	curie
DOE	Department of Energy
EPA	Environmental Protection Agency
GBq	gigabecquerels
H-3	tritium
mCi	millicurie
MFAP	mixed fission and activation products
mrem	millirem
mSv	millisievert
NCRP	National Council on Radiation Protection and Measurements
NPP	nuclear power plant
ODCM	Offsite Dose Calculation Manual
PWR	pressurized-water reactor
RG	Regulatory Guide
SI	International System of Units (abbreviation is from the French: *Le Système International d'Unités*)
Sv	sievert
USGS	United States Geological Survey
U.S. NRC	United States Nuclear Regulatory Commission

1 INTRODUCTION

1.1 Purpose

This report describes radioactive effluents from commercial nuclear power plants (NPPs) in the U.S. during calendar year 2012. It is based on an extensive amount of information submitted to the Nuclear Regulatory Commission (NRC) by all U.S. NPP licensees. The original information was submitted by the NPPs in their Annual Radioactive Effluent Release Reports (ARERRs) and comprises several thousand pages of data. The ARERRs may be viewed in their entirety on the NRC Web site at: http://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html.

For the years between 1972 and 1993, this type of annual information was condensed into a tabular format and published as a large volume of tabulated data (Refs. [1–22]). An evaluation of the practice of generating tabular annual reports revealed the need for a more concise summary report that presented the information in a more intuitive, graphic format (Ref. [23]). As a result, this style of improved reports was created. This report joins a series of previous reports on radioactive effluents presented in the revised graphic format (Refs. [24–28]).

The purpose of this report is to condense an extremely large volume of technical information into a few tables and figures from which the reader can quickly, if broadly, characterize the effluents from any operating U.S. NPP. These tables and figures are designed to provide easily understandable information for the public at large, while also providing experienced professionals with enough information to evaluate trends in industry performance and to identify potential performance issues for individual power plants. Those users wanting more extensive and detailed information are encouraged to retrieve the original ARERRs from the NRC Web site.

1.2 Scope

This report summarizes data from all NPPs in commercial operation between January 1, 2012 and December 31, 2012. The list of NPPs included in this report is provided in Table 1.1. The NPP type—boiling-water reactor (BWR) or pressurized-water reactor (PWR)—is indicated in the table. The table also includes a list of shutdown reactors no longer in commercial operation that are either in decommissioning or have been decommissioned.

Some of the shutdown reactors have been totally dismantled during the decommissioning process. As a result, for some shutdown reactors, no visible structures or facilities are present at the locations listed in Table 1.1.

Table 1.1 Nuclear Power Plants, 2012

Plant Name	Type	Full Plant Name	Location
Arkansas 1, 2	PWR	Arkansas Nuclear One (ANO), Units 1, 2	Russellville, AR
Beaver Valley 1, 2	PWR	Beaver Valley, Units 1, 2	Shippingport, PA
Braidwood 1, 2	PWR	Braidwood Generating Station, Units 1, 2	Braceville, IL
Browns Ferry 1, 2, 3	BWR	Browns Ferry Nuclear Plant, Units 1, 2, 3	Decatur, AL
Brunswick 1, 2	BWR	Brunswick Steam Electric Plant, Units 1, 2	Southport, NC
Byron 1, 2	PWR	Byron Generating Station, Units 1, 2	Byron, IL
Callaway	PWR	Callaway Plant, Unit 1	Callaway, MO
Calvert Cliffs 1, 2	PWR	Calvert Cliffs Nuclear Power Plant, Units 1, 2	Lusby, MD
Catawba 1, 2	PWR	Catawba Nuclear Station, Units 1, 2	York, SC
Clinton	BWR	Clinton Power Station	Clinton, IL
Columbia	BWR	Columbia Station	Richland, WA
Comanche Peak 1, 2	PWR	Comanche Peak Steam Electric Station, Units 1, 2	Glen Rose, TX
Cook 1, 2	PWR	Donald C. Cook Nuclear Plant, Units 1, 2	Bridgman, MI
Cooper	BWR	Cooper Nuclear Station	Brownville, NE
Crystal River 3	PWR	Crystal River, Unit 3	Crystal River, FL
Davis-Besse	PWR	Davis-Besse Nuclear Power Station, Unit 1	Oak Harbor, OH
Diablo Canyon 1, 2	PWR	Diablo Canyon, Units 1, 2	Avila Beach, CA
Dresden 2, 3	BWR	Dresden Generating Station, Units 2, 3	Morris, IL
Duane Arnold	BWR	Duane Arnold Energy Center	Palo, IA
Farley 1, 2	PWR	Joseph M. Farley Nuclear Plant, Units 1, 2	Ashford, AL
Fermi 2	BWR	Fermi 2 Nuclear Power Plant	Newport, MI
FitzPatrick	BWR	James A. FitzPatrick Nuclear Power Plant	Lycoming, NY
Ft. Calhoun	PWR	Ft. Calhoun Station, Unit 1	Ft. Calhoun, NE
Ginna	PWR	R.E. Ginna Nuclear Power Plant, Unit 1	Ontario, NY
Grand Gulf	BWR	Grand Gulf Nuclear Station, Unit 1	Port Gibson, MS
Harris	PWR	Shearon Harris Nuclear Power Plant, Unit 1	New Hill, NC
Hatch 1, 2	BWR	Edwin I. Hatch Nuclear Plant, Units 1, 2	Baxley, GA
Hope Creek	BWR	Hope Creek Generating Station, Unit 1	Hancock’s Bridge, NJ
Indian Point 2, 3	PWR	Indian Point Energy Center, Units 2, 3	Buchanan, NY
Kewaunee	PWR	Kewaunee Power Station	Kewaunee, WI
LaSalle 1, 2	BWR	LaSalle County Generating Station, Units 1, 2	Marseilles, IL
Limerick 1, 2	BWR	Limerick Generating Station, Units 1, 2	Saratoga, PA

Table 1.1 Nuclear Power Plants, 2012 (continued)

Plant Name	Type	Full Plant Name	Location
McGuire 1, 2	PWR	McGuire Nuclear Station, Units 1, 2	Huntersville, NC
Millstone 2, 3	PWR	Millstone Power Station, Units 2, 3	Waterford, CT
Monticello	BWR	Monticello Nuclear Generating Plant	Monticello, MN
Nine Mile Point 1, 2	BWR	Nine Mile Point Nuclear Station, Units 1, 2	Lycoming, NY
North Anna 1, 2	PWR	North Anna Power Station, Units 1, 2	Mineral, VA
Oconee 1, 2, 3	PWR	Oconee Nuclear Station, Units 1, 2, 3	Seneca, SC
Oyster Creek	BWR	Oyster Creek Nuclear Generating Station	Forked River, NJ
Palisades	PWR	Palisades Nuclear Plant	Covert, MI
Palo Verde 1, 2, 3	PWR	Palo Verde Nuclear Generating Station, Units 1, 2, 3	Phoenix, AZ
Peach Bottom 2, 3	BWR	Peach Bottom Atomic Power Station, Units 2, 3	Delta, PA
Perry	BWR	Perry Nuclear Power Plant, Unit 1	Perry, OH
Pilgrim	BWR	Pilgrim Nuclear Power Station, Unit 1	Plymouth, MA
Point Beach 1, 2	PWR	Point Beach Nuclear Plant, Units 1, 2	Two Rivers, WI
Prairie Island 1, 2	PWR	Prairie Island Nuclear Generating Plant, Units 1, 2	Welch, MN
Quad Cities 1, 2	BWR	Quad Cities Generating Station, Units 1, 2	Cordova, IL
River Bend	BWR	River Bend Station, Unit 1	St. Francisville, LA
Robinson 2	PWR	H. B. Robinson Steam Electric Plant, Unit 2	Hartsville, SC
Salem 1, 2	PWR	Salem Nuclear Generating Station, Units 1, 2	Hancock’s Bridge, NJ
San Onofre 2, 3	PWR	San Onofre Nuclear Generating Station, Units 2, 3	San Clemente, CA
Seabrook	PWR	Seabrook Station, Unit 1	Seabrook, NH
Sequoyah 1, 2	PWR	Sequoyah Nuclear Plant, Units 1, 2	Soddy-Daisy, TN
South Texas 1, 2	PWR	South Texas Project Electric Generating Station, Units 1, 2	Wadsworth, TX
St. Lucie 1, 2	PWR	St. Lucie Nuclear Plant, Units 1, 2	Ft. Pierce, FL
Summer	PWR	Virgil C. Summer Nuclear Station, Unit 1	Jenkinsville, SC
Surry 1, 2	PWR	Surry Power Station, Units 1, 2	Surry, VA
Susquehanna 1, 2	BWR	Susquehanna Steam Electric Station, Units 1, 2	Berwick, PA
Three Mile Island 1	PWR	Three Mile Island Generating Station, Unit 1	Harrisburg, PA
Turkey Point 3, 4	PWR	Turkey Point Nuclear Plant, Units 3, 4	Princeton, FL
Vermont Yankee	BWR	Vermont Yankee Nuclear Plant, Unit 1	Vernon, VT
Vogtle 1, 2	PWR	Vogtle Electric Generating Plant, Units 1, 2	Waynesboro, GA

Table 1.1 Nuclear Power Plants, 2012 (continued)

Plant Name	Type	Full Plant Name	Location
Waterford 3	PWR	Waterford Steam Electric Station, Unit 3	Killona, LA
Watts Bar 1	PWR	Watts Bar Nuclear Plant, Unit 1	Spring City, TN
Wolf Creek	PWR	Wolf Creek Generating Station, Unit 1	Burlington, KS
Reactors No Longer In Commercial Operation in 2012			
Big Rock Point	BWR	Big Rock Point Restoration Project	Charlevoix, MI
Dresden 1	BWR	Dresden Generating Station, Unit 1	Morris, IL
Haddam Neck	PWR	Haddam Neck Nuclear Plant Site	Haddam Neck, CT
Humboldt Bay	BWR	Humboldt Bay Power Plant, Unit 3	Eureka, CA
Indian Point 1	PWR	Indian Point Energy Center, Unit 1	Buchanan, NY
La Crosse	BWR	La Crosse Boiling-Water Reactor	Genoa, WI
Maine Yankee	PWR	Maine Yankee	Bath, ME
Millstone 1	PWR	Millstone Power Station, Unit 1	Waterford, CT
Rancho Seco	PWR	Rancho Seco, Unit 1	Herald, CA
San Onofre 1	PWR	San Onofre Nuclear Generating Station, Unit 1	San Clemente, CA
Three Mile Island 2	PWR	Three Mile Island Nuclear Station, Unit 2	Middletown, PA
Trojan	PWR	Trojan Nuclear Plant, Unit 1	Portland, OR
Yankee-Rowe	PWR	Yankee Nuclear Power Station	Franklin Co., MA
Zion 1, 2	PWR	Zion Generating Station, Units 1, 2	Warrenville, IL

The NRC uses the information on radioactive releases, along with other information collected during routine inspections of each facility, to ensure NPPs are operated within regulatory requirements. One of those requirements includes maintaining radiation doses from radioactive effluents “as low as is reasonably achievable” (ALARA). For this summary report, only information submitted with regard to NRC reporting requirements and guidance is included. Information not related to the NRC requirements for radioactive effluents or the NRC guidance on radioactive effluents is not included in this summary report. Additionally, information on solid radioactive waste is not included in this report.

Some reactors are no longer operating. For the 2012 data shown in the tables and figures of this report, those reactors are treated as follows. The Big Rock Point, Haddam Neck, Humboldt Bay, La Crosse, Maine Yankee, Rancho Seco, Trojan, Yankee-Rowe, Zion Unit 1, and Zion Unit 2 reactor sites are shut down and are not collocated with an operating reactor. The data from these shutdown reactors are not included in this report. The Millstone Unit 1 and Three Mile Island Unit 2 reactors are shut down and are collocated with one or more operating reactors. For these shutdown reactors, the licensee reports data for the shutdown unit separately from the operating units, and the results from these shutdown reactors are not included in this report on operating reactors. For the Dresden Unit 1, Indian Point Unit 1, and San Onofre Unit 1 reactors, which are shut down and collocated beside two operating units, the licensee reports the sum of the effluents from the shutdown unit with one or both of the operating units. For these shutdown reactors, the effluent data are included with (and attributed to) one or more of the operating units in this report.

Crystal River Unit 3 ceased power generation in 2010, but will be included in the count of operating reactors until the licensee notifies the NRC of their intent to permanently cease operations. The historical data from all reactors, including the reactors that are no longer operating, are included in Figures 3.15 and 3.16, which depict the long-term trend of radioactive effluents.

1.3 Source of Data

Each commercial nuclear power plant in the United States is authorized by the NRC to release small amounts of radioactive materials to the environment as specified in the licensing documents for the plant. NRC regulations require each NPP to establish and maintain a program for monitoring radioactive effluents (per Title 10 of the *Code of Federal Regulations* [CFR] Part 50.36a and 10 CFR Part 50, Appendix I, Section IV.B) and to report these effluents in an Annual Radioactive Effluent Release Report (ARERR) (per 10 CFR 50.36a) (Ref. [29]). In accordance with the regulatory framework, licensees submit their reports to the NRC in a format outlined by Regulatory Guide (RG) 1.21 (Ref. [30]), or an equivalent format.

The information included in this document was obtained from the licensees' ARERRs. Individual licensee reports are available through the NRC Public Document Room, One White Flint North, 11555 Rockville Pike (first floor), Rockville, Maryland 20852, phone 1-800-397-4209 or 301-415-4737, and directly from the NRC's public Web site at: http://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html.

The data from these reports are also entered into a database that is maintained by the NRC. The public may access this database through an NRC Web site (http://www.reirs.com/effluent/). The data are entered into the database as reported by each site.

1.4 Limitations of Data

Some NPPs have more than one reactor unit located at a site. If the licensee reports data separately for each reactor unit, those data are included as reported by the licensee. Because some licensees operate multi-unit sites with a common radioactive waste processing system, these licensees report total effluents from the site instead of reporting the totals from each reactor unit. This complicates the task of presenting the effluent information in a manner that allows both (1) a direct comparison of one reactor unit with another, and (2) a direct comparison of each reactor unit with NRC limits and regulations.

For purposes of this report, the data are reported on a per-unit basis. For multi-unit sites where the effluents are from a common radioactive waste system, the effluents are divided equally between the units. For example, Catawba has two units (1 and 2) with a common radioactive waste processing system. For this report, the total effluents for Catawba were split equally between Unit 1 and Unit 2. For other multi-unit sites, the effluent activity is not divided equally between the units. For example, in the case of Beaver Valley, the licensee reports gaseous effluents from four sources: Unit 1, Unit 2, a common plant vent, and a common building vent. In this case, the releases from the common vents are split equally between Unit 1 and Unit 2, and the totals for each unit then are calculated. This method of splitting the data has been applied to radionuclide activity data and radiation dose data at some multi-unit sites. The affected NPPs and the type of data affected are listed in Table 1.2.

Although there are other methods of reporting effluent data (e.g., on the basis of thermal or electrical power generation), the per reactor-unit basis (1) is most intuitive, (2) is most directly comparable with the NRC required design objectives and limiting conditions for operation (i.e., referred to as ALARA criteria in this report), and (3) is easily derived from the effluent data supplied by the licensee. This approach satisfies a primary objective for this report which is to allow the reader to quickly formulate reasonable comparisons between reactors and the regulatory limits. It should be noted, however, that for some multi-unit sites, the actual contributions from each unit might be different than the equal distributions calculated with this approach, such as when a plant is undergoing a major or extended outage.

The report may include licensees' corrections submitted to the NRC up to the time of publication. If a licensee submits amended data in accordance with NRC regulatory guidance, the NRC reserves the right to update the data in future reports. For the most current data, the reader should use the NPPs' ARERRs which are available on the NRC Web site.

Table 1.2 Reactors for Which the NRC Has Reported Data on a Unit-Specific Basis

Boiling-Water Reactors (BWRs)	R	D
Browns Ferry 1, 2, 3	✓	✓
Brunswick 1, 2	✓	✓
Dresden 1, 2, 3	✓	
LaSalle 1, 2	✓	✓
Limerick 1, 2	✓	✓
Nine Mile Point 1, 2		✓
Peach Bottom 2, 3	✓	✓
Quad Cities 1, 2	✓	✓
Susquehanna 1, 2	✓	

Pressurized-Water Reactors (PWRs)	R	D
Beaver Valley 1, 2	✓	
Calvert Cliffs 1, 2	✓	✓
Catawba 1, 2	✓	✓
Comanche Peak 1, 2	✓	✓
Cook 1, 2	✓	✓
Diablo Canyon 1, 2	✓	✓
Indian Point 1, 2	✓	✓
McGuire 1, 2	✓	✓
North Anna 1, 2	✓	✓
Oconee 1, 2, 3	✓	✓
Point Beach 1, 2	✓	✓
Prairie Island 1, 2	✓	✓
San Onofre 1, 2, 3	✓	✓
Sequoyah 1, 2	✓	✓
Surry 1, 2	✓	✓

Notes:
R = Radionuclide Data, D = Dose Data

2 DESCRIPTION OF THE DATA

2.1 Introduction

Radioactive materials may be disposed of in one of three forms: solid, liquid, or gas. This report summarizes the disposal of radioactive materials in liquid and gaseous effluents from commercial nuclear power plants. Note: Data on solid radioactive waste shipped from a nuclear power plant site is provided in each licensee's ARERR, and data on solid waste disposed in licensed waste disposal facilities is available from the Department of Energy Manifest Information Management System (MIMS) database at URL: http://mims.doe.gov/.

As described in Section 1.3, owners and operators of NPPs are required to report the radioactive effluents from their facilities to the NRC. The two basic characteristics most often used to describe radioactive effluents are the amount of radioactivity (curies or millicuries) and radiation dose (mrem). Radioactivity will be referred to as "activity" and radiation dose will simply be referred to in this document as "dose."

For this report, activity can be thought of as the amount of radioactive material present in radioactive effluents. The units for measuring activity are further described in Section 2.2. The activities of various radionuclides in radioactive effluents from NPPs are presented in Sections 3.1 through 3.5.

Although the amount of activity is an important, inherent characteristic that helps to describe radioactive effluents, it is not—by itself—a good indicator of the potential health effects from exposure to the radiation. Health effects are dependent on many factors, such as the radionuclide, the activity of the radionuclide, the type of radiation emitted by the radionuclide, the energy of the radiation, the uptake of the radionuclide into the human body, and the metabolism of the radionuclide by the human body. To properly describe the potential health effects from exposure to radioactive materials, a combined measure of risk (i.e., dose) that accounts for all of these differences is needed.

The units for measuring dose (mrem) are described in more detail in Section 2.3. The methods and models for calculating dose from radioactive effluents are discussed in Section 2.4. The actual dose values due to radioactive effluents from NPPs are presented in Section 3.6.

Radiation is around us all of the time. The human body—each of us—contains some natural radioactive materials such as radioactive carbon and radioactive potassium. Natural radioactive materials are also in rocks, in soil, in the air we breathe, and in the food we eat. As a result, humans have been exposed to radiation since the dawn of man. Over the last 100 years, man has developed new radioactive materials and new machines that create additional sources of radiation. These new sources include radioactive materials used in medicine, research, industry, and nuclear power plants. Section 2.5 contains basic information on the doses received by the average member of the U.S. population each year from all sources of radiation, including commercial NPPs.

2.2 Measuring Radioactivity in Radioactive Effluents

In order to present the liquid and airborne (gaseous) effluent data in a manner that is both useful and concise, only significant radionuclides are included in the tables and figures in this report. Using the guidance in Revision 2 of RG 1.21 (Ref. [30]), licensees evaluate radionuclides that have either a significant activity or a significant dose contribution in NPP effluents. The radionuclides chosen for inclusion in this report are shown in Tables 2.1 and 2.2.

Activity is a measure of the number of atoms that transform (historically referred to as decay) in a given period of time and is reported in various units, normally either curies (Ci) or becquerels (Bq). In the United States, the traditional unit for reporting activity is the Ci. One Ci is equal to 37,000,000,000 (37 billion) radioactive atoms transforming in one second. In this document, activity will be reported as curies and millicuries (mCi). A curie is equal to one thousand millicuries. In countries that have adopted the International System of Units (or SI units), activity is reported in units of becquerels (Bq). One Bq is one atomic disintegration (transformation) or decay per second. One curie equals 37,000,000,000 becquerels, which may be expressed in scientific notation as 3.7E+10 becquerels or 3.7 x 10^{10} becquerels. One curie is sometimes expressed as 37 gigabecquerels or simply 37 GBq.

One curie of cobalt-60 and one curie of hydrogen-3 have the same activity; however, when an atom of cobalt-60 transforms, the atomic transformations typically produce one moderately energetic beta particle and two highly energetic gamma rays. By contrast, when an atom of hydrogen-3 (tritium) transforms, it emits a single, low-energy beta particle. Sensitive instruments can detect and measure the transformation products that are unique to each radionuclide. Cobalt and hydrogen are just two examples of elements that can be radioactive. Other examples are shown in Tables 2.1 and 2.2.

The reporting of radionuclides in liquid and gaseous wastes is commonly grouped into categories (Ref. [30]). These categories are described in Tables 2.1 and 2.2 as noble gases, iodines, particulates, tritium, carbon, and gross alpha activity. Each category contains one or more radionuclides. Beginning with the 2010 annual effluent summary report, a new radionuclide category has been added for carbon-14 (C-14) in gaseous effluents.

Table 2.1 Radionuclides in Gaseous Effluents

Gaseous Effluent Category	Common Radionuclides	Significant Radionuclides
Fission and Activation Gases (sometimes referred to as Noble Gases)	Krypton (85, 85m, 87, 88) Xenon (131, 131m, 133, 133m, 135, 135m) Argon (41)	Kr-85 Xe-133 Xe-135 All (Sections 3.2, 3.3, and 3.6)
Iodines	Iodine (131, 132, 133, 134, 135)	I-131 All (Section 3.6)
Particulates	Cobalt (58, 60) Cesium (134, 137) Chromium (51) Manganese (54) Niobium (95)	Co-58 Co-60 Cs-134 Cs-137 All (Section 3.6)
Tritium	Hydrogen (3)	H-3
Carbon	Carbon (14)	C-14
Gross Alpha	Total alpha activity	Not Presented in this Report

The radionuclides listed in this report are the most significant radionuclides discharged from a site. For example, although Table 2.1 lists 11 radionuclides in the category called “fission and activation gases,” only the 3 most significant radionuclides (Kr-85, Xe-133, and Xe-135) were selected for inclusion in Table 3.1 and Figure 3.1 for noble gas radionuclides. These three were chosen because these radionuclides are the most significant, are representative of the overall effluent releases, and because as their activities increase, the activities of other fission and activation gases typically increase as well. Conversely, if the activities of these three radionuclides are very low, the activities of other fission and activation gases also tend to be low. All noble gas radionuclides are included in Sections 3.2 Short-Term Trend in Gaseous Effluents, 3.3 Long-Term Trend in Gaseous Effluents, and 3.6 Radiation Doses from Gaseous and Liquid Effluents.

Table 2.2 Radionuclides in Liquid Effluents

Liquid Effluent Category	Common Radionuclides	Significant Radionuclides
Mixed Fission and Activation Products	Iron (55) Cobalt (58, 60) Cesium (134, 137) Chromium (51) Manganese (54) Zirconium (95) Niobium (95) Iodine (131, 133, 135)	Fe-55 Co-58 Co-60 Cs-134 Cs-137 I-131 All (Sections 3.4, 3.5 and 3.6)
Tritium	Hydrogen (3)	H-3
Dissolved and Entrained Noble Gases	Krypton (85, 85m, 87, 88) Xenon (131, 133, 133m, 135, 135m)	Not Presented in this Report
Gross Alpha	Total alpha activity	Not Presented in this Report

Much information about the operation of plant systems can be obtained from the radionuclides present in radioactive effluents. Additionally, the ratios of the activities of radionuclides can provide insights into fuel integrity, radioactive waste system operation, and general radioactive waste handling practices at a site. The reader who is interested in seeing the activities of all radionuclides released from any particular NPP is encouraged to review the detailed, site-specific ARERRs provided on the NRC Web site.

Laboratory instruments can identify which radionuclides are present in radioactive effluents. The instruments can also measure the activities (curies or becquerels) of the radionuclides. As a result, many discussions about radioactive effluents focus on the curies (or becquerels) released. Although activity measures the rate of atomic transformations, it does not provide a direct measure of the potential health effects from exposure to radionuclides. When discussing potential health effects, the concept of dose is used. Radiation dose is discussed in more detail in the following paragraphs.

2.3 Dose Units and Limits

The traditional unit for reporting radiation dose in the United States is the rem. Small exposures are often reported as millirem (mrem) or as fractions of a mrem. One thousand mrem equals one rem. Other countries report radiation dose in units of sieverts (Sv). One sievert equals 100 rem. One millirem equals 0.00001 sievert or 0.01 millisievert (mSv). The number 0.00001 can be represented in scientific notation as 1×10^{-5} or 1E-05.

Radioactive effluents discharged from NPPs are controlled by regulations. NRC regulations (10 CFR 20.1301) specify that the annual dose to individual members of the public does not exceed 100 mrem (1 millisievert) (Ref. [31]). In addition, the Environmental Protection Agency (EPA) has established environmental radiation protection standards for nuclear power operations that the annual dose to any member of the public does not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ.

Typically, the median dose from radioactive effluents to members of the public is so low (usually less than 1 mrem in a year) that the radionuclides and the dose in the environment cannot be measured directly. As a result, hypothetical doses are typically calculated based on the measurements at the point of release from the plant.

2.4 Radiation Dose to the Public

Licensees are required by 10 CFR 50.36a to establish Technical Specifications which require that operating procedures for the control of effluents be established and followed, and that the radioactive waste system be maintained and used to keep average annual effluent releases at small percentages of the public dose limits (Ref. [31]). The Technical Specifications establish the licensee’s Radioactive Effluent Controls Program, which is used to ensure plant operations keep radioactive effluent releases ALARA and meet the ALARA criteria in 10 CFR Part 50, Appendix I (Ref. [29]). The ALARA criteria are established as a small fraction (typically about 3 percent) of the NRC safety limits for dose to members of the public.

The licensee is required to keep levels of radioactive material in effluents ALARA, even under unusual operating conditions. The ALARA criteria are design objectives and limiting conditions for operation, not safety limits. If releases ever exceed design objectives, the licensee is required to take corrective actions to ensure the plant systems are functioning as designed and to report this information to the NRC.

The Radioactive Effluent Controls Program requires licensees to determine the public dose from the release of radioactive effluents. The methods of determining dose are described in the licensee’s Offsite Dose Calculation Manual (ODCM). The ODCMs are available through the NRC Public Document Room. Any changes to the ODCM are reported to the NRC and are provided in the licensee’s ARERR.

The ODCM contains both the offsite dose calculation methodologies and a radiological environmental monitoring program. Those dose calculations are based on:

- actual measurements of the radioactive materials discharged to the unrestricted area;
- models of how radionuclides are dispersed and diluted in the environment;
- models of how radionuclides are incorporated into animals, plants, and soil; and
- biokinetic models of human uptake and metabolism of radioactive materials.

The dose calculation models are designed to calculate the dose either to a real individual closest to the NPP or conservatively to a hypothetical individual exposed to the highest concentrations of radioactive materials from radioactive effluents. This person is often referred to as the maximum exposed individual (or maximum exposed hypothetical individual). The parameters and assumptions used in these dose calculations typically include conservative assumptions that tend to overestimate the dose. As a result, the actual doses received by real individuals are often much less than those calculated. Guidance for these calculations is provided in NRC RG 1.109 (Ref. [32]).

The calculated annual organ doses and annual total body doses are included in Section 3.6. All the doses calculated by a licensee are reported in the NPPs’ ARERRs. Summaries of the calculated doses are provided in Tables 3.19 through 3.22, and are shown graphically in Figures 3.17 through 3.22.

2.5 Other Sources of Radiation Dose to the U.S. Population

Doses from NPP effluents were discussed in the previous sections. This section discusses the doses that the average American typically receives each year from naturally occurring background radiation and all other sources of radiation. With the information presented in this section, the reader can compare the doses received from NPP effluents with the doses received from natural, medical, and other sources of radiation. This comparison provides some context to the concept of radiation dose effects.

In March 2009, the National Council on Radiation Protection and Measurements (NCRP) published Report No. 160 as an update to the 1987 NCRP Report No. 93, "Ionizing Radiation Exposure of the Population of the United States" (Refs. [33] , [34]). Report No. 160 describes the doses to the U.S. population from all sources of ionizing radiation for 2006, the most recent data available at the time the NCRP report was written. The NCRP report also includes information on the variability of those doses from one individual to another. The NCRP estimated that the average person in the United States receives about 620 mrem of radiation dose each year from all sources; i.e., both—natural background radiation and man-made radiation sources. NCRP Report No. 160 describes each of the sources of radiation that contribute to this dose, including:

- naturally occurring sources (natural background) such as cosmic radiation from space, terrestrial radiation from radioactive materials in the earth, and naturally occurring radioactive materials in the food people eat and in the air people breathe;
- medical sources from diagnosis and treatment of health disorders using radioactive pharmaceuticals and radiation-producing equipment;
- consumer products (such as household smoke detectors);
- industrial processes, security devices, educational tools, and research activities; and
- exposures of workers that result from their occupations.

Figure 2.1 is a pie chart showing the relative contributions of these sources of radiation to the dose received by the average American person. Larger contributors to dose are represented by proportionally larger slices of the pie. Doses to the public from NPPs are included in the industrial category; while doses to workers from nuclear power generation are included in the category of occupational dose.

Doses to the public due to effluents from NPPs are less than 0.1 percent (one-tenth of one percent) of what the average person receives each year from all sources of radiation. Doses to workers from occupational exposures, including those received from work at NPPs, also are less than 0.1 percent of the dose to members of the public from all sources.

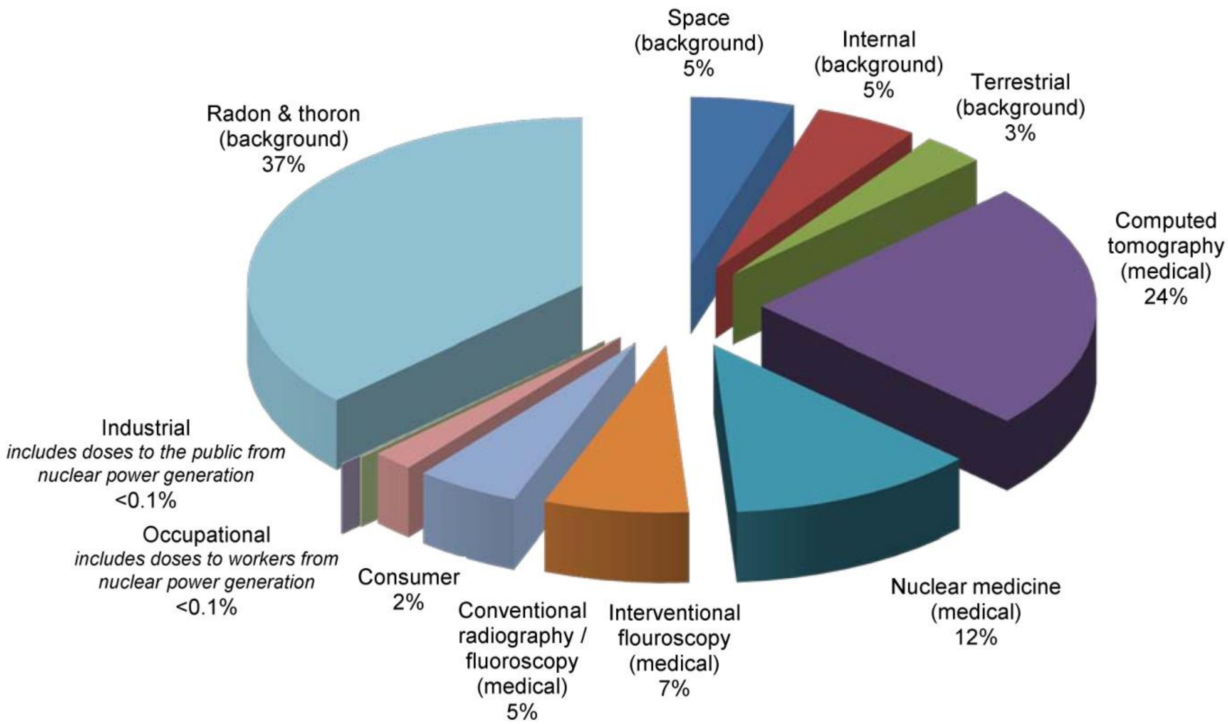


Figure 2.1 Sources of Radiation Exposure to the U.S. Population

The chart above shows the contribution of various sources of exposure to the total collective dose and the total dose per individual in the U.S. population for 2006. Values have been rounded to the nearest 1%, except for those <1% [less than 1%]. *Credit: Modification to image courtesy of National Council on Radiation Protection and Measurements.*

3 EFFLUENT DATA

3.1 Radioactive Materials in Liquid and Gaseous Effluents

The activity of the most significant radionuclides discharged in liquid and gaseous effluents for 2012 are shown in Tables 3.1 through 3.14. The data from these tables are illustrated graphically in Figures 3.1 through 3.14. The tables and figures are organized by the two types of reactors used in the United States: boiling-water reactors (BWRs) and pressurized-water reactors (PWRs). The tables and figures are further subdivided into liquid and gaseous effluents. Finally, the data are subdivided into the radionuclide categories (common radionuclides and significant radionuclides) as listed in Tables 2.1 and 2.2. These tables and figures allow a detailed comparison of each reactor's effluents with other reactors of the same type.

As described in Section 2.2, only the most significant radionuclides are included in the tables and graphs in Section 3.1. However, the total radiation dose from all radionuclides discharged from the reactors is included in Section 3.6, Radiation Doses from Liquid and Gaseous Effluents.

For comparison between plants, median values are included in some tables and figures. The median is the midpoint of the data such that half of the power plants will have greater activity and dose values than the median plant and half of the power plants will have values equal to or lower than the median plant. The median is a method of estimating a central or typical value while avoiding bias caused by extremely high or low values in the data set. All operating nuclear plant units are included when calculating the medians, even those sites for which no measurable release of a particular radionuclide is reported.

All licensees are required to have and use sensitive radioactive effluent measurement capabilities. Many times, radioactive effluent releases are so low in concentration that a release cannot be detected. If no value is listed for a particular radionuclide in a table, it is because the licensee reported that the radionuclide was not detected at that NPP. Blanks in data fields are generally used instead of zeros in order to make it easier for the reader to quickly identify the positive values.

On the following pages, the tables are presented first. In general, the information in each table is organized in descending order of activity. The facilities discharging the most activity are shown near the top of each table, while the facilities discharging the least activity are shown toward the bottom of each table. The median is shown in the middle of each data set. Tables with information on more than one radionuclide are listed by the total activity per plant, in descending order.

The figures are shown following the tables. In general, the information is organized in each figure in descending order of activity. The facilities discharging the most activity of the selected radionuclides are shown near the top of the figure, while the facilities discharging the least activity of the radionuclides are shown toward the bottom of each figure. The median is shown in the middle of each data set.

Figures with information on more than one radionuclide are listed by the total activity per plant, in descending order of activity. Figures with information on more than one radionuclide are shown in multi-colored graphs. For example, Figure 3.1 is a multi-colored graph. In figures with multi-colored graphs, the total activity of the selected radionuclides is shown on the right side of the graph, while the relative contribution of each radionuclide to the total activity is shown on the left side of the graph. The relative contributions of each nuclide are shown—in multiple colors—as a percent of the total activity. A multi-colored graph allows the reader to compare not only the activity but also the relative amounts of significant radionuclides released by the various facilities. Multi-colored graphs contain two separate scales of measurement. The total activity is shown on a logarithmic scale, while the radionuclide percentages of the total activity are shown on a linear scale.

Table 3.1 BWR Gaseous Releases — Fission and Activation Gases, 2012
Shown in Descending Order of Total Activity

BWR Facility	Kr-85 (Ci)	Xe-133 (Ci)	Xe-135 (Ci)	Total (Ci)
LaSalle 1		7.10E+02	1.20E+01	7.22E+02
LaSalle 2		7.10E+02	1.20E+01	7.22E+02
Hope Creek		2.16E+02	3.15E+01	2.48E+02
Grand Gulf		1.29E+02	1.13E+02	2.43E+02
Monticello		1.77E+02	5.73E+01	2.35E+02
Oyster Creek		3.01E+00	1.39E+02	1.42E+02
Perry	3.23E-03	8.55E+01	1.28E+01	9.82E+01
Brunswick 1	1.41E+00	5.74E+00	3.69E+01	4.41E+01
Brunswick 2	1.41E+00	5.74E+00	3.69E+01	4.41E+01
Hatch 2		2.57E+01	3.16E+00	2.88E+01
Hatch 1		2.57E+01	3.08E+00	2.87E+01
Nine Mile Point 2		1.78E+01	4.00E+00	2.18E+01
Limerick 1	1.07E+00	1.03E+01	8.69E+00	2.01E+01
Limerick 2	1.07E+00	1.03E+01	8.69E+00	2.01E+01
River Bend		2.70E+00	1.59E+01	1.86E+01
Peach Bottom 2	8.40E-01	1.16E+01	3.81E+00	1.62E+01
Peach Bottom 3	8.40E-01	1.16E+01	3.81E+00	1.62E+01
BWR Median Release		**3.36E+00**	**3.81E+00**	**1.34E+01**
Dresden 2	6.30E-02	1.15E+01	1.78E+00	1.34E+01
Dresden 3	6.30E-02	1.15E+01	1.78E+00	1.34E+01
FitzPatrick		3.36E+00	7.71E+00	1.11E+01
Duane Arnold			1.04E+01	1.04E+01
Cooper		4.37E-01	6.79E+00	7.23E+00
Nine Mile Point 1	1.75E-01		2.48E+00	2.66E+00
Quad Cities 1		5.97E-01	1.64E+00	2.24E+00
Quad Cities 2		5.97E-01	1.64E+00	2.24E+00
Pilgrim		3.46E-01	2.52E-01	5.98E-01
Fermi 2		9.22E-02	8.68E-02	1.79E-01
Vermont Yankee			8.02E-02	8.02E-02
Browns Ferry 1				
Browns Ferry 2				
Browns Ferry 3				
Clinton				
Columbia				
Susquehanna 1				
Susquehanna 2				

Table 3.2 BWR Gaseous Releases — Iodine, 2012
Shown in Descending Order of Activity

BWR Facility	I-131 (Ci)
LaSalle 1	3.09E-02
LaSalle 2	3.09E-02
Monticello	9.79E-03
Brunswick 1	3.73E-03
Brunswick 2	3.73E-03
Browns Ferry 1	2.81E-03
Browns Ferry 2	2.81E-03
Browns Ferry 3	2.81E-03
Oyster Creek	2.64E-03
Hope Creek	1.87E-03
Nine Mile Point 2	1.81E-03
River Bend	1.13E-03
Fermi 2	9.67E-04
Dresden 2	9.27E-04
Dresden 3	9.27E-04
Pilgrim	7.83E-04
FitzPatrick	7.65E-04
BWR Median Release	**5.12E-04**
Quad Cities 1	5.12E-04
Quad Cities 2	5.12E-04
Hatch 2	4.46E-04
Grand Gulf	4.18E-04
Hatch 1	3.72E-04
Nine Mile Point 1	2.99E-04
Peach Bottom 2	2.86E-04
Peach Bottom 3	2.86E-04
Cooper	1.86E-04
Duane Arnold	1.11E-04
Limerick 1	6.76E-05
Limerick 2	6.76E-05
Perry	5.98E-05
Vermont Yankee	2.57E-05
Clinton	6.38E-06
Columbia	4.51E-06
Susquehanna 1	
Susquehanna 2	

Table 3.3 BWR Gaseous Releases — Particulates, 2012
Shown in Descending Order of Total Activity

BWR Facility	Co-58 (Ci)	Co-60 (Ci)	Cs-134 (Ci)	Cs-137 (Ci)	Total (Ci)
Oyster Creek	5.41E-03	8.78E-03		5.80E-05	1.43E-02
Nine Mile Point 2	1.40E-04	1.61E-03			1.75E-03
LaSalle 1	3.21E-05	7.94E-04			8.26E-04
LaSalle 2	3.21E-05	7.94E-04			8.26E-04
Dresden 2	2.76E-05	7.76E-04		1.34E-06	8.05E-04
Dresden 3	2.76E-05	7.76E-04		1.34E-06	8.05E-04
Cooper	2.35E-05	7.52E-04		4.60E-06	7.80E-04
Nine Mile Point 1	1.45E-05	7.21E-04			7.36E-04
Browns Ferry 1	8.64E-05	4.40E-04		2.72E-05	5.53E-04
Browns Ferry 2	8.64E-05	4.40E-04		2.72E-05	5.53E-04
Browns Ferry 3	8.64E-05	4.40E-04		2.72E-05	5.53E-04
Monticello		2.35E-04		1.94E-04	4.29E-04
Hope Creek		3.30E-04			3.30E-04
Quad Cities 1		2.95E-04		1.09E-05	3.06E-04
Quad Cities 2		2.95E-04		1.09E-05	3.06E-04
Brunswick 1	2.57E-05	2.38E-04		2.03E-05	2.84E-04
Brunswick 2	2.57E-05	2.38E-04		2.03E-05	2.84E-04
BWR Median Release	**1.26E-06**	**1.88E-04**			**2.44E-04**
Duane Arnold	5.57E-05	1.88E-04		2.09E-07	2.44E-04
Fermi 2	2.06E-05	1.83E-04			2.04E-04
Peach Bottom 2	1.26E-06	1.72E-04	1.42E-07		1.74E-04
Peach Bottom 3	1.26E-06	1.72E-04	1.42E-07		1.74E-04
Grand Gulf	1.25E-05	4.26E-05		4.03E-06	5.91E-05
Columbia		3.53E-05			3.53E-05
Susquehanna 1		2.83E-05			2.83E-05
Susquehanna 2		2.83E-05			2.83E-05
FitzPatrick	3.25E-06	1.57E-05			1.89E-05
Pilgrim		7.11E-06		3.54E-06	1.07E-05
Vermont Yankee		7.15E-06			7.15E-06
Hatch 1		2.06E-06		2.64E-07	2.32E-06
River Bend		5.90E-07			5.90E-07
Hatch 2		6.03E-08		2.64E-07	3.25E-07
Limerick 1		3.30E-11			3.30E-11
Limerick 2		3.30E-11			3.30E-11
Clinton					
Perry					

Table 3.4 BWR Gaseous Releases — Tritium, 2012
Shown in Descending Order of Activity

BWR Facility	H-3 (Ci)
Fermi 2	2.16E+02
Browns Ferry 1	1.99E+02
Browns Ferry 2	1.99E+02
Browns Ferry 3	1.99E+02
Brunswick 1	1.11E+02
Brunswick 2	1.11E+02
Nine Mile Point 2	7.40E+01
Quad Cities 1	4.16E+01
Quad Cities 2	4.16E+01
Oyster Creek	4.09E+01
FitzPatrick	3.59E+01
Limerick 1	3.59E+01
Limerick 2	3.59E+01
Duane Arnold	3.50E+01
Columbia	3.43E+01
Pilgrim	2.97E+01

BWR Facility	H-3 (Ci)
BWR Median Release	**2.84E+01**
Peach Bottom 2	2.84E+01
Peach Bottom 3	2.84E+01
Monticello	2.77E+01
Nine Mile Point 1	2.37E+01
Hatch 1	2.21E+01
Grand Gulf	2.12E+01
Clinton	2.11E+01
Cooper	1.79E+01
Hatch 2	1.62E+01
River Bend	1.49E+01
Dresden 2	1.05E+01
Dresden 3	1.05E+01
LaSalle 1	8.13E+00
LaSalle 2	8.13E+00
Vermont Yankee	3.84E+00
Perry	3.61E+00
Susquehanna 1	3.47E+00
Susquehanna 2	3.47E+00
Hope Creek	1.44E-03

Table 3.5 BWR Gaseous Releases — Carbon-14, 2012
Shown in Descending Order of Activity

BWR Facility	C-14 (Ci)
Susquehanna 1	1.90E+01
Susquehanna 2	1.90E+01
Perry	1.86E+01
Peach Bottom 2	1.78E+01
Peach Bottom 3	1.78E+01
LaSalle 1	1.70E+01
LaSalle 2	1.70E+01
Columbia	1.69E+01
Hope Creek	1.64E+01
Limerick 1	1.64E+01
Limerick 2	1.64E+01
Nine Mile Point 2	1.63E+01
Clinton	1.62E+01
Dresden 2	1.51E+01
Dresden 3	1.51E+01
Quad Cities 1	1.44E+01
Quad Cities 2	1.44E+01

BWR Facility	C-14 (Ci)
BWR Median Release	**1.42E+01**
Hatch 1	1.42E+01
Hatch 2	1.42E+01
Browns Ferry 1	1.14E+01
Browns Ferry 2	1.14E+01
Browns Ferry 3	1.14E+01
Grand Gulf	1.13E+01
River Bend	1.10E+01
Cooper	1.07E+01
Brunswick 1	1.03E+01
Brunswick 2	1.03E+01
Oyster Creek	1.00E+01
Fermi 2	9.45E+00
FitzPatrick	8.89E+00
Pilgrim	8.56E+00
Nine Mile Point 1	8.40E+00
Duane Arnold	7.95E+00
Vermont Yankee	7.59E+00
Monticello	6.60E+00

Table 3.6 PWR Gaseous Releases — Fission and Activation Gases, 2012
Shown in Descending Order of Total Activity

PWR Facility	Kr-85 (Ci)	Xe-133 (Ci)	Xe-135 (Ci)	Total (Ci)
San Onofre 2	9.25E+00	4.57E+01	2.18E-02	5.50E+01
San Onofre 3	9.25E+00	4.57E+01	2.18E-02	5.50E+01
Calvert Cliffs 1	4.29E+01	8.07E+00	5.67E-01	5.15E+01
Calvert Cliffs 2	4.29E+01	8.07E+00	5.67E-01	5.15E+01
Vogtle 2		1.09E+01	1.16E+01	2.26E+01
Palisades		5.14E+00	1.92E+00	7.06E+00
Oconee 1	9.04E-03	6.30E+00	3.07E-03	6.31E+00
Oconee 2	9.04E-03	6.30E+00	3.07E-03	6.31E+00
Oconee 3	9.04E-03	6.30E+00	3.07E-03	6.31E+00
Callaway	2.65E+00	1.42E+00	2.54E-01	4.33E+00
Palo Verde 2		3.92E+00	6.59E-02	3.99E+00
Waterford 3		1.50E-01	3.11E+00	3.26E+00
Indian Point 2		2.23E+00	3.47E-01	2.58E+00
Ginna		1.80E+00	2.73E-02	1.83E+00
St. Lucie 1	1.06E-04	1.32E+00	9.40E-03	1.33E+00
Millstone 2	7.30E-01	4.02E-01	1.21E-02	1.14E+00
Millstone 3	1.02E+00	5.74E-03	4.42E-04	1.02E+00
South Texas 2		1.02E+00		1.02E+00
Watts Bar 1	1.18E-06	7.96E-01	1.45E-01	9.41E-01
South Texas 1		9.16E-01	2.31E-03	9.18E-01
Byron 1		8.69E-01	1.76E-03	8.71E-01
Byron 2		7.58E-01	1.75E-03	7.59E-01
Surry 1		6.13E-01	1.37E-01	7.51E-01
Surry 2		6.13E-01	1.37E-01	7.51E-01
Davis-Besse		7.03E-01	3.13E-03	7.07E-01
St. Lucie 2		4.04E-01	3.04E-01	7.07E-01
Cook 1	3.25E-01	3.73E-01	9.80E-04	6.99E-01
Cook 2	3.25E-01	3.73E-01	9.80E-04	6.99E-01
Turkey Point 3		6.66E-01	9.43E-04	6.67E-01
Farley 1		5.78E-01	2.73E-02	6.05E-01
Palo Verde 3		9.25E-02	4.32E-01	5.25E-01
Sequoyah 1		4.15E-01	2.36E-02	4.39E-01
Sequoyah 2		4.15E-01	2.36E-02	4.39E-01

Table 3.6 PWR Gaseous Releases — Fission and Activation Gases, 2012 (continued)
Shown in Descending Order of Total Activity

PWR Facility	Kr-85 (Ci)	Xe-133 (Ci)	Xe-135 (Ci)	Total (Ci)
PWR Median Release		**3.29E-01**	**3.15E-03**	**4.24E-01**
Comanche Peak 1	3.71E-01	5.00E-02	3.15E-03	4.24E-01
Comanche Peak 2	3.71E-01	5.00E-02	3.15E-03	4.24E-01
Braidwood 1		3.80E-01	2.41E-02	4.04E-01
Braidwood 2		3.80E-01	2.41E-02	4.04E-01
Salem 2	0.00E+00	3.38E-01	5.90E-02	3.97E-01
Summer	4.80E-02	1.74E-01	1.68E-01	3.90E-01
Harris		3.80E-01	4.89E-03	3.85E-01
Three Mile Island 1	2.93E-01	6.51E-02		3.58E-01
Catawba 1	4.69E-04	3.29E-01	1.96E-02	3.49E-01
Catawba 2	4.69E-04	3.29E-01	1.96E-02	3.49E-01
Arkansas 2	2.97E-01			2.97E-01
North Anna 1	6.95E-04	2.48E-01	1.80E-03	2.51E-01
North Anna 2	6.95E-04	2.48E-01	1.80E-03	2.51E-01
Robinson 2	9.83E-03	2.12E-01		2.21E-01
Turkey Point 4		1.87E-01	9.43E-04	1.88E-01
Point Beach 1		1.75E-01	1.05E-02	1.85E-01
Point Beach 2		1.75E-01	1.05E-02	1.85E-01
Salem 1		1.34E-01	5.19E-03	1.39E-01
Kewaunee		5.10E-02	1.45E-04	5.11E-02
Beaver Valley 1		3.63E-02	9.39E-03	4.57E-02
Beaver Valley 2		3.63E-02	9.39E-03	4.57E-02
McGuire 1	1.12E-03	3.87E-02	6.19E-04	4.04E-02
McGuire 2	1.12E-03	3.87E-02	6.19E-04	4.04E-02
Indian Point 3		2.69E-02	2.70E-06	2.69E-02
Prairie Island 1	2.22E-02	3.14E-03		2.53E-02
Prairie Island 2	2.22E-02	3.14E-03		2.53E-02
Diablo Canyon 1	1.33E-02	1.65E-03		1.49E-02
Diablo Canyon 2	1.33E-02	1.65E-03		1.49E-02
Wolf Creek	3.09E-04	9.81E-03	6.57E-04	1.08E-02
Seabrook			9.82E-04	9.82E-04
Farley 2		4.21E-04		4.21E-04
Palo Verde 1		1.43E-04		1.43E-04
Arkansas 1				
Crystal River 3				
Ft. Calhoun				
Vogtle 1				

Table 3.7 PWR Gaseous Releases — Iodine, 2012
Shown in Descending Order of Activity

PWR Facility	I-131 (Ci)
Calvert Cliffs 1	7.58E-04
Calvert Cliffs 2	7.58E-04
Palisades	3.80E-04
San Onofre 2	1.66E-04
San Onofre 3	1.66E-04
Millstone 2	1.07E-04
Braidwood 1	5.57E-05
Salem 2	3.52E-05
Braidwood 2	3.19E-05
Palo Verde 3	2.70E-05
Cook 1	1.29E-05
Cook 2	1.29E-05
Vogtle 1	8.94E-06
Farley 1	8.61E-06
Farley 2	8.61E-06
Watts Bar 1	8.38E-06
Byron 2	8.22E-06
Palo Verde 2	6.87E-06
Byron 1	5.51E-06
Beaver Valley 2	2.91E-06
Davis-Besse	1.78E-06
Waterford 3	1.32E-06
Robinson 2	1.13E-06
Point Beach 1	1.04E-06
Point Beach 2	1.04E-06
South Texas 2	9.01E-07
Sequoyah 1	8.50E-07
Sequoyah 2	8.50E-07
North Anna 1	8.45E-07
North Anna 2	8.45E-07
St. Lucie 2	6.81E-07
Palo Verde 1	1.90E-07
South Texas 1	1.05E-07
Beaver Valley 1	4.26E-08

PWR Facility	I-131 (Ci)
PWR Median Release	**3.92E-08**
Ginna	3.92E-08
Oconee 1	6.00E-09
Oconee 2	6.00E-09
Oconee 3	6.00E-09
Arkansas 1	
Arkansas 2	
Callaway	
Catawba 1	
Catawba 2	
Comanche Peak 1	
Comanche Peak 2	
Crystal River 3	
Diablo Canyon 1	
Diablo Canyon 2	
Ft. Calhoun	
Harris	
Indian Point 2	
Indian Point 3	
Kewaunee	
McGuire 1	
McGuire 2	
Millstone 3	
Prairie Island 1	
Prairie Island 2	
Salem 1	
Seabrook	
St. Lucie 1	
Summer	
Surry 1	
Surry 2	
Three Mile Island 1	
Turkey Point 3	
Turkey Point 4	
Vogtle 2	
Wolf Creek	

Table 3.8 PWR Gaseous Releases — Particulates, 2012
Shown in Descending Order of Total Activity

PWR Facility	Co-58 (Ci)	Co-60 (Ci)	Cs-134 (Ci)	Cs-137 (Ci)	Total (Ci)
Turkey Point 4	1.87E-01	4.75E-04		3.24E-07	1.87E-01
Beaver Valley 1	7.00E-04	1.93E-04		4.12E-06	8.97E-04
Beaver Valley 2	5.34E-04	1.43E-04			6.77E-04
Turkey Point 3	1.04E-06	4.75E-04		5.37E-07	4.77E-04
Palisades	1.76E-04	2.47E-05		1.07E-06	2.02E-04
Palo Verde 3	1.78E-04	9.03E-06			1.87E-04
San Onofre 2	1.59E-04	5.46E-06		3.26E-06	1.68E-04
San Onofre 3	1.59E-04	5.46E-06		3.26E-06	1.68E-04
Braidwood 2		8.86E-05			8.86E-05
Watts Bar 1	1.91E-05	4.58E-05			6.49E-05
Palo Verde 2	3.56E-05	9.17E-06			4.48E-05
Surry 1	3.52E-05	2.00E-06		1.18E-07	3.73E-05
Surry 2	3.52E-05	2.00E-06		1.18E-07	3.73E-05
Davis-Besse	2.73E-05				2.73E-05
St. Lucie 1		7.74E-06		1.14E-05	1.92E-05
Prairie Island 1	3.16E-06			1.02E-05	1.33E-05
Prairie Island 2	3.16E-06			1.02E-05	1.33E-05
Braidwood 1		1.17E-05			1.17E-05
South Texas 1	5.54E-06	4.33E-06			9.87E-06
North Anna 1	2.76E-06	6.34E-06		9.12E-08	9.18E-06
North Anna 2	2.76E-06	6.34E-06		9.12E-08	9.18E-06
Diablo Canyon 1	1.76E-06	5.10E-06			6.86E-06
Diablo Canyon 2	1.76E-06	5.10E-06			6.86E-06
Point Beach 1	2.95E-06	3.65E-06		1.28E-07	6.73E-06
Point Beach 2	2.95E-06	3.65E-06		1.28E-07	6.73E-06
Waterford 3	1.82E-06	1.43E-07	4.55E-07	2.40E-06	4.81E-06
Indian Point 2	4.57E-06				4.57E-06
McGuire 1	4.99E-07	3.28E-06			3.78E-06
McGuire 2	4.99E-07	3.28E-06			3.78E-06
Millstone 2	7.88E-07	1.28E-06		9.45E-07	3.01E-06
Calvert Cliffs 1				1.88E-06	1.88E-06
Calvert Cliffs 2				1.88E-06	1.88E-06
St. Lucie 2				1.86E-06	1.86E-06
Byron 2	1.13E-06				1.13E-06

Table 3.8 PWR Gaseous Releases — Particulates, 2012 (continued)
Shown in Descending Order of Total Activity

PWR Facility	Co-58 (Ci)	Co-60 (Ci)	Cs-134 (Ci)	Cs-137 (Ci)	Total (Ci)
PWR Median Release	**1.08E-07**				**1.07E-06**
Crystal River 3				1.07E-06	1.07E-06
Farley 1		7.36E-07			7.36E-07
Kewaunee	7.06E-07				7.06E-07
Sequoyah 1	6.90E-07				6.90E-07
Sequoyah 2	6.90E-07				6.90E-07
Palo Verde 1	5.28E-07				5.28E-07
Robinson 2	1.14E-07	7.63E-09		2.06E-08	1.43E-07
Vogtle 1	1.08E-07				1.08E-07
Vogtle 2	1.08E-07				1.08E-07
South Texas 2	2.60E-08	7.74E-09			3.37E-08
Seabrook	7.26E-09				7.26E-09
Millstone 3	4.77E-11	1.09E-11	3.77E-12	4.62E-12	6.70E-11
Arkansas 1					
Arkansas 2					
Byron 1					
Callaway					
Catawba 1					
Catawba 2					
Comanche Peak 1					
Comanche Peak 2					
Cook 1					
Cook 2					
Farley 2					
Ft. Calhoun					
Ginna					
Harris					
Indian Point 3					
Oconee 1					
Oconee 2					
Oconee 3					
Salem 1					
Salem 2					
Summer					
Three Mile Island 1					
Wolf Creek					

Table 3.9 PWR Gaseous Releases — Tritium, 2012
Shown in Descending Order of Activity

PWR Facility	H-3 (Ci)
Palo Verde 2	1.03E+03
Palo Verde 3	7.63E+02
Braidwood 2	3.87E+02
Braidwood 1	1.84E+02
Harris	1.59E+02
Three Mile Island 1	1.43E+02
Seabrook	1.16E+02
Salem 2	1.11E+02
Catawba 1	1.10E+02
Catawba 2	1.10E+02
Millstone 3	8.58E+01
Cook 1	8.14E+01
Cook 2	8.14E+01
South Texas 1	7.05E+01
Kewaunee	6.55E+01
McGuire 1	6.21E+01
McGuire 2	6.21E+01
Oconee 1	6.03E+01
Oconee 2	6.03E+01
Oconee 3	6.03E+01
Diablo Canyon 1	5.76E+01
Diablo Canyon 2	5.76E+01
Salem 1	5.76E+01
Palo Verde 1	5.56E+01
Waterford 3	5.44E+01
Davis-Besse	5.23E+01
South Texas 2	5.21E+01
St. Lucie 1	5.07E+01
Watts Bar 1	4.83E+01
Vogtle 1	4.66E+01
San Onofre 2	4.50E+01
San Onofre 3	4.50E+01
Ginna	4.17E+01

PWR Facility	H-3 (Ci)
PWR Median Release	**3.98E+01**
Sequoyah 1	3.98E+01
Sequoyah 2	3.98E+01
Byron 2	3.79E+01
Point Beach 1	3.50E+01
Point Beach 2	3.50E+01
Wolf Creek	3.35E+01
Farley 2	3.09E+01
Callaway	2.81E+01
Arkansas 2	2.80E+01
St. Lucie 2	2.76E+01
Comanche Peak 1	2.58E+01
Comanche Peak 2	2.58E+01
Byron 1	1.76E+01
Surry 1	1.74E+01
Surry 2	1.74E+01
Indian Point 3	1.70E+01
Millstone 2	1.67E+01
Palisades	1.44E+01
Indian Point 2	1.43E+01
Arkansas 1	1.39E+01
Vogtle 2	1.23E+01
North Anna 1	1.05E+01
North Anna 2	1.05E+01
Turkey Point 3	7.25E+00
Robinson 2	6.60E+00
Beaver Valley 1	5.82E+00
Crystal River 3	5.27E+00
Farley 1	5.26E+00
Beaver Valley 2	4.39E+00
Prairie Island 1	3.68E+00
Prairie Island 2	3.68E+00
Calvert Cliffs 1	3.10E+00
Calvert Cliffs 2	3.10E+00
Turkey Point 4	2.42E+00
Ft. Calhoun	1.31E+00
Summer	1.13E-03

Table 3.10 PWR Gaseous Releases — Carbon-14, 2012
Shown in Descending Order of Activity

PWR Facility	C-14 (Ci)
Wolf Creek	2.14E+01
Callaway	1.32E+01
North Anna 1	1.31E+01
North Anna 2	1.31E+01
Millstone 3	1.24E+01
Vogtle 1	1.21E+01
Vogtle 2	1.21E+01
Comanche Peak 1	1.17E+01
Comanche Peak 2	1.17E+01
Diablo Canyon 2	1.12E+01
Salem 1	1.12E+01
Arkansas 2	1.09E+01
Cook 1	1.09E+01
Cook 2	1.09E+01
Indian Point 3	1.08E+01
Salem 2	1.04E+01
Waterford 3	1.01E+01
Indian Point 2	9.92E+00
Diablo Canyon 1	9.88E+00
Davis-Besse	9.81E+00
McGuire 1	9.65E+00
McGuire 2	9.65E+00
Sequoyah 1	9.65E+00
Sequoyah 2	9.65E+00
Catawba 1	9.57E+00
Catawba 2	9.57E+00
Seabrook	9.55E+00
Watts Bar 1	9.30E+00
Farley 1	9.28E+00
Farley 2	9.28E+00
Surry 1	8.94E+00
Surry 2	8.94E+00
Arkansas 1	8.76E+00
Summer	8.60E+00

PWR Facility	C-14 (Ci)
PWR Median Release	8.40E+00
Millstone 2	8.40E+00
Three Mile Island 1	8.40E+00
Harris	7.88E+00
Calvert Cliffs 2	7.60E+00
St. Lucie 2	7.52E+00
Oconee 1	7.39E+00
Oconee 2	7.39E+00
Oconee 3	7.39E+00
Robinson 2	7.36E+00
South Texas 1	7.30E+00
South Texas 2	7.30E+00
Ginna	6.80E+00
St. Lucie 1	6.68E+00
Turkey Point 4	6.46E+00
Calvert Cliffs 1	6.40E+00
Palisades	6.39E+00
Kewaunee	6.28E+00
Point Beach 1	5.84E+00
Point Beach 2	5.84E+00
Byron 2	4.50E+00
Prairie Island 1	4.35E+00
Prairie Island 2	4.35E+00
Braidwood 2	4.17E+00
Braidwood 1	4.14E+00
Byron 1	3.97E+00
Turkey Point 3	3.15E+00
Palo Verde 1	2.72E+00
Palo Verde 2	2.72E+00
Palo Verde 3	2.72E+00
Beaver Valley 1	2.00E+00
San Onofre 3	1.17E+00
San Onofre 2	2.30E-01
Beaver Valley 2	8.42E-02
Crystal River 3	
Ft. Calhoun	

Table 3.11 BWR Liquid Releases — Fission and Activation Products, 2012
Shown in Descending Order of Total Activity

BWR Facility	Co-58 (Ci)	Co-60 (Ci)	Cs-134 (CI)	Cs-137 (Ci)	Fe-55 (Ci)	I-131 (Ci)	Total (Ci)
Grand Gulf	5.25E-04	1.17E-02	9.52E-06	1.26E-03	3.16E-02	1.31E-05	4.52E-02
Hope Creek	1.38E-04	1.90E-02	2.17E-04	5.06E-03	4.98E-03	3.09E-06	2.94E-02
Perry	7.31E-04	2.54E-02		8.77E-06			2.61E-02
Quad Cities 1	1.09E-04	2.73E-03	3.27E-06	7.71E-05			2.92E-03
Quad Cities 2	1.09E-04	2.73E-03	3.27E-06	7.71E-05			2.92E-03
Peach Bottom 2		1.72E-03		9.61E-05	1.91E-04		2.00E-03
Peach Bottom 3		1.72E-03		9.61E-05	1.91E-04		2.00E-03
Hatch 1	7.77E-05	9.81E-04		1.70E-04	3.15E-04		1.54E-03
Susquehanna 1	1.07E-04	1.26E-03					1.37E-03
Susquehanna 2	1.07E-04	1.26E-03					1.37E-03
Brunswick 1	3.39E-05	2.15E-04		2.81E-05		2.78E-04	5.55E-04
Brunswick 2	3.39E-05	2.15E-04		2.81E-05		2.78E-04	5.55E-04
Limerick 1	1.88E-05	3.57E-04	1.35E-06	6.84E-06		4.29E-07	3.84E-04
Limerick 2	1.88E-05	3.57E-04	1.35E-06	6.84E-06		4.29E-07	3.84E-04
Browns Ferry 1		1.01E-04	4.10E-06	2.00E-04	2.58E-06		3.08E-04
Browns Ferry 2		1.01E-04	4.10E-06	2.00E-04	2.58E-06		3.08E-04
Browns Ferry 3		1.01E-04	4.10E-06	2.00E-04	2.58E-06		3.08E-04
BWR Median Release		**6.20E-05**					**6.20E-05**
River Bend		6.20E-05					6.20E-05
Hatch 2	2.15E-06	2.38E-05					2.60E-05
Dresden 2		1.35E-05					1.35E-05
Dresden 3		1.35E-05					1.35E-05
Clinton							
Columbia							
Cooper							
Duane Arnold							
Fermi 2							
FitzPatrick							
LaSalle 1							
LaSalle 2							
Monticello							
Nine Mile Point 1							
Nine Mile Point 2							
Oyster Creek							
Pilgrim							
Vermont Yankee							

Table 3.12 BWR Liquid Releases — Tritium, 2012
Shown in Descending Order of Activity

BWR Facility	H-3 (Ci)
Grand Gulf	1.02E+02
Brunswick 1	9.62E+01
Brunswick 2	9.62E+01
River Bend	3.88E+01
Susquehanna 1	3.73E+01
Susquehanna 2	3.73E+01
Hope Creek	2.98E+01
Perry	2.31E+01
Hatch 1	1.06E+01
Limerick 1	8.14E+00
Limerick 2	8.14E+00
Peach Bottom 2	4.82E+00
Peach Bottom 3	4.82E+00
Hatch 2	4.40E+00
Browns Ferry 1	3.19E+00
Browns Ferry 2	3.19E+00
Browns Ferry 3	3.19E+00

BWR Facility	H-3 (Ci)
BWR Median Release	**3.31E-01**
Oyster Creek	3.31E-01
FitzPatrick	2.11E-01
Vermont Yankee	1.06E-01
Pilgrim	9.90E-02
Quad Cities 1	4.40E-02
Quad Cities 2	4.40E-02
Dresden 2	2.00E-03
Dresden 3	2.00E-03
Duane Arnold	1.09E-03
Clinton	
Columbia	
Cooper	
Fermi 2	
LaSalle 1	
LaSalle 2	
Monticello	
Nine Mile Point 1	
Nine Mile Point 2	

Table 3.13 PWR Liquid Releases — Fission and Activation Products, 2012
Shown in Descending Order of Total Activity

PWR Facility	Co-58 (Ci)	Co-60 (Ci)	Cs-134 (Ci)	Cs-137 (Ci)	Fe-55 (Ci)	I-131 (Ci)	Total (Ci)
Millstone 2	1.14E-02	4.22E-03	1.85E-04	1.20E-03	6.84E-02	3.28E-05	8.54E-02
Vogtle 1	3.98E-03	2.75E-03	5.00E-04	2.23E-03	4.78E-02	2.68E-06	5.73E-02
Sequoyah 1	4.95E-02	3.37E-03		1.04E-04	3.59E-03		5.65E-02
Sequoyah 2	4.95E-02	3.37E-03		1.04E-04	3.59E-03		5.65E-02
Kewaunee	5.49E-03	1.12E-02			3.19E-02		4.86E-02
Turkey Point 3	2.88E-02	5.16E-03	7.42E-04	1.96E-03	9.42E-03	6.89E-06	4.61E-02
Turkey Point 4	2.88E-02	5.16E-03	7.42E-04	1.96E-03	9.42E-03	6.89E-06	4.61E-02
San Onofre 2	2.94E-02	4.51E-03	1.27E-04	2.65E-04	7.40E-03	1.10E-04	4.18E-02
San Onofre 3	2.94E-02	4.51E-03	1.27E-04	2.65E-04	7.40E-03	1.10E-04	4.18E-02
Watts Bar 1	4.16E-03	1.48E-03	3.19E-05	2.09E-04	2.99E-02		3.58E-02
Millstone 3	2.16E-03	3.01E-03	6.18E-04	1.16E-03	2.35E-02		3.04E-02
Harris	2.24E-02	2.37E-03		1.10E-04	5.41E-05		2.50E-02
Beaver Valley 1	1.15E-02	3.05E-03		1.68E-03	3.65E-03		1.99E-02
Beaver Valley 2	1.15E-02	3.05E-03		1.68E-03	3.65E-03		1.99E-02
Callaway	1.05E-05	1.57E-02	1.66E-04	2.63E-03			1.85E-02
Arkansas 2	3.01E-03	6.24E-04	3.85E-05	3.01E-04	1.40E-02		1.80E-02
Vogtle 2	1.52E-03	8.78E-04	1.47E-04	7.09E-04	1.11E-02		1.43E-02
Farley 1	6.68E-03	3.69E-03	9.02E-07	7.31E-05	1.18E-03		1.16E-02
Prairie Island 1	6.64E-03	1.11E-03		1.47E-05	3.18E-03		1.09E-02
Prairie Island 2	6.64E-03	1.11E-03		1.47E-05	3.18E-03		1.09E-02
Catawba 1	3.80E-03	6.90E-03		3.25E-05			1.07E-02
Catawba 2	3.80E-03	6.90E-03		3.25E-05			1.07E-02
Diablo Canyon 1	1.19E-03	3.85E-03		1.03E-05	3.64E-03		8.69E-03
Diablo Canyon 2	1.19E-03	3.85E-03		1.03E-05	3.64E-03		8.69E-03
Indian Point 3	5.52E-04	7.40E-03	5.72E-06	3.72E-04	3.13E-04		8.64E-03
Waterford 3	3.05E-03	3.22E-03	1.07E-05	4.86E-05	2.07E-03		8.40E-03
Ginna	8.07E-03	2.17E-04					8.29E-03
Davis-Besse	6.95E-03	4.09E-04	1.69E-05	1.59E-04	5.91E-04		8.13E-03
Farley 2	2.75E-03	3.98E-03		1.30E-04	8.74E-04	2.53E-05	7.76E-03
North Anna 1	1.38E-03	6.03E-03	3.15E-05	2.56E-04			7.70E-03
North Anna 2	1.38E-03	6.03E-03	3.15E-05	2.56E-04			7.70E-03
Arkansas 1	2.99E-03	2.66E-03	3.40E-05	1.22E-03	7.28E-04		7.63E-03
Braidwood 1	4.38E-03	3.17E-03					7.56E-03
Braidwood 2	4.38E-03	3.17E-03					7.56E-03

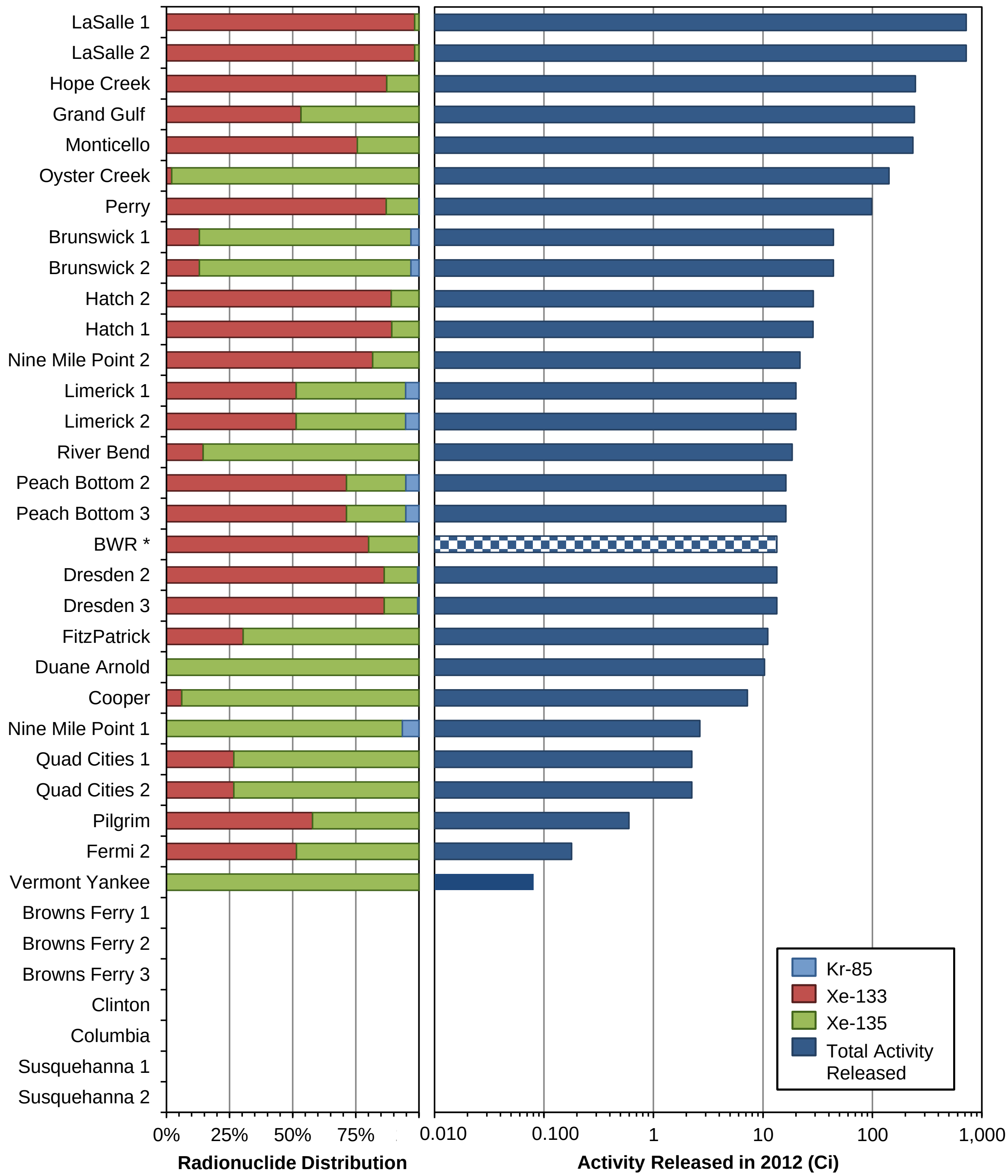
Table 3.13 PWR Liquid Releases — Fission and Activation Products, 2012 (continued)
Shown in Descending Order of Total Activity

PWR Facility	Co-58 (Ci)	Co-60 (Ci)	Cs-134 (Ci)	Cs-137 (Ci)	Fe-55 (Ci)	I-131 (Ci)	Total (Ci)
PWR Median Release	**2.41E-03**	**1.98E-03**		**4.86E-05**	**2.50E-04**		**7.36E-03**
Summer	3.71E-04	5.68E-03	8.21E-06	1.93E-04	1.11E-03		7.36E-03
Salem 1	6.14E-03	9.51E-04					7.09E-03
St. Lucie 1	2.41E-03	1.87E-03		2.06E-05	2.70E-03	8.25E-06	7.00E-03
St. Lucie 2	2.41E-03	1.87E-03		2.06E-05	2.70E-03	8.25E-06	7.00E-03
Byron 1	4.19E-03	2.68E-03	6.10E-06				6.88E-03
Byron 2	4.19E-03	2.68E-03	6.10E-06				6.88E-03
Oconee 1	6.01E-03	7.43E-04	9.00E-06	2.81E-05			6.79E-03
Oconee 2	6.01E-03	7.43E-04	9.00E-06	2.81E-05			6.79E-03
Oconee 3	6.01E-03	7.43E-04	9.00E-06	2.81E-05			6.79E-03
Indian Point 2	2.46E-03	2.77E-04		2.64E-03			5.38E-03
McGuire 1	2.12E-03	2.89E-03	2.18E-06	2.59E-05		7.30E-07	5.04E-03
McGuire 2	2.12E-03	2.89E-03	2.18E-06	2.59E-05		7.30E-07	5.04E-03
Palisades	2.13E-03	1.80E-03		2.89E-04	6.39E-04	2.17E-05	4.88E-03
Comanche Peak 1	2.35E-03	2.48E-04			1.85E-03		4.45E-03
Comanche Peak 2	2.35E-03	2.48E-04			1.85E-03		4.45E-03
Point Beach 1	1.92E-03	2.44E-03		6.75E-07			4.36E-03
Point Beach 2	1.92E-03	2.44E-03		6.75E-07			4.36E-03
Seabrook	3.85E-03	3.86E-04					4.23E-03
South Texas 1	3.99E-04	1.98E-03		3.49E-05	1.71E-03		4.12E-03
Surry 1	1.24E-03	3.43E-04		8.11E-04		3.90E-06	2.40E-03
Surry 2	1.24E-03	3.43E-04		8.11E-04		3.90E-06	2.40E-03
Salem 2	1.71E-03	6.61E-04	8.90E-06				2.38E-03
Robinson 2	7.72E-04	9.42E-04		8.05E-06	1.19E-04	2.30E-07	1.84E-03
Calvert Cliffs 1	6.40E-05	2.81E-04	3.62E-05	3.85E-04	5.55E-04	6.88E-07	1.32E-03
Calvert Cliffs 2	6.40E-05	2.81E-04	3.62E-05	3.85E-04	5.55E-04	6.88E-07	1.32E-03
South Texas 2	1.57E-04	5.33E-04	3.70E-05	1.27E-04	2.50E-04		1.11E-03
Ft. Calhoun	5.91E-05	4.71E-05	1.94E-05	8.54E-04			9.80E-04
Three Mile Island 1	2.68E-05	1.68E-04		7.08E-05	1.32E-04		3.98E-04
Cook 1	2.07E-04	1.73E-04	6.00E-07	1.43E-05			3.95E-04
Cook 2	2.07E-04	1.73E-04	6.00E-07	1.43E-05			3.95E-04
Wolf Creek	2.27E-04	4.88E-05	4.12E-07	4.27E-05			3.19E-04
Crystal River 3		8.40E-05		1.35E-04			2.19E-04
Palo Verde 1							
Palo Verde 2							
Palo Verde 3							

Table 3.14 PWR Liquid Releases — Tritium, 2012
Shown in Descending Order of Activity

PWR Facility	H-3 (Ci)
Watts Bar 1	2.71E+03
Diablo Canyon 1	1.84E+03
Diablo Canyon 2	1.84E+03
Waterford 3	1.65E+03
South Texas 1	1.61E+03
Byron 1	1.33E+03
Byron 2	1.33E+03
Braidwood 1	1.29E+03
Braidwood 2	1.29E+03
Comanche Peak 1	1.22E+03
Comanche Peak 2	1.22E+03
Indian Point 3	1.14E+03
Seabrook	1.09E+03
Wolf Creek	1.09E+03
Vogtle 1	9.91E+02
Cook 1	9.43E+02
Cook 2	9.43E+02
Sequoyah 1	9.00E+02
Sequoyah 2	9.00E+02
Summer	8.98E+02
Indian Point 2	8.49E+02
Beaver Valley 1	8.18E+02
Beaver Valley 2	8.18E+02
Arkansas 2	7.82E+02
Ginna	7.14E+02
Surry 1	6.82E+02
Surry 2	6.82E+02
Harris	6.50E+02
Salem 1	6.39E+02
Davis-Besse	6.32E+02
Millstone 3	5.92E+02
Salem 2	5.84E+02
Farley 2	5.78E+02

PWR Facility	H-3 (Ci)
PWR Median Release	**5.64E+02**
Calvert Cliffs 1	5.64E+02
Calvert Cliffs 2	5.64E+02
McGuire 1	5.23E+02
McGuire 2	5.23E+02
Millstone 2	5.17E+02
Farley 1	4.97E+02
San Onofre 2	4.87E+02
San Onofre 3	4.87E+02
Callaway	4.61E+02
Point Beach 1	4.15E+02
Point Beach 2	4.15E+02
Turkey Point 3	4.07E+02
Turkey Point 4	4.07E+02
Catawba 1	3.81E+02
Catawba 2	3.81E+02
North Anna 1	3.75E+02
North Anna 2	3.75E+02
Arkansas 1	3.59E+02
Palisades	3.30E+02
Three Mile Island 1	2.57E+02
Oconee 1	2.53E+02
Oconee 2	2.53E+02
Oconee 3	2.53E+02
Prairie Island 1	2.36E+02
Prairie Island 2	2.36E+02
Vogtle 2	1.89E+02
Kewaunee	1.72E+02
St. Lucie 1	1.11E+02
St. Lucie 2	1.11E+02
Robinson 2	1.07E+02
South Texas 2	7.70E+01
Ft. Calhoun	2.94E+00
Crystal River 3	6.34E-01
Palo Verde 1	
Palo Verde 2	
Palo Verde 3	



** BWR average radionuclide mix and median activity released.*

Figure 3.1 BWR Gaseous Releases — Fission and Activation Gases

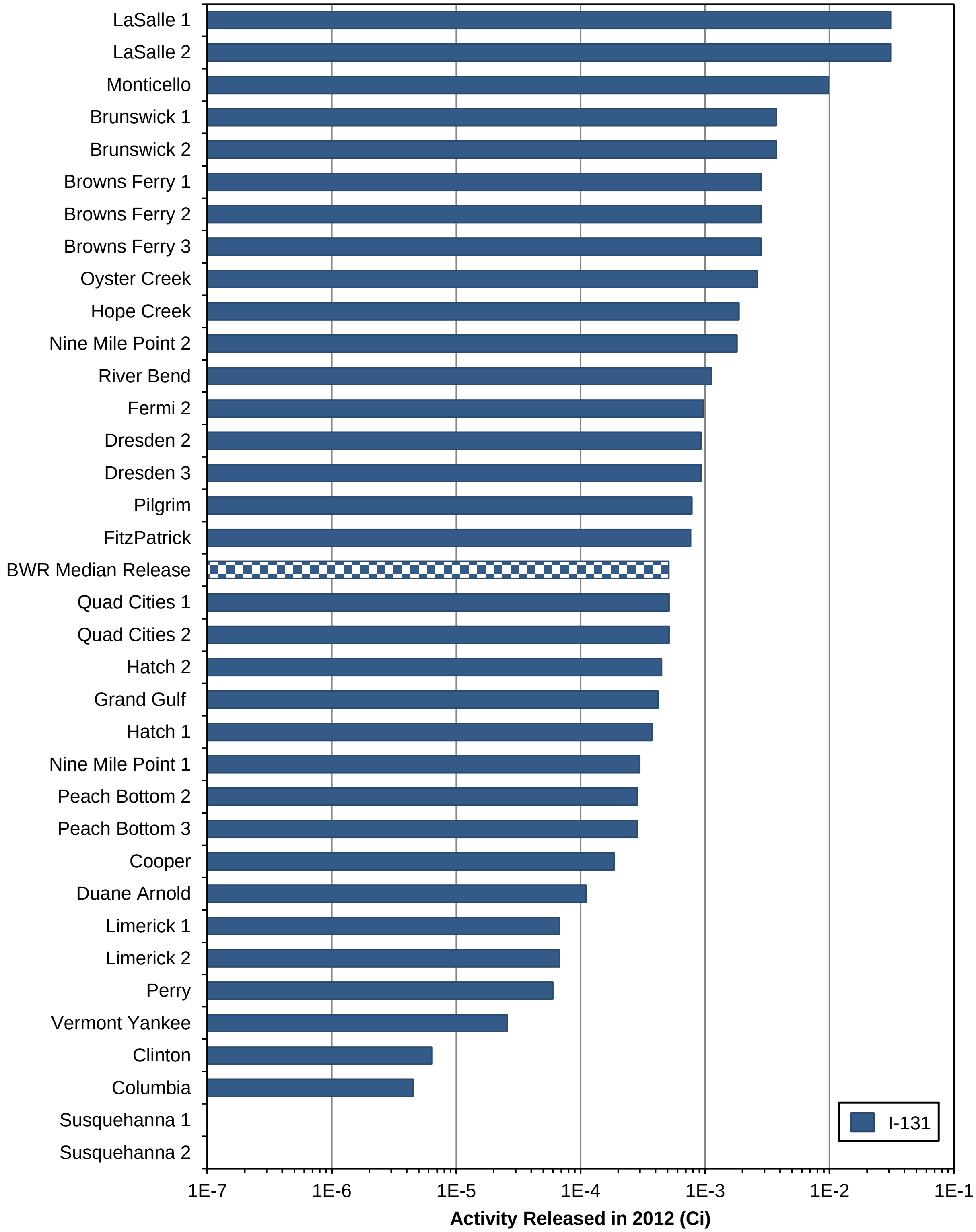
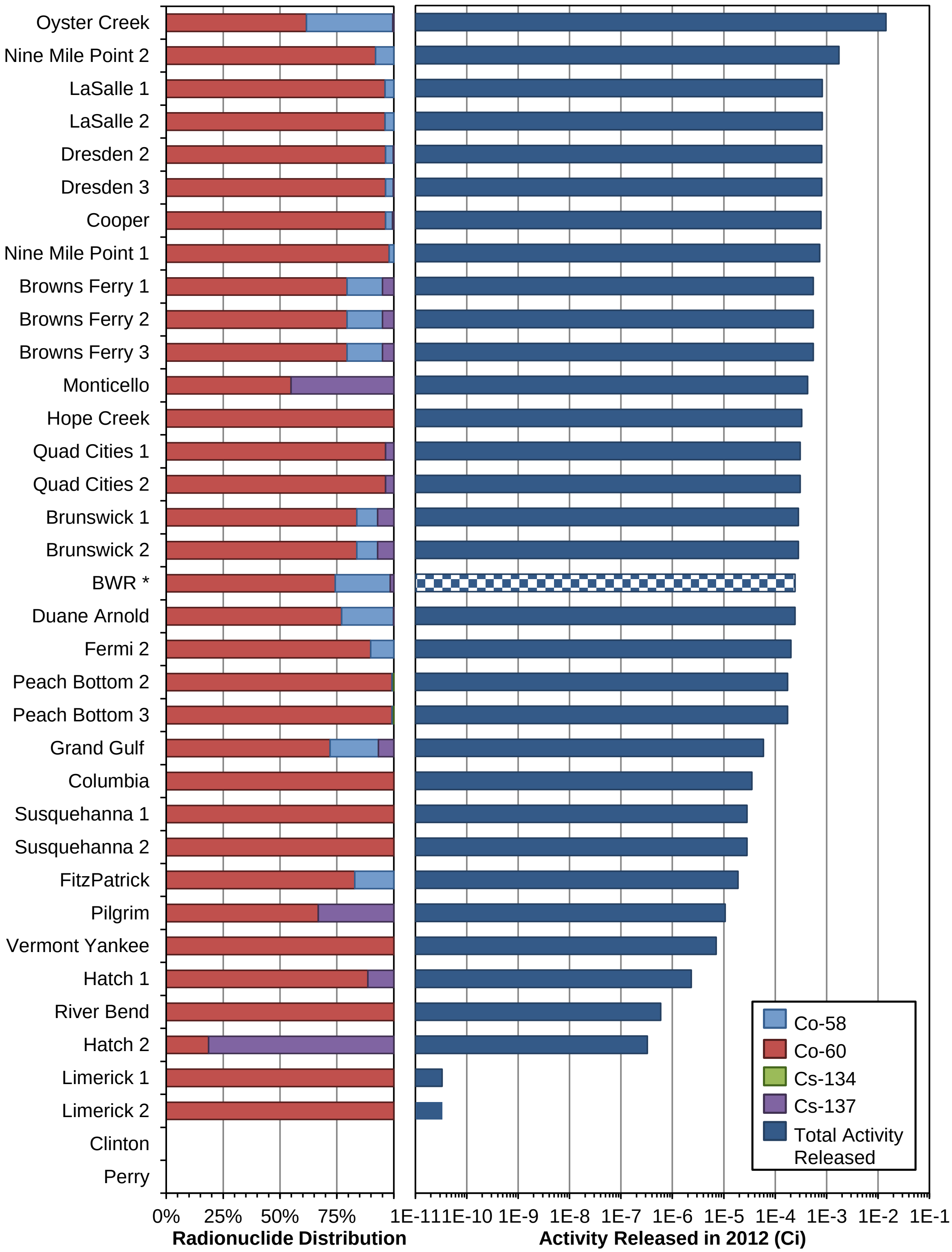


Figure 3.2 BWR Gaseous Releases — Iodine



** BWR average radionuclide mix and median activity released.*

Figure 3.3 BWR Gaseous Releases — Particulates

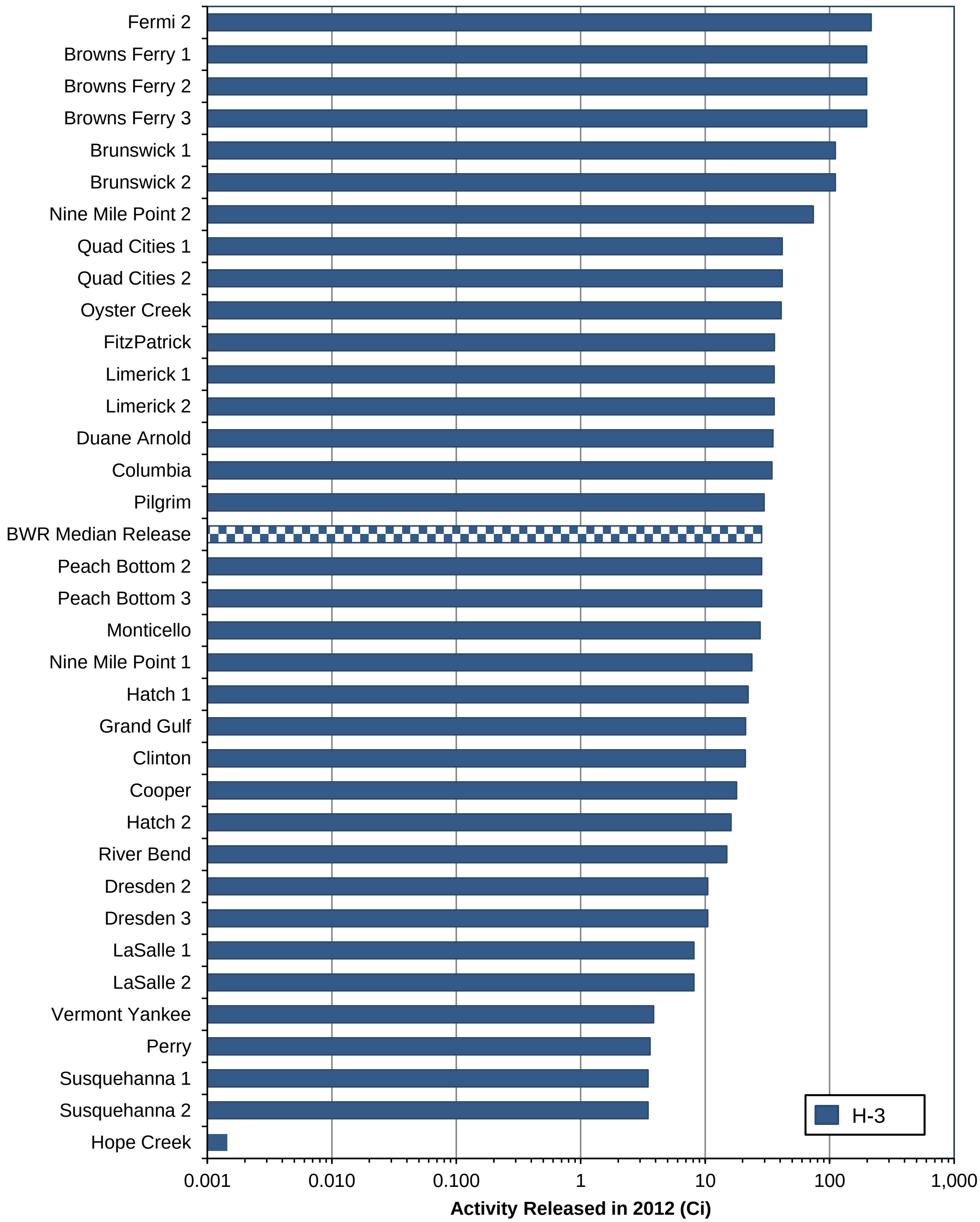


Figure 3.4 BWR Gaseous Releases — Tritium

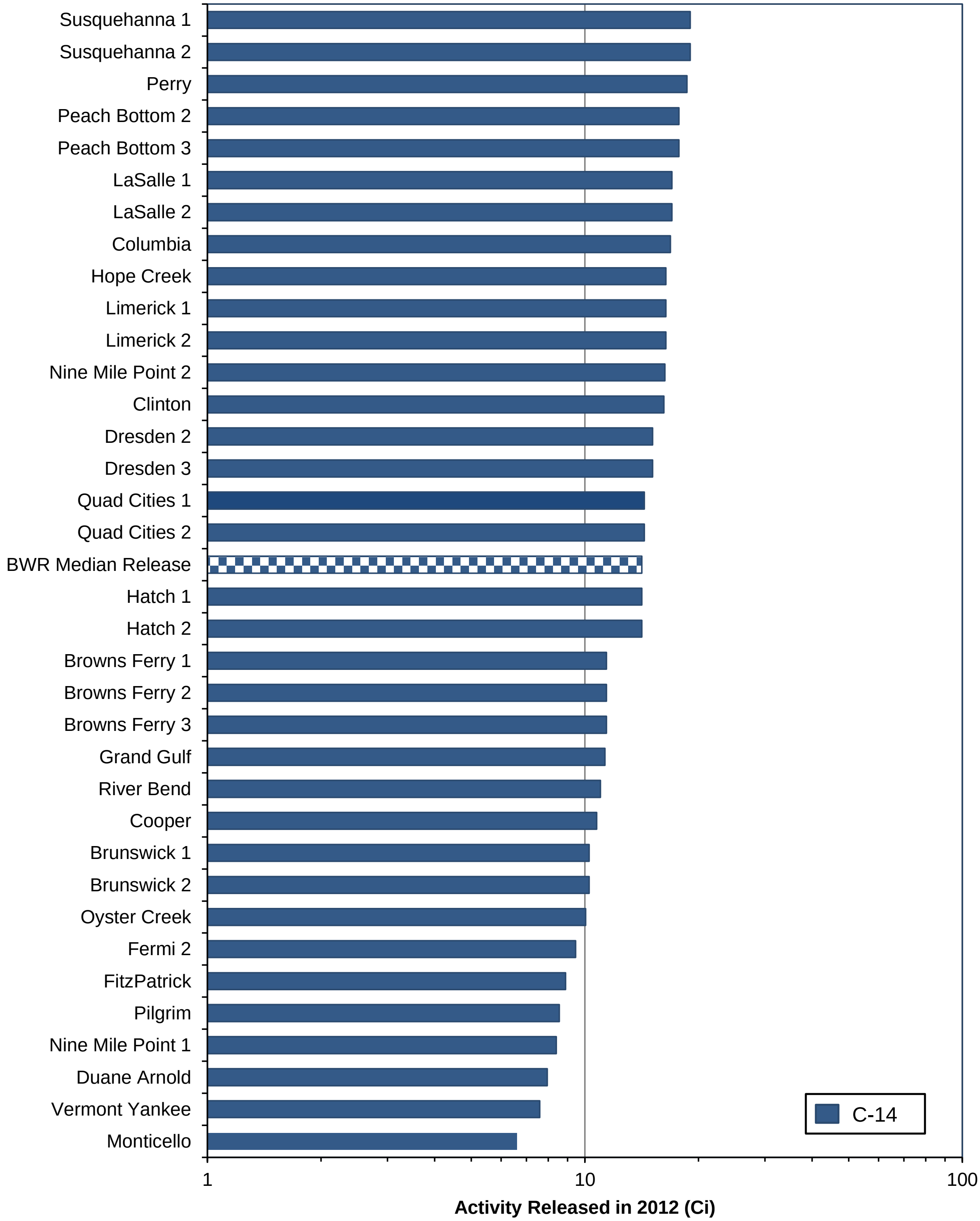
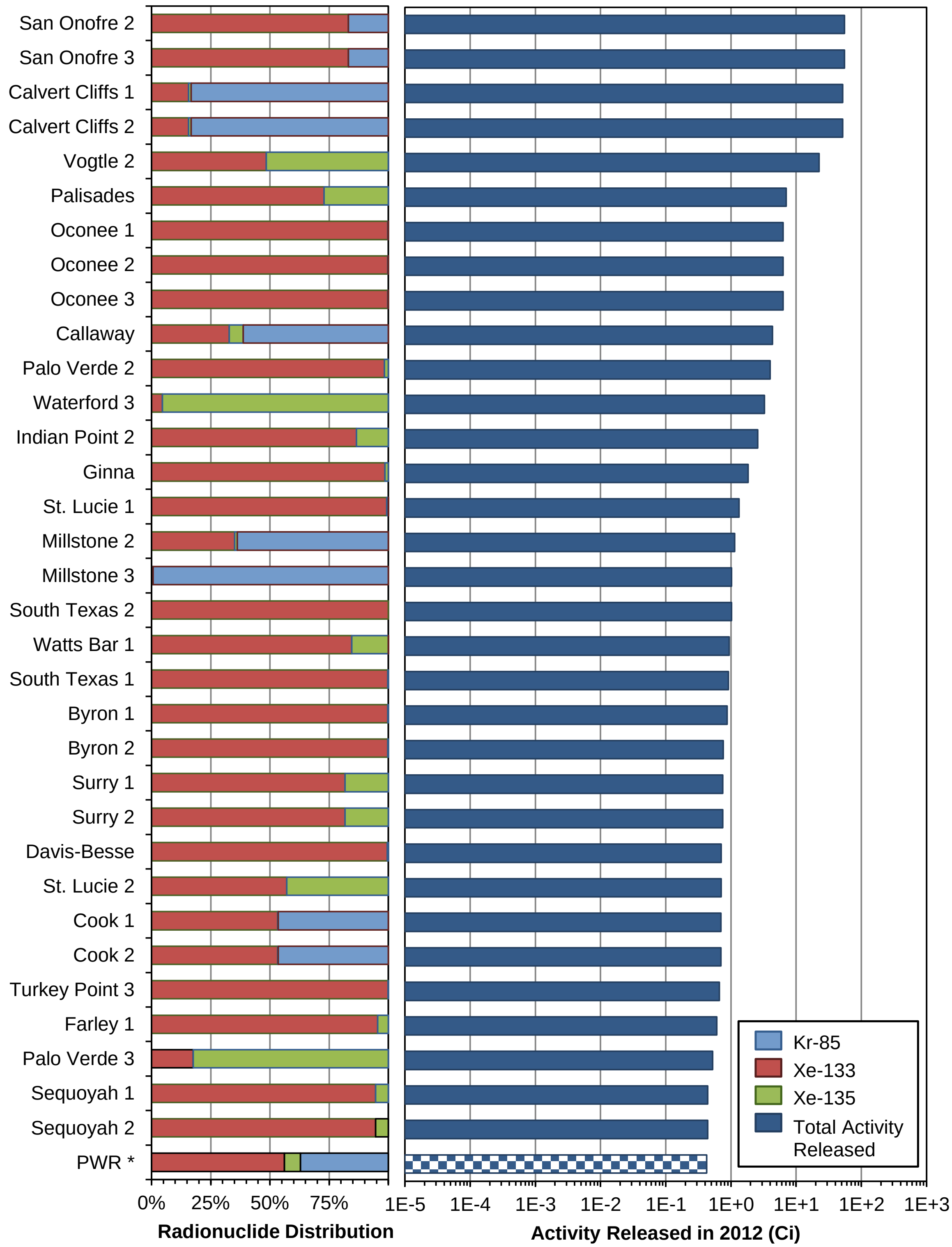
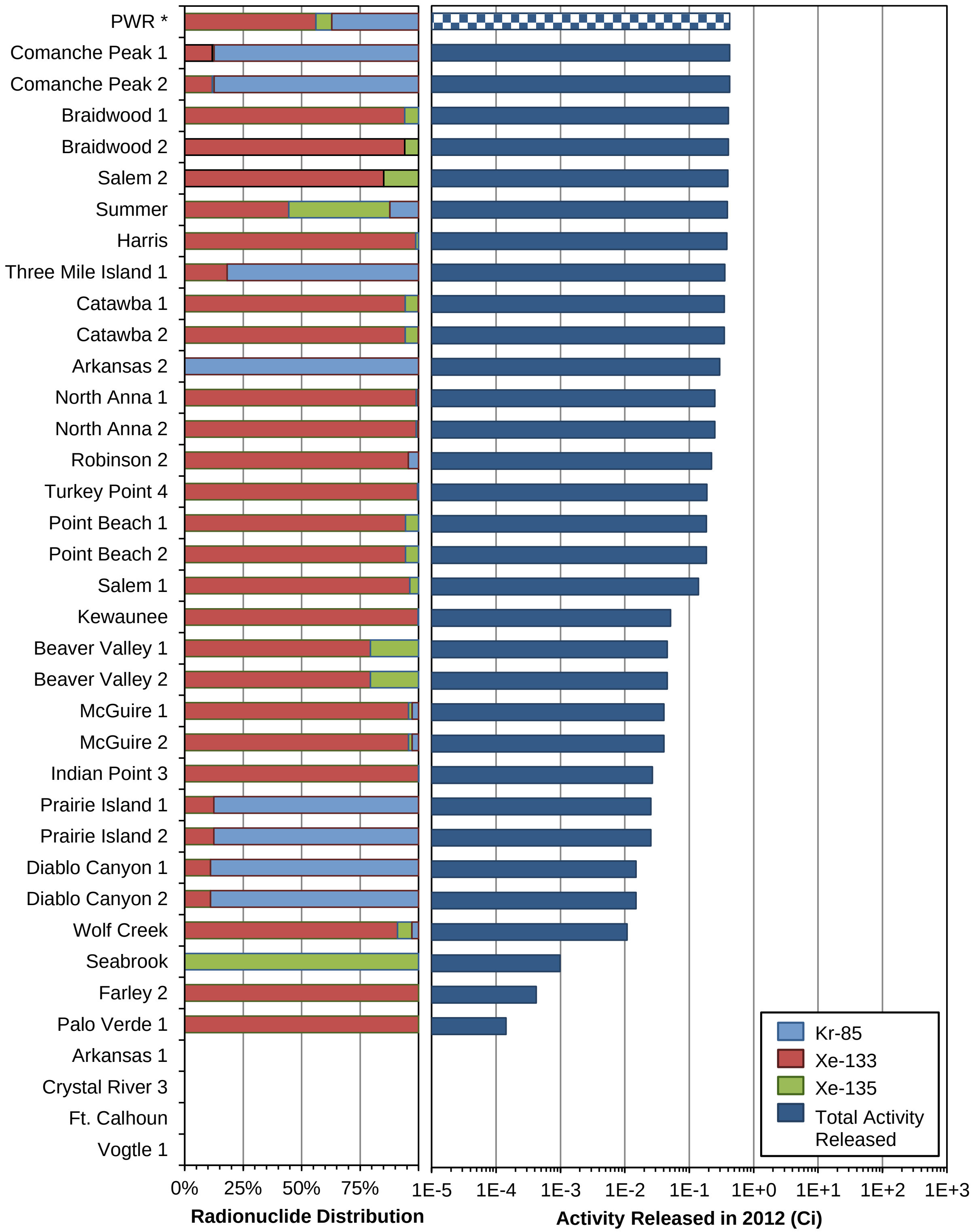


Figure 3.5 BWR Gaseous Releases — Carbon-14



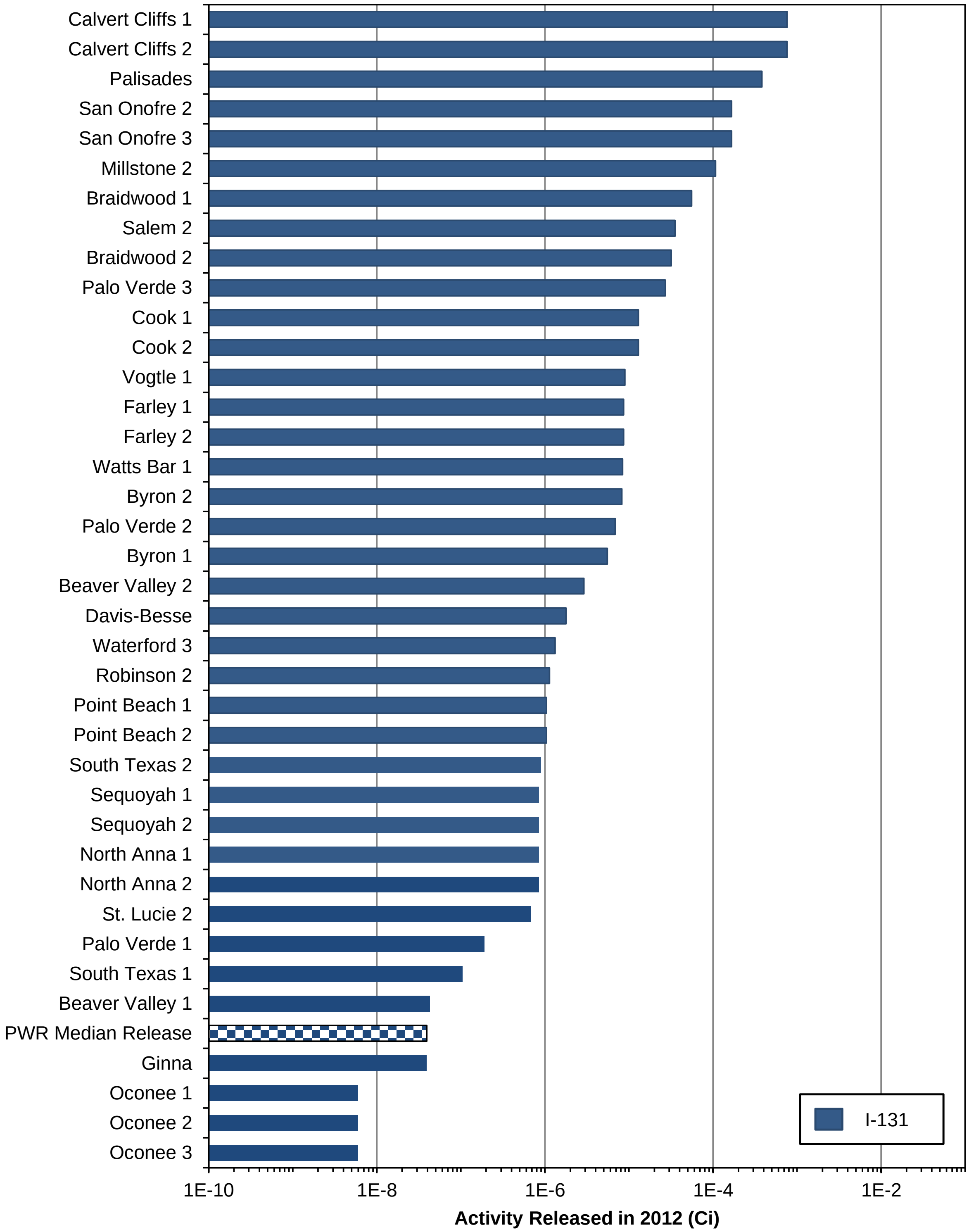
** PWR average radionuclide mix and median activity released.*

Figure 3.6 PWR Gaseous Releases — Fission and Activation Gases



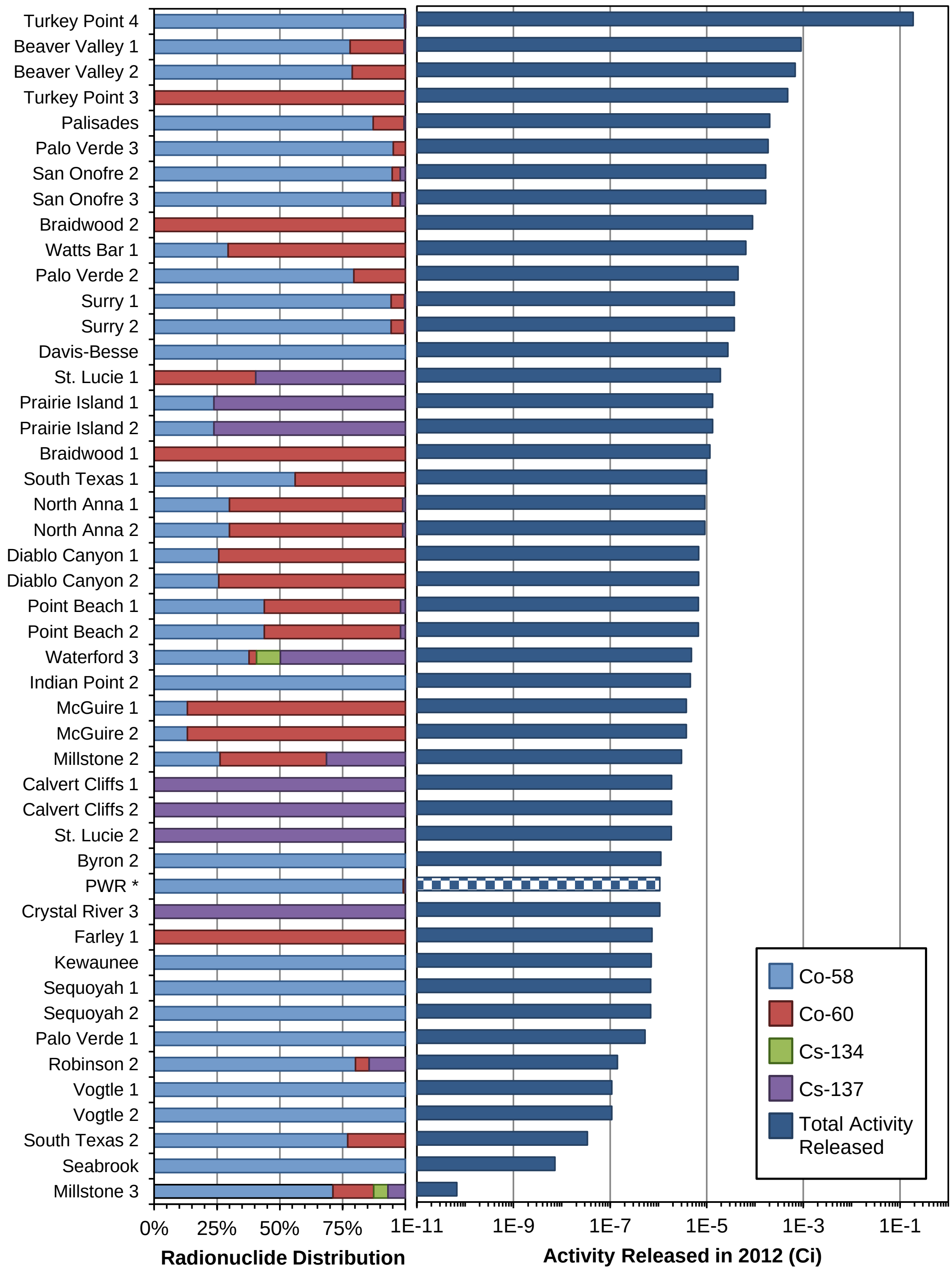
** PWR average radionuclide mix and median activity released.*

Figure 3.6 PWR Gaseous Releases — Fission and Activation Gases (continued)



Note: See Table 3.7 for list of nuclear power plants with no releases of iodine reported.

Figure 3.7 PWR Gaseous Releases — Iodine



Note: See Table 3.8 for list of nuclear power plants with no releases of selected particulates reported.
** PWR average radionuclide mix and median activity released.*

Figure 3.8 PWR Gaseous Releases — Particulates

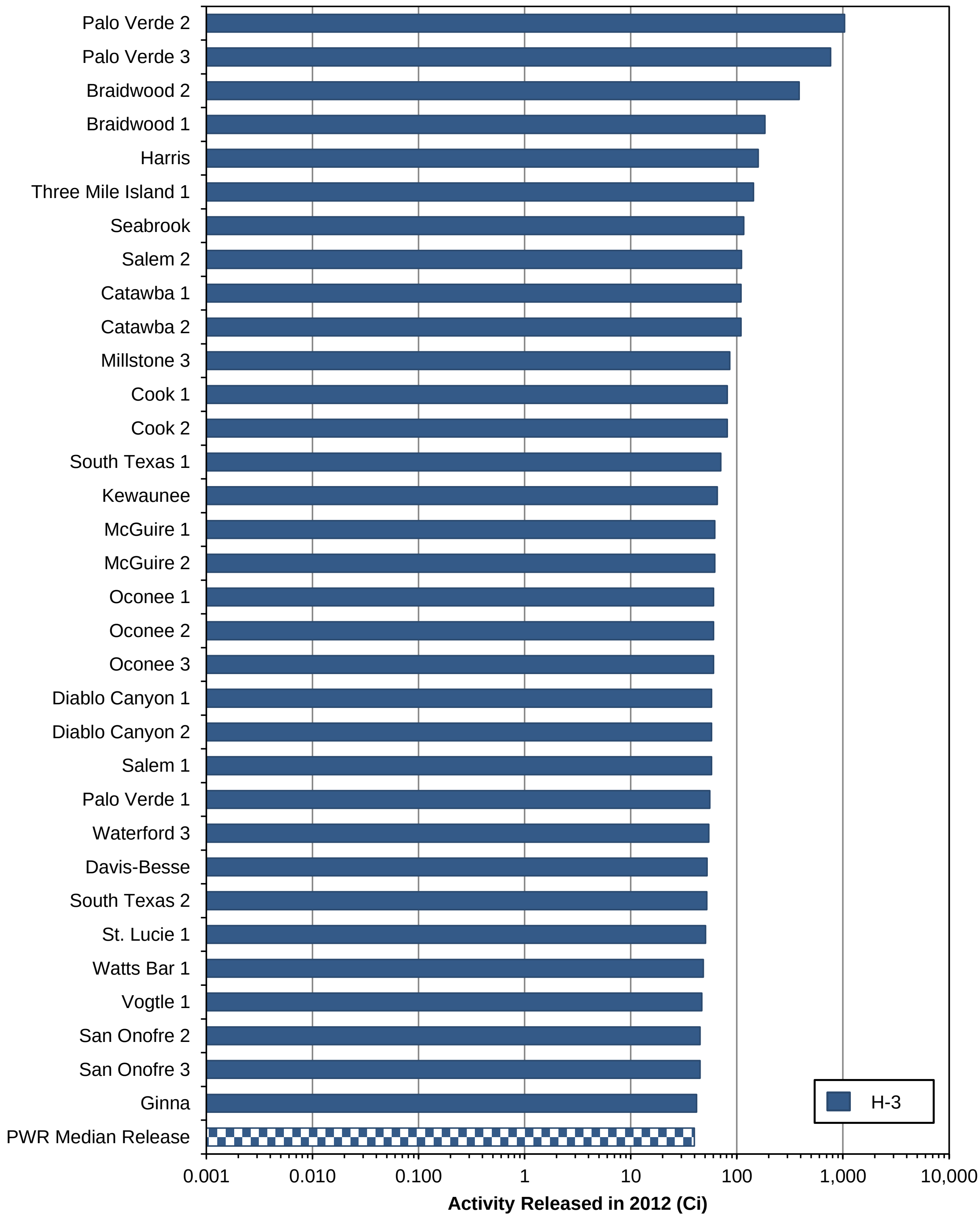


Figure 3.9 PWR Gaseous Releases — Tritium

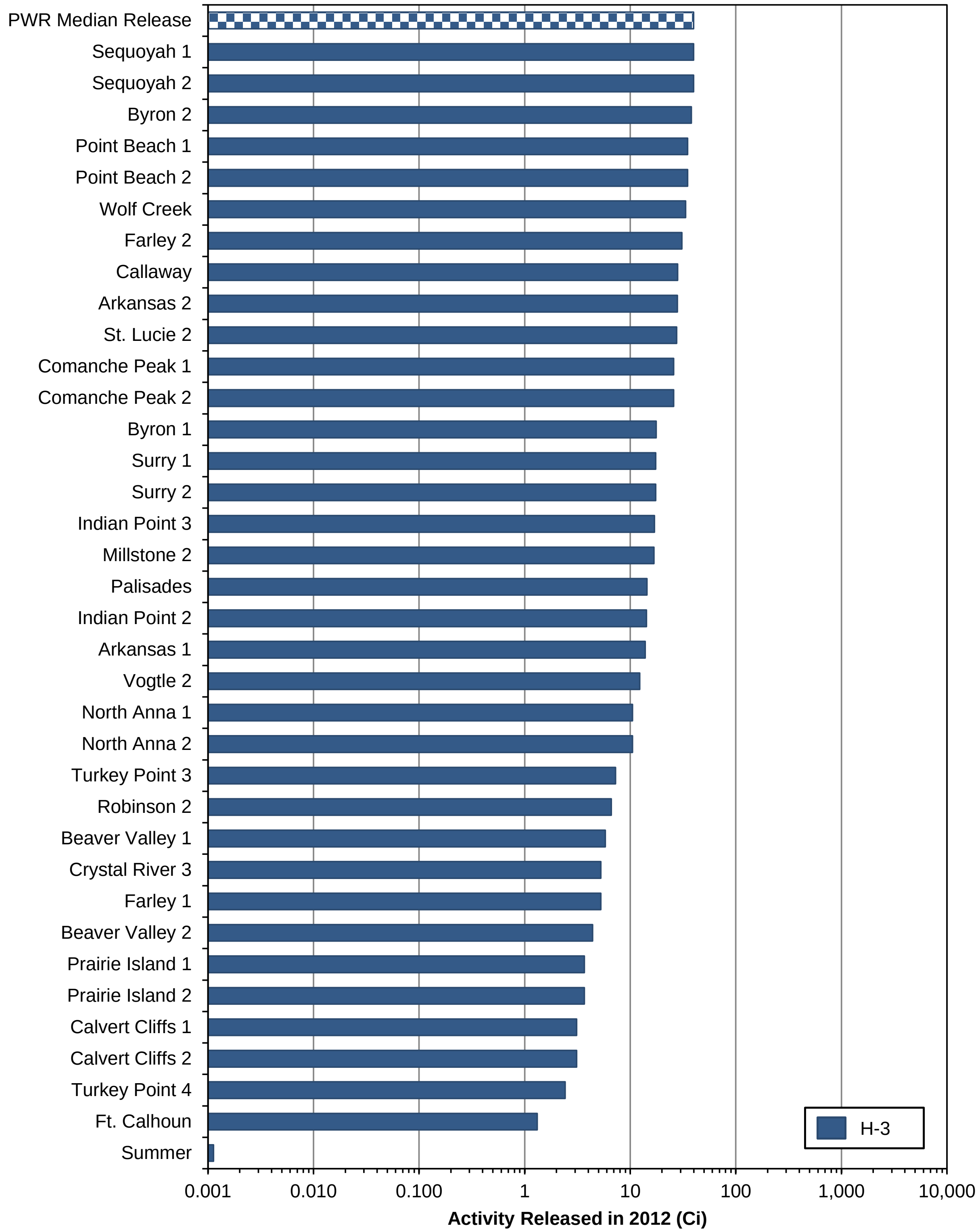


Figure 3.9 PWR Gaseous Releases — Tritium (continued)

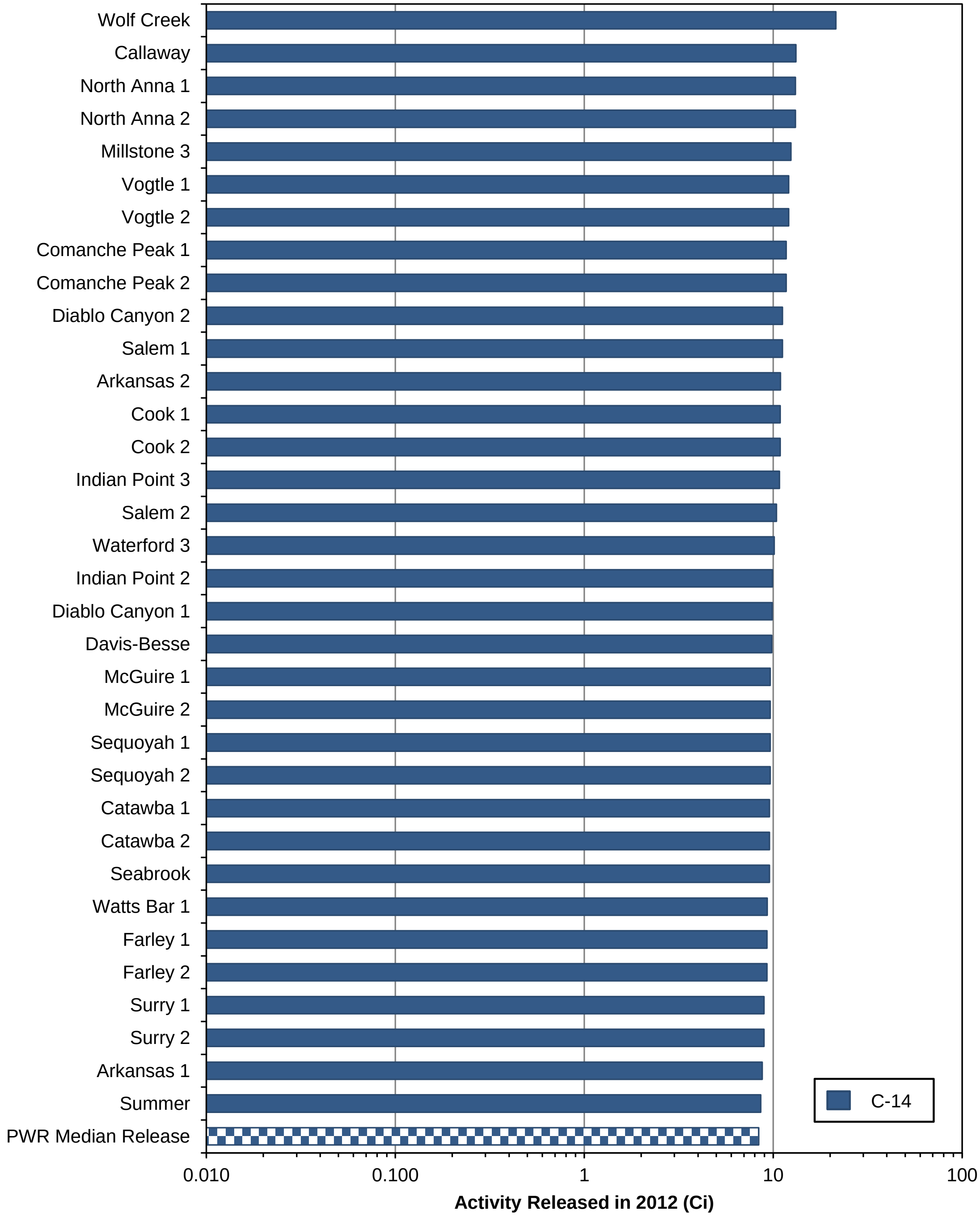


Figure 3.10 PWR Gaseous Releases — Carbon-14

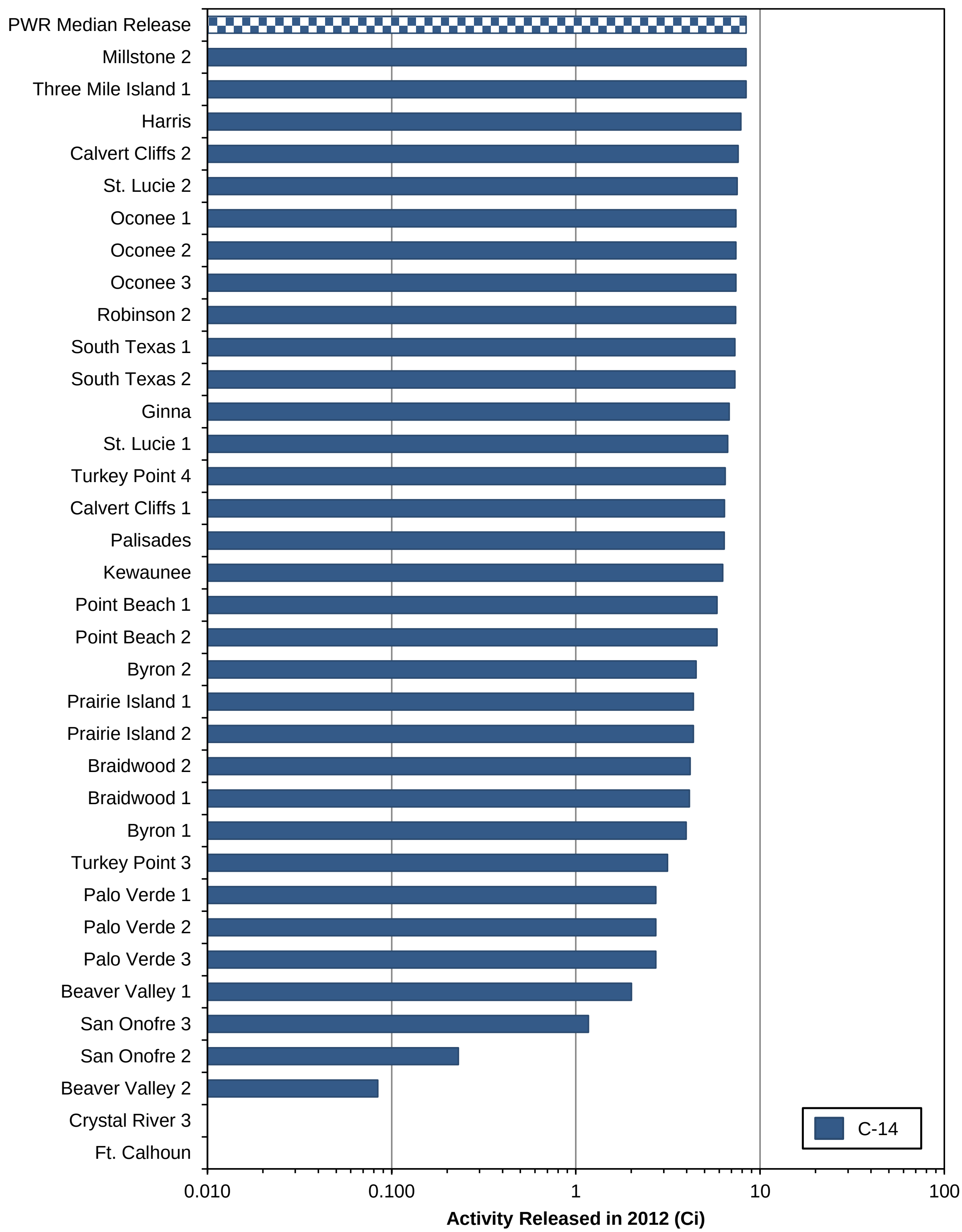
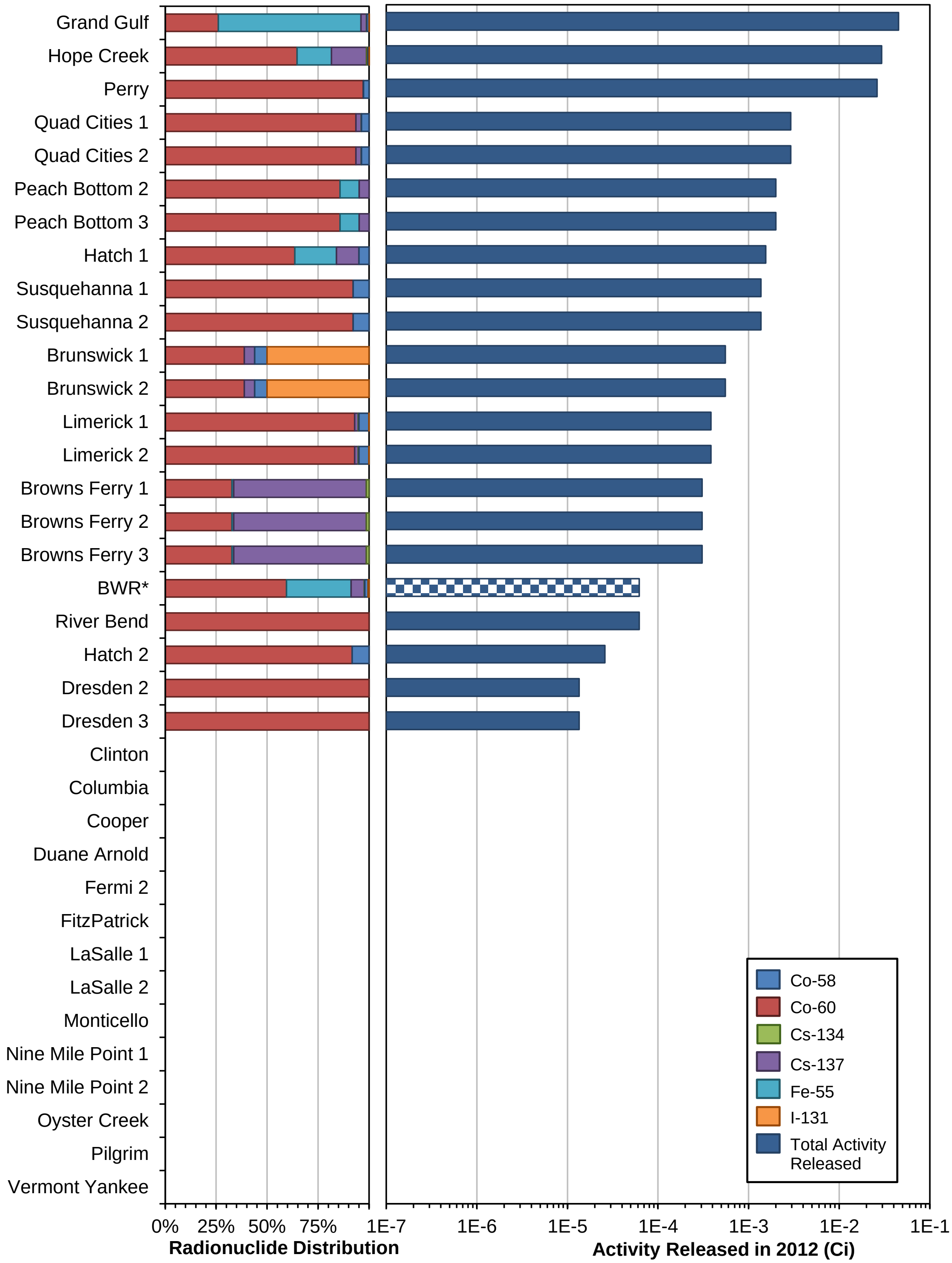


Figure 3.10 PWR Gaseous Releases — Carbon-14 (continued)



** BWR average radionuclide mix and median activity released.*

Figure 3.11 BWR Liquid Releases — Fission and Activation Products

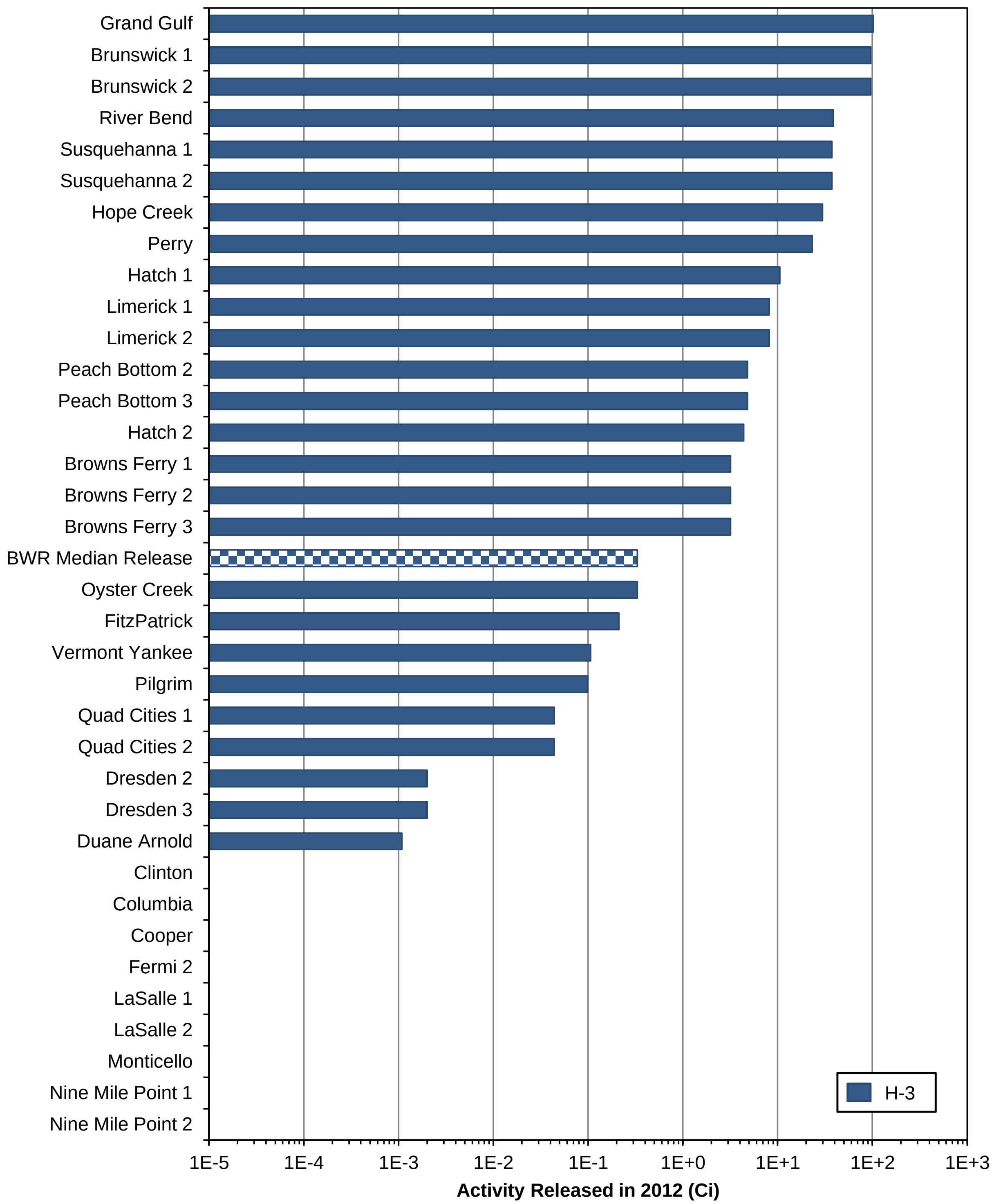
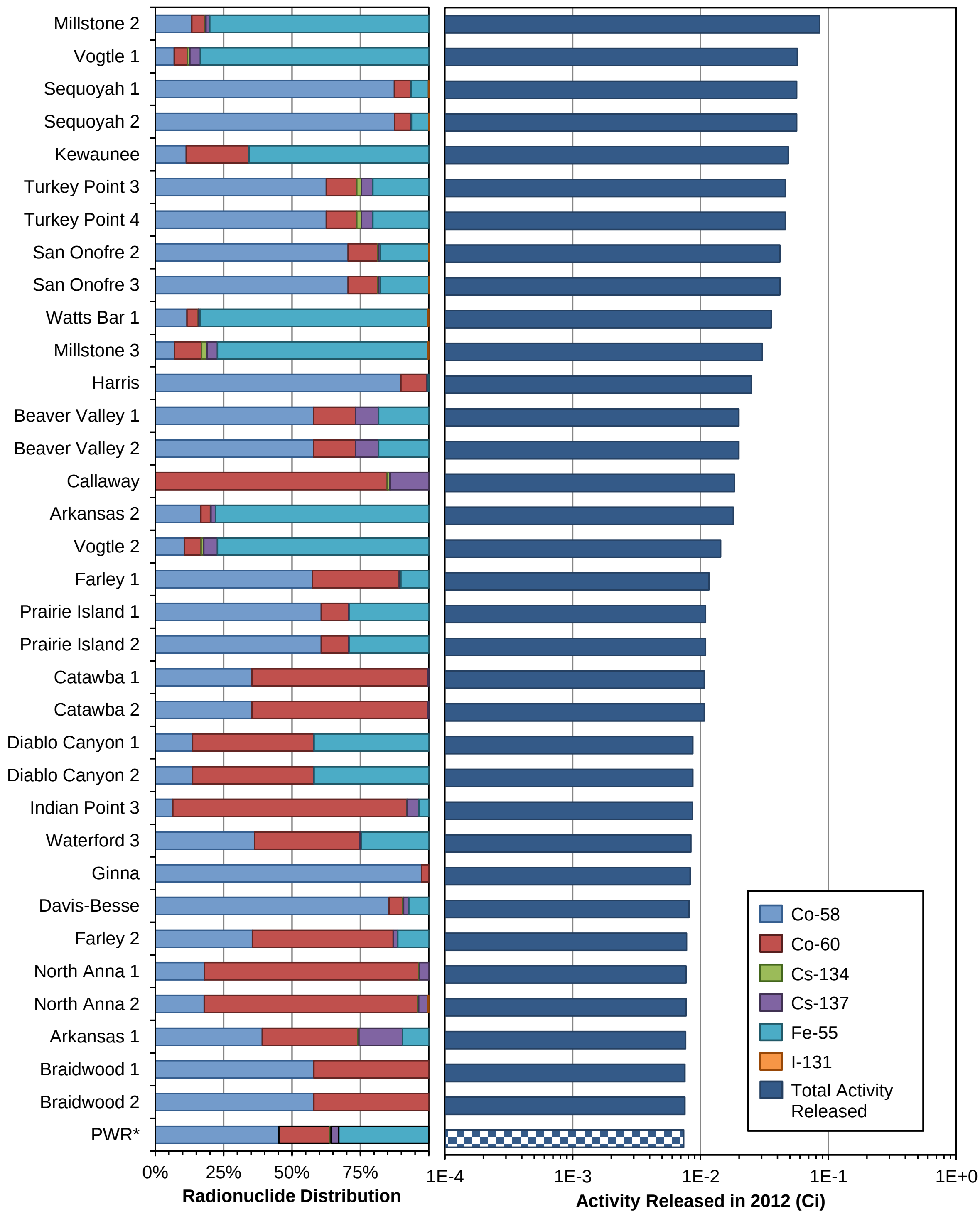
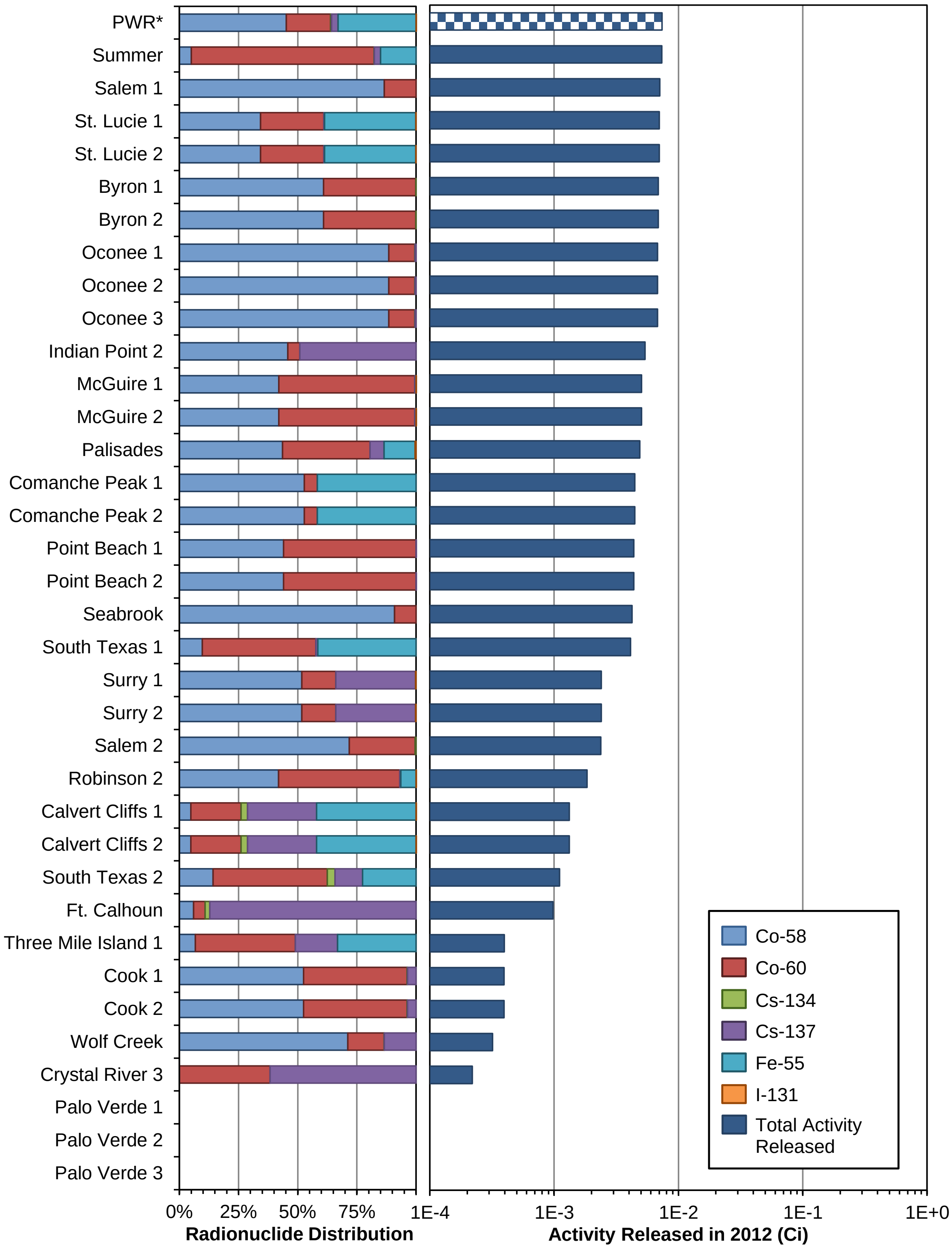


Figure 3.12 BWR Liquid Releases — Tritium



** PWR average radionuclide mix and median activity released.*

Figure 3.13 PWR Liquid Releases — Fission and Activation Products



** PWR average radionuclide mix and median activity released.*

Figure 3.13 PWR Liquid Releases — Fission and Activation Products (continued)

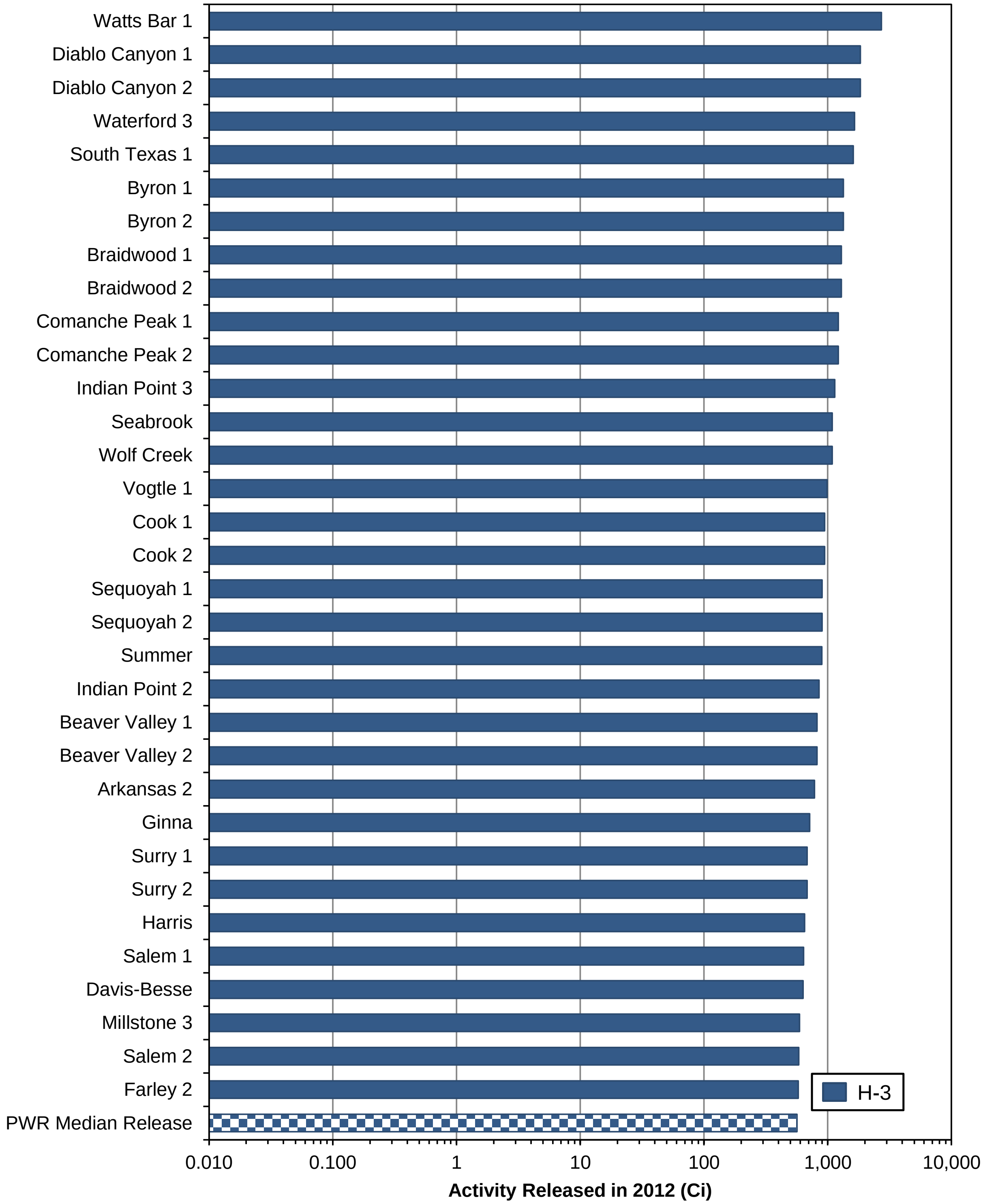


Figure 3.14 PWR Liquid Releases — Tritium

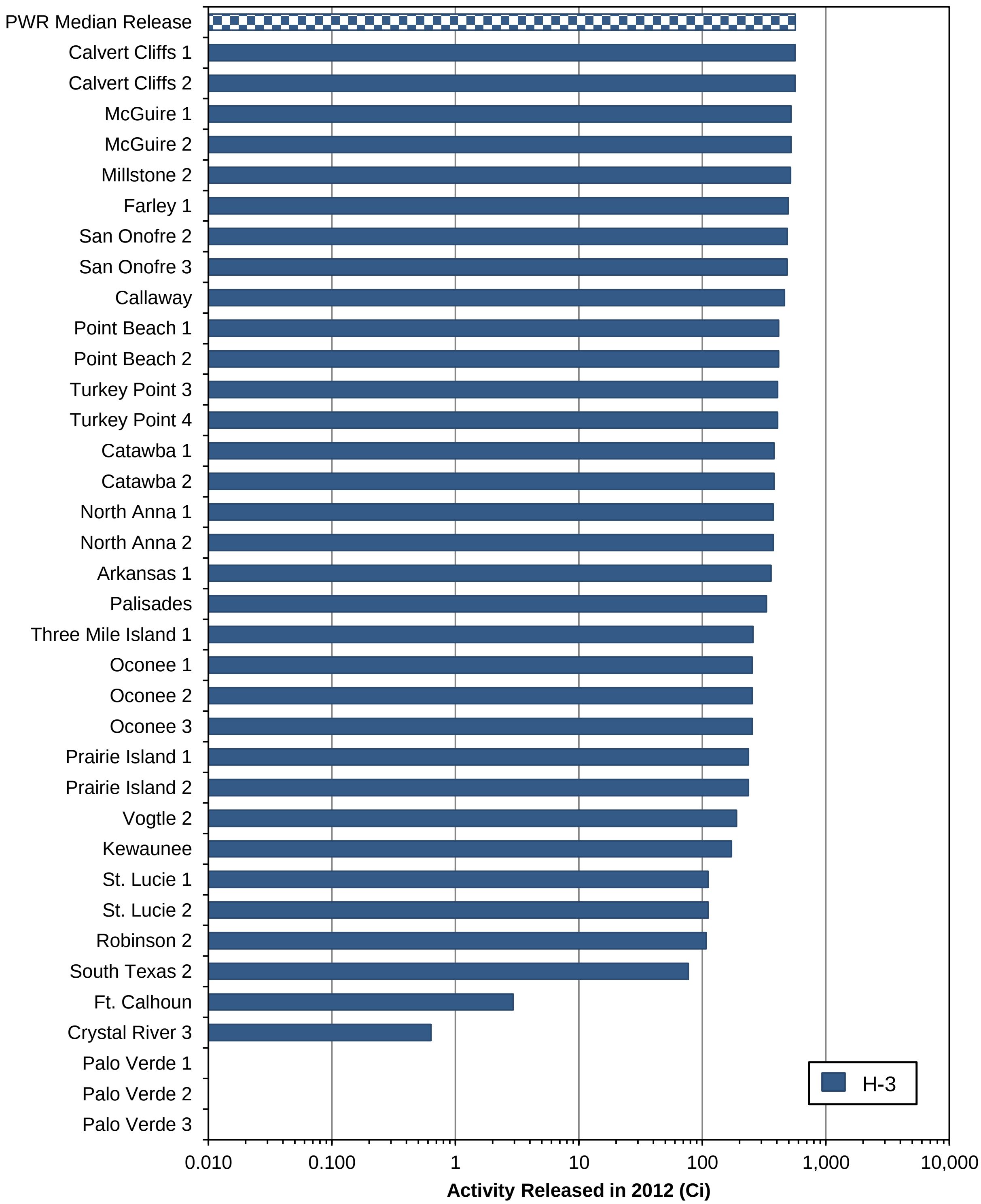


Figure 3.14 PWR Liquid Releases — Tritium (continued)

3.2 Short-Term Trend in Gaseous Effluents

In the previous section, only the significant radionuclides from each of the categories in Table 2.1 were shown in the tables and figures. Although particular focus on the significant radionuclides yields useful information, many less-significant radionuclides are typically present in radioactive gaseous effluents. This section provides the reader with information to gain a better understanding of the total releases of gaseous effluents from a facility.

A long-standing, historical measure of the licensee's ability to control gaseous effluents is based on the activities of noble gases discharged in gaseous effluents. This category of radionuclides—noble gases—is described in Table 2.1. The noble gases category includes all radionuclides in gaseous effluents except iodines, particulates, carbon-14 (C-14), and tritium. Although the doses from noble gases are generally small, the activity and doses from other radionuclides (such as iodines and mixed fission and activation products) will generally only be elevated if the activity of noble gases is elevated. As a result, a plant's total noble gas release is sometimes used as a primary indicator of fuel integrity and the quality of a plant's gaseous radiological effluent control program. The amount of C-14 released as a gaseous effluent is directly related to the amount of power produced rather than to the quality of a plant's effluent control program.

Tables 3.15 and 3.16 show the short-term trend in the total activity of all noble gases in gaseous effluents for the last 5 years for BWRs and PWRs, respectively. The facilities are listed in alphabetical order for ease of reference when searching for a site.

Table 3.15 shows that the discharges of noble gases from all BWRs in 2012 ranged from a low of 0 curies to a maximum of 1,840.5 curies, resulting in a median value of 61.5 curies. Table 3.16 shows that the discharge of noble gases from all PWRs in 2012 ranged from a low of 0 curies to a maximum of 197.8 curies, resulting in a median value of 1.1 curies.

Fluctuations in the short-term data are within the range of expected values, based on power production and the increasing sensitivity of measurement techniques. For example, a plant that has an extremely sensitive measurement capability is capable of detecting extremely low concentrations of noble gas. Due to the amount of air discharged from the ventilation system, the plant is likely to report a certain amount of noble gas released. Meanwhile, a plant with a slightly less sensitive measurement capability may not be detecting the same extremely low concentration of noble gas and thus may report a low or zero amount of noble gas discharged. Overall, the nuclear power industry has steadily reduced the amount of radioactivity discharged into the environment (see Section 3.3 for the long-term trend in gaseous effluents).

Table 3.15 Short-Term Trend in Noble Gases in Gaseous Effluents, BWRs, Curies (Ci)
Shown in Alphabetical Order

Facility	2008	2009	2010	2011	2012
Browns Ferry 1	0.0	0.0	0.0	0.0	231.0
Browns Ferry 2	0.0	0.0	0.0	0.0	231.0
Browns Ferry 3	0.0	0.0	0.0	0.0	231.0
Brunswick 1	846.0	348.5	224.5	139.7	88.3
Brunswick 2	846.0	348.5	224.5	139.7	88.3
Clinton	0.0	0.0	1.1	6.8	0.8
Columbia	91.4	90.0	186.3	75.2	67.3
Cooper	14.3	54.8	1.5	2.7	41.4
Dresden 2	82.1	30.7	25.3	15.9	34.5
Dresden 3	82.1	30.7	25.3	15.9	34.5
Duane Arnold	11.4	11.4	2.5	5.5	12.8
Fermi 2	15.4	14.4	17.5	3.2	4.8
FitzPatrick	188.9	53.0	101.8	43.1	61.2
Grand Gulf	443.3	182.0	518.9	446.4	452.5
Hatch 1	0.0	2.9	45.9	28.1	42.8
Hatch 2	0.0	2.9	75.2	23.4	42.9
Hope Creek	1.2	22.8	41.1	0.4	262.5
LaSalle 1	791.0	2,003.0	957.5	1,205.5	1,840.5
LaSalle 2	791.0	2,003.0	957.5	1,205.5	1,840.5
Limerick 1	36.7	14.1	27.1	93.3	35.8
Limerick 2	36.7	14.1	27.1	93.3	35.8
Monticello	1,059.0	1,503.0	1,484.0	958.0	797.0
Nine Mile Point 1	0.3	9.8	0.0	0.8	2.7
Nine Mile Point 2	359.4	447.7	406.3	339.2	104.2
Oyster Creek	7.6	15.4	398.9	226.3	209.1
Peach Bottom 2	303.5	511.0	386.5	288.0	259.5
Peach Bottom 3	303.5	511.0	386.5	288.0	259.5
Perry	2.4	1.2	2.6	0.2	103.0
Pilgrim	310.5	115.1	27.7	11.6	0.7
Quad Cities 1	85.6	85.8	200.8	139.9	61.5
Quad Cities 2	85.6	85.8	200.8	139.9	61.5
River Bend	204.2	99.2	120.5	83.4	34.4
Susquehanna 1	0.0	0.0	1.2	0.0	0.0
Susquehanna 2	0.0	0.0	1.2	0.0	0.0
Vermont Yankee	0.0	0.0	0.0	0.0	0.1
MEDIAN	**36.7**	**30.7**	**41.1**	**28.1**	**61.5**

Table 3.16 Short-Term Trend in Noble Gases in Gaseous Effluents, PWRs, Curies (Ci)
Shown in Alphabetical Order

Facility	2008	2009	2010	2011	2012
Arkansas 1	21.9	8.7	0.1	0.0	0.0
Arkansas 2	74.1	320.7	30.1	9.1	52.5
Beaver Valley 1	0.1	7.4	0.4	6.2	0.1
Beaver Valley 2	1.7	0.1	0.7	6.2	0.1
Braidwood 1	30.4	5.2	0.5	0.7	0.4
Braidwood 2	369.5	6.0	0.5	1.0	0.4
Byron 1	3.6	11.5	0.4	0.3	197.8
Byron 2	7.9	0.6	0.4	1.1	0.8
Callaway	110.6	209.6	165.6	19.6	4.5
Calvert Cliffs 1	331.5	134.4	101.7	47.3	53.3
Calvert Cliffs 2	331.5	134.4	101.7	47.3	53.3
Catawba 1	1.8	1.9	1.9	1.7	1.6
Catawba 2	1.8	1.9	1.9	1.7	1.6
Comanche Peak 1	498.5	2.5	1.9	18.7	0.7
Comanche Peak 2	498.5	2.5	1.9	18.7	0.7
Cook 1	18.5	2.7	3.2	1.3	1.6
Cook 2	18.5	2.7	3.2	1.3	1.6
Crystal River 3	3.3	0.1	0.0	0.0	0.0
Davis-Besse	27.0	178.3	112.2	1.4	0.8
Diablo Canyon 1	26.9	1.4	0.6	5.1	0.7
Diablo Canyon 2	26.9	1.4	0.6	5.1	0.7
Farley 1	27.2	17.8	42.3	3.4	5.1
Farley 2	5.9	16.4	8.6	3.1	1.2
Ft. Calhoun	3.8	3.5	2.0	0.8	0.0
Ginna	4.6	3.5	1.2	2.4	2.5
Harris	0.3	2.7	0.2	0.3	0.4
Indian Point 2	47.3	1.8	1.7	0.3	2.9
Indian Point 3	0.1	0.7	0.2	0.5	0.1
Kewaunee	0.1	0.1	0.0	0.1	0.1
McGuire 1	1.1	1.6	1.1	1.4	1.1
McGuire 2	1.1	1.6	1.1	1.4	1.1
Millstone 2	19.0	36.6	2.3	9.2	1.3
Millstone 3	61.8	9.4	28.2	4.2	1.0
North Anna 1	0.7	27.4	44.2	2.6	0.3
North Anna 2	0.7	27.4	44.2	2.6	0.3

Table 3.16 Short-Term Trend in Noble Gases in Gaseous Effluents, PWRs, Curies (Ci) (continued)
Shown in Alphabetical Order

Facility	2008	2009	2010	2011	2012
Oconee 1	5.9	6.9	15.8	9.9	6.3
Oconee 2	5.9	6.9	15.8	9.9	6.3
Oconee 3	5.9	6.9	15.8	9.9	6.3
Palisades	12.1	34.3	62.1	10.4	13.8
Palo Verde 1	0.9	9.9	0.8	1.1	0.2
Palo Verde 2	131.1	1.7	1.1	3.8	4.8
Palo Verde 3	0.3	23.5	0.7	4.2	15.5
Point Beach 1	0.6	0.5	0.7	3.1	0.5
Point Beach 2	0.6	0.5	0.7	3.1	0.5
Prairie Island 1	0.3	0.6	0.1	0.4	0.1
Prairie Island 2	0.3	0.6	0.1	0.4	0.1
Robinson 2	156.2	0.2	0.5	0.3	0.8
Salem 1	0.6	28.2	0.3	0.2	49.2
Salem 2	0.9	0.8	0.2	0.5	0.5
San Onofre 2	25.0	52.9	63.2	51.4	56.4
San Onofre 3	25.0	52.9	63.2	51.4	56.4
Seabrook	0.3	0.2	0.0	0.9	0.1
Sequoyah 1	4.7	2.4	2.5	1.6	2.0
Sequoyah 2	4.7	2.4	2.5	1.6	2.0
South Texas 1	15.4	3.9	2.7	6.5	2.5
South Texas 2	20.9	2.6	30.5	7.1	2.0
St. Lucie 1	7.9	1.7	22.3	29.5	3.3
St. Lucie 2	2.3	5.8	30.2	18.5	4.7
Summer	1.4	1.7	0.0	0.3	0.7
Surry 1	0.5	0.7	0.3	0.4	0.8
Surry 2	0.5	0.7	0.3	0.4	0.8
Three Mile Island 1	0.4	2.2	6.1	115.7	0.7
Turkey Point 3	60.0	162.2	0.7	0.6	1.8
Turkey Point 4	52.8	126.2	0.7	0.6	0.2
Vogtle 1	1.3	270.0	1.0	2.8	0.7
Vogtle 2	645.1	760.1	216.6	56.5	22.8
Waterford 3	525.6	3560.2	0.0	7.4	3.6
Watts Bar 1	3.8	5.4	7.4	5.6	50.6
Wolf Creek	0.9	0.9	0.6	0.7	0.4
MEDIAN	**5.9**	**3.5**	**1.2**	**2.6**	**1.1**

3.3 Long-Term Trend in Gaseous Effluents

This section discusses the long-term trend of noble gases in gaseous effluents from nuclear power plants in the United States.

NRC regulations require radioactive effluents to be ALARA. As a result of improved radioactive effluent control programs, the amount of activity of radioactive effluents has steadily decreased over time. The trend in the median noble gas activity of gaseous effluents since 1975 is shown in Figure 3.15. All power reactors that have operated in the United States are included, some of which are now shut down.

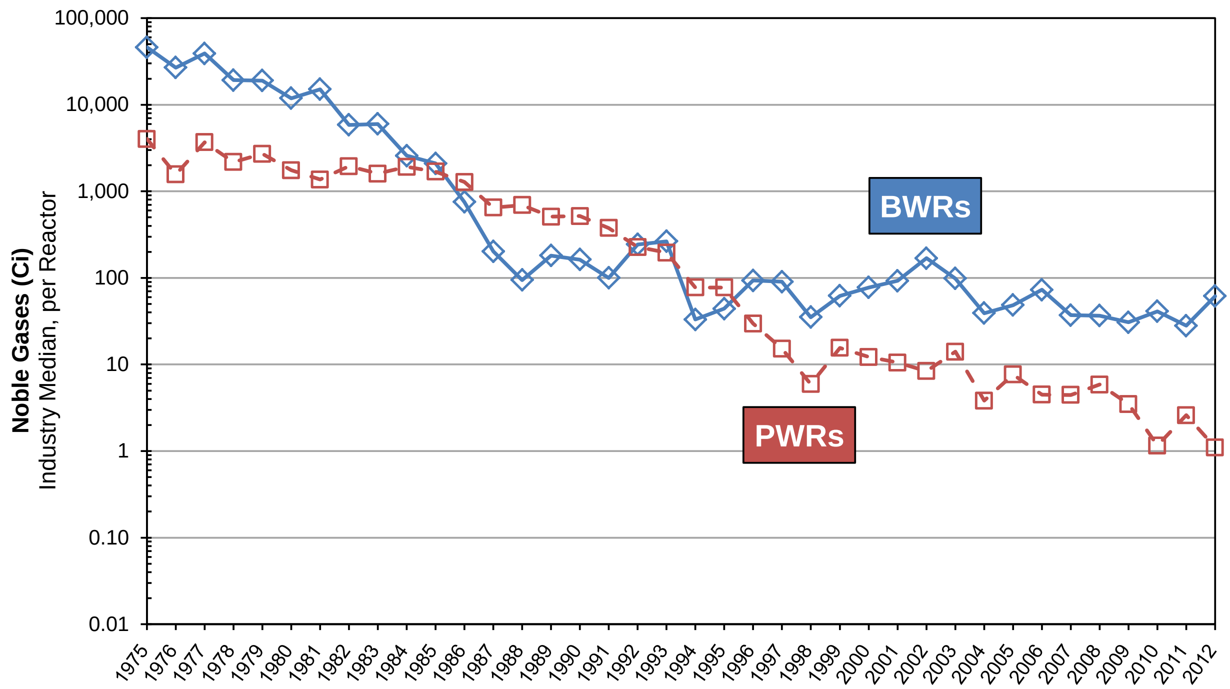


Figure 3.15 Long-Term Trend in Noble Gases in Gaseous Effluents

Figure 3.15 indicates a long-term, downward trend in the amount of noble gases in gaseous effluents from both BWRs and PWRs. The magnitude of the reduction is significant. For example, in 1975, the median release for BWRs was greater than 40,000 curies; however, in 2012, the median was 61.5 curies. That change corresponds to a 99.8 percent reduction in noble gas effluents over the last 37 years.

One of the primary contributors to the reduction in noble gas effluents is improved fuel integrity in both BWRs and PWRs. The use of advanced off-gas systems in BWRs is also responsible for reductions in the BWR industry averages. Lastly, contributions from the operations, maintenance, chemistry, and health physics departments at the various facilities have improved the handling and processing of gaseous waste to further improve and optimize effluent performance.

3.4 Short-Term Trend in Liquid Effluents

In Section 3.1, only the significant radionuclides discharged in liquid and gaseous effluents were shown in the tables and figures. Although particular focus on the significant radionuclides yields useful information, many other radionuclides are typically present in radioactive liquid effluents. This section provides the reader with a tool to gain a better understanding of the total releases of liquid effluents from a facility.

An indicator of the licensee's ability to control liquid effluents is based on the activity of the mixed fission and activation products (MFAPs) discharged in liquid effluents. This category of radionuclides—MFAPs—is described in Table 2.2. It includes all radionuclides in liquid effluents except tritium, C-14, noble gases, and gross alpha activity. MFAPs can be effectively reduced by liquid radioactive waste treatment systems installed in each NPP. As a result, MFAPs are sometimes used as a primary indicator of the overall control and handling of radioactive liquid effluents at a site.

Tables 3.17 and 3.18 show the short-term trend in MFAPs in liquid effluents for BWRs and PWRs, respectively. In these tables, no MFAP radionuclides are left out. For each reactor unit, the activities of all MFAPs are added together. In this way, the yearly total of all MFAPs in liquid effluents from a reactor are represented by a single number. That number gives the total activity (as millicuries) of MFAPs discharged in liquid effluents at each reactor for each of the years listed.

The facilities are listed in alphabetical order for ease of reference when searching for a site. Fluctuations in these short-term data are within the range of expected values, based on power production and the increasing sensitivity of measurement techniques. Overall, the nuclear power industry has steadily reduced the amount of radioactivity discharged into the environment (see Section 3.5 for the long-term trend in liquid effluents).

Table 3.17 Short-Term Trend in Mixed Fission and Activation Products in Liquid Effluents, BWRs, millicuries (mCi)

Shown in Alphabetical Order

Facility	2008	2009	2010	2011	2012
Browns Ferry 1	3.8	17.0	6.1	4.9	26.0
Browns Ferry 2	3.8	203.0	6.1	4.9	26.0
Browns Ferry 3	3.8	34,600.0[1]	3,810.0[1]	4.9	26.0
Brunswick 1	4.0	5.8	2.2	2.2	1.3
Brunswick 2	4.0	5.8	2.2	2.2	1.3
Clinton	0.0	0.0	0.0	0.0	0.0
Columbia	0.0	0.0	0.0	0.0	0.0
Cooper	4.7	0.4	3.6	7.9	0.0
Dresden 2	0.1	2.8	0.0	0.0	0.0
Dresden 3	0.1	2.8	0.0	0.0	0.0
Duane Arnold	0.0	0.0	0.9	0.0	0.0
Fermi 2	0.0	0.0	0.0	0.0	0.0
FitzPatrick	0.0	0.0	0.0	0.0	0.0
Grand Gulf	371.0	62.0	15.2	26.6	83.8
Hatch 1	23.9	2.8	1.4	1.3	2.6
Hatch 2	8.3	3.1	4.2	1.3	0.4
Hope Creek	16.6	57.5	70.3	31.0	31.9
LaSalle 1	0.0	0.0	0.0	0.0	0.0
LaSalle 2	0.0	0.0	0.0	0.0	0.0
Limerick 1	34.7	2.0	1.3	0.7	0.6
Limerick 2	34.7	2.0	1.3	0.7	0.6
Monticello	0.0	0.0	0.0	0.0	0.0
Nine Mile Point 1	0.0	0.4	0.0	0.0	0.0
Nine Mile Point 2	3.1	0.0	0.3	0.0	0.0
Oyster Creek	0.0	0.0	0.0	0.0	0.0
Peach Bottom 2	127.3	63.8	35.1	0.1	2.8
Peach Bottom 3	127.3	63.8	35.1	0.1	2.8
Perry	14.7	23.7	9.6	37.4	32.9
Pilgrim	0.0	1.4	36.9	3.8	0.0
Quad Cities 1	0.9	4.2	10.8	4.3	3.6
Quad Cities 2	0.9	4.2	10.8	4.3	3.6
River Bend	8.7	1.1	0.5	0.5	0.1
Susquehanna 1	1.2	4.4	55.8	11.4	1.8
Susquehanna 2	1.2	4.4	55.8	11.4	1.8
Vermont Yankee	0.0	0.0	0.0	0.0	0.0
MEDIAN	**1.2**	**2.8**	**1.4**	**0.7**	**0.4**

[1] Browns Ferry had a condensate leak which resulted in a discharge of a short-lived (less than 2 hours) radionuclide Fluorine-18, causing minor amounts of public dose.

Table 3.18 Short-Term Trend in Mixed Fission and Activation Products in Liquid Effluents, PWRs, millicuries (mCi)
Shown in Alphabetical Order

Facility	2008	2009	2010	2011	2012
Arkansas 1	43.0	21.2	60.4	59.6	11.3
Arkansas 2	47.2	50.2	13.1	38.2	24.4
Beaver Valley 1	198.9	110.2	57.5	50.9	26.1
Beaver Valley 2	198.9	110.2	57.5	50.9	26.1
Braidwood 1	51.6	136.0	13.5	67.2	541.7
Braidwood 2	51.6	136.0	13.5	67.2	541.7
Byron 1	0.0	11.1	5.5	12.6	9.0
Byron 2	0.0	11.1	5.5	12.6	9.0
Callaway	253.7	70.2	209.8	138.0	90.2
Calvert Cliffs 1	40.5	13.1	71.6	5.9	1.7
Calvert Cliffs 2	40.5	13.1	71.6	5.9	1.7
Catawba 1	22.2	34.4	19.6	34.0	13.9
Catawba 2	22.2	34.4	19.6	34.0	13.9
Comanche Peak 1	7.6	1.9	8.2	3.3	6.9
Comanche Peak 2	7.6	1.9	8.2	3.3	6.9
Cook 1	4.5	1.7	2.7	0.3	0.7
Cook 2	4.5	1.7	2.7	0.3	0.7
Crystal River 3	7.4	30.5	14.2	3.1	0.3
Davis-Besse	16.2	12.7	39.9	11.4	15.4
Diablo Canyon 1	14.5	21.6	24.3	16.8	16.4
Diablo Canyon 2	14.5	21.6	24.3	16.8	16.4
Farley 1	17.5	10.9	44.4	54.3	87.9
Farley 2	33.8	19.2	53.5	126.8	76.1
Ft. Calhoun	11.0	2.7	2.0	2.0	1.1
Ginna	5.1	4.7	1.3	6.0	9.2
Harris	19.8	15.7	12.9	12.9	32.0
Indian Point 2	54.6	37.3	56.2	16.4	26.5
Indian Point 3	14.3	25.3	10.6	23.3	20.8
Kewaunee	22.8	11.4	13.8	27.5	69.3
McGuire 1	57.5	17.4	22.4	45.0	11.0
McGuire 2	57.5	17.4	22.4	45.0	11.0
Millstone 2	112.8	84.2	17.3	130.2	112.1
Millstone 3	80.4	33.7	76.8	76.5	52.6
North Anna 1	61.3	12.2	3.7	5.7	8.0
North Anna 2	61.3	12.2	3.7	5.7	8.0

Table 3.18 Short-Term Trend in Mixed Fission and Activation Products in Liquid Effluents, PWRs, millicuries (mCi) (continued)
Shown in Alphabetical Order

Facility	2008	2009	2010	2011	2012
Oconee 1	7.0	8.5	15.1	15.3	8.6
Oconee 2	7.0	8.5	15.1	15.3	8.6
Oconee 3	7.0	8.5	15.1	15.3	8.6
Palisades	17.6	217.3	61.5	20.7	11.3
Palo Verde 1	0.0	0.0	0.0	0.0	0.0
Palo Verde 2	0.0	0.0	0.0	0.0	0.0
Palo Verde 3	0.0	0.0	0.0	0.0	0.0
Point Beach 1	60.1	48.3	38.9	0.0	0.0
Point Beach 2	60.1	48.3	38.9	0.0	0.0
Prairie Island 1	380.8	203.6	137.8	31.8	17.0
Prairie Island 2	380.8	203.6	137.8	31.8	17.0
Robinson 2	11.7	2.9	13.8	2.9	4.6
Salem 1	19.0	18.1	41.3	21.7	9.9
Salem 2	9.5	5.9	18.9	13.9	13.5
San Onofre 2	20.0	8.9	15.8	6.2	57.3
San Onofre 3	20.0	8.9	15.8	6.2	57.3
Seabrook	24.4	10.9	15.4	16.5	7.3
Sequoyah 1	40.8	10.2	12.8	7.6	58.4
Sequoyah 2	40.8	10.2	12.8	7.6	58.4
South Texas 1	9.6	14.8	11.9	15.3	8.9
South Texas 2	12.9	8.1	14.6	16.0	2.8
St. Lucie 1	14.3	66.9	67.6	87.0	37.4
St. Lucie 2	14.3	66.9	67.6	87.0	37.4
Summer	22.9	14.6	14.2	11.7	14.6
Surry 1	14.0	11.0	5.1	9.8	2.9
Surry 2	14.0	11.0	5.1	9.8	2.9
Three Mile Island 1	0.2	0.3	0.2	0.6	0.4
Turkey Point 3	58.8	82.0	32.2	25.8	75.2
Turkey Point 4	58.8	82.0	32.2	25.8	75.2
Vogtle 1	31.0	9.9	37.7	101.3	106.6
Vogtle 2	50.8	37.7	14.1	6.6	29.9
Waterford 3	23.8	32.3	6.6	17.4	10.8
Watts Bar 1	50.8	88.8	48.0	267.5	38.6
Wolf Creek	105.1	46.8	11.3	4.5	9.0
MEDIAN	**22.2**	**14.8**	**15.1**	**15.3**	**11.3**

3.5 Long-Term Trend in Liquid Effluents

This section discusses the long-term trend of MFAPs in liquid effluents from nuclear power plants in the United States. NRC regulations require radioactive effluents to be ALARA. As a result of improved radioactive effluent control programs, the amount of activity of radioactive effluents has steadily decreased over time. The trend in the median MFAP activity of liquid effluents since 1975 is shown in Figure 3.16. All power reactors that have operated in the United States are included, some of which are now shut down.

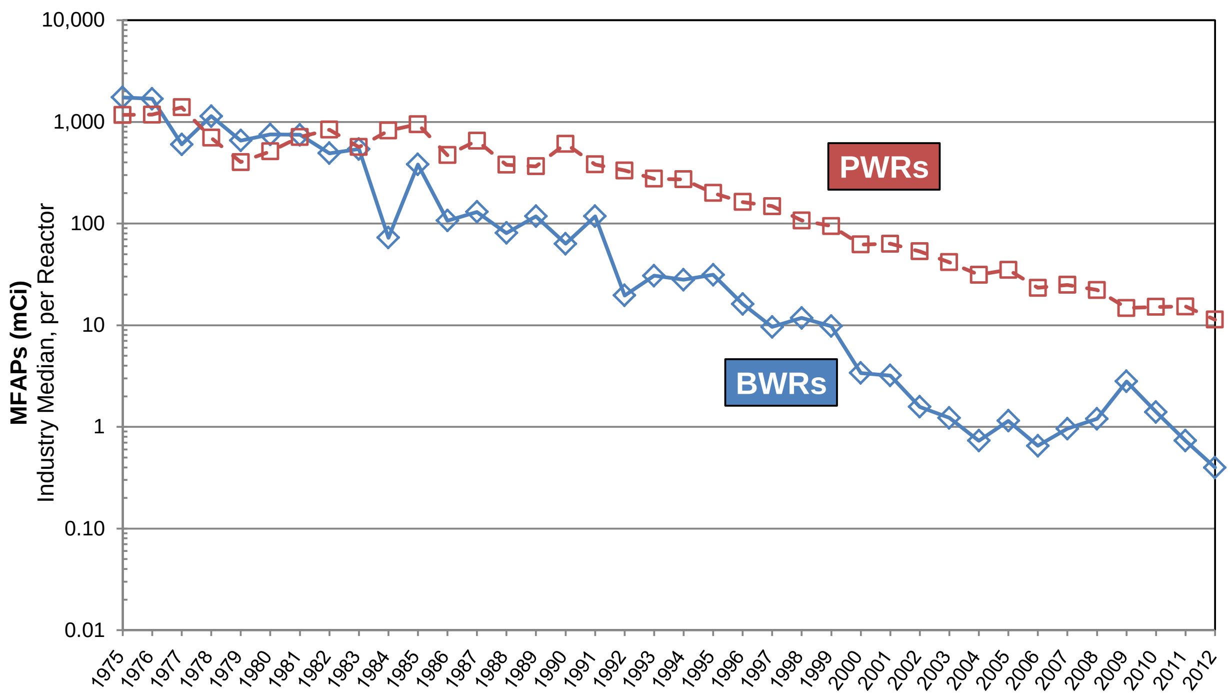


Figure 3.16 Long-Term Trend in MFAPs in Liquid Effluents

Figure 3.16 indicates a long-term, downward trend in the amounts of MFAPs in liquid effluents from both BWRs and PWRs. The magnitude of the reduction is significant. For example, in 1975, the median activity of liquid effluents from BWRs was greater than 1,100 millicuries; however, in 2012, the median was 0.4 millicuries. That corresponds to a 99.9 percent reduction in MFAPs in liquid effluents over the last 37 years.

One of the primary contributors to the reduction in liquid effluents is improved fuel integrity in both BWRs and PWRs. Additionally, many BWRs recycle (or re-use) some or all of the reactor water. The recycling of reactor water at BWRs is one reason why effluents from BWRs are generally lower than from PWRs. The PWR design requires the use of boron in the reactor water, which makes water reuse impractical, whereas BWRs do not use boron in reactor water. The lack of boron in BWR reactor water allows the BWRs to recycle (or re-use) reactor water which contributes to lower liquid releases in BWRs, particularly for tritium. The use of advanced liquid radioactive waste processing systems has also significantly lowered liquid effluents. Lastly, improvements in the handling and processing of liquid waste made by the operations, maintenance, chemistry, and health physics departments at the various facilities have further reduced the amount of effluent releases and public dose.

Figure 3.16 shows that from 2005 to 2009, there was a small increase in the median liquid effluents from BWRs. An analysis of this increase in median MFAP activity of liquid effluents from BWRs indicates a small change in the control of liquid effluents at some BWRs. For many decades, some BWRs have embraced a zero-release strategy for radioactive liquid effluents. Such a strategy has cost advantages, because it is expensive to discharge very high-quality water that could be reused in plant systems. Additionally, a zero-release strategy conserves the natural resources and virtually eliminates radioactive liquid effluents in those BWRs that adopt this strategy.

The zero-release strategy is partly responsible for the decreases in the median MFAP liquid activity releases during the 1980s, 1990s, and beyond 2000, which can be seen in Figure 3.16. This strategy can be very effective in reducing the amount of liquid activity. However, within the last 10 years, it was recognized that at some sites using a zero-release strategy, releasing tritium as a gaseous release (rather than as a liquid effluent release) has the potential to increase doses to members of the public. This relative increase in public exposure, due to release of tritium as a gaseous release instead of as a liquid release, can be attributed to four factors:

- Waste water in some plants has been recycled (instead of discharged as a liquid effluent).
- As waste water is recycled, the tritium concentration in the water increases over time.
- When all radioactive liquid releases are eliminated, tritium is released through the gaseous release points.
- The dose due to tritium discharged from a gaseous release point can, depending on plant design and site characteristics, be higher than the dose from the same amount of tritium discharged from a liquid release point.

However, a plant that allows some liquid effluent releases can shift the release of tritium from a gaseous release point to a liquid release point, thereby lowering public doses. This strategy can cause a slight increase in the amount of activity of MFAPs in liquid effluents and a small decrease in total public dose.

3.6 <u>Radiation Doses from Gaseous and Liquid Effluents</u>

The maximum annual organ doses for 2012 from gaseous and liquid effluents are shown in Tables 3.19 through 3.22. The data from these tables are illustrated graphically in Figures 3.17 through 3.20. These tables and figures contain annual organ doses (for gaseous and liquid effluents) and annual total body doses (for liquid effluents).

In accordance with regulatory requirements and the calculation methodologies of RG 1.109 (Ref. [32]), the doses are calculated for the individuals receiving the highest total body and organ doses. As a result, these doses are often referred to as the maximum total body and the maximum organ doses. Additionally, licensees are required to calculate the organ doses for six separate organs in the human body: bone, liver, thyroid, kidney, lung, and intestines. Only the highest of the organ doses is shown in this report. Because these doses are calculated for the individual receiving the highest dose from liquid and gaseous effluents, these individuals are typically located in close proximity to the facility. As a result, doses to other individuals, especially those located farther away from the facility, are expected to be significantly lower than those shown in this report.

The doses shown in the tables and graphs of this section include contributions from all radionuclides in the type of effluent shown (i.e., gaseous or liquid).

The NRC ALARA criteria, discussed in Section 2.4, are included in the tables and figures for purposes of comparison. Since many plants have more than one operating reactor, the ALARA criteria are shown on a per reactor basis.

If the licensee does not report a dose, a blank entry is used to indicate that either (1) no releases occurred (e.g., the NPP is a zero-discharge plant) or (2) no exposure pathway exists. Also, blanks in data fields are generally used instead of zeros in order to make it easier for the reader to quickly identify the positive values.

Historically, C-14 has not been considered a principal radionuclide, since the amount of activity in gaseous effluents was dominated by the xenon and krypton radionuclides. As a result, C-14 has not been reported as a radioactive effluent. In addition, the release of C-14 from NPPs has been insignificant compared to the natural production and world inventory of C-14 (Ref. [35]). Although the amount of C-14 released from NPPs has not increased, steady improvements in nuclear power plant effluent management practices have resulted in a 99.8 percent decrease in the amount of activity from noble gas effluents released to the environment (see Figure 3.15, “Long-Term Trend in Noble Gases in Gaseous Effluents”).

However, a recent NRC review of the significance of C-14 releases on public dose has resulted in the NRC reclassifying C-14 as a principal radionuclide. Releases of C-14 have now been included beginning with the 2010 report.

For comparison purposes, median dose values are included in the tables and figures. The median is the midpoint of the data. Approximately half of the power plants will report doses greater than the median and approximately half will report doses lower than the median. The median is a method of estimating a central or typical value while avoiding bias caused by extremely high or low values in the data set. All sites are included when calculating the medians, even those sites for which no dose is reported.

For example, in Table 3.19, the BWR median annual organ dose due to gaseous effluents is highlighted in bold in the center of the table. In this case, the median dose is 0.204 mrem. This represents the typical annual organ dose, due to all gaseous effluents, from all BWRs operating in the United States in 2012. Figures 3.21 and 3.22 show the 5-year trend in the median maximum annual organ doses in gaseous and liquid effluents, respectively. The sharp increase in the dose from gaseous effluents is the result of inclusion of C-14 in the gaseous effluent data beginning in 2010. The median organ doses for liquid effluents from BWRs and PWRs have remained consistently low between 2008 and 2012 as seen in Figure 3.22.

A comparison between doses from gaseous effluents and liquid effluents can be made by examining Figures 3.21 and 3.22; and shows, in general, most of the dose from NPP effluents comes from the gaseous effluents. As a result, licensees wanting to lower doses may choose to focus additional efforts on reducing the radionuclides in gaseous effluents.

The evaluation of effluent data can be a key factor in understanding radioactive effluents. By gaining a better understanding of radioactive effluents, it is possible to exercise more control in reducing doses from such effluents. This helps to ensure radioactive effluents are ALARA.

The tables in this section indicate that the highest total body dose from all of the facilities was 0.343 mrem (Table 3.21), and the highest organ dose from all of the facilities was 7.06 mrem (Table 3.19). For purposes of comparison, 1 mrem is less than the radiation dose from any one of the following:

- the dose received in 1 week from skiing in the Rocky Mountains;
- the dose received in 4 weeks from the natural potassium in each person's body; or
- the dose received in 8 weeks by a homeowner with a brick or stone house.

The basis for each of these three natural background dose values is based on information from the U.S. Geological Survey (USGS) (Ref. [36]). Radiation exposure to cosmic rays at the high altitudes of Colorado would result in a dose of about 70 mrem per year. Additionally, the dose from rocks and soil in the mountains of Colorado would be about 40 mrem per year. The total of these two values is about 110 mrem per year for a person in the high elevations of Colorado. A person in Florida, who is typically at sea level and surrounded by the native Florida terrain, would receive about 40 mrem per year from rocks, soil, and cosmic radiation. As a result, people living at the high altitudes of Colorado receive about 70 mrem per year more radiation dose than a person living in Florida. People from Florida skiing in the Rocky Mountains for a week would be expected to receive an additional dose—above what they might normally have received if they had stayed in Florida—of about 1.3 mrem.

According to a DOE report prepared by the Pacific Northwest National Laboratory (Ref. [37]), the average 150-pound individual receives about 1.1 mrem per month or 14 mrem per year from the natural potassium-40 that is incorporated into the human body.

NCRP Report No. 95 (Ref. [38]) indicates that the radiation exposure from living in a brick, stone, adobe, or concrete home is about 7 mrem per year. At this annual dose rate, the exposure received in 8 weeks would be about 1.1 mrem.

NPPs in the United States discharge small but measurable amounts of radioactive materials in radioactive effluents. All of these radioactive releases must comply with NRC requirements. These requirements are in place to ensure (1) the radwaste processing systems at NPPs are operating properly, (2) the doses to members of the public are within the public dose limits, and (3) the doses to members of the public are ALARA.

Table 3.19 BWR Gaseous Effluents — Maximum Annual Organ Dose, 2012
Shown in Descending Order of Organ Dose

BWR Facility	Annual Organ Dose (mrem)
Grand Gulf	7.06E+00
River Bend	4.70E+00
Brunswick 1	1.98E+00
Brunswick 2	1.98E+00
Cooper	1.27E+00
Vermont Yankee	1.05E+00
Oyster Creek	5.60E-01
Susquehanna 2	3.57E-01
Limerick 1	3.14E-01
Limerick 2	3.14E-01
Susquehanna 1	3.00E-01
Peach Bottom 2	2.75E-01
Peach Bottom 3	2.75E-01
FitzPatrick	2.34E-01
Quad Cities 1	2.21E-01
Quad Cities 2	2.21E-01
BWR Median Dose	**2.04E-01**
Nine Mile Point 1	2.04E-01
Nine Mile Point 2	2.04E-01
Hope Creek	1.97E-01
Hatch 1	1.59E-01
Hatch 2	1.59E-01
Fermi 2	1.57E-01
LaSalle 1	1.52E-01
LaSalle 2	1.52E-01
Pilgrim	9.80E-02
Monticello	7.52E-02
Browns Ferry 1	6.87E-02
Browns Ferry 2	6.87E-02
Browns Ferry 3	6.87E-02
Dresden 2	5.90E-02
Dresden 3	5.90E-02
Duane Arnold	5.60E-02
Clinton	3.60E-02
Columbia	3.32E-02
Perry	1.23E-03
ALARA Criteria	**15**

Table 3.20 PWR Gaseous Effluents — Maximum Annual Organ Dose, 2012
Shown in Descending Order of Organ Dose

PWR Facility	Annual Organ Dose (mrem)
Waterford 3	4.11E+00
Beaver Valley 1	3.40E+00
Watts Bar 1	3.33E+00
Catawba 1	2.25E+00
Catawba 2	2.25E+00
Wolf Creek	1.30E+00
Braidwood 2	1.12E+00
Braidwood 1	1.11E+00
Cook 1	1.05E+00
Cook 2	1.05E+00
Harris	8.09E-01
Sequoyah 1	7.73E-01
Sequoyah 2	7.73E-01
Summer	7.04E-01
North Anna 1	5.12E-01
North Anna 2	5.12E-01
Robinson 2	5.10E-01
McGuire 1	4.38E-01
McGuire 2	4.38E-01
Byron 1	4.32E-01
Byron 2	4.32E-01
Farley 1	4.11E-01
Farley 2	4.11E-01
Davis-Besse	3.33E-01
Indian Point 3	3.32E-01
Indian Point 2	3.07E-01
Arkansas 2	3.02E-01
Palo Verde 1	2.94E-01
Palo Verde 2	2.94E-01
Palo Verde 3	2.94E-01
St. Lucie 2	2.59E-01
Millstone 2	2.52E-01
Arkansas 1	2.41E-01
St. Lucie 1	2.38E-01

PWR Facility	Annual Organ Dose (mrem)
PWR Median Dose	**1.94E-01**
Kewaunee	1.94E-01
Diablo Canyon 1	1.79E-01
Diablo Canyon 2	1.79E-01
Seabrook	1.50E-01
Palisades	1.49E-01
Three Mile Island 1	1.36E-01
Turkey Point 4	1.26E-01
Point Beach 1	1.20E-01
Point Beach 2	1.20E-01
Oconee 1	1.10E-01
Oconee 2	1.10E-01
Oconee 3	1.10E-01
Comanche Peak 1	1.09E-01
Comanche Peak 2	1.09E-01
Salem 1	1.00E-01
Salem 2	9.48E-02
Vogtle 1	8.46E-02
Vogtle 2	8.46E-02
South Texas 1	6.73E-02
South Texas 2	6.68E-02
Surry 1	6.25E-02
Surry 2	6.25E-02
Turkey Point 3	6.09E-02
Beaver Valley 2	5.90E-02
Prairie Island 1	4.88E-02
Prairie Island 2	4.88E-02
San Onofre 2	3.18E-02
San Onofre 3	3.18E-02
Calvert Cliffs 1	3.00E-02
Calvert Cliffs 2	3.00E-02
Ginna	1.94E-02
Millstone 3	1.67E-02
Callaway	1.01E-02
Ft. Calhoun	2.43E-03
Crystal River 3	1.31E-03
ALARA Criteria	**15**

Table 3.21 BWR Liquid Effluents — Maximum Annual Total Body and Organ Dose, 2012
Shown in Descending Order of Organ Dose

BWR Facility	Total Body Dose (mrem)	Organ Dose (mrem)
Grand Gulf	3.43E-01	6.35E-01
Perry	2.67E-03	3.77E-03
Brunswick 1	2.24E-03	2.44E-03
Brunswick 2	2.24E-03	2.44E-03
Peach Bottom 2	1.68E-04	1.89E-03
Peach Bottom 3	1.68E-04	1.89E-03
River Bend	1.32E-03	1.38E-03
Susquehanna 1	8.60E-04	1.08E-03
Susquehanna 2	8.60E-04	1.08E-03
Hatch 1	6.57E-04	9.03E-04
Limerick 1	4.90E-04	5.50E-04
Limerick 2	4.90E-04	5.50E-04
Hatch 2	6.04E-05	7.50E-05
Hope Creek	2.10E-05	6.22E-05
FitzPatrick	5.19E-05	5.19E-05
BWR Median Dose	**2.10E-05**	**4.70E-05**
Browns Ferry 1	4.03E-05	4.70E-05
Browns Ferry 2	4.03E-05	4.70E-05
Browns Ferry 3	4.03E-05	4.70E-05
Quad Cities 1	1.39E-05	2.28E-05
Quad Cities 2	1.39E-05	2.28E-05
Vermont Yankee	1.58E-05	1.58E-05
Duane Arnold	2.48E-06	2.48E-06
Oyster Creek	1.55E-06	1.55E-06
Dresden 2	2.55E-08	1.26E-07
Dresden 3	2.55E-08	1.26E-07
Pilgrim	9.26E-08	9.26E-08
Clinton		
Columbia		
Cooper		
Fermi 2		
LaSalle 1		
LaSalle 2		
Monticello		
Nine Mile Point 1		
Nine Mile Point 2		
ALARA Criteria	**3**	**10**

Table 3.22 PWR Liquid Effluents — Maximum Annual Total Body and Organ Dose, 2012
Shown in Descending Order of Organ Dose

PWR Facility	Total Body Dose (mrem)	Organ Dose (mrem)
Oconee 1	1.96E-02	2.20E-01
Oconee 2	1.96E-02	2.20E-01
Oconee 3	1.96E-02	2.20E-01
Wolf Creek	1.94E-01	1.94E-01
North Anna 1	1.34E-01	1.39E-01
North Anna 2	1.34E-01	1.39E-01
Byron 1	8.03E-02	1.38E-01
Byron 2	8.03E-02	1.38E-01
Farley 1	1.07E-02	1.30E-01
Beaver Valley 1	8.59E-02	1.07E-01
Beaver Valley 2	8.59E-02	1.07E-01
Farley 2	9.69E-03	9.89E-02
Comanche Peak 1	8.56E-02	8.57E-02
Comanche Peak 2	8.56E-02	8.57E-02
Vogtle 1	4.32E-02	6.21E-02
McGuire 1	7.42E-02	6.10E-02
McGuire 2	7.42E-02	6.10E-02
St. Lucie 1	1.07E-02	4.71E-02
St. Lucie 2	1.07E-02	4.71E-02
Catawba 1	3.90E-02	3.87E-02
Catawba 2	3.90E-02	3.87E-02
Braidwood 1	2.41E-02	3.43E-02
Braidwood 2	2.41E-02	3.43E-02
Harris	2.32E-02	3.35E-02
Kewaunee	3.73E-03	2.20E-02
Watts Bar 1	2.00E-02	2.05E-02
Three Mile Island 1	1.77E-02	1.85E-02
Millstone 2	1.28E-03	1.72E-02
Cook 1	2.34E-02	1.58E-02
Cook 2	2.34E-02	1.58E-02
San Onofre 2	2.38E-03	1.42E-02
San Onofre 3	2.38E-03	1.42E-02
Vogtle 2	1.02E-02	1.31E-02
Callaway	8.60E-03	1.24E-02

PWR Facility	Total Body Dose (mrem)	Organ Dose (mrem)
PWR Median Dose	**6.28E-03**	**1.14E-02**
Davis-Besse	4.49E-03	1.14E-02
Ft. Calhoun	6.39E-03	9.83E-03
South Texas 1	9.25E-03	9.28E-03
Summer	6.28E-03	6.72E-03
Sequoyah 1	6.35E-03	6.40E-03
Sequoyah 2	6.35E-03	6.40E-03
Point Beach 1	3.42E-03	3.97E-03
Point Beach 2	3.42E-03	3.97E-03
Millstone 3	9.10E-04	3.23E-03
Ginna	2.91E-03	2.91E-03
Palisades	2.03E-03	2.79E-03
Waterford 3	1.53E-03	1.59E-03
Arkansas 1	1.10E-03	1.40E-03
Arkansas 2	1.30E-03	1.30E-03
Prairie Island 1	7.60E-04	1.01E-03
Prairie Island 2	7.60E-04	1.01E-03
Seabrook	5.40E-04	9.76E-04
Calvert Cliffs 1	5.00E-04	5.00E-04
Calvert Cliffs 2	5.00E-04	5.00E-04
South Texas 2	4.48E-04	4.52E-04
Diablo Canyon 1	2.47E-04	4.37E-04
Diablo Canyon 2	2.47E-04	4.37E-04
Indian Point 3	2.64E-04	4.32E-04
Indian Point 2	3.12E-04	3.60E-04
Surry 1	1.40E-04	1.56E-04
Surry 2	1.40E-04	1.56E-04
Robinson 2	5.14E-05	3.70E-05
Salem 2	1.67E-05	2.84E-05
Salem 1	1.22E-05	2.03E-05
Crystal River 3	1.66E-06	2.51E-06
Turkey Point 3	3.66E-04	
Turkey Point 4	3.66E-04	
Palo Verde 1		
Palo Verde 2		
Palo Verde 3		
ALARA Criteria	**3**	**10**

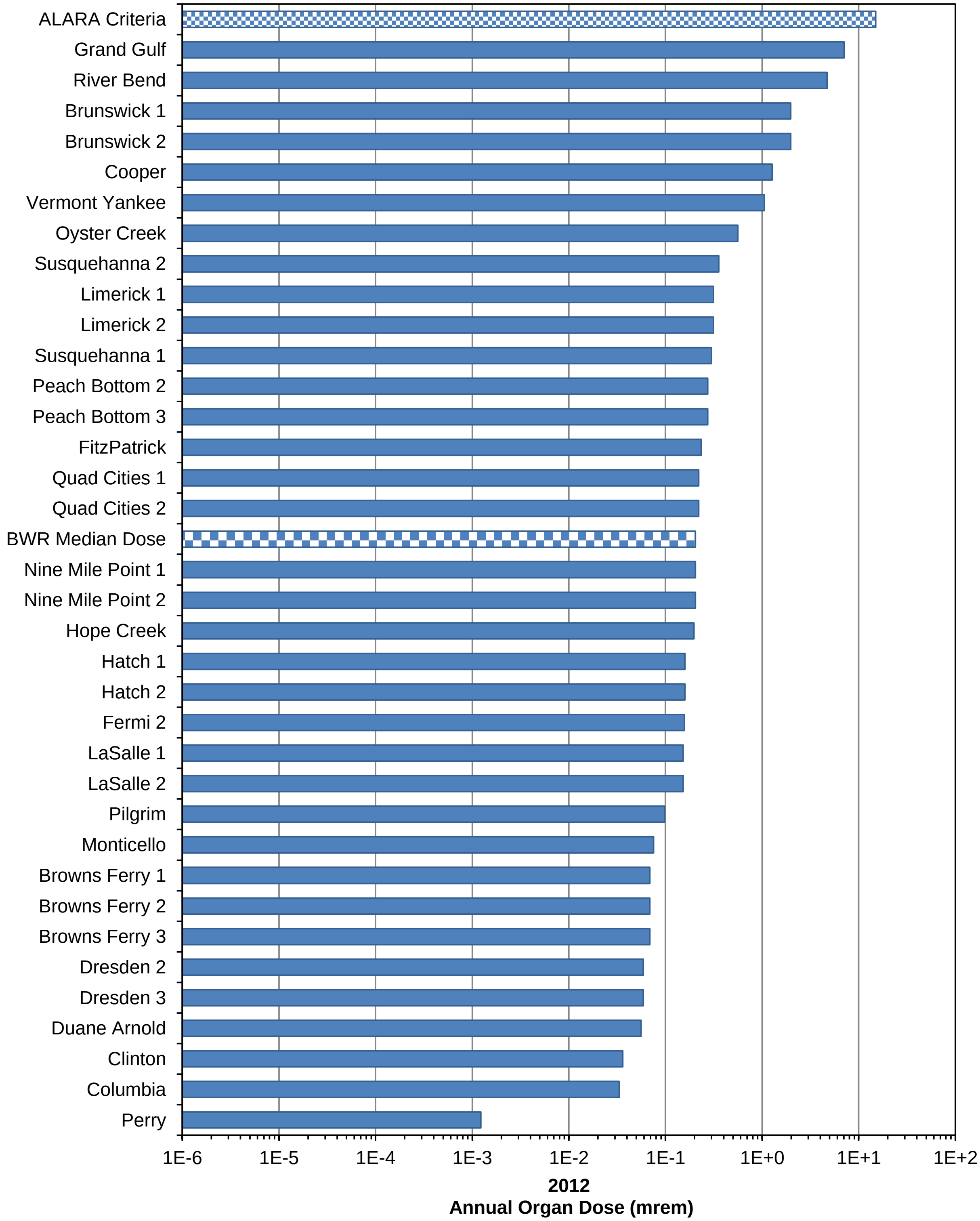


Figure 3.17 BWR Gaseous Effluents — Maximum Annual Organ Dose

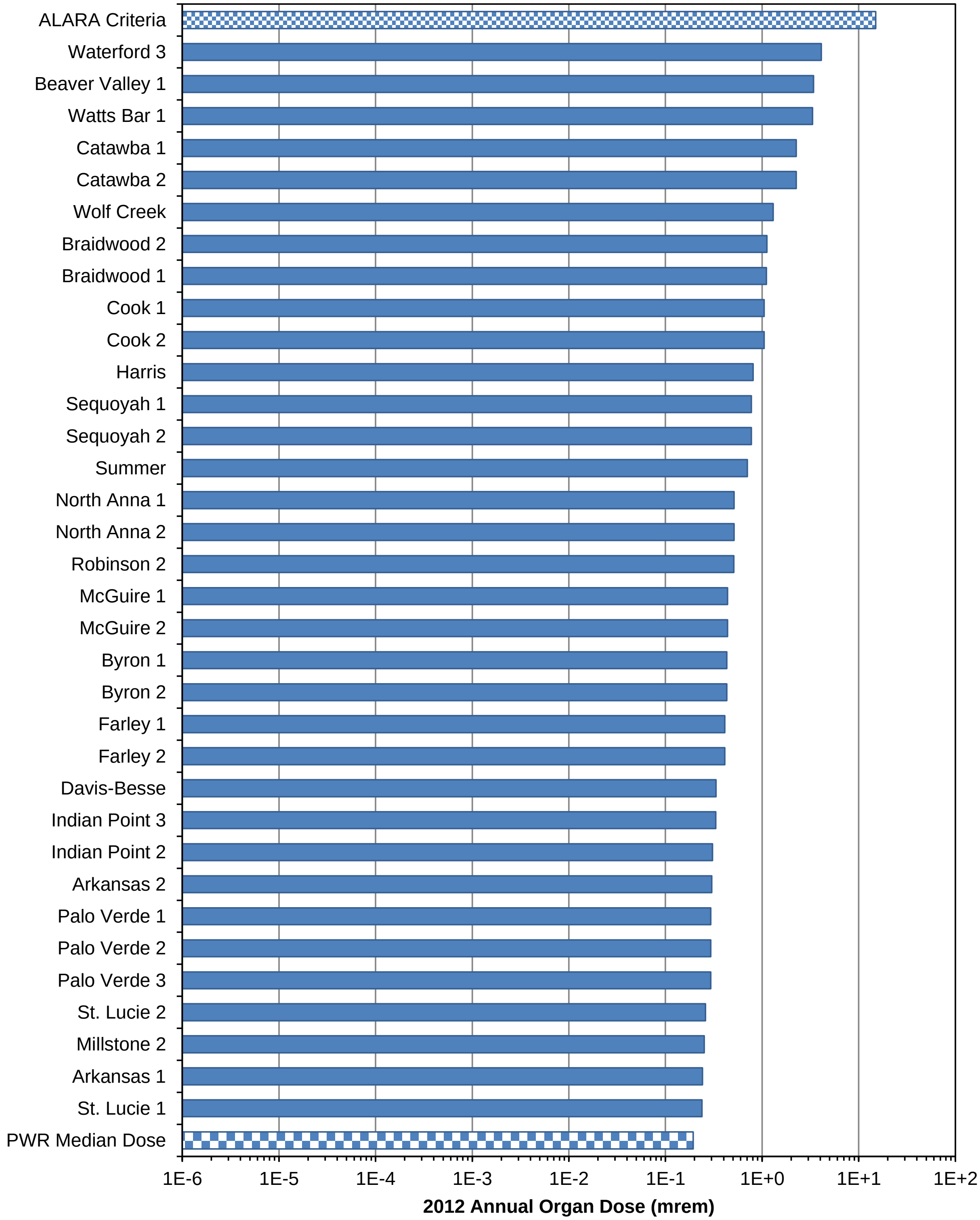


Figure 3.18 PWR Gaseous Effluents — Maximum Annual Organ Dose

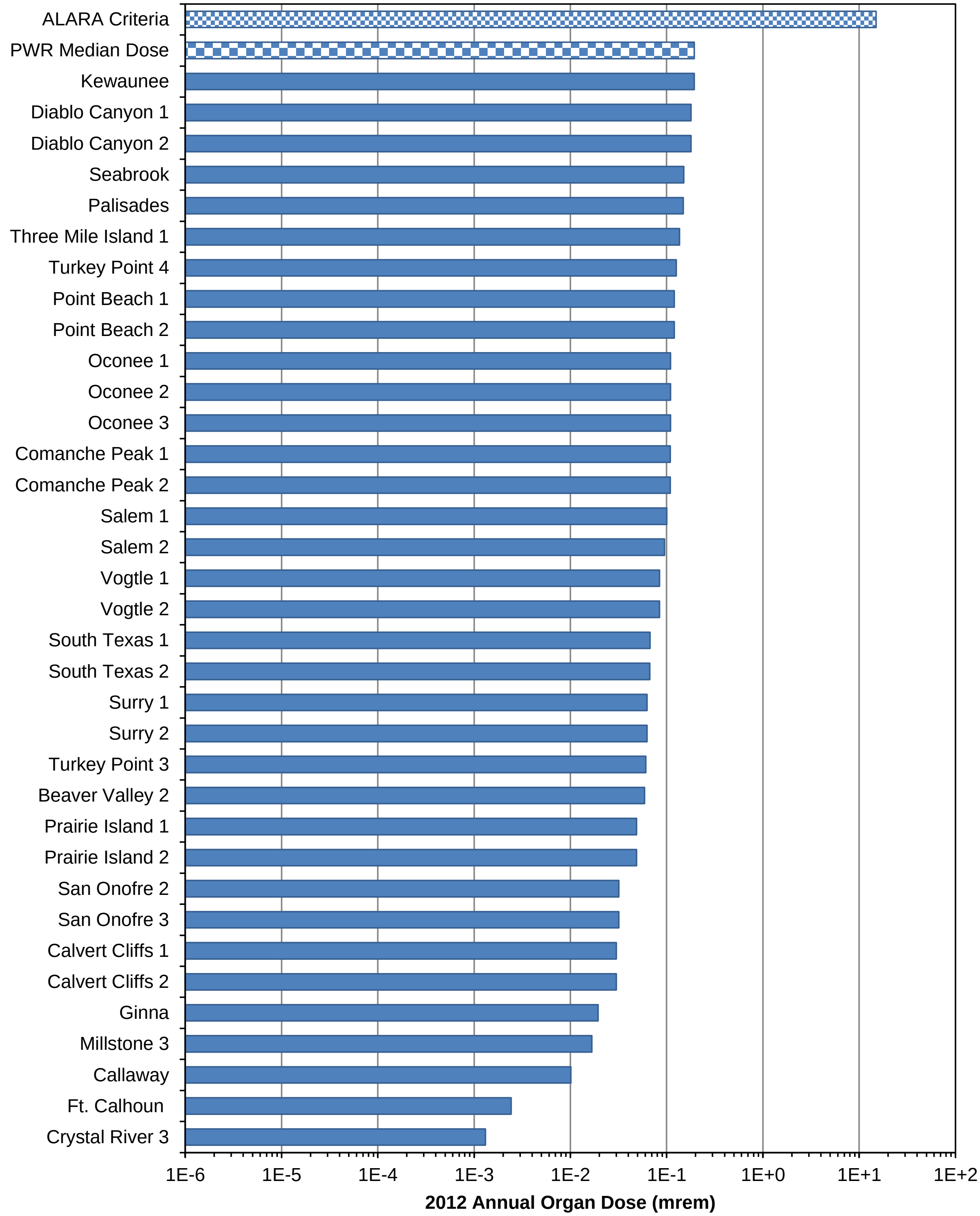


Figure 3.18 PWR Gaseous Effluents — Maximum Annual Organ Dose (continued)

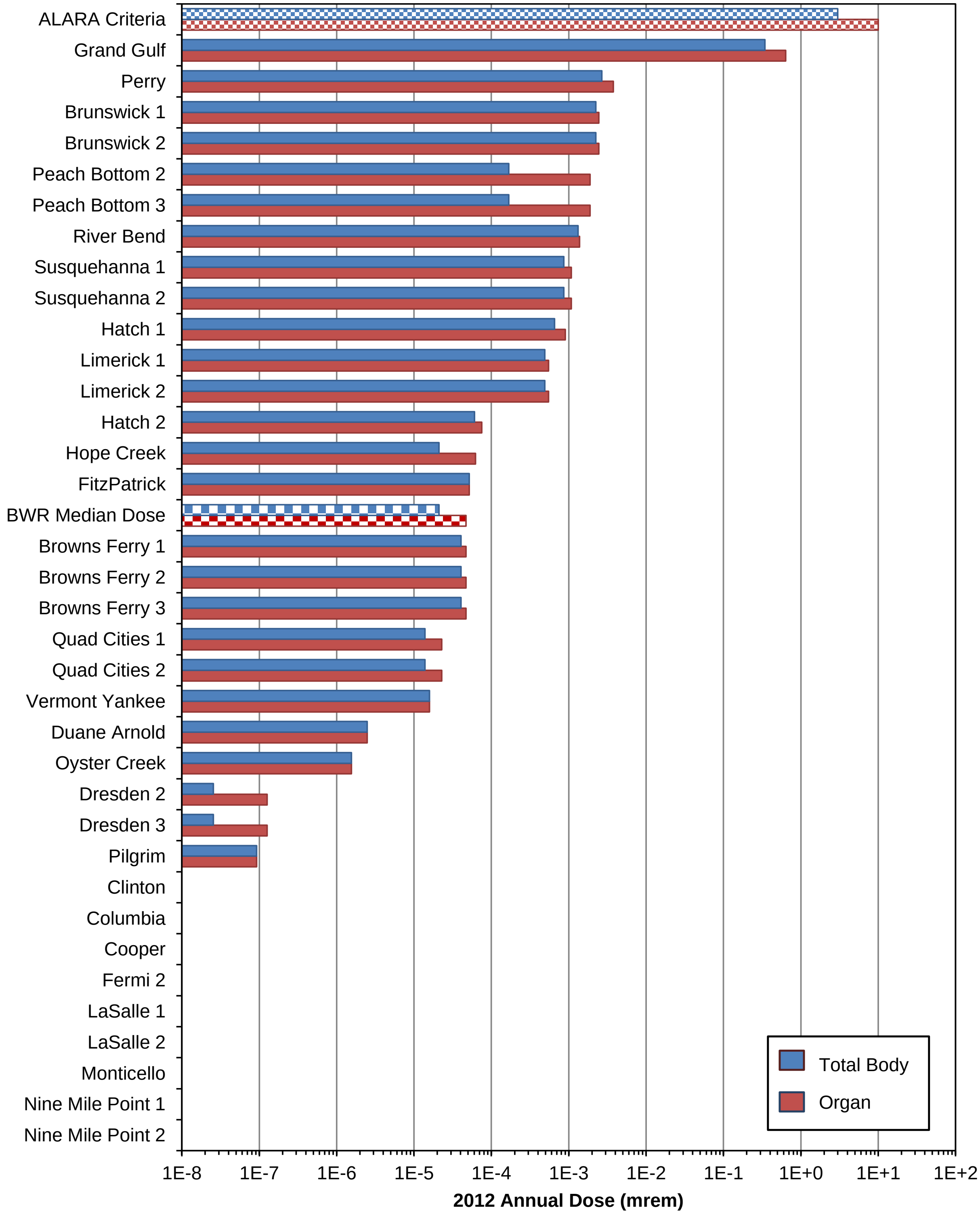


Figure 3.19 BWR Liquid Effluents — Maximum Annual Total Body and Organ Dose

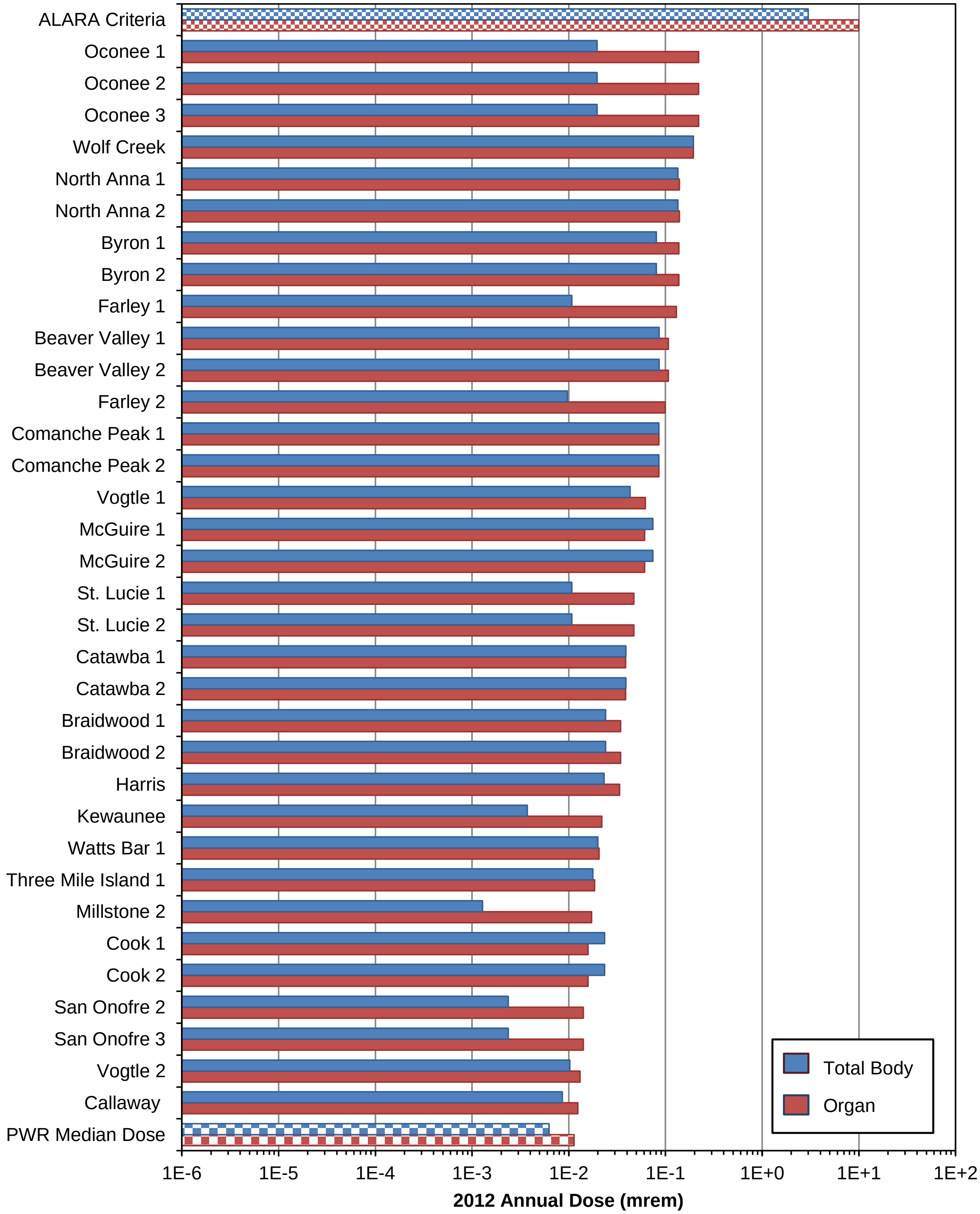


Figure 3.20 PWR Liquid Effluents — Maximum Annual Total Body and Organ Dose

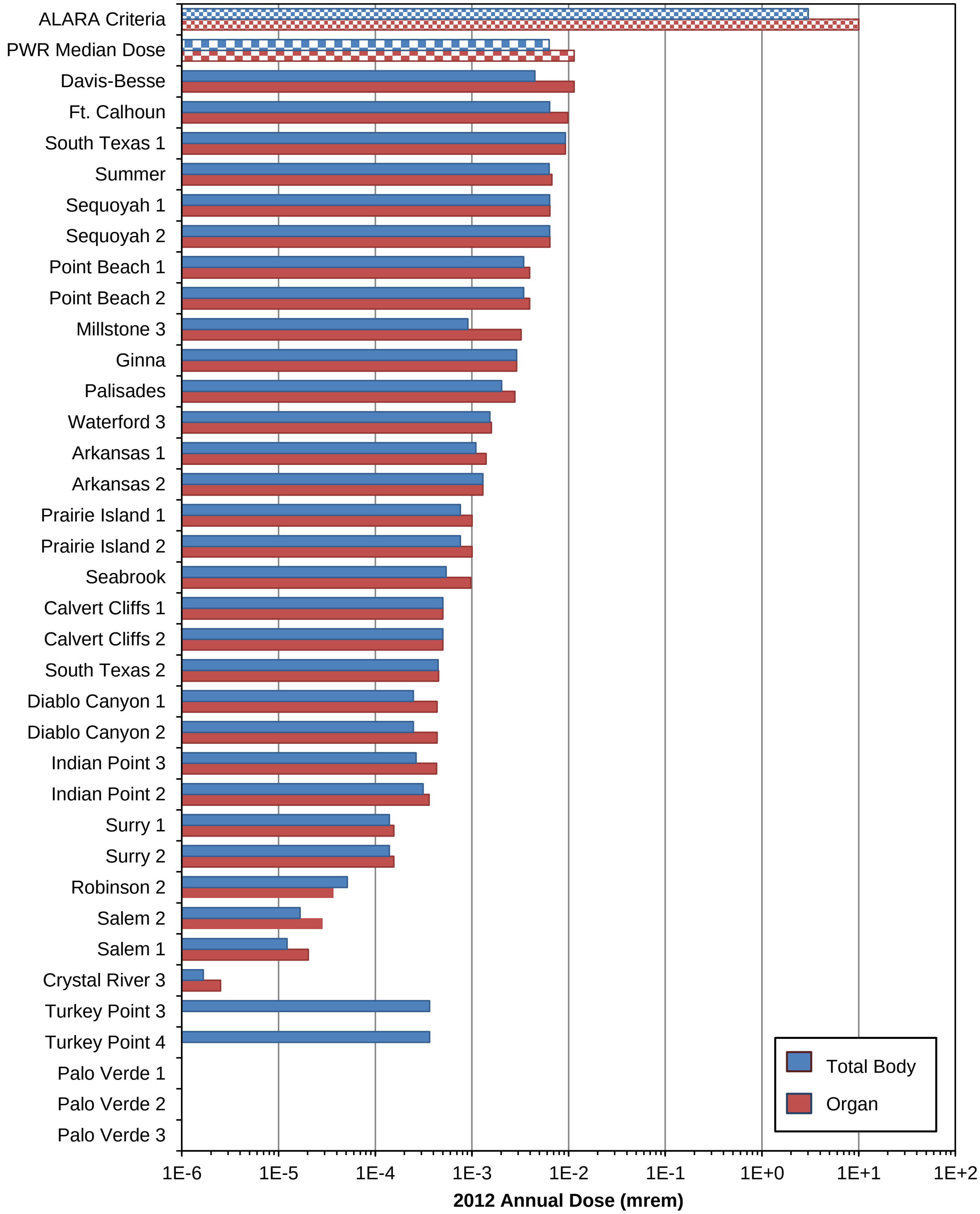
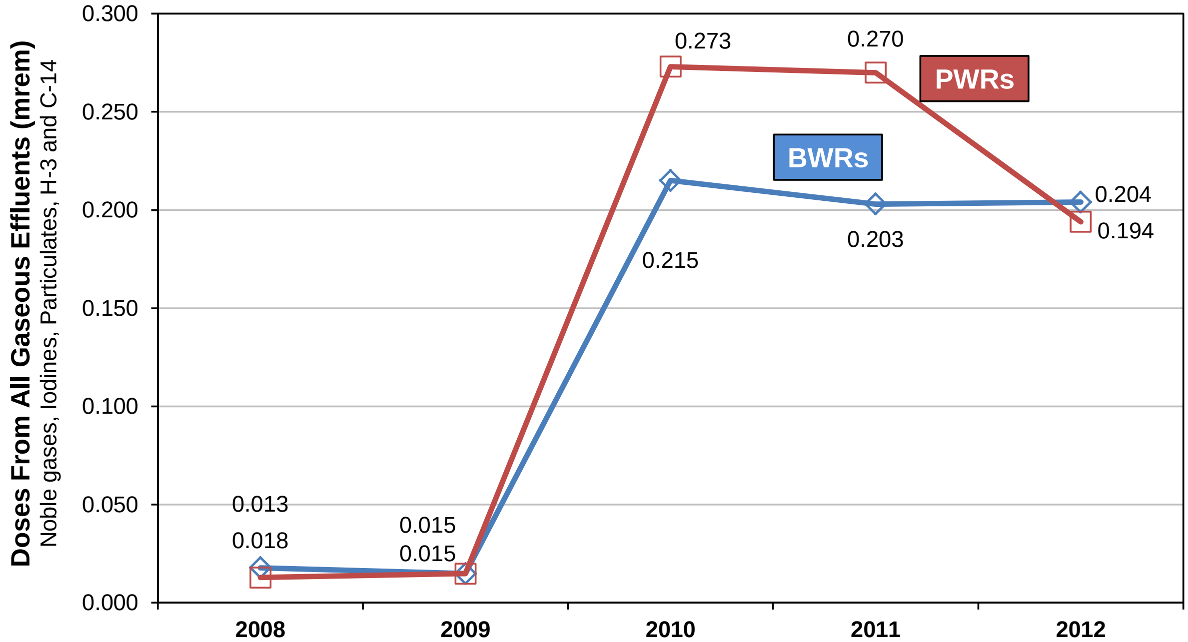


Figure 3.20 PWR Liquid Effluents — Maximum Annual Total Body and Organ Dose (continued)



Note: The increase in reported organ dose beginning in 2010 is due largely to the addition of a radionuclide category for C-14 in Table 2.1. See text at the beginning of Section 3.6 for more information on the addition of C-14.

Figure 3.21 Median Maximum Annual Organ Dose, Gaseous Effluents 5-Year Trend, 2008-2012

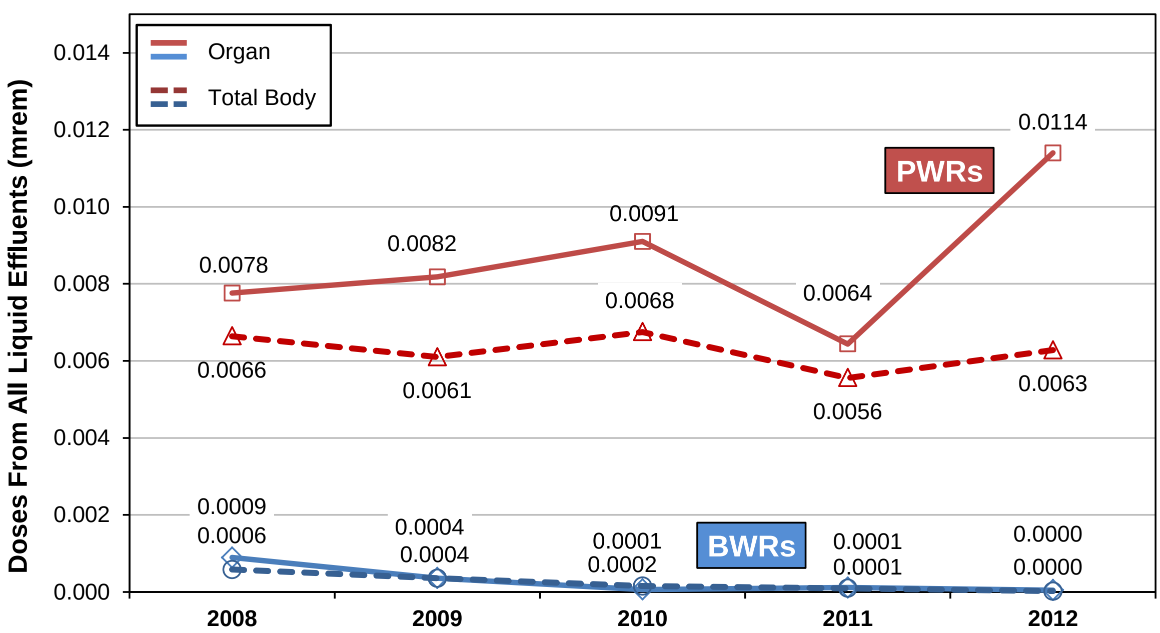


Figure 3.22 Median Maximum Annual Dose, Liquid Effluents 5-Year Trend, 2008-2012

4 SUMMARY

The information contained in this report summarizes the liquid and gaseous effluents and public doses from all United States nuclear power plants (NPPs) in commercial operation for calendar year 2012. Although all NPPs released radioactive materials in 2012, none of the effluents from any NPP resulted in an exceedance of any NRC or EPA public dose limit, or any NRC ALARA criteria.

The radionuclides selected for inclusion in this report are either the most common radionuclides or the most significant radioactive effluents and are particularly useful indicators of overall releases. The radionuclides selected also provide additional information about operational practices at a site. Nuclear power plants have reduced their radioactive effluents by more than 99 percent in a long-term decreasing trend in radioactive effluents (i.e., mixed fission and activation products in liquid effluents and noble gases in gaseous effluents) since the mid-1970s.

For additional context, the median dose resulting from radioactive effluents are provided for comparison to the ALARA criteria, to the natural background sources of radiation, and other sources of radiation exposure to the U.S. population. Comparisons of the radioactive effluents between NPPs may indicate differences in fuel conditions, fuel cycle length, radioactive waste processing equipment, reactor types, reactor ages, electrical outputs, and operating conditions. Each of these factors can have an effect on radioactive effluents.

More complete and detailed information, including copies of the NPPs' ARERRs, is available to the public on the NRC Web site.

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6 GLOSSARY

Activity or radioactivity: The rate of radioactive transformations of a radionuclide, measured in the traditional unit of the curie (Ci) or the international standard unit of the becquerel (Bq).

Background (radiation): Radiation from cosmic sources; naturally occurring radioactive material, including radon (except as a decay product of source or special nuclear material); and global fallout as it exists in the environment from the testing of nuclear explosive devices and from past nuclear accidents such as Chernobyl that contribute to background radiation and are not under the control of the licensee. Background radiation does not include radiation from source, byproduct, or special nuclear materials regulated by the Nuclear Regulatory Commission.

Effluent discharge, radioactive discharge: The portion of an effluent release that reaches an unrestricted area.

Effluent release, radioactive release: The emission of an effluent from a plant structure into the site environment.

Exposure pathway: A mechanism by which radioactive material is transferred from the (local) environment to humans. There are three commonly recognized exposure pathways: inhalation, ingestion, and direct radiation.

Fission and activation gases: The noble (chemically non-reactive) gases formed from the splitting (fission) of the uranium-235 isotope in a nuclear reactor or the creation of radioactive atoms from non-radioactive atoms (activation) by the capture of neutrons or gamma rays that are released during the fission process.

Gaseous effluents: Airborne effluents.

Iodines: The measured radioactive isotopes of iodine or of other non-metal elements in group 17 of the Periodic Table of Elements. Licensees might report any combination of the iodine isotopes, I-131, I-132, I-133, I-134, and I-135.

Maximum exposed individuals: Individuals characterized as maximum with regard to food consumption, occupancy, and other usage of the region in the vicinity of the plant site. As such, they represent individuals with habits that are considered to be maximum reasonable deviations from the average for the population in general. Additionally, in physiological or metabolic respects, the maximum exposure individuals are assumed to have those characteristics that represent the averages for their corresponding age group in the general population.

Member of the public (10 CFR Part 20): Any individual except when that individual is receiving an occupational dose.

Monitoring: The measurement of radiation levels, concentrations, surface area concentrations, or quantities of radioactive material and the use of results of these measurements to evaluate potential exposures and doses.

Noble gas: One of six noble gases (helium, neon, argon, krypton, xenon, and radon) with an oxidation number of 0 that prevents it from forming compounds readily. All noble gases have the maximum number of electrons possible in their outer shell (two for helium, eight for all others), making them unreactive.

Occupational dose: as defined in 10 CFR 20.1003, means the dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation or to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include doses received from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive material and released under [10 CFR] 35.75, from voluntary participation in medical research programs, or as a member of the public.

NUREG: A publication by or for the NRC containing non-sensitive information related to NRC's mission that does not contain regulatory requirements and is published in a formal agency series to ensure the "…dissemination to the public of scientific and technical information related to atomic energy…" as mandated by the Atomic Energy Act of 1954, as amended. Each publication bears an agency designator (e.g., NUREG-number-year).

Particulates: Radioactive materials that are entrained in the gaseous effluents and are not included in any other effluent category.

Site boundary: That line beyond which the land or property is not owned, leased, or otherwise controlled by the licensee.

Tritium: The radioactive isotope of hydrogen (H-3).

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10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

In 2012, there were 104 commercial nuclear power plants (NPPs) licensed to operate on 65 sites in the United States (U.S.) regulated by the Nuclear Regulatory Commission (NRC). Each year, each power reactor sends a report to the NRC that identifies the radioactive liquid and gaseous effluents discharged from the facility. This report summarizes that information and presents the information in a format intended for both nuclear professionals and the general public.

The reader can use this report to quickly characterize the radioactive discharges from any U.S. NPP in 2012. The radioactive effluents from one reactor can be compared with other reactors. The results can also be compared with typical (or median) effluents for the industry, including short-term trends and long-term trends.

Although all operating NPPs released some radioactive materials in 2012, all effluents discharged were within the NRC's and the Environmental Protection Agency's (EPA's) public dose limits, and NRC ALARA criteria. Additionally, the doses from radioactive effluents were much less than the doses from other sources of natural radiation that are commonly considered safe. This indicates radioactive effluents from NPPs in 2012 had no significant impact on the health and safety of the public or the environment.

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