Groundwater Monitoring Guidance for Decommissioning Planning – 16228

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ABSTRACT

The Electric Power Research Institute (EPRI) is preparing a document called *Groundwater Monitoring Guidance for Decommissioning Planning*. This guidance is the first part of a multi-year EPRI project which summarizes experiences with both operational and decommissioning groundwater protection programs and compares the two in order to identify data gaps. The EPRI guidance will show how to address these data gaps and provide recommended decommissioning preparatory actions. The second part of this project will addresses the long term stewardship of a groundwater protection program after the permanent shutdown of the plant during the SAFSTOR period and/or during the active decommissioning of the plant. This paper will discuss the content of the first EPRI guidance document that is focused on decommissioning planning.

INTRODUCTION

Leaks and spills at nuclear power plants can lead to licensed material, such as tritium, potentially reaching soil and the groundwater around structures, systems and components of the facility. EPRI has developed a program to provide the industry with technical guidance, support, and technologies for leak detection, groundwater and soil monitoring, characterization, and remediation. By implementing groundwater monitoring programs, nuclear power plants are able to detect and address groundwater contamination events and understand impacts on future decommissioning. In the United States (U.S.), all nuclear power plants have committed to implementing groundwater protection programs per the Nuclear Energy Institute (NEI) 07-07*, Industry Groundwater Protection Initiative – Final Guidance Document*. [1]

Nuclear power plants need to implement life of plant groundwater monitoring programs, including monitoring during decommissioning. These groundwater protection programs not only inform plant personnel of leaks, spills, and groundwater contamination events to be addressed during operations, but also provide information necessary for planning and execution of decommissioning. In the United States, the United States Nuclear Regulatory Commission (NRC) *Decommissioning Planning Rule* [2], which took effect in 2012, requires an assessment of the effect of leaks and spills on the future decommissioning of the site. These requirements are based on

decommissioning experience in the United States and Europe which shows that groundwater contamination can impact decommissioning waste generation, cost, and schedule.

The EPRI guidance report will, *Groundwater Monitoring Guidance for Decommissioning Planning*:

- Summarize experiences with both operational and decommissioning groundwater protection programs
- Compare the experiences in order to identify data, groundwater monitoring network and programmatic gaps.
- Provide guidance as to how to address these gaps and recommended actions that can be taken toward the end of plant operations and during the early stages of decommissioning.

The EPRI guidance report will be applicable to international nuclear power plants for groundwater protection and decommissioning planning.

DECOMMISSIONING PLANNING

Based on lessons learned during early decommissioning projects and power plants in operation, plants worldwide have initiated ground water monitoring programs applicable during plant operations. In many countries, these programs are mandatory, and prompt remediation is required when groundwater contamination is detected. For example, in the United States, when the *Decommissioning Planning Rule* [2] took effect, groundwater protection programs had already been implemented at nuclear power plants as part of the industry's voluntary *Groundwater Protection Initiative* (GPI).

Separate but related to the new rules, the NRC is also considering regulations related to prompt remediation of radioactive contamination during plant operation. The technical content of the NRC regulations and similar regulations in other countries, combined with applicable EPRI research, are useful for both currently operating and shutdown nuclear power plants in the planning and execution of groundwater monitoring and remediation to facilitate site decommissioning.

U.S. NRC Decommissioning Planning Rule

On June 17, 2011, the NRC promulgated certain changes to Section 10 Code of Federal Regulations Part 20 (10 CFR Part 20), "Standards for Protection Against Radiation," that the NRC has called the *Decommissioning Planning Rule* (DPR) [2]. A summary of the changes related to decommissioning planning are as follows:

- Licensees shall, to the extent practical, conduct operations to minimize the introduction of residual radioactivity into the site, including the subsurface.
- Licensees shall survey site areas, including the subsurface, that are reasonable to evaluate:
  - The magnitude and extent of radiation levels; and
  - Concentrations or quantities of residual radioactivity; and
  - The potential radiological hazards of the radiation levels and residual radioactivity detected.
- Records from surveys describing the location and amount of subsurface residual radioactivity identified at the site must be kept with records important for decommissioning (i.e., in the 10 CFR 50.75(g) file).

As can be seen from the above, the primary goal of the *Decommissioning Planning Rule* is to clarify that the NRC regulations also apply to subsurface radionuclide contamination. The NRC issued Regulatory Guide 4.22 *Decommissioning Planning During Operation* [3] to provide guidance as to how the Decommissioning Planning Rule can be implemented.

NRC Regulatory Guide 4.22, Decommissioning Planning During Operation

The NRC published acceptable methods to meet the requirements in the DPR in Regulatory Guide 4.22 *Decommissioning Planning During Operation*. [3] A summary of the methods that are applicable to nuclear power plants is contained in the following list:

- Operations need to be conducted so as to minimize the introduction of significant residual radioactivity into the site
- Surveys need to be conducted to identify the extent of significant residual radioactivity at their sites, including the subsurface
- Licensees having significant residual radioactivity on their sites are to retain survey results with records important to decommissioning in accordance with 10 CFR 50.75(g).
- For nuclear power plants, implementing the guidance in the following Nuclear Energy Institute documents is considered adequate to meet the DPR:
  - For plants with license applications submitted prior to August 21, 1997, NEI 07-07, *Industry Ground Water Protection Initiative—Final Guidance Document*, [1]

- For plants with license applications submitted after August 20, 1997, NEI-08-08, Revision 3, *Generic FSAR Template Guidance for Life Cycle Minimization of Contamination* [4].

U.S. NUCLEAR POWER INDUSTRY GUIDANCE APPLICABLE TO THE DPR

Nuclear Energy Institute 07-07, Groundwater Protection Initiative

As discussed in the last section, the NRC guidance concerning the DPR states that the subsurface survey requirements of the DPR are met by implementing the guidance of NEI 07-07 *Industry Ground Water Protection Initiative – Final Guidance Document* [1]. The following is a listing of the actions required by NEI 07-07 that are applicable to surveys for residual radioactivity in subsurface areas:

1. "Improve management of situations involving inadvertent radiological releases that get into groundwater" – This action statement of NEI 07-07 requires all power plant licensees to have a Ground Water Protection Initiative (GPI) Program. This action statement also refers to the *EPRI Groundwater Protection Guidelines for Nuclear Power Plants* [5] as one approach that can be used to design the features of a GPI Program.
2. "Ensure that the site characterization of geology and hydrology provides an understanding of predominant ground water gradients based upon current site conditions."
3. "Identify site risks based on plant design and work practices."
    a. "Evaluate all systems, structures, or components (SSCs) that contain or could contain licensed material and for which there is a credible mechanism for the licensed material to reach ground water."
    b. "Evaluate work practices that involve licensed material and for which there is a credible mechanism for the licensed material to reach groundwater."
4. "Establish an on-site ground water monitoring program to ensure timely detection of inadvertent radiological releases to ground water."
5. "Establish a remediation protocol to prevent migration of licensed material off-site and to minimize decommissioning impacts."
6. "Ensure that records of leaks, spills, remediation efforts are retained and retrievable to meet the requirements of 10 CFR 50.75(g)."

DECOMMISSIONING REGULATIONS AND GUIDANCE OUTSIDE THE U.S.

The following provides a listing of guidance documents published outside of the U.S. that can be helpful in addressing the monitoring and remediation needed to address groundwater contamination. Utilities outside the U.S. that are members of EPRI and are operating and/or decommissioning nuclear power plants are using the guidance from the EPRI Groundwater Protection Program and experiences from the EPRI

Decommissioning Program in evaluating real or potential groundwater contamination at their sites.

World Health Organization

One published international standard for radionuclides in drinking water, that is not specific to nuclear power plants, is that provided by the World Health Organization (WHO) in *Guidelines for Drinking-water Quality* [6]. This guideline is based on a dose standard of 0.1 mSv/yr (10 mrem/yr) for drinking water. Per the International Commission on Radiation Protection [7], a dose of 0.1 mSv/yr (10 mrem/yr) from drinking water gives an estimated annual cancer risk of approximately 5.5×10^{-6}. This WHO guideline publishes a drinking water guideline for tritium of 10,000 Bq/L (270,000 pCi/L).

European Commission Directive on Quality of Human Consumption Water

The Council of the European Union Directive 98/83 on *Quality of Human Consumption Water* [8] used the same dose standard of 0.1 mSv/yr (10 mrem/yr) for drinking water as the World Health Organization guidelines discussed above.

Canadian Federal Guidelines

The government in Canada, in a Health Canada publication *Guidelines for Canadian Drinking Water Quality* [9], has established Maximum Acceptable Concentrations (MACs) for the most commonly detected natural and artificial radionuclides in Canadian drinking water sources. The following is a summary of this Canadian government guideline technical document.

The MACs for radionuclides that have been significant during the operation and decommissioning of a nuclear power plant are listed in the Table I below. The MACs are based on exposure solely to a specific radionuclide. The radiological effects of two or more radionuclides in the same drinking water source are considered to be additive. Thus, the sum of the ratios of the observed concentration to the MAC for each contributing radionuclide should not exceed one (1).

The MACs are derived using internationally accepted equations and principles and are based solely on health considerations. The MACs are based on a reference dose of 0.1 mSv/yr (10 mrem/yr), which represents a lifetime excess risk (i.e., above background levels), based on Canadian regulatory authority calculations, of both fatal and non-fatal cancers of 7.3×10^{-6}. The MAC for tritium is 7,000 Bq/L (189,000 pCi/L).

The allowable concentrations in drinking water for various regulatory agencies and organizations in various countries are shown in Table I for radionuclides that have been significant to groundwater contamination at nuclear power plants.

TABLE I. Comparison of Selected International Standards for Drinking Water

Radionuclide	WHO Drinking Water Guidelines Bq/L (pCi/L)	Canada: Maximum Acceptable Concentration Bq/L (pCi/L)	U.S. NRC: Typical Groundwater Site Release Limits[a] Bq/L (pCi/L)	U.S. EPA Maximum Contaminant Levels[b] (i.e. Drinking Water Standards) Bq/L (pCi/L)
Dose Standard[c]	0.1 mSv/yr (10 mrem/yr)	0.1 mSv/yr (10 mrem/yr)	0.25 mSv/yr (25 mrem/yr)	0.04 mSv/yr (4 mrem/yr)
H-3	7,000 (189,000)	10,000 (270,000)	24,000 (652,000)	740 (20,000)
Sr-90	5 (135)	10 (270)	135 (5)	0.3 (8)

a. Values from the Haddam Neck (nuclear power plant) License Termination Plan [10]

b. Per U.S. Environmental Protection Agency (EPA) Document 816-D-00-002, *Implementation Guidance for Radionuclides* [11]

c. All dose is Total Effective Dose Equivalent except the EPA Maximum Contaminant Levels (MCLs) which are calculated as Total Body Dose

GUIDELINES FOR GROUNDWATER REMEDIATION

The following describes the *EPRI Groundwater Protection Guidelines* that guidance for groundwater and soil remediation.

EPRI Groundwater and Soil Remediation Guidelines

The *EPRI Groundwater and Soil Remediation Guidelines for Nuclear Power Plants* [12] provide the guidance that can be used to establish a decision making protocol for soil or groundwater remediation at nuclear power plant sites. For plants in the United States, these guidelines can be used to satisfy the remediation evaluation protocol requirement of NEI 07-07. The remediation evaluation protocol that is described in NEI 07-07 should be established prior to a leak or spill event (i.e. as part of the site's groundwater protection program) and can include the evaluation steps outlined in this EPRI guidelines document (depicted in Fig. 1.) The EPRI guidelines provides a process by which remediation objectives, site investigation criteria and draft site release limits are developed that can be used to evaluate the need for remediation in the event of a

leak or spill. A nuclear power plant in any country can use this protocol by incorporating their site-specific and country specific criteria. The overarching considerations that should be included in the decision-making protocol are:

1. Potential for off-site migration of contamination following an inadvertent release
2. Potential impacts to decommissioning planning and costs, such as increases in contaminated materials requiring disposal at decommissioning
3. Potential to exceed site release criteria at license termination
4. Potential impacts to plant operation and business practices

The *EPRI Groundwater and Soil Remediation Guidelines* contains guidance statements describing the actions to be performed at the critical steps in the process. A summary of these guidance statements is contained in Table II. This process is also shown graphically in the flowchart in Fig. 1.

TABLE II. Summary of Groundwater and Soil Remediation Guidance Statements [8]

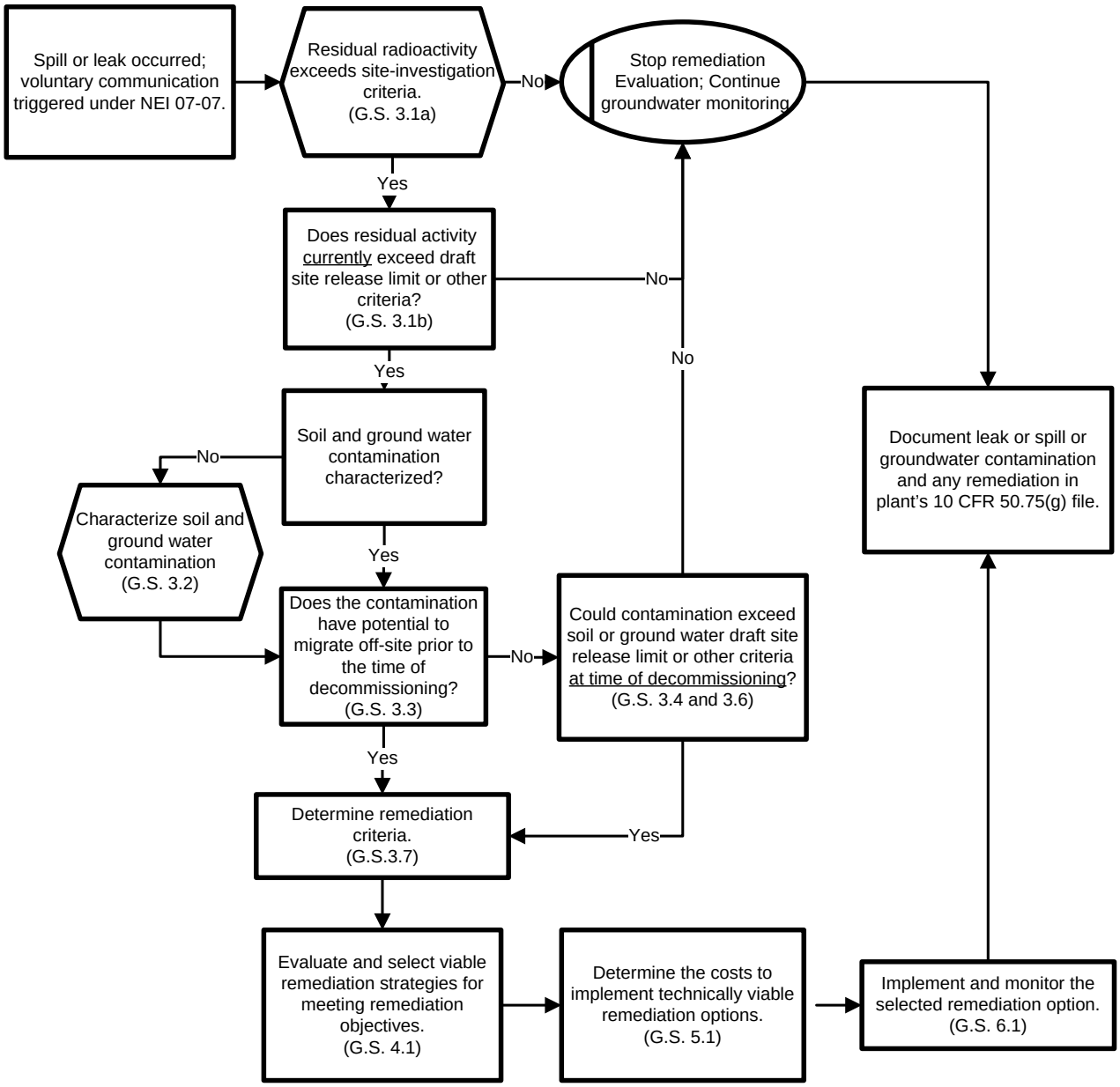
Guidance Number	Guidance Statement
2.1	Define remediation objectives.
2.2	Establish site-specific investigation criteria that will be used to evaluate the outcome of initial leak or spill response.
2.3	Determine draft site release limits for soil and groundwater. These draft site release limits define the allowable concentrations in soil and groundwater that meet the NRC site release criteria at license termination.
3.1	Once initial leak or spill response is complete, survey the area to determine if residual radioactivity exists. a: If residual radioactivity is below the investigation criteria determined in Guidance Statement 2.2, further remediation evaluations are not required. b: If residual radioactivity is below the draft site release limits defined per Guidance Statement 2.3, further remediation evaluations are not required.
3.2	Characterize the extent of soil and groundwater contamination.

TABLE II. Summary of Groundwater and Soil Remediation Guidance Statements, cont' [8]

Guidance	Guidance Statement

Number	
3.3	Evaluate the potential for contamination to migrate off-site prior to the time of decommissioning.
3.4	Estimate the extent of soil and groundwater contamination at the time of decommissioning.
3.6	Compare the radionuclide concentrations that are projected to remain in the soil and groundwater at the time of decommissioning (determined per Guidance Statement 3.4) to the draft site release limits (determined per Guidance Statement 2.2). If the projected radionuclide concentrations are below the draft site release limits defined per Guidance Statement 2.2, further remediation evaluations are not required.
3.7	Define remediation criteria.
4.1	Evaluate and select viable remediation strategies for meeting remediation objectives. Both remediation during operation and remediation during decommissioning should be considered in order to make informed decisions about when to implement remediation.
5.1	Determine the costs to implement the technically viable remediation options chosen per Guidance Statement 4.1.
6.1	Implement and monitor the selected remediation option.

Note 1: Guidance statements are numbered to be consistent with the chapter and section containing these guidance statements.



Note 1: Steps may be skipped in this flowchart, as applicable to given conditions at the facility under review.

Note 2: Remediation options may be implemented during operation or decommissioning based on the technical and business evaluation of the licensee. If the decision is made to delay remediation until decommissioning, a more accurate evaluation of remediation criteria and technologies may be possible at that time due to the availability of information about the future use of the site and site release/license termination strategy. Remediation options may include passive technologies (such as monitored natural attenuation) or aggressive technologies (such as removal of soil or bedrock.)

Fig. 1 EPRI Groundwater and Soil Remediation Flow Chart [12]

The *EPRI Groundwater and Soil Remediation Guidelines* also provides the information necessary to evaluate remediation options with respect to technical feasibility, safety, and cost in order to determine if remediation is less costly and/or more effective during operation or during decommissioning. Based on this evaluation, the user will then be able to make a site-specific and informed business decision for each incident or contamination detection on whether to remediate during operation or during decommissioning.

While the process in this guideline does not prescribe a particular remediation option, it does describe a number of options for consideration at a nuclear power plant site with soil and/or groundwater contamination. More importantly, the guideline provides an outline of a decision making process for the remediation of soil and groundwater that will support a well-defined business decision, meet regulatory requirements, and maintain the health and safety of the public and the environment.

Although the remediation decision process presented in the EPRI Groundwater and Soil Remediation Guidelines is discussed in the context of leaks and spill, this process is also applicable to other situations where contamination is detected in soil including:

- Performing site characterization sampling
- Excavating soil as part of a plant modification project
- Evaluating soil for unconditional release or during release of the site at decommissioning

SUMMARY AND CONCLUSIONS

Recent regulation and regulatory guidance in the U.S. has increased the focus on subsurface radionuclide contamination at nuclear power plants. International guidance concerning drinking water standards also provides standards for consideration during the operation and decommissioning.

Guidance provided in Nuclear Energy Institute 07-07, *Industry Groundwater Protection Initiative* and the guidelines such as the *EPRI Soil and Groundwater Remediation Guidelines* and the *EPRI Groundwater Protection Guidelines* provide information and protocols that can be used to help address these regulations and guidance during operations and decommissioning of nuclear facilities.

EPRI is now developing a report titled *Groundwater Monitoring Guidance for Decommissioning Planning*. This report will summarize experiences with both operational and decommissioning groundwater protection programs with the objective of identifying any data, monitoring network, and programmatic gaps related

to decommissioning planning. Through this report, EPRI will provide guidance as to how to address these gaps and recommended actions that can be taken toward the end of plant operations and during the early stages of decommissioning. This technical guidance document will be applicable to international nuclear power plants.

REFERENCES

[1] Nuclear Energy Institute, "Industry Ground Water Protection Initiative—Final Guidance Document," NEI 07-07, Washington, DC, August 2007.

[2] U.S. Nuclear Regulatory Commission, "Decommissioning Planning Rule," Federal Register, Volume 76, Number 117, June 17, 2011, pp. 35512–35575.

[3] U.S. Nuclear Regulatory Commission. "Decommissioning Planning During Operations." Regulatory Guide 4.22. 2012.

[4] Nuclear Energy Institute, "Generic FSAR Template Guidance for Life Cycle Minimization of Contamination," NEI 08-08, Revision 3, Washington, DC, September 2009.

[5] *Groundwater Protection Guidelines for Nuclear Power Plants: Revision 1*. EPRI, Palo Alto, CA: 2013. 3002000546.

[6] World Health Organization, Guidelines for Drinking-water Quality, 4th Edition, 2011

[7] ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-4).

[8] Council of the European Union, Directive 98/83/EC on the Quality of Water for Human Consumption Water, November 1998.

[9] Health Canada publication, Guidelines for Canadian Drinking Water Quality, Guideline Technical Document, May 2009.

[10] Haddam Neck Plant License Termination Plan, Revision 4, November 2006.

[11] U.S. EPA Document 816-D-00-002, Implementation Guidance for Radionuclides, 2000.

[12] *Groundwater and Soil Remediation Guidelines for Nuclear Power Plants*. EPRI, Palo Alto, CA: 2010. 1021104.