Knowledge Management Topic

Public Protection Standards And NRC Regulation of Groundwater Contamination

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Introduction

The U.S. Nuclear Regulatory Commission (NRC) regulatory approach to groundwater contamination is an amalgam of NRC and U.S. Environmental Protection Agency (EPA) generated approaches to groundwater contamination that are applied in diverse ways by different NRC programs. This knowledge management paper seeks to provide some insight into the regulation of groundwater contamination across NRC program areas.

This paper is not encyclopedic and does not delve into all the details in the regulations and guidance documents. It is a snapshot in time of my understanding. The reader is advised that programs evolve and change over time. The observations in this paper should not be taken as the final word. Finally, the observations and opinions expressed in this paper are solely my own and do not represent the official opinions of either the NRC or the EPA.

Purpose and Scope

The EPA and the NRC have regulatory programs to protect the public from groundwater contamination. However, the programs of EPA and NRC sometimes differ in their approach. These differences in approach are a natural result of their different regulatory responsibilities and unique regulatory and legislative histories.

All NRC groundwater regulatory programs incorporate both NRC concepts and some EPA concepts. The intent of this knowledge management paper is to describe at a high level, how NRC and EPA regulatory concepts are incorporated into different NRC program areas. Also included are some short appendices that provide more detail on selected topics.

When dealing with groundwater contamination, regulatory uncertainty is highest when contaminate concentrations are low. When contaminate concentrations are high, it is much easier to conclude that groundwater quality has been degraded and the health of groundwater consumers could be threatened. When contaminate concentrations are low it is more difficult to determine (1) if groundwater contamination exists, (2) if groundwater contamination is a threat to public health, (3) to what extent have groundwater resources been degraded, and (4) has groundwater contamination been adequately cleaned up.

Summary of Significant Regulatory Concepts and Approaches

This section identifies and summarizes the major NRC and EPA standards and regulatory concepts (approaches) that have been incorporated into the regulation of groundwater contamination by different NRC programs.

Concept 01: Protecting the Public from Low-Level Radiation

The regulatory range for low-level radiation exposure, extends from zero up to about 10,000 total mrem. This range also encompasses natural background radiation, which varies locally in the United States, but averages about 300 mrem/yr.

NRC and EPA have established regulatory standards and regulations to protect the public from even the very small dose levels that are found at the smallest levels of the low-level radiation exposure range. These regulations and standards regulate human-generated exposures to the public from zero to 100 mrem/yr. The level of risk at these low exposure levels is so small, that the detrimental effects from radiation cannot be determined. At these levels, both the NRC and EPA conservatively assume radiation effects using what is commonly known as the "linear no threshold hypothesis model". This model assumes that even the smallest radiation exposure carries a cancer risk and that cancer risks double as the amount of exposure doubles (GAO 2000).

Concept 02: Harmonization of Radiological and Chemical Risks

For radioactive material, EPA has the responsibility for establishing generally applicable environmental standards for the protection of the general environment. NRC has the responsibility for implementing and enforcing these standards within its programs.

EPA issues environmental radiation protection standards as mandated under the Presidential Reorganization Plan No. 3 of 1970. In addition, Congress enacted statutes providing EPA with the authority to regulate both chemical and radiological hazardous materials in specific environmental media. Through these statutes, most notably the Clean Air Act (CAA); the Safe Drinking Water Act (SDWA); and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), EPA is responsible for regulating both chemical and certain radiological hazards.

As a result, EPA is faced with the challenge of establishing standards and regulations for radiation that are consistent with its standards and regulations for chemical carcinogens. In effect, within EPA programs, radiation and individual radionuclides have to meet the same level of cancer risk criteria as non-radionuclide hazardous groundwater constituents (EPA 2000).

EPA has addressed this issue by establishing a range of acceptable risk of between one chance in a million and one chance in ten thousand (10^{-6} to 10^{-4}) of an individual getting cancer from radiological or chemical constituents (GAO 2000).

Concept 03: Top Down/Bottom Up

In its radiological standards and risk management practices, the NRC favors a "top-down" approach. Whereas, in implementing the harmonization of radiological and chemical risks, the EPA favors a "bottom-up" approach (GAO 2000, Tran, Locke, and Burke 2000).

In practice, the "top-down" approach sets a radiological upper dose standard and then encourages lower doses using as "low as reasonably achievable" (ALARA) processes. Appendix A contains examples of ALARA requirements in NRC regulations. To illustrate; using the "top-down" approach, a maximum allowable radiological dose might be set at a level that equates to 10^{-3} risk of an individual getting cancer. ALARA practices might then be used to reduce the risk below 10^{-3}.

In contrast, the "bottom-up" approach sets a goal (standard) and then allows the goal to increase if site specific factors such as cost, feasibility, and field experience allow. For example, if a risk range of 10^{-6} to 10^{-4}, for a groundwater contaminant cannot be achieved at a site, the allowable level of contamination may be increased based on considerations of technical feasibility, cost, and other factors.

In actual practice, it is possible that both the "top-down" and "bottom-up" regulatory approaches may converge on a level of risk that would be acceptable to both the EPA and the NRC (Tran, Locke, and Burke 2000).

Unfortunately, there is a potential for disagreements and misunderstandings to occur between staff and management steeped in either of the two approaches. NRC staff may view an EPA standard as too strict, as viewed through the lens of the "top-down" approach, groundwater contamination via ALARA would be required to be reduced further. Conversely EPA staff may consider an NRC standard as too lenient, as viewed through the lens of the "bottom-up" approach, site conditions may allow higher levels of contamination.

All programs at the NRC use the "top-down" (ALARA) approach, but in the regulation of groundwater contamination some NRC programs also use the "bottom-up" approach. Understanding these two different regulatory concepts can be very helpful when NRC and EPA staff interact and work together on-site specific groundwater issues.

Concept 04: A Common Dose Standard For All

To promote consistency in radiation regulation, on January 13, 1977, EPA promulgated the uranium fuel cycle standard (EPA 2000, Walker 2000). The EPA, NRC, DOE, and other implementing agencies have incorporated this standard into their regulations *(EPA 2000).* This

standard is found in EPA regulations in 40 CFR 190 and in NRC regulations in 10 CFR 20.1301(e).

This standard applies to exposures from nuclear fuel cycle radionuclides to the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material. It applies to all phases of the uranium fuel cycle, including: nuclear power plant operations, fuel fabrication and fuel reprocessing, chemical conversion, waste management, storage, and disposal; uranium milling; and cleanup of former milling operations. It does not apply to mining operations, transportation of radioactive material, or waste disposal operations. EPA has created other standards for these activities (EPA 2000).

This standard is an all pathways dose standard. This means the dose via the groundwater pathway would be imbedded in the dose calculated from all the pathways (i.e, surface water, air, food, etc). The dose resulting from the sum of all the pathways would then be compared to the standard.

This standard established an annual dose equivalent not to exceed:

- 25 mrem/yr to the whole body;
- 75 mrem/yr to the thyroid;
- 25 mrem/yr to any other organ for any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment (EPA 2001, Walker 2000).

The NRC considers this standard to be an upper limit of allowable dose. As previously mentioned to further reduce the dose to the public, the NRC requires licensees to use, to the extent practical, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are ALARA.

Concept 05: NRC Total Effective Dose Limit for Individual Members of the Public

In addition to the Uranium Fuel Cycle Standard, NRC regulations contain a total effective dose equivalent limit of 100 mrem/yr to individual members of the public from the licensed operation (10 CFR 20.1301(a)(1)). This standard is in addition to the Uranium Fuel Cycle Standard. Like the Uranium Fuel Cycle Standard, this is an all pathways dose limit standard. Also like the Uranium Fuel Cycle Standard, this is an upper limit of the allowable dose. To further reduce the dose to the public, the NRC requires licensees to operate licensed facilities to reduce the dose to ALARA.

Concept 06: NRC Unrestricted Use Dose Limit

The NRC has established an all pathways radiological dose limit for formerly licensed sites and properties that are considered safe for unrestricted use. From a radiological hazard standpoint,

properties approved for unrestricted use are considered safe for public use and no longer need to be regulated by the NRC.

This limit is judged against exposure to a “critical group”. A “critical group” is the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances (10 CFR 20.1003 Definitions). A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are ALARA (10 CFR 20.1402). These limits to public exposure, apply both outside and inside the boundaries of an area being decommissioned.

Concept 07: EPA Drinking Water Regulations and Maximum Contaminant Levels

To protect groundwater resources from contamination, EPA favors an approach that references drinking water standards applicable to community water systems. These standards are called Maximum Contaminant Levels (MCLs). MCLs have been generated for a long list of chemical and radioactive substances (GAO 2000). The NRC has incorporated maximum contaminate limits into some of its regulatory programs.

EPA has established MCLs for both radiological and non-radiological hazardous constituents. Using MCLs, EPA’s approach to managing radiation risks follows a single substance/single pathway chemical risk management strategy. This differs from the multiple pathway approach of the Uranium Fuel Cycle Standard (see Concept 04), where the dose from radionuclides in the groundwater pathway are incorporated into the total dose from all other pathways (Tran, Locke, and Burke 2000).

EPA regulation 40 CFR 141 establishes maximum contaminant levels for radionuclides in community water systems. It establishes the following maximum contaminant levels for radionuclides:

- 20,000 pCi/l for tritium;
- 15 pCi/l for gross alpha particle activity (including radium-226, but excluding radon and uranium;
- 8 pCi/l for strontium-90;
- 5 pCi/l combined for radium-226 and radium-228;
- 4 mrem/yr annual dose equivalent to the total body or any internal organ from beta particle and photon radioactivity from man-made radionuclides.

An MCL is the legal threshold limit on the amount of a contaminant that is allowed in public water systems under the Safe Drinking Water Act. The goal of MCLs is to identify the maximum level of a contaminant, below which adverse health effects from consumption of water containing the contaminant are prevented. Compliance with MCLs are based on contaminant

concentrations in water. Unlike a dose standard, compliance can be readily confirmed by the laboratory analysis of groundwater samples. To evaluate compliance against a dose standard, calculations and modeling must be performed to determine the dose.

Within a public water system, the EPA believes Congress intended MCLs to apply to water at the tap. However, EPA has discretion to require monitoring at other locations within the public water supply system; if such monitoring is representative of levels at the tap (EPA 2016). This means the many thousands of taps in a public system do not have to be individually monitored.

Many community water systems depend on groundwater as the source of water. By protecting the quality of groundwater supplying a public water supply system; the water quality at the many taps in the public water supply system can be protected from groundwater contamination. Therefore, State and Federal programs may reference MCLs to protect the quality of groundwater that supplies public water systems.

The public is familiar with their use of MCLs to characterize groundwater. MCLs are used across many local, state and Federal programs. State programs as well as local health departments may use MCLs to evaluate the groundwater quality of private well owners. Federal and State programs may use MCLs to characterize the quality of groundwater resources that are either currently being used or might be used in the future. Individual well owners may use MCLs to evaluate if the water from their well poses a hazard or needs treatment.

<u>Concept 08: EPA Groundwater Protection Strategy</u>

The use of MCLs in groundwater protection is heavily influenced by the EPA’s groundwater protection strategy. Elements of this strategy are incorporated into some NRC programs and almost all NRC environmental reviews that include an evaluation of groundwater quality.

Several different Federal statutes provide EPA with the authority to prevent and control both sources of groundwater contamination and to clean up existing groundwater contamination. During the early 1980s, EPA recognized that these authorities were fragmented among many different statutes and were largely undefined. Therefore, in 1984, the Agency adopted a groundwater protection strategy to articulate EPA’s role in a national groundwater protection program (EPA 1984, 1991).

In 1990, EPA revisited this strategy. The outcome was a strategy that set forth an approach that continues to direct the course of the EPA’s groundwater protection activities. While the groundwater protection strategy is an important regulatory tool, it is not a regulation, but an agency strategy. Since 1984, elements of this strategy have been incorporated into individual EPA groundwater protection programs. It also guides States, Tribes, local governments, and other parties that EPA works with to carry out the agency’s groundwater responsibilities (EPA 1984, 1991).

The strategy includes a description of how MCLs will be used as "reference points" in carrying out ground-water programs under the Safe Drinking Water Act, and water quality standards (WQSs) under the Clean Water Act. It also describes how these reference points will be applied in groundwater contamination prevention and remediation activities (EPA 1991).

The overall goal of EPA's groundwater strategy is to prevent adverse effects to human health and the environment and to protect the environmental integrity of the nation's groundwater resources. In determining appropriate prevention and protection strategies, EPA considers the use, value, and vulnerability of the resource, as well as social and economic values (EPA 1991, 2013). The strategy describes how groundwater should be protected to ensure that the nations currently used and reasonably expected drinking water supplies, both public and private, do not pose adverse health risks and are preserved for present and future generations (EPA 1991). The strategy states that guidelines adopted by EPA for groundwater protection should consider the highest beneficial use to which groundwater with significant value as a water resource can presently or could potentially be put. Three classes of groundwater are identified along with the different levels of protection for each class (EPA 1984).

This focus on groundwater as an important resource to be protected for present and future generations, means EPA, State, and Tribal water protection programs will not only seek to protect groundwater resources that are currently being used, but will also seek to protect groundwater resources that are not presently being used, but might be used in the future.

This is a significant difference from an all pathways dose analysis. The all pathways dose analysis evaluates the dose to the public from the total of all pathways based on what the groundwater is currently being used for. Whereas the groundwater protection strategy evaluates health risk based solely only on groundwater quality (i.e. a single path) even if it is not presently being consumed.

For example, if radionuclides find their way into a groundwater resource that is not presently being used as a source of water, using the Uranium Fuel Cycle Standard, the groundwater pathway might not show up as a contributor dose in the total dose calculation. However, if later, the groundwater be used as a source of drinking water; at that time, it might show up as a contributor to the total dose. In contrast, a regulatory program using the EPA groundwater protection strategy would seek to protect (prevent degradation) of a groundwater resource, whether-or-not anyone is presently using it.

For the all pathways analysis to be applied when no one is consuming the groundwater assumptions about the future need to be made. Assumptions might include where the groundwater is consumed, who consumes the water, how much they consume and their environment. Some programs such as the NRC Decommissioning and the Spent Nuclear Fuel and High-Level Waste Disposal programs include these types of assumptions, even if no one is presently consuming the groundwater.

Concept 09: Groundwater is Both a Pathway and a Resource

For the consideration of environmental impacts, groundwater is both a pathway and a resource. By way of analogy, birds are also a resource and a pathway. If birds where to transport radiological contamination off site; an evaluation of impacts on human health, would include the bird pathway in the calculation of dose to the public. However, the dose calculation would not describe the impact of contamination on the bird population. To evaluate the impact on the bird population other approaches must be used.

If groundwater transporting radiological contamination was consumed by humans; an evaluation of impacts on human health would include the groundwater pathway in the calculation of dose to the public. However, the dose calculation would not describe the impact of the contamination on the groundwater as a present-or-future resource. To evaluate the impact on the groundwater as a resource other approaches must be used.

As the NRC has not established standards that are specific to drinking water quality; it is not unusual for NRC prepared National Environmental Policy Act (NEPA) documents (environmental assessments and reports, etc.) to reference MCLs when describing impacts to groundwater resources. This has the advantage of referencing a standard that is specific to only groundwater, which can be readily evaluated against water quality data. Even if the groundwater resource is not presently being used, MCLs can be used to characterize the suitability of the groundwater quality for some future use. Therefore, as appropriate, MCLs are referenced, in environmental analyses across all NRC program areas. Further, in satisfaction of its NEPA responsibilities NRC, may use MCLS to describe the impact of non-radionuclide hazardous contaminants.

The following table illustrates which and when NRC programs use MCLs.

Table One: Use of MCLs in NRC program areas.

Program Area	Reference Maximum Contaminate Limits (MCLs)							
	Safety Program*						Environmental Studies**	
	During Operations		During Decommissioning		During Groundwater Restoration & Closure Monitoring			
	On Site	Off Site	On Site	Off Site	On Site	Off Site	On Site	Off Site
Operating Reactor			X	X			X	X
New Reactor			X	X			X	X
Fuel Cycle			X	X			X	X
Low-Level Waste							X	X
Uranium Recovery	X	X			X	X	X	X
Spent Fuel & High Level Waste		X					X	X
Interim Storage			X	X			X	X

* Maximum Contaminate Limits are referenced or referenced as appropriate to comply with NRC health and safety requirements.

** Environmental impact statements, assessments, and other reports produced in satisfaction of National Environmental Policy Act (NEPA) requirements.

NRC Program Areas

For individual NRC program areas, the following sections include brief descriptions of NRC regulations to protect the public from groundwater contamination. As appropriate, reference is made to the use of the (1) top down (ALARA) all pathways dose approach; (2) single substance-single pathway chemical risk management bottom up approach; (3) protection of groundwater as a resource for present and future users; and (4) use of MCL's.

Decommissioning Nuclear Facilities

It is important to note, that during decommission, exposure standards apply both outside and inside the site boundary of a site being decommissioned. The NRC decommissioning program regulates the decontamination and decommissioning of materials facilities, fuel cycle facilities, nuclear power plants, research reactors, test reactors, and uranium recovery facilities. Decommissioning is the removal of a nuclear facility from service after its useful life has ended. It involves the reduction of residual radioactivity to a level that permits the release of the property and the termination of the NRC license. NRC rules establish site-release criteria and provide for unrestricted and (under certain conditions) restricted release of a site. To regulate groundwater cleanup, NRC staff reference the top down all pathways approach in 10 CFR 20. However, NRC decisions must also be responsive to EPA MCLs, as NRC has agreed to consult with EPA when at the time of license termination, groundwater contamination exceeds EPA's MCLs.

While NRC decommissioning criteria in 10 CFR 20 apply to most programs, they do not apply to uranium and thorium recovery facilities and uranium solution extraction facilities (10 CFR 20.1401). In addition, the decommissioning criteria in 10 CFR 20 for high-level and low-level waste disposal facilities only apply to ancillary surface facilities that support radioactive waste disposal activities. This is because these programs have their own groundwater standards (see the following Sections on Low-Level Waste, Uranium Recovery and the disposal of High-Level Waste).

Some decommissioning requirements apply to a site while it is still operating. During operations and decommissioning licensees must implement procedures and practices that minimize the occurrence of leaks and spills and identify them soon after they occur. Furthermore during operations, for some licenses, when a spill of radioactive material occurs, licensees will need to adjust their surety plan to reflect increased decommissioning costs (10 CFR 20.1406(c), 10 CFR 20.1501, 10 CFR 30.35(c), 10 CFR 20.1402).

The NRC uses an all pathways radiological standard coupled with an ALARA approach to determine if a site is acceptable for unrestricted release. In 10 CFR 20.1402 it is stated that "a site will be considered acceptable for unrestricted use if the residual radioactivity, that is distinguishable from background radiation, results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are ALARA". The critical is the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances. When calculating TEDE to the average member of the critical group the licensee shall determine the peak annual TEDE dose expected within the first 1000 years after decommissioning.
This requires the staff to evaluate (1) how residual radioactivity can move through the environment, (2) where can humans be exposed, (3) what are likely future land use(s), (4) what are the exposure group's habits that will determine exposure (NRC 2006a and 2006b).

Alternate criteria that are greater than the criteria in 10 CFR 20.142 may also be used to determine when decommissioning activities could cease. However, the use of alternate criteria to terminate a license requires the approval of the Commission. This approval must consider NRC staff's recommendations addressing comments provided by the Environmental Protection Agency and the public that were submitted pursuant to 10 CFR 20.1405 (from 10 CFR 20.1404).

On August 3, 1999, the Congressional House Committee on Appropriations recognized there may be circumstances at specific NRC licensed sites undergoing decommissioning, where the EPA's expertise may be of critical use to the NRC. In the interest of ensuring that sites do not face dual regulation from both the NRC and EPA, the Committee strongly encouraged both agencies to enter into a memorandum of understanding (MOU) clarifying the circumstances for EPA's involvement at NRC sites.

Following the recommendation, NRC and EPA entered into an MOU with respect to the decommissioning of NRC licensed sites. In the MOU, both agencies recognized their common commitment to protect public health and safety and the environment. The MOU describes a basic framework for the relationship between the agencies as they fulfill their respective responsibilities for radiological decommissioning and decontamination of NRC-licensed sites. Since September 8, 1983, EPA has generally not listed sites on the CERCLA National Priorities List that are subject to NRC's licensing authority.

In the MOU, EPA reaffirmed its previous 1983 deferral policy and expected that any need for EPA Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) involvement in the decommissioning of NRC licensed sites should continue to occur very infrequently. EPA expects the vast majority of facilities decommissioned under NRC authority will be decommissioned in a manner that is fully protective of human health and the environment. However, some sites being decommissioned under NRC authority may need consultation with the EPA so that both agencies can fulfill their respective regulatory responsibilities. The MOU recognized that NRC applies an all pathways dose standard that includes groundwater as a pathway. However, in the cleanup of sites pursuant to CERCLA, EPA customarily establishes a separate ground-water cleanup standard that uses certain MCLs (from 40 CFR 141) promulgated for radionuclides and other substances pursuant to the Safe Drinking Water Act.

NRC agreed to consult with EPA when ground-water contamination at the time of license termination exceeded EPA's MCLs. NRC also agreed to consult with EPA when NRC contemplates either restricted release or the use of alternate criteria for license termination. It is through this MOU that an MCL analysis is introduced into the NRC decommissioning program.

<u>Operating Nuclear Power Reactors</u>

To evaluate the dose to the public, this program uses the Uranium Fuel Cycle Standard (NRC regulations in 10 CFR 20.1301(e) and EPA regulations in 40 CFR 190. In addition, the NRC uses the total effective dose equivalent limit of 100 mrem/yr to individual members of the public from the licensed operation (10 CFR 20.1301(1)(a)). These are top down (ALARA) all pathways standards, where dose via the groundwater pathway would just be one pathway that would be included in the calculated dose from all pathways.

For radionuclides released in liquid effluents from nuclear power plants an ALARA numerical guide has been established. Under this guide the calculated annual total quantity of all radioactive material above background to be released from each light-water-cooled nuclear power reactor to unrestricted areas will not result in an estimated annual dose or dose commitment from liquid effluents for any individual in an unrestricted area from all pathways of exposure in excess of 3 mrems to the total body or 10 mrems to any organ (10 CFR 50.34a and Appendix I of 10 CFR 50). See Appendix B for further details.

The NRC has also established numerical guides for design objectives and limiting conditions for operation. While these guides are not radiation protection standards, they are part of the NRC licensing, monitoring, and inspection activities (Appendix B).

As part its evaluation of an operating nuclear power reactor license renewal application, the NRC staff conducts an environmental review (i.e. license renewal) (relevant sections of 10 CFR 51 including 10 CFR 51.53, 10 CFR 50.95, and Appendix B of Subpart A of part 51). The environmental review uses a top down (ALARA) all pathways standard to evaluate radionuclide impacts on human health. However, to describe the impact of radionuclides on the groundwater as a resource, MCLs are likely to be used. The use of MCL's in this way is an acceptable approach identified in NRC 2013b.

In a license renewal environmental impact statement, the issue titled "Radionuclides Released to Groundwater" is where the impact on groundwater resources from radiological contamination is evaluated. The evaluation encompasses the intrinsic quality of the resource and current and potential future uses of the resource. See Appendix C for further details.

To satisfy NEPA requirements in the description of environmental impacts, MCLs may also be used to describe impacts on groundwater resources from non-radiological contaminants. As previously mentioned, this is generally true across all NRC programs for environmental impact statements.

New Reactor Program

The top down all pathways approach for the licensing of new reactors is the same as for operating nuclear power reactors.

Fuel Cycle Program

The NRC licenses all commercial fuel cycle facilities. These facilities turn uranium into nuclear fuel for commercial power reactors. The top down all pathways approach for fuel cycle facilities is the same as for operating nuclear power reactors.

Low-Level Waste Disposal Program

Low-level radioactive waste (LLW) consists of items contaminated with radioactive material or exposed to neutron radiation. This waste can include contaminated clothing, rags, mops, filters, reactor water treatment residues, equipment, tools, medical waste, and laboratory animal carcasses and tissues. Commercial LLW can be disposed of in facilities licensed by either the NRC or Agreement States. The facilities are designed, constructed, and operated to meet NRC safety standards (NRC 2016a).

To protect the general population from releases of radioactivity, disposal sites must meet an all pathways (ALARA) dose standard. Operations at the land disposal facility must be conducted in

compliance with the standards for radiation protection set out in 10 CFR 20, except for releases of radioactivity in effluents from the land disposal facility, which are governed by 10 CFR 61.41 (from 10 CFR 61.43). The standard in 10 FR 61.41 is the same as the Uranium Fuel Cycle Standard found in EPA regulations in 40 CFR 190 and NRC regulations in 10 CFR 20.1301(e).

Uranium Recovery

The NRC does not regulate conventional mining activities but does regulate the processing of uranium ore. Three types of uranium recovery facilities process uranium: (1) conventional mills, (2) heap-leach facilities and (3) in-situ recovery facilities. As discussed further below, the Uranium Recovery Program is unique in the regulation of both radionuclide and non-radionuclide contaminants in groundwater.

A conventional uranium mill extracts uranium from ore that is transported to the mill from mining operations. Heap-leach facilities also extract uranium from ore. However, at these facilities, the ore is placed in piles or heaps on top of liners. Then sulfuric acid is dripped onto the piles, dissolving the uranium in the ore. The acidic waters that now contain the dissolved uranium are then piped to a processing plant, which removes the uranium (NRC 2016a).

In-Situ Recovery facilities extract uranium directly from underground uranium ore deposits using wells that inject and recover a solution of native ground water typically mixed with oxygen or hydrogen peroxide and sodium bicarbonate or carbon dioxide. After the mixture is injected into the groundwater, this solution extracts the uranium from the rock. The solution, which now contains uranium, is pumped to the land surface where the uranium is removed from the solution (NRC 2016a).

In addition to the NRC all pathway dose regulations in 10 CFR 20 the uranium recovery program also incorporates (1) the chemical risk management of the bottom up approach, (2) the single substance-single pathway approach, (3) the protection of groundwater as a resource for present and future users, and (4) the use of MCLs.

For conventional mills, the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) was enacted by Congress to provide for the disposal, long-term stabilization, and the control of uranium mill tailings in a safe and environmentally sound manner. The Act directed EPA to set generally applicable health and environmental standards at both active and inactive mill tailings sites.

This Act also established two different programs; labeled Title I and Title II. The Title I program was established to cover remedial actions at abandoned mill tailings sites that had produced uranium for the federal government weapons program. A Title II program was established to regulate commercial conventional mills.

EPA considers Title I and Title II mill tailing sites as hazardous waste disposal sites. As such, the groundwater standards for Title I sites and Title II sites are consistent with, but not identical

to EPA Resource Conservation and Recovery Act (RCRA) requirements (EPA 2001). This means the Title I and Title II programs not only regulate radionuclide hazardous waste, but also regulate non-radiological chemical hazardous waste.

These two programs also include the basic elements of the EPA groundwater protection strategy. For example, in the Title I and Title II regulations, the definition of an underground source of drinking water means that the groundwater quality of an aquifer will be protected even if nobody is currently using the water in the aquifer. The regulations also contain prescriptive guidance on where groundwater is to be monitored (point of compliance), what constituents are to be monitored, and how concentration limits are to be established and compliance determined. They also contain directions for establishing alternative concentration limits, supplemental standards, monitoring plans, corrective actions, and the use of MCLs.

In the Title I program, DOE is responsible for cleanup and remediation of abandoned sites and the EPA is responsible for setting cleanup standards for both radiological and non-radiological hazardous constituents in groundwater. The EPA Title I standards are contained in 40 CFR Part 192. The NRC does not license these sites but is required to evaluate DOE's design and implementation and to concur that they meet the Title I standards set by the EPA.

For the Title II program, EPA established generally applicable standards for both radiological and non-radiological hazardous constituents. The EPA Title II standards are contained within 40 CFR Part 192 and relevant sections in 40 CFR 264. Title II sites regulated by the NRC and NRC Agreement States.

Title II regulations are consistent with the EPA Title II standards. Therefore, compliance with NRC regulations in 10 CFR 40 means a Title II site complies with the relevant EPA standards in 40 CFR 192. This addressed the issue of dual regulation by both the NRC and EPA.

Either directly or indirectly through State programs, the EPA regulates well fields at in-situ recovery sites via the EPA Under-Ground Injection Control regulations. The NRC also regulates the well fields either directly or indirectly through an Agreement-State Program. However, unlike EPA, the NRC has not established regulations that apply to the well fields. Therefore, the regulation of well field activities, such as groundwater monitoring, corrective action, and groundwater restoration are accomplished through license conditions, based on best practice.

The NRC in-situ recovery groundwater regulatory program incorporates many elements of the EPA program. Like Title II sites regulated through 10 CFR 40, groundwater quality is regulated using data from laboratory determined concentrations of radiological and chemical constituents in the groundwater. The in-situ recovery program seeks to protect the quality of the groundwater as a present and future resource. It regulates the concentrations of both radiological and non-radiological hazardous constituents in the groundwater. However, it also seeks to cleanup non-hazardous non-radiological constituents as the concentrations of which may make the water undrinkable.

Spent Nuclear Fuel and High-Level Waste Disposal

Spent nuclear fuel (SNF) and high-level radioactive waste (HLW) have been produced since the 1940s, mainly due to commercial power production and defense activities. Since then, the proper disposal of these wastes has been the responsibility of the Federal government. The current U.S. policy governing permanent disposal of high-level radioactive waste is defined by the Nuclear Waste Policy Act of 1982, as amended, and the Energy Policy Act of 1992. These acts specify that high-level radioactive waste will be disposed underground, in a deep geologic repository (NRC 2010).

This program is unique as licensing decisions are not based not on perfect performance by the repository, but on hypothetical failure modes. In addition, licensing decisions consider very long time periods of repository operation and use performance assessment analyses that include failure uncertainties and their probability of occurrence. The program also incorporates a concept of multiple barriers such as the waste package barriers and the engineered barriers.

In addition, to NRC all pathway dose regulations in 10 CFR 20, this program incorporates (1) the single substance-single pathway chemical risk management bottom up approach, (2) the protection of groundwater as a resource for present and future users, and (3) the use of MCL's.

The Nuclear Waste Policy Act of 1982 charges DOE to construct and operate a repository for spent fuel and other HLW and to obtain a license for the repository from the NRC. It also directs EPA to set generally applicable environmental radiation protection standards for the repository based on authority established under other laws; and it requires the NRC to implement those standards by incorporating them into its licensing requirements for SNF and HLW repositories. If the NRC grants DOE a license, it must ensure that DOE safely constructs, operates, and eventually closes the repository (NRC 2010).

The regulatory history associated with the licensing of a repository has resulted in the creation of two standards by the EPA and two regulations by the NRC. The EPA standard in 40 CFR 191 and the NRC regulations in 10 CFR 60 were originally written to apply to any type of geology and location that might be chosen to hold a repository. Now they apply to every site but the Yucca Mountain site in Nevada.

This is because, after Yucca Mountain was chosen to be characterized as a possible repository site; Congress passed a new law specific to Yucca Mountain (Section 801 of the Energy Policy Act of 1992). This law directed EPA to develop a new standard and the NRC to develop corresponding new regulations. Both the new standard and new regulations (40 CFR 197 and 10 CFR 63) are applicable only to a repository sited at Yucca Mountain. They do not apply to a repository proposed at another location.

This meant, the previous standard and regulations (40 CFR 191 and 10 CFR 60) no longer applied to a repository at Yucca Mountain but would apply to a repository at another location. Therefore, there are two separate EPA standards and two separate NRC regulations for SNF

and HLW repositories. As applicable, NRC reviewers also reference 10 CFR 20 standards (10 CFR 20.13).

The EPA standard in 40 CFR 191 (i.e. applicable to any location, but Yucca Mountain) sets an all pathways radiological dose limit for a repository that provides a reasonable expectation of dose for up to 10,000 years after disposal. This is an all pathways dose analysis. For 10,000 years; the undisturbed performance of the disposal system shall not cause the annual committed effective dose to any member of the public in the accessible environment to exceed 15 mrems (40 CFR 191.15 Individual Protection Requirements).

This standard also contains an environmental standard to protect underground sources of drinking water in the accessible environment from radiological contamination for up to 10,000 years after disposal. The repository should be designed to provide a reasonable expectation that after disposal, undisturbed performance shall not cause the levels of radioactivity in any underground source of drinking water in the accessible environment, to exceed the limits specified in 40 CFR part 141 (as they existed on January 19, 1994). These are MCLs for radionuclides (40 CFR 141.15 and 141.16). They are:

- 5 picoCurie/L for combined radium-226 and radium-228.
- 15 picoCurie/ L for Gross alpha activity (including radium-226 but excluding radon
- and uranium).
- 4 millirem annual dose equivalent to the total body or any internal organ based on drinking 2 liters of water per day.

It is important to note that before 10 CFR 60 can be applied to another repository site, it needs to be revised. The regulations have not been updated to incorporate the applicable EPA standard (40 CFR 191) and it may need to be revised to incorporate relevant concepts contained in the EPA standard applicable to Yucca Mountain (40 CFR 197). In the federal register notice for the promulgation of 10 CFR 63 the Commission recognized that its generic part 60 requirements will need updating. The Commission explained that since the initial technical criteria at 10 CFR part 60 were promulgated more than 15 years ago, there has been notable evolution in the capability of technical methods for assessing the performance of a geologic repository. The Commission stated that these new methods were not envisioned when the part 60 criteria were established.

The Commission recognized that its generic part 60 requirements will need updating if applied to sites other than Yucca Mountain. However, the Commission elected not to conduct an update of part 60 now but, instead, decided to place all the regulations needed for the licensing of a repository at Yucca Mountain in a separate CFR part.

For a repository sited at Yucca Mountain, the EPA Yucca standard in 40 CFR 197 sets all pathways dose limits for the repository for both disturbed and undisturbed releases. It also applies even if no one is presently consuming the groundwater. It contains one dose limit for up to 10,000 years after disposal and another dose limit for the period after 10,000 years, but within

the period of geologic stability. The period of geologic stability is defined to end one million years after disposal. The DOE must comply with both dose limits using performance assessments.

To perform a dose analysis even if no one is consuming the groundwater, the standard and regulations for Yucca Mountain contain the concept of a maximally exposed individual and the environment they live in (reference biosphere). The maximally exposed individual is a hypothetical person living in a community with characteristics of the Town of Amargosa Valley. As described in 10 CFR Part 63.312 the reasonably maximally exposed individual is a hypothetical person who meets the following criteria:

a) Lives in the accessible environment above the highest concentration of radionuclides in the plume of contamination;
b) Has a diet and living style representative of the people who now reside in the Town of Amargosa Valley, Nevada. DOE must use projections based upon surveys of the people residing in the Town of Amargosa Valley, Nevada, to determine their current diets and living styles and use the mean values of these factors in the assessments conducted for 10 CFR Parts63.311 and 63.321;
c) Uses well water with average concentrations of radionuclides based on an annual water demand of 3000 acre feet;
d) Drinks 2 liters of water per day from wells drilled into the groundwater at the location specified in paragraph (a) of this section; and
e) Is an adult with metabolic and physiological considerations consistent with present knowledge of adults.

The reasonably maximally exposed individual is selected to represent those persons in the vicinity of Yucca Mountain who are reasonably expected to receive the greatest exposure to radioactive material released from a geologic repository at Yucca Mountain. Characteristics of the reference biosphere and the reasonably maximally exposed individual are to be based on current human behavior and biospheric conditions in the region, as described in § 63.305 and § 63.312.

As previously stated, performance assessment is used to judge compliance with the EPA standard. For a Yucca Mountain repository performance assessment means an analysis that: estimates the dose incurred by the reasonably maximally exposed individual, including the associated uncertainties, as a result of releases caused by all significant features, events, processes, and sequences of events and processes, weighted by their probability of occurrence.

Following disposal, the DOE must demonstrate there is a reasonable expectation that a reasonably maximally exposed individual receives no more than 15 mrem annual committed effective dose equivalent. After 10,000 years, the DOE must demonstrate a reasonably maximally exposed individual receives no more than 100 mrem annual committed effective dose equivalent.

The EPA Yucca standard in 40 CFR 197 also contains an environmental standard to protect underground sources of drinking water in the accessible environment from radiological contamination. This environmental standard is similar to the standard in 40 CFR 191 with the exception that it contains the concept of a "representative volume" (NRC 2003). The EPA standard and NRC regulations in10 CFR 63 define the representative volume as containing 3,000 acre-feet of water and prescribe its location, and how it is to be determined.

Depending on the radionuclide, the estimated concentrations must either be below a specified concentration or result in an annual, drinking water dose to the whole body or any organ of no greater than 0.04 mSv (4 mrem). The environmental standard is only applicable for undisturbed performance up to 10,000 years after closure of the repository. During this time period, DOE must demonstrate that there is a reasonable expectation that, for 10,000 years of undisturbed performance after disposal, releases of radionuclides from waste in the Yucca Mountain disposal system into the accessible environment will not cause the level of radioactivity in the representative volume of groundwater to exceed (10 CFR 63.331):

- 5 picoCurie/L for combined radium-226 and radium-228.5;
- 15 picoCurie/ L for Gross alpha activity (including radium-226 but excluding radon
- and uranium);
- 0.04 mSv (4 millirem) per year to the whole body or any organ, based on drinking 2 liters of water per day from the representative volume for combined beta and photon emitting radionuclides.

These are the same concentrations listed in the EPA standard in 40 CFR 191. These are MCLs for radionuclides (40 CFR 141.15 and 141.16. Therefore, in keeping with the EPA underground protection strategy, the EPA Yucca Standard protects underground sources of drinking water whether or not they are currently being used.

With the closure of a repository, disposal is complete, and no further evaluations against the EPA standard and NRC regulations relative to groundwater are performed.

Interim Storage Program

This program uses an all pathways dose approach. The NRC licenses interim storage facilities for spent fuel or high-level radioactive waste. Two types of interim storage facilities are defined; independent and monitored retrievable. Independent spent fuel storage installation facilities are designed and constructed for the interim storage of spent nuclear fuel. These storage facilities are operated by commercial licensees; whereas monitored retrievable storage installations are designed, constructed, and operated by DOE. Their purpose is to receive, transfer, handle, package, possess, safeguard, and store spent nuclear fuel and high-level radioactive waste.

For normal operations at interim storage and monitored retrieval storage sites, an all pathways dose criteria to the public for normal operations is contained in 10 CFR 72.104. This regulation

directs that "during normal operations and anticipated occurrences, the annual dose equivalent to any real individual who is located beyond the controlled area must not exceed 0.25 mSv (25 mrem) to the whole body, 0.75 mSv (75 mrem) to the thyroid and 0.25 mSv (25 mrem) to any other critical organ." This is the same as the Uranium Fuel Cycle Standard found in EPA regulations in 40 CFR 190 and NRC regulations in 10 CFR 20.1301(e). The regulations also have an ALARA component. This component requires operational restrictions to be established to meet as low as is reasonably achievable objectives for radioactive materials in effluents and direct radiation levels (72.104(b)).

Appendix A: Examples of NRC ALARA Regulations

Examples of the ALARA approach in NRC regulations are:

10 CFR 20.1406(a) requires that applicants for licenses other than early site permits and manufacturing licenses under 10 CFR Part 52, whose applications are submitted after August 20, 1997; describe how the facility will be designed to comply with the ALARA approach. The application should contain a description of how the facility design and procedures for operation will (1) minimize to the extent practicable, contamination of the facility and the environment, (2) facilitate eventual decommissioning, and (3) minimize, to the extent practicable, the generation of radioactive waste.

10 CFR 20.1406(b) requires that applicants for standard design certifications, standard design approvals, and manufacturing licenses under 10 CFR Part 52, whose applications are submitted after August 20, 1997, describe in the application how facility design will minimize, to the extent practicable, contamination of the facility and the environment,

10 CFR 20.1406(c) requires licensees, to the extent practical, to conduct operations to minimize the introduction of residual radioactivity into the site, including the subsurface, in accordance with the existing radiation protection requirements in Subpart B, "Radiation Protection Programs," and radiological criteria for license termination in Subpart E, "Radiological Criteria for License Termination," of 10 CFR Part 20.

Appendix B: Summary of ALARA Process for Operating Nuclear Power Reactors

The ALARA process is based on a robust regulatory framework that protects the public and environment. "*This framework is composed of several components including regulations, licensing, and guidance to the regulated community, oversight, enforcement, and emergency response. Applicants for an NRC license must meet the applicable regulatory requirements to obtain a license to construct and operate a nuclear reactor, and to otherwise use and possess radioactive material. These regulations are based on established engineering principles for safe plant design and operation. Before issuing a license, the NRC assesses the license application to ensure that safety measures are technically and scientifically sound, all requirements are met, and the appropriate safety systems and radioactive waste processing systems are in place to limit effluent releases to as low as reasonably achievable (ALARA) to protect the public and the environment*" (NRC 2017).

"*When a nuclear power plant begins operation, the NRC assigns specially trained NRC staff as resident inspectors in permanent positions at the site. These NRC resident inspectors have unfettered access to all of the site information and provide continual oversight and inspection of the facility. The NRC inspectors ensure licensees meet the regulations and the terms of their license to operate safely. When violations are identified, the NRC takes the appropriate*

enforcement action. The NRC requires licensees to have an emergency response organization which conducts periodic drills to demonstrate readiness in case of a plant emergency. As part of its ongoing oversight, the NRC staff routinely collects and analyzes licensed facility operational experience. The NRC staff uses this information to make appropriate changes to its regulatory framework, on a generic basis, through rulemaking and the issuance of guidance, and on a case-by-case basis, to an individual facility's licensing basis (e.g., changes to license conditions)" (NRC 2017).

"The NRC regulatory framework includes limits on the discharge of radioactive material to the environment and inspections to verify that licensees meet these limits. These discharges must be within the public dose limits and ALARA. To quantify the impact of these discharges, NRC regulations require that licensees conduct radiological environmental monitoring programs to measure radiation and radioactivity levels in the environment around each nuclear power plant. The radiological environmental monitoring program collects environmental monitoring data to verify the effectiveness of the plant systems that control the release of radioactive materials and to demonstrate compliance with the public dose limits. The environmental monitoring program includes monitoring water and air samples at offsite locations where the highest concentrations of radionuclides are expected and measuring direct radiation from the plant using environmental dosimeters. In addition, the NRC requires licensees to sample and analyze various receptor pathways such as water, milk, soil, sediment, vegetation, and foodstuffs. The NRC requires licensees to report the results of the radiological environmental monitoring program annually to the agency. The licensee reports containing these results can be found at http://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html" (NRC 2017).

<u>Effluent and monitoring regulations and regulatory guidance supporting the implementation of ALARA</u>

- 10 CFR 50.34a, Design objectives for equipment to control releases of radioactive material in effluents - nuclear power reactors.
- 10 CFR 50.36a, Technical specifications on effluents from nuclear power reactors.
- 10 CFR Part 20, Standards for Protection Against Radiation.
- 10 CFR 50.72, Immediate notification requirements for operating nuclear power reactors.
- 10 CFR 50.73, Licensee event report system.
- 10 CFR 50.75(g), Reporting and recordkeeping for decommissioning planning.
- 10 CFR Part 50, Appendix I, Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low As Is Reasonably Achievable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents. (40 FR 19437 as an effective rule on May 5, 1975).
- Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I (Rev. 1, 10/75).
- Regulatory Guide 4.1, Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants. (1/73).

- Regulatory Guide 4.2, Preparation of Environmental Reports for Nuclear Power Stations. (Rev. 2, 7/76).
- Regulatory Guide 4.5, Assessment of Abnormal Radionuclide Discharges in Ground Water to the Unrestricted Area at Nuclear Power Plant Sites. (3/17).
- Regulatory Guide 4.8, Environmental Technical Specifications for Nuclear Power Plants (12/75) and Branch Technical Position (Rev. 1, 11/79; specific to environmental monitoring program).
- Regulatory Guide 4.15, Quality Assurance for Radiological Monitoring Program (Normal Operation) - Effluent Streams and the Environment.
- Regulatory Guide 1.21, Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants. (Rev. 1, 6/74).
- Regulatory Guide 1.143, Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants. (Rev. 2, 11/01).
- NUREG-0472, Radiological Effluent Technical Specifications for PWRs. (2/80).
- NUREG-0473, Radiological Effluent Technical Specifications for BWRs. (7/79).
- NUREG-1430, Technical Specifications for Babcock and Wilcox Plants. Rev 3.
- NUREG-1431, Technical Specifications for Westinghouse Plants. Rev 3.
- NUREG-1432, Technical Specifications for Combustion Engineering Plants. Rev 3.
- NUREG-1433, Technical Specifications for General Electric BWR/4 Plants. Rev 3.
- NUREG-1434, Technical Specifications for General Electric BWR/6 Plants. Rev 3.
- 10 CFR Part 50, Appendix A; Design Criteria 60, Control of Releases of Radioactive Materials to the Environment.
- 10 CFR Part 50, Appendix A; Design Criteria 61, Fuel storage and handling and radioactivity control.
- 10 CFR Part 50, Appendix A; Design Criteria 64, Monitoring Radioactivity Releases.
- 40 CFR Part 190, Environmental Radiation Protection Standards for Nuclear Power Operations. (1/77).

Appendix C: Environmental Analysis of Groundwater as a Resource for Operating Nuclear Reactors

On June 20, 2013, the NRC amended its environmental protection regulations in 10 CFR 51 by updating the Commission's 1996 findings on the environmental effect of renewing the operating license of a nuclear power plant. Regulation § 51.53 (c)(3)(ii)(P) was part of this amendment. It requires license renewal applicants to:

- Project the impact of any documented inadvertent releases of radionuclides into groundwater over the license renewal term.

- The projection must also include impacts to not only aquifers, but to rivers, lakes, ponds, and oceans).

- Include this information in the environmental report.

The final rule also redefined the number and scope of the environmental impact issues that must be addressed by the NRC during license renewal environmental reviews. New issues were added that were not addressed in previous environmental reports. A new Category 2 issue was added titled ‘Radionuclides released to groundwater’. A Category 2 issue requires the staff to perform a plant-specific review. This new issue was added to Table B–1 in Appendix B to 10 CFR Part 51.

In 2013, the Generic Environmental Impact Statement (GEIS) for the License Renewal of Nuclear Power Plants was revised to incorporate this new issue (NRC 2013a). As described in the 2013 GEIS, the purpose of the new issue titled ‘Radionuclides released to groundwater’’ is to evaluate the potential contamination and degradation of groundwater resources resulting from the release of radioactive liquids into the groundwater from nuclear power plants. For this new issue the federal register notice for the final rule explained that, “*while the NRC’s regulations in 10 CFR part 20 and in 10 CFR part 50 limit the amount of radioactive material released (i.e., from routine and inadvertent sources) from a nuclear power plant into the environment, the regulations are focused on protecting the public, not the quality of the groundwater. Therefore, as required by NEPA, the NRC must consider the potential impacts to the groundwater from radioactive liquids released into groundwater*” (78 FR 37282).

With the exception of the Human Health analysis, the 2013 GEIS (NRC 2013a) did not rely on the Commission’s radiological safety program and associated regulations and dose limits to describe and rank impacts to resources. For example, the NRC staff’s evaluation of dose to terrestrial organisms and aquatic organisms (NRC 2013a, pages 4-61 to 4-64 and pages 105 and 107) reference a U.S. Department of Energy guideline for radiation dose rates from environmental sources that contains numerical recommendations to limit the radiation dose to aquatic biota, riparian and terrestrial mammals and to plants. For the issue of “Radionuclides Released to Groundwater” the 2013 GEIS relied on background water quality concentrations and on EPA maximum contaminant levels (MCLs) to describe the radiological impacts on the groundwater (NRC 2013a, pages 4-51 to 4-54).

In a license renewal SEIS, the affected environment chapter should contain a description of the groundwater, the location of radionuclides in the groundwater, and their projected location over the period of license renewal. Relevant aspects of this information would be incorporated into the all pathways dose analysis in Human Health analysis to determine dose to workers and the public. It would also be incorporated into the radionuclides in groundwater issue to determine the impact on the groundwater as a resource.

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