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Groundwater Protection Guidelines for Nuclear Power Plants

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REPORT SUMMARY

The nuclear power industry has entered into a voluntary initiative to implement groundwater monitoring programs at all nuclear power plant sites. This EPRI guideline provides essential technical guidance to nuclear power utilities on the necessary elements of a sound groundwater protection program.

Background

Over the last ten years, several nuclear power plants have detected small quantities of radioactivity in soil and groundwater from inadvertent releases of licensed material. Although investigation has shown that these contamination incidents have an insignificant radiation dose consequence, the nuclear power industry has entered into a voluntary initiative to implement groundwater monitoring programs at all sites in order to assure local stakeholders that the public health and safety are being protected.

Objectives

- To minimize potential unplanned, unmonitored releases to the environment from plant operations.
- To demonstrate a commitment to control licensed radioactive material.
- To minimize long-term effects associated with potential groundwater and subsurface contamination through prevention and early detection.

Approach

A group of over 50 professionals, representing 30 nuclear power utilities, organizations, and consulting firms, shared their collective experiences and expertise to develop, by consensus, this guideline document. This group also included representatives from EPRI, NEI (Nuclear Energy Institute), and ANI (American Nuclear Insurers), who played significant roles in the development of the technical and programmatic guidance found in this document. This project team also enhanced the document with experience gained through detailed on-site evaluations of groundwater monitoring programs at eleven commercial nuclear power stations.

Results

This EPRI document provides the nuclear power industry with a practical guideline for designing and implementing a technically sound groundwater protection program tailored to site-specific hydrogeologic characteristics and the conditions of the plant's systems, structures, and components. The evaluation and prioritization of systems, structures and components (SSCs), and work practices with regard to their potential to cause soil or groundwater contamination is an important part of the monitoring program. It will allow plant management to prioritize possible

mitigation efforts to eliminate or reduce the potential for groundwater contamination that may be caused by SSCs or work practices.

This groundwater protection guideline also addresses the following program areas: determination of the groundwater flow profile through the use of a Site Conceptual Model; locating, installing and testing groundwater monitoring wells; establishing a groundwater sampling and analysis process; evaluating sampling and monitoring data; program validation and review; communications with stakeholders; and potential mitigating actions.

EPRI Perspective

EPRI developed these Guidelines in response to an industry-wide need for guidance implementing technically sound and standardized groundwater monitoring programs. The Guidelines presents a graded approach to ensure that each nuclear power plant can implement a groundwater monitoring program appropriate for their site. The collaborative effort with NEI and a utility committee represents the industry's proactive management of groundwater protection issues. By developing and implementing these EPRI Guidelines in a timely manner, the industry can work with regulators and other stakeholders to develop groundwater monitoring programs that address public concerns related to groundwater contamination. EPRI will update and revise these guidelines every two to three years, to ensure that the Guidelines are up-to-date with industry experiences, lessons learned, and developing technologies.

Keywords

Groundwater
Groundwater contamination
Groundwater modeling
Hydrogeology
Monitoring well
Tritium

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1 INTRODUCTION

This document was prepared by a team of experts to provide the nuclear power industry with guidelines for the implementation of *groundwater*[1] protection programs at nuclear power plants. The objectives of these guidelines are to demonstrate a commitment to controlling licensed material, minimize potential unplanned, unmonitored releases to the environment from plant operations, and minimize long-term costs associated with potential groundwater and *subsurface* contamination.

Technical guidance is provided for implementing a two-phased groundwater protection program. The first phase consists of evaluations done to further the understanding of the risk for soil or groundwater contamination at the site posed by systems, structures, components or work practices. This part of the program provides consideration elements for evaluating the relative risk of systems and components for contaminating groundwater. This evaluation process allows the utility to understand the existing and potential risk of groundwater contamination at their site and also to prioritize any mitigation actions required to reduce this risk.

The second phase of the program provides guidance for implementing a comprehensive baseline groundwater monitoring program. The Guidelines provide the utility with detailed recommendations for developing a *site conceptual model*, installing monitoring wells, and analyzing and interpreting data. If, based on the user's understanding of the existing or potential risk of groundwater contamination, a more detailed understanding of the site hydrogeology is required, the Guidelines recommend several tools and methods for consideration as part of the *graded approach* to groundwater monitoring.

The baseline program described in this Guideline is an example of a technically sound groundwater protection program that should be implemented across the commercial nuclear power industry. Other technically sound, documented approaches comparable to the program outlined in this guidance may also be used.

Utilities can use the guidance in this document to develop site specific implementation plans to optimize the resources and time needed to ensure the protection of groundwater at and near their plants. In some cases the results of this evaluation will require significantly more resources and time than have been historically allocated to groundwater protection. To make the best use of available resources, plants should begin implementation of these guidelines by first evaluating those systems, structures and components (SSCs) and work practices that have a higher relative risk of failure and could lead to groundwater contamination.

[1] Terms that are defined in the Glossary are, on their first occurrence, shown in italics.

The overall implementation of the groundwater protection program is shown graphically in the flowchart in Figure 1-1. The graded approach is explained in Section 2, and detailed descriptions of the groundwater protection program elements are provided in the Sections 3 through 8. Specific requirements and recommendations within each program element are given in "Guidance Statements," which are also found in Sections 3 through 8, and are tabulated in Appendix A.

While this Guideline provides a framework for investigating impacts to groundwater, it does not elaborate on the use of specific hydrogeologic techniques for conducting investigations. References for such techniques are provided throughout the Guideline and in Section 11 and 12.

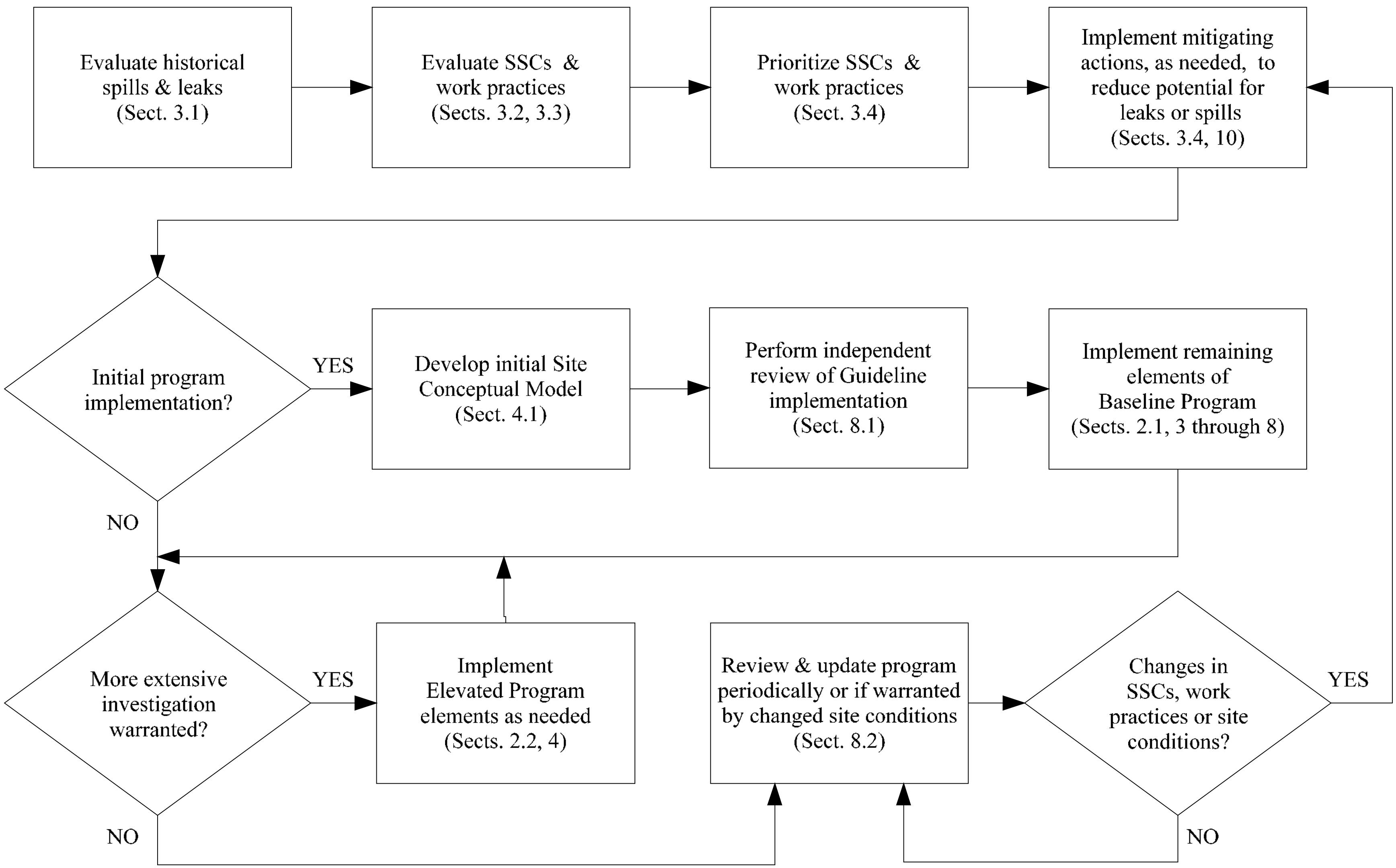

Figure 1-1
Implementing the Groundwater Protection Program

2
GRADED APPROACH FOR THE GROUNDWATER PROTECTION PROGRAM

2.1 Baseline Program

The "Baseline Program" is an example of a technically sound groundwater protection program that should be implemented across the commercial nuclear power industry. Other technically sound and documented programs may be used in lieu of this Baseline Program. Table 2-1 provides an overview of the elements that make up the Baseline Program.

The Guidance Statements that make up the Baseline Program are identified in Sections 3 through 8 by the word "[BASELINE]" in square brackets. They are also listed in Appendix A.

2.2 Elevated Program

At sites with a higher risk contamination situation (e.g., more complex hydrogeology, closer proximity of leak/spill to the site boundary, greater amount of contamination), additional tools may be needed in order to properly characterize and predict the migration of contamination in groundwater. The "Elevated Program" is a set of more sophisticated groundwater characterization methodologies that may be used in such situations, at the discretion of the licensee.

The elements of the Elevated Program are also described in Section 4, alongside those of the Baseline Program. As with the Guidance Statements of the Baseline Program, the Guidance Statements of the Elevated Program are identified by the word "[ELEVATED]" in square brackets. They are also listed in Appendix A. Table 2-1 provides an overview of the elements that make up the Elevated Program. Also in Table 2-1, the Elevated Program elements that are generally more appropriate for the most complex contamination situations are flagged with an asterisk.

Table 2-1
Summary of Baseline and Elevated Program Elements

Baseline Program

Potential Subsurface Release Evaluation
- Evaluate historical leaks and spills (3.1)
- Evaluate SSCs (3.2)
- Evaluate work practices (3.3)
- Prioritize SSCs and work practices (3.4)

Site Conceptual Model
- Develop the initial Site Conceptual Model (4.1)
- Examine photos, drawings and previous hydrogeologic reports (4.2, 4.3)
- Evaluate potential receptors of groundwater contamination (4.4)
- Make preliminary estimate of groundwater flow characteristics (4.5)
- Determine horizontal distribution and movement of contaminant plume (4.6.2)

Location, Installation & Testing of Groundwater Monitoring Wells
- Establish and document DQOs for well drilling (5.1)
- Evaluate configuration management, permitting requirements, accessibility, location of wells (5.2)
- Install monitoring wells (5.3)
- Develop and implement a maintenance program for monitoring wells (5.4)

Groundwater Sampling & Analysis Process
- Review state and local regulations (6.1)
- Establish and document DQOs for groundwater sampling (6.2)
- Establish sample collection procedures (6.3)
- Establish analyte list (6.4)
- Establish MDC requirements and criteria for positive detection (6.5)
- Establish sample volume, container, and preservation requirements (6.6)
- Establish sampling schedule (6.7)
- Validate analytical results (6.8)

Sampling & Monitoring Data Evaluation
- Evaluate analytical data (7.1)
- Evaluate field water-quality indicator data (7.2)
- Provide for management and data quality assessment of analytical data (7.3)
- Evaluate ambient radionuclide concentrations (7.4)
- Review and revise the Site Conceptual Model (7.5)

Program Validation & Review
- Perform initial independent review (8.1)
- Revalidate potential sources of subsurface contamination (8.2)

Elevated Program
(Asterisks indicate elements possibly needed for contamination situations of relatively greater complexity.)

Site Conceptual Model
- Determine vertical distribution and movement of contaminant plume (4.6.3)
- Conduct aquifer tests (4.6.4)
- Consider use of water-level transducers (4.7.1)
- Conduct geophysical testing (4.7.2) *
- Consider use of hydraulic conductivity testing (4.7.3) *
- Consider use of hydrophysical testing (4.7.4) *
- Evaluate need for fate and transport numerical modeling (4.8) *

3
EVALUATION OF POTENTIAL SUBSURFACE RELEASES

Each subsection of this chapter constitutes a distinct "Program Element," and has one or more "Guidance Statements" that provide the specific groundwater protection program actions and attributes. As indicated in the square brackets following each Guidance Statement number, each Guidance Statement in this section is part of the Baseline Program.

The evaluation of potential subsurface releases should, at a minimum, include review and implementation of the Baseline Program elements listed in this section. Those Guidance Statements that include the word "shall" are considered mandatory elements of a technically sound groundwater monitoring program.

3.1 Evaluation of Historical Leaks and Spills

Guidance Statement 3.1a [BASELINE]: ***Spills with the potential to release plant-related radionuclides to the environment, and other subsurface contaminating events, shall be evaluated and documented. Obtain an estimate of the date, location, volume, and quantity of radioactivity for all documented spills. Such information should be filed in the 10 CFR 50.75(g) file, if it is not already there.***

Guidance Statement 3.1b [BASELINE]: ***Evaluate any remedial actions taken in response to a spill to determine the quantity of the spill that may have been recovered, and the quantity which remains as a potential ongoing source of groundwater contamination.***

While records pertaining to spills are required to be retained in accordance with 10CFR50.75(g), documentation of historical spills prior to the institution of this rule in 1988 may not be readily available. To the extent practical, an attempt to document these earlier events and to develop knowledge of the locations and magnitudes of subsurface contaminating events should be made through discussions with selected site employees. The results of these discussions should be documented to identify the approximate time and location of potentially undocumented spills. Additional information regarding spills and the unintentional radiological contamination of systems may be found in records used to address NRC IE Bulletin No. 80-10 (Reference 1).

Note that friskers and scanning instruments used during response operations may not have detected all *analytes* at levels consistent with environmental regulatory criteria. If confirmatory samples of environmental media were collected and analyzed after remediation of a spill, determine if the minimum detectable concentrations of the analyses were equal to or lower than the applicable regulatory criteria.

3.2 Evaluation of Systems, Structures and Components

In order to better understand the potential for SSCs to impact soil or groundwater, the following actions should be considered.

3.2.1 Evaluation of System, Structure and Component Design

Guidance Statement 3.2.1a [BASELINE]: ***A comprehensive evaluation of systems, structures and components (SSCs) that contain or could contain radioactive liquids, whether above or below grade, shall be performed. Only those SSCs that have a credible potential for releasing radioactive liquid to soil or groundwater need be considered in this evaluation. Examples of SSCs of concern include, but are not limited to, radwaste systems, sumps and drains, spent fuel storage pools and leak detection systems, and secondary systems. Identify the SSCs of concern and evaluate their applicable components, their locations, their age, and their current physical condition.***

The intent of this Guidance Statement is to identify credible pathways for groundwater contamination and to prioritize mitigation and monitoring efforts, not to require licensees to redesign SSCs that are in good condition and are operating in accordance with regulatory requirements, their license, and their Final Safety Analysis Report (FSAR). The licensee may take credit for evaluations already completed, such as Design Change Packages, equipment modifications, and configuration changes. The use of such prior evaluations shall be documented.

Some SSCs, for one reason or another, will not be included in the design evaluation. Unless the reason for leaving an SSC out of the design evaluation is obvious, that reason should be documented.

To allow better visualization of the SSCs and how releases from them might affect groundwater, depiction of these systems on a three-dimensional view of the site can provide a useful tool.

Guidance Statement 3.2.1b [BASELINE]: ***Where possible, sample and analyze the contents of the identified SSCs for plant-related radionuclides. As a minimum, analyze for gamma emitters and tritium.***

Guidance Statement 3.2.1c [BASELINE]: ***Use a database or spreadsheet tool for the collection and use of data pertaining to SSCs to ensure that summary results are documented, retained, and readily retrievable.***

The following attributes should be considered for a database or spreadsheet tool:

- Be maintained in a single location and regularly backed up by the nuclear records department, using the process described in ANI Information Bulletin 80-1A (Reference 2).
- Have database read and write privileges clearly established for various classes of users.
- Records of changes are maintained if data contained within the database can be altered.

3.2.2 Identification of Current Preventive Maintenance and Inspection Programs

In order to better understand the existing preventive maintenance and inspection programs for systems, structures, and components, the following actions should be considered:

Guidance Statement 3.2.2a [BASELINE]: ***For each SSC identified in Section 3.2.1, review and summarize the preventive maintenance, surveillance, and inspection programs that are in place to ensure their integrity. Ensure that the preventive maintenance and inspection program includes , at a minimum, a periodic assessment of the below-grade or inaccessible SSCs, and a periodic visual assessment of the above-grade and accessible SSCs.***

Preventive maintenance inspection procedures could include verification of effective cathodic protection for underground systems, isolation and pressure or volume drop testing of pipe runs, inspection of telltale leak detection systems, inspection of secondary containment systems, verification of the operation of installed leak detection and tank overfill alarm systems, and nondestructive evaluation (NDE) techniques that are appropriate and effective for each system or component.

Guidance Statement 3.2.2b [BASELINE]: ***For those SSCs where inspections and verifications are not being performed, evaluate the need for such activities based on the condition of and the potential likelihood for an inadvertent release posed by the SSC.***

3.2.3 Evaluation of Potential Ongoing Releases

In order to better understand the condition of SSCs regarding the potential for ongoing releases, the following action should be considered:

Guidance Statement 3.2.3 [BASELINE]: ***Evaluate the SSCs identified during the implementation of Section 3.2.1 of this guidance document with regard to their potential for leaks to the environment or for the existence of an unanalyzed pathway. Consider the age of the SSC, its current physical condition, its maintenance history, and the results of any leak testing or other means of verifying SSC integrity.***

Evaluate both systems that contain high concentrations of radionuclides that potentially could be leaking at a low rate, and systems that contain low concentrations of radionuclides with the potential to leak at high rates. Examples of the former conditions include the spent fuel pool, the refueling water storage tank, sumps for valve penetration rooms, chemistry sampling lines for primary systems, both lined and unlined concrete pits within the primary or secondary side of the plant, building construction joints below grade, and the radwaste discharge pipeline (with regard to tritium). Examples of the latter condition include secondary cooling water tanks and pipelines, secondary side steam condensate, unlined retention basins, foundation drains, roof drains, and storm drains. Note: Storm drains, roof drains and foundation drains are included in the program to better define the mechanism involved in the transport of radionuclides on the site.

Discharge pathways and structures used for releasing permitted liquid effluent discharges to the environment also have the potential to affect groundwater. While such structures are designed to direct liquid effluents from the process building to the point of discharge, these structures may not be designed to be water-tight, and potentially could allow leakage or percolation into the ground beneath the structure. Such components should also be considered in the SSC evaluation.

Effluents from power plants are often evaluated as either airborne or waterborne pathways. There may be dynamic interrelationships between those release pathways, such as downwash of airborne effluents onto the site during precipitation events, that warrant consideration when evaluating contributions from various sources as potential pathways to groundwater. On-site monitoring, groundwater assessment, and effluent-reporting programs may be affected as knowledge increases regarding those interrelationships.

3.3 Evaluation of Work Practices

Guidance Statement 3.3 [BASELINE]: ***Work practices shall be evaluated to assess their potential for contributing to groundwater contamination. Only those work practices that have a credible potential for causing or allowing the release of radioactive liquid to soil or groundwater need be considered in this evaluation. If groundwater contamination is confirmed, consider former work practices that may no longer be in use. Document the results of this work practice evaluation.***

Evaluate both routine operational work practices and those associated with non-routine projects or outages.

The following are examples of work practices that have the potential to impact soil or groundwater:

- The method by which liquids containing radioactivity are sampled or drained, and the precautions taken for eliminating spills to the ground.
- The procedure for monitoring the filling of tanks, particularly with regard to the potential for the tank capacity to be exceeded.
- The method of controlling hydrolaser wands and hoses in refueling cavities and spent fuel pools, i.e., in light of the potential for siphoning liquid out of the structure if left unattended and with no check valve in place.
- Work practices related to the packaging of radioactive waste for shipment and storage, and the potential exposure of radioactive material or contaminated surfaces to weathering and subsequent release to soil or groundwater.

In addition to reviewing routine and non-routine work practices, consideration should be given to temporary Radiation Control Areas (RCAs) or work areas that are used for the storage or staging of contaminated equipment, or for work on such equipment. For example, temporary RCAs established for packaging or dismantling large components such as steam generators should be assessed as a potential source of inadvertent contamination, unless appropriate contamination control measures have been implemented.

3.4 Prioritization of SSCs and Work Practices

After each surface or subsurface SSC and work practice is identified in accordance with Sections 3.2.1 and 3.3, respectively, rank them with regard to their potential to contaminate groundwater. This will allow plant management to prioritize possible mitigation efforts to eliminate or reduce the potential for groundwater contamination that may be caused by the SSC or work practice of higher relative risk.

The factors that determine the relative prioritization of SSCs or work practices are subject to change with the passage of time. These changes may result from aging equipment, modifications to procedures and processes, changes in local, state or federal regulations, changes in the makeup or viewpoint of stakeholders, and other causes. Consequently, the relative risk factors that contribute to an SSC's or work practice's priority ranking should be re-evaluated periodically. See Section 8.2 for recommendations on periodic reviews.

4
ESTABLISHING A SITE CONCEPTUAL MODEL

Each subsection of this chapter constitutes a distinct "Program Element," and has one or more "Guidance Statements" that provide the specific groundwater protection program actions and attributes. Each Guidance Statement includes, in square brackets, the identification of the program that it is part of. "[BASELINE]" indicates that the statement is part of the Baseline Program, and "[ELEVATED]" indicates that the statement is part of the Elevated Program. The Elevated Program elements that are generally more appropriate for the most complex contamination situations are flagged with an asterisk.

The development of the initial Site Conceptual Model described in Guidance Statement 4.1 is considered a required element of the Baseline Program. Include the other Baseline Program elements described in this section in the subsequent development of a more complete Site Conceptual Model. The "Elevated Program" elements described in this section may be used to enhance the Site Conceptual Model, depending on the complexity of the site hydrogeology and the contamination situation at the site.

A Site Conceptual Model integrates available information regarding contaminants of concern, plant SSCs, historical and potentially ongoing releases, and site hydrogeology to form a unifying hypothesis explaining the observed groundwater contaminant distribution, source areas, transport pathways, contaminant fate in the environment, and risk to receptors. In formulating a hypothesis, assumptions are initially made about many factors, including the types and thicknesses of geologic materials at the site, their hydraulic properties, the location and timing of contaminant releases, and how these contaminants travel through the groundwater system. These assumptions must be proven by collecting data to determine these physical factors and by confirming the validity of the assumptions. This process relies upon an iterative sequence of: 1) observation of the physical system under study; 2) formulating a hypothesis to explain the observations; 3) testing (experimentation) to confirm or deny the hypothesis; and 4) revising the hypothesis to explain the experimental data.

The Site Conceptual Model forms the basis for the design of a hydrogeologic investigation of a site. It is used to make informed decisions regarding where and how deep monitoring wells should be drilled, what they should be sampled for, how frequently samples should be collected, and what types of geophysical or hydraulic testing might be useful. It also provides the framework for interpretation of all investigative data. See Section 7.5 for guidance on the periodic review of the Site Conceptual Model.

4.1 Developing the Initial Site Conceptual Model

Guidance Statement 4.1 [BASELINE]: ***An initial Site Conceptual Model shall be developed.***

The first step in designing an investigation is to develop an initial Site Conceptual Model, based on existing information. This information might include the site operating history, potential contaminant sources, plant layout, and site hydrogeology. The initial Site Conceptual Model is a non-numerical, site hydrogeological model, which when used in conjunction with other data, attempts to form a preliminary hypothesis of how and where the releases of contaminants occurred or may occur, how they have moved or may move through the environment, and what impact they may have on human health and the environment. In formulating a hypothesis, as described above, assumptions are made about many factors, including the types and thicknesses of geologic materials at the site, their hydraulic properties, the location and timing of contaminant releases, and how these contaminants traveled through the groundwater system. The initial Site Conceptual Model is used to guide the placement of the initial monitoring wells, and the data from these wells are used to confirm the validity of these assumptions.

The following Baseline Program elements described in this section should be considered in the subsequent development of a more complete Site Conceptual Model.

4.2 Aerial Photos and Engineering Drawings

Guidance Statement 4.2 [BASELINE]: ***Examine references such as existing site construction era photos, aerial photos, and engineering drawings that show foundations, pipes, conduits, storm drains, and other SSCs that are located below the water table and that may divert local groundwater and contaminant flow.***

Aerial photos and engineering drawings taken during plant construction or modification may reveal impervious surfaces, compacted soil, areas of excavated bedrock, bermed areas, and surface impoundments that could divert infiltrating *surface water* and affect the mobility of contaminants within the *vadose zone*. These photos and drawings may be useful tools in understanding the position of SSCs relative to the water table, the direction of groundwater flow, the depth to bedrock, and other geologic horizons of interest. They also may be used to construct a three-dimensional view of the site to allow better visualization of the SSCs and how releases from them might impact groundwater.

4.3 Previous Hydrogeologic Reports

Guidance Statement 4.3a [BASELINE]: ***Examine, when available, reports of previous hydrogeologic investigations of the site.***

These reports may provide site-specific information regarding the direction of groundwater flow. The reports may also describe the geologic materials that underlie the site and provide estimates of the rate at which they transmit groundwater. These parameters are important determinants in understanding the direction and rate of contaminant transport. Verify that the assumptions and conclusions of the hydrogeologic investigations are still valid following the completion of site construction.

Guidance Statement 4.3b [BASELINE]: ***If monitoring wells were installed during previous hydrogeologic studies of the site and are to be used in a site groundwater protection program, verify that they were constructed in accordance with current standards.***

References 7, 9 and 12 provide current standards for the construction of monitoring wells.

4.4 Potential On-Site and Off-Site Receptors of Groundwater Contamination

Guidance Statement 4.4a [BASELINE]: ***Identify the source(s) of water that could represent a source of exposure to the public (e.g., drinking water or food/feed irrigation water). Include water sources both on-site and on properties near the utility owner-controlled property. Also identify the uses of such water sources.***

Unless the natural groundwater quality is not acceptable for consumption or irrigation (e.g., it is brackish), presume all aquifers in the vicinity of the site to be a potential source of water suitable for irrigation or for human or animal consumption, even if not presently used as such, as they may be developed for this purpose in the future. This evaluation should clearly define the site boundary and will provide an initial estimate of the locations of potential receptors of plant-related groundwater contamination.

Guidance Statement 4.4b [BASELINE]: ***Compile, document, and periodically re-validate the location, depth, use, and yield of water wells and springs at on-site and near-site locations.***

A programmatic mechanism to periodically assess changes in off-site water use may be added as a supplemental component of the Annual Land Use Census required within Radiological Environmental Monitoring Programs.

Guidance Statement 4.4c [BASELINE]: ***Identify the existence of wetlands or estuaries down-gradient from the site.***

Down-gradient wetlands or estuaries may provide critical habitat for wildlife. Exposure to radioactivity through pathways such as hunting and fishing should be considered in this evaluation.

4.5 State and Local Regulations

Guidance Statement 4.5 [BASELINE]: ***Review applicable state and local regulations relating to radioactive contamination of groundwater.***

State or local regulations may focus on concentrations at or near background levels and may consider ecological risk in addition to human health risk. For these reasons, state or local standards may be lower than would be required based solely on human health risk to an off-property member of the public. State or local regulations may also prescribe when and how the release of radioactive materials to the environment must be reported and what actions must be taken to respond to any such release.

4.6 Preliminary Estimates of Groundwater Flow Characteristics

4.6.1 Groundwater Elevation

Guidance Statement 4.6.1 [BASELINE]: ***Evaluate records relating to groundwater elevation. Include in the evaluation such records as site or regional maps that show surface waters and topography, preconstruction boring information, the location, depth, and static water elevation in building sumps and stand-pipes, the location and operating water level in active sumps and supply wells, and the elevation of nearby surface waters, unlined retention ponds, and canals.***

Monitoring wells may not be available for determining groundwater elevations at sites where hydrogeologic investigations have not been conducted. As an alternative, the observed water elevations at the locations noted above can be plotted on a site map to provide an approximate distribution of groundwater elevations across the site and help determine the general flow direction.

4.6.2 Pre-Operational Groundwater and Geologic Data

Guidance Statement 4.6.2 [BASELINE]: ***Evaluate geologic studies that were conducted during the initial siting investigation of the plant.***

Although these studies were not focused on groundwater contamination, reports from the siting investigation can provide insight into the types of geologic material that exist on-site and the general direction and rate of groundwater flow. Caution should be exercised here since these site characteristics may have been altered due to construction activities.

4.6.3 Regional Hydrogeologic Characteristics

Guidance Statement 4.6.3a [BASELINE]: ***Review reports and mapping by the U.S. Geological Survey and the State Geological Survey.***

These reports and maps will provide geologic information about the region in which the site is located. An understanding of the regional setting is helpful in understanding the structure and distribution of the geologic materials that influence groundwater flow across a site.

Guidance Statement 4.6.3b [BASELINE]: ***Ensure that applicable site licensing basis documents are consistent with the information contained in referenced regional reports.***

4.7 Site-Specific Groundwater Flow Profile

4.7.1 Well Installation

Both *investigation wells* and *monitoring wells* may be used to collect information needed to develop a site-specific groundwater flow profile. The purpose of an investigation well generally is to allow rapid collection of soil, groundwater or soil gas samples during drilling for examination and testing. These wells are often installed by the direct-push method and are relatively shallow (no more than about 20 feet [6 m] deep). Investigation wells are typically not used for long-term monitoring. Their casings are removed and boreholes sealed after environmental media have been sampled from them. If investigation wells are to be used as monitoring wells, they should be constructed and maintained in accordance with the same recognized standards as those for monitoring wells. (See the Glossary for definitions of “investigation well” and “monitoring well.”) Specific details and Guidance Statements on the subject of well installation are presented in Section 5.

4.7.2 Horizontal Distribution and Movement

Guidance Statement 4.7.2 [BASELINE]: ***Locate monitoring wells so as to adequately characterize the horizontal groundwater flow.***

Initial efforts at detection of radiological contamination likely will focus on the water table (shallow) aquifer because this unit will be closest to the contaminant sources that are, in most cases, at or near the ground surface. If contamination is detected, additional investigation likely will be required. This additional investigation probably will include more wells drilled in the shallow aquifer to delineate the extent of impact. If contamination is confirmed, additional wells should be drilled in underlying strata to characterize the vertical distribution and movement of contaminants, as discussed in Section 4.7.3. The direction of horizontal flow and potential for contaminant transport can be determined by measuring the elevation of water levels within several wells completed in the same aquifer.

4.7.3 Vertical Distribution and Movement

Guidance Statement 4.7.3 [ELEVATED*]: ***If contamination is detected in the shallow aquifer, then install additional monitoring wells to characterize the vertical extent of the plume and more fully characterize the horizontal extent.***

Wells should be drilled through the shallow aquifer and, as appropriate, into one or more water-bearing formations beneath the shallow aquifer, so as to bound the upper and lower extent of the zone of contamination. Measurement of the concentrations of analytes within the shallow and deeper aquifers will indicate the extent to which contaminants have been transported vertically within the groundwater flow domain. The direction of vertical flow potential and the potential for transport of contaminants between aquifers can be estimated by comparing the elevations of water levels within several wells completed within the different aquifers.

4.7.4 Flow Regimes, Connectivity, and Hydraulic Conductivity

Guidance Statement 4.7.4 [ELEVATED*]: ***If radiological contamination of multiple water-bearing zones is confirmed, conduct aquifer tests in the various strata to determine whether hydraulic connection exists between strata.***

If radiological contamination of multiple water-bearing zones is confirmed, aquifer tests will help to identify hydraulic connection between zones. Aquifer testing will also provide a measure of the resistance to flow (hydraulic conductivity) of the geologic material that comprise the strata. These data help to characterize the water transmitting properties of the geologic materials beneath the site and give insight as to the probable flow paths of contaminants that may enter the groundwater flow system. The data are also used as input when constructing a numerical model of the flow system. See Section 4.8.3 for additional information on aquifer testing and hydraulic conductivity.

4.8 Measurement of Physical Parameters

4.8.1 Water-Level Transducers

Water levels in wells and surface water bodies are an indicator of flow potential and direction. Water levels fluctuate continuously in response to several processes, including recharge by precipitation, groundwater recession, tidal flow, and pumping of nearby wells.

Guidance Statement 4.8.1 [ELEVATED*]: ***Consider the use of data-logging pressure transducers to record changes in water level in selected monitoring wells.***

The resulting data provide a measure of the hydraulic gradient within an aquifer, between aquifers, or between an aquifer and a surface water body. These data can also be used to calculate the time of travel for contaminants in groundwater, and provide an indication of connectivity between aquifers or between aquifers and surface water bodies. They can also be used to define the distribution of hydraulic head in a numerical flow model of the site.

4.8.2 Geophysical Testing

Guidance Statement 4.8.2 [ELEVATED*]: ***Characterize the hydraulic characteristics of the groundwater system in greater detail if features such as bedrock or site-specific complexities in stratigraphy have the potential to affect contaminant flow and need further assessment.***

In addition to well drilling, aquifer testing, and environmental media sampling and analysis, geophysical testing is another method used to determine the hydraulic characteristics of a groundwater system. Some useful geophysical techniques are described below.

Electrical resistivity and seismic methods are useful surface methods for identifying aquifer boundaries such as the interface between the overburden and bedrock. They may also be capable of imaging buried structures or compacted fill that could form a barrier to groundwater flow. Down-hole resistivity, heat-pulse flow meters, and hydrophysical logging can be used to identify discrete water-bearing zones and flow direction within fractured consolidated rock aquifers. There are also several bedrock borehole imaging techniques that are useful in identifying bedrock features and structure within and between boreholes.

Some of the more common imaging techniques include down-hole cameras and optical televiewers, acoustical televiewers, down-hole radar, and cross-borehole radar. These imaging techniques are digitally recorded, oriented, and corrected for borehole deviation so that features identified in boreholes can be located and mapped in three dimensions. This information can be very useful in mapping hydraulically active geologic features and the extent and flow path of a groundwater contaminant.

4.8.3 Hydraulic Conductivity Testing

Aquifer testing can be used to determine various aquifer parameters. Hydraulic conductivity is typically of greatest interest because it is used to calculate the rate of groundwater flow. Hydraulic conductivity can be determined by aquifer testing, but it also can be estimated using porosity and grain size data.

Guidance Statement 4.8.3 [ELEVATED*]: ***Consider conducting aquifer testing to estimate the rate of groundwater flow.***

Aquifer testing requires that a well be pumped at a known rate for a period that may range from a few hours to a few days. The water levels in the pumped well and nearby wells are monitored during and after the pumping period. The measurements are plotted on hydrographs showing the change of water level with time. These hydrographs can be evaluated to calculate aquifer parameters, including hydraulic conductivity.

Because aquifer testing may be conducted in areas where groundwater is contaminated, the water pumped during the testing should be properly managed. In many cases proper management will consist of containment of the pumped groundwater and disposal through the plant's existing permitted liquid effluent discharge pathway. (Refer also to Guidance Statement 6.3b.) The licensee should evaluate whether or not a revision to the plant Offsite Dose Calculation Manual (ODCM) is required to create a permitted discharge pathway for contaminated groundwater.

Because aquifer tests are relatively complex undertakings, only a limited number of them are usually employed. These tests typically would be conducted in selected wells in specific areas of interest. Such areas might include an identified contaminant plume, an area where remediation of groundwater may be anticipated, or an area where detailed estimates of aquifer hydraulic parameters are required for development of a contaminant transport numerical model. With aquifer testing, there is a risk of drawing contaminants from higher contamination areas to lower contamination areas, depending on the hydraulic gradients established in the pump down test.

4.8.4 Hydrophysical Testing

At those plants where contamination has been confirmed in a fractured bedrock aquifer, detailed characterization of the flow domain will be required. Hydrophysical testing is one technique that has been used successfully to achieve that detailed characterization.

Guidance Statement 4.8.4 [ELEVATED*]: ***Hydrophysical testing may be conducted to identify water-bearing fractures and fractured zones within consolidated bedrock formations.***

This subsurface measurement tool is most often used in open bedrock boreholes prior to installing a well screen and casing, so that direct measurements of the bedrock formation can be made. To conduct this test, the groundwater in a borehole completed in a fractured bedrock aquifer is replaced with de-ionized water. The resistivity of the water in the well is then measured during several passes of a monitoring probe up and down the well. Because the resistivity of de-ionized water is relatively high, and that of groundwater is significantly lower, the zones where groundwater enters the well through discrete water-bearing fractures can be identified.

In most applications hydrophysical testing can be used to accurately quantify the specific yield and conductivity of individual fractures or fracture zones within the formation. The results of hydrophysical testing within a borehole allow investigators to accurately identify the magnitude and location of water-bearing features within the borehole and the surrounding fractured bedrock formation. This test method may be used in selected bedrock wells to identify those discrete zones where contaminant transport occurs, such as within an identified contaminant plume, in an area where remediation of groundwater may be anticipated, or in areas where detailed estimates of aquifer hydraulic parameters are required for development of a contaminant transport numerical model.

4.9 Fate and Transport Numerical Modeling

Guidance Statement 4.9 [ELEVATED*]: ***Evaluate the need for a fate and transport numerical model, and develop one if appropriate.***

A contaminant *fate and transport numerical model* may provide an important tool for understanding and predicting the spatial and temporal variations of contaminant concentrations in groundwater. The model could also be an important tool in communicating site conditions to stakeholders by predicting contaminant travel times and concentrations at selected compliance points and by providing graphic depiction of contaminant plumes. It should be understood that a detailed site characterization is required to determine appropriate values for the site-specific hydrogeologic parameters needed to construct a numerical fate and transport model. The level of effort required to develop such a model may not be justified at sites where groundwater contaminant concentrations are low and plume characteristics are well understood.

5
LOCATING, INSTALLING AND TESTING GROUNDWATER MONITORING WELLS

Each subsection of this chapter constitutes a distinct "Program Element," and has one or more "Guidance Statements" that provide the specific groundwater protection program actions and attributes. As indicated in the square brackets following each Guidance Statement number, each Guidance Statement in this section is part of the Baseline Program.

The installation of an effective network of groundwater monitoring wells should, at a minimum, include review and implementation of the Baseline Program elements listed in this section.

5.1 Data Quality Objectives for Well Drilling

Guidance Statement 5.1 [BASELINE]: ***Consider the establishment and documentation of a Data Quality Objectives (DQO) process for well drilling.***

As described in the EPA document "Guidance for the Data Quality Objectives Process" (Reference 10):

> "The DQO Process is a series of logical steps that guides managers or staff to a plan for the resource-effective acquisition of environmental data….The DQO Process is used to establish performance and acceptance criteria, which serve as the basis for designing a plan for collecting data of sufficient quality and quantity to support the goals of the study."

The following items are determined and documented through the DQO process:

- Purpose of each well
- Design objectives for each well
- Rationale for the location and depth of each well
- Types of soil and groundwater samples that will be collected from each well
- Types of analyses that will be performed
- Intended use of the resulting investigative data

Whatever decision-making process is used must be documented. Therefore, it is strongly recommended that a DQO process be used.

5.2 Well Installation Considerations

5.2.1 Configuration Management for Well Drilling

Guidance Statement 5.2.1a [BASELINE]: ***Document monitoring well construction details.***

When evaluating the results of analysis of samples from a monitoring well, it is helpful to have an understanding of the construction details of the well. Examples of construction details to be documented can be found in References 7 and 9 and include the following:

- Drilling method
- Total well depth
- Depth interval over which the well is open to the aquifer (screen zone)
- Approximate depth to groundwater in the well
- Type and thickness of any filter material adjacent to the screen zone
- Type and thickness of any seal that isolates the screen zone from overlying or underlying strata
- Method of well development

Guidance Statement 5.2.1b [BASELINE]: ***Establish a database for the collection and use of well construction data to ensure that summary results are documented, retained, and readily retrievable.***

The following elements should be considered for a database or spreadsheet tool:

- Be maintained in a single location and be backed up regularly by the nuclear records department, using the process described in ANI Information Bulletin 80-1A (Reference 2).
- Have database read and write privileges clearly established for various classes of users.
- Records of change are maintained if data contained within the database can be altered.

5.2.2 Permitting Requirements for Well Drilling

Guidance Statement 5.2.2 [BASELINE]: ***Review the regulations of state and local agencies to identify jurisdictional requirements for drilling groundwater monitoring wells.***

A permit listing specific construction details of a monitoring well must be filed in many states when a well is drilled. Similarly, a permit is required to be filed when a monitoring well is permanently removed from service. In some instances wells must be drilled or permanently removed from service by a well-drilling contractor licensed in the state.

5.2.3 Well Location

<u>**Guidance Statement 5.2.3 [BASELINE]**</u>**:** ***Locate wells based upon the Site Conceptual Model and the results of the evaluation of each SSC and work practice.***

One or more wells located near and downgradient from an SSC determined to be a priority with respect to groundwater monitoring will allow identification of groundwater impacts that may result from leaks, spills, or the existence of an unanalyzed pathway from that SSC. If two or more "high priority" SSCs are in close proximity, one monitoring well located downgradient from their location may be adequate to determine if either is leaking. If contamination is confirmed by groundwater monitoring, additional wells may be needed to determine which SSC is the source.

A minimum of three wells is required to describe the plane of the theoretical "water table" and infer a direction of groundwater flow. Changes in topography and site stratigraphy will affect groundwater flow and influence the number of wells required to determine changes in groundwater and contaminant flow directions over the area of interest.

Placement of wells within the flow path of contaminants emanating from a source is fundamental to identifying the source. However, within unconsolidated soil, groundwater flow diffuses across the flow-front, generally resulting in a widening plume with distance downgradient from a contaminant source. For this reason, well locations generally can be offset by ten feet (3 m) or more to avoid utilities, structures, and other obstacles, while still providing data useful for tracking the contaminant plume. This generality is less applicable in fractured bedrock flow domains, where contaminant flow is within discrete fracture systems that may not allow diffusion over a broad flow-front. Direction of fracture trends may differ from the predominant groundwater flow direction.

If the site hydrogeological profile identifies wells used for drinking water that are located either on or off the owner-controlled property and within the flowpath of a potential groundwater contaminant plume, monitoring wells should be placed upgradient from the water wells but downgradient of the potential source to monitor potential impacts to them.

5.2.4 Sampling Accessibility

<u>**Guidance Statement 5.2.4 [BASELINE]**</u>**:** ***Verify that monitoring wells are installed with sufficient diameter to allow proper sampling.***

A 2-inch (5.1 cm) diameter casing will generally be needed in wells more than approximately 25 feet (7.6 m) deep to allow the use of a submersible pump. Larger diameter wells may be needed for wells more than about 100 feet (30.5 m) deep or to accommodate multi-zone samplers (References 7 and 9).

5.3 Monitoring Well Construction

Guidance Statement 5.3a [BASELINE]: ***Install and document monitoring wells under the supervision of a qualified geoscientist/engineer.***

Many states license or certify professional geologists. These professionals can be considered to be a qualified supervising geoscientist for the purposes of this Guideline. In the absence of state licensing requirements, a qualified supervising geoscientist/engineer should have a four-year university degree in a geoscience discipline and/or applicable professional experience investigating groundwater contamination, including the design, installation, and use of monitoring wells.

Guidance Statement 5.3b [BASELINE]: ***Construct and maintain both investigation wells and monitoring wells in accordance with recognized standards.***

Recognized standards include state guidelines or regulations for installation of monitoring wells, ASTM D5092-04e1 "Standard Practice for Design and Installation of Ground Water Monitoring Wells" (Reference 7), ASTM D5978-96(2005) "Standard Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells" (Reference 8), and USEPA "Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells" (Reference 9).

Care must be taken to avoid commingling of groundwater from separate aquifers by providing a conduit that allows hydraulic communication between zones where none previously existed. The annular space between borehole and well casing must be properly sealed over the entire depth of the well, except in the zone where groundwater is to be sampled. Following recognized well construction and maintenance standards will help to assure that samples obtained from the wells are representative of aquifer conditions, and that the data resulting from analysis of the samples are defensible.

Guidance Statement 5.3c [BASELINE]: ***Install both investigation wells and monitoring wells with the appropriate size and depth, with screened intervals within the zones most likely to be impacted by a release from the plant.***

Guidance Statement 5.3d [BASELINE]: ***Sample, examine, and log the geologic materials penetrated as both investigation and monitoring wells are drilled.***

Examination of the geologic materials that are penetrated as wells are drilled allows the determination of the subsurface stratigraphy that influences groundwater and contaminant transport beneath the site. The collected samples can be analyzed for the presence of radionuclides. They can also be tested to determine various soil properties such as porosity, density, grain size distribution, moisture content, and organic carbon content. By comparing soil and water radionuclide concentrations, site specific distribution coefficient (K_d) values may be determined.

These parameters are useful in characterizing the local aquifer materials. For example, soil porosity and grain size can be used to calculate hydraulic conductivity. The hydraulic gradient and calculated hydraulic conductivity then can be used to calculate the average linear velocity of groundwater and estimate the travel time of the most mobile contaminant to any specified compliance point, such as a site boundary.

5.4 Maintenance Program for Monitoring Wells

Guidance Statement 5.4a [BASELINE]: ***Develop and implement a maintenance program for monitoring wells.***

Surface water that can enter a monitoring well through a broken well casing or improperly sealed surface completion could potentially contaminate the local groundwater or change its chemical characteristics. To be certain that the groundwater sampled from a monitoring well is representative of the water quality within the aquifer near the well, it is important to maintain the integrity of the well casing and surface completion by periodically inspecting these components and promptly initiating any necessary repairs, as discussed in References 8 and 11.

Similarly, contaminated surface water can infiltrate groundwater through penetrations of pipes and utility poles through impervious surfaces such as concrete or asphalt paving. This contaminated water can impact nearby monitoring wells. Care needs to be taken to ensure that penetrations of generally impervious surfaces are properly sealed.

If the results of analysis of a groundwater sample are to be relied upon to form an opinion regarding the existence of groundwater contamination, assurance of the quality of the well construction and maintenance practices is required, regardless of the type of monitoring well. The installation process for an investigation well installed by the direct-push method differs from that of other methods, but prevention of surface water infiltration, provision for well-head protection, and confirmation that the well depth remains consistent over time (to show that the well screen has not become filled with silt) are requirements common to all monitoring well types. Sample and trend the physiochemical performance of wells in accordance with ASTM-5978 (Reference 8).

Guidance Statement 5.4b [BASELINE]: ***Construct monitoring well surface completions using a licensed well drilling contractor or under the supervision of a qualified geoscientist/engineer.***

See the supporting information for Guidance Statement 5.3 for a description of “qualified geoscientist/engineer”. Refer to References 7 and 9 for information on the construction of monitoring well surface completions.

Guidance Statement 5.4c [BASELINE]: ***Include surface completion inspections for all wells in the site groundwater monitoring program as a formal and documented inspection process.***

Some state environmental agencies specify surface completion requirements and inspection frequencies. At a minimum, the surface completion should be evaluated during each sampling event, or every two years if sampling takes place less frequently. Refer to ASTM D5978-96(2005) “Standard Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells” (Reference 8), ASTM D5787-95(2000) “Standard Practice for Monitoring Well Protection” (Reference 11), and ASTM D6724-04 "Standard Guide for Installation of Direct Push Ground Water Monitoring Wells" (Reference 12) for further discussion on these topics.

Guidance Statement 5.4d [BASELINE]: ***Decommission monitoring wells that are no longer useful for their intended purpose in accordance with appropriate standards.***

Appropriate standards for decommissioning of groundwater monitoring wells include those that may be provided by the state Department of Environmental Protection (or its equivalent) or ASTM 5299-99 (Reference 13).

6
ESTABLISHING A GROUNDWATER SAMPLING AND ANALYSIS PROCESS

Each subsection of this chapter constitutes a distinct "Program Element," and has one or more "Guidance Statements" that provide the specific groundwater protection program actions and attributes. As indicated in the square brackets following each Guidance Statement number, each Guidance Statement in this section is part of the Baseline Program.

The implementation of an effective groundwater sampling and analysis process should, at a minimum, include review and implementation of the Baseline Program elements listed in this section.

6.1 Data Quality Objectives for Groundwater Sampling

Guidance Statement 6.1 [BASELINE]: ***Establish and document Data Quality Objectives (DQOs), or an equivalent strategy, for each sampling campaign in the form of a sampling plan or procedure.***

The following groundwater sampling features are determined and documented through the DQO process:

- Purpose and objectives of the samples
- Number of samples needed for a representative data set
- Sampling method(s)
- Water-quality indicators to be measured during sampling and their acceptance criteria
- Method for managing sampling wastes
- Sample analytes
- Sample holding time(s)
- Required sample volume, container type(s), and preservative(s)
- Number and type of field quality control samples
- Sample handling, labeling, storage, shipment, and chain-of-custody procedures
- Qualification and training requirements for sampling personnel
- Applicable regulatory limits

- Analytical methods and required Minimum Detectable Concentrations
- Required analytical method uncertainties
- Number and type of laboratory quality control samples and acceptance criteria for their analysis
- Required number of samples per analytical batch
- Alternate actions to be taken if samples cannot be obtained
- Alternate actions to be taken if MDCs are not met
- Method for validation of sample analytical results

See Section 5.1 for a discussion of the DQO process. Refer to applicable state guidance or permit conditions and the following documents for further discussion on DQOs as they relate to groundwater sampling: EPA 542-S-02-001 "Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers" (Reference 14); EPA/600/R-00/007 "Data Quality Objectives Process for Hazardous Waste Site Investigations: EPA QA/G-4HW" (Reference 15); and *Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring* (Reference 16).

The decision making process that is used for sampling and analysis must be documented. Therefore, it is strongly recommended that a DQO process be used.

6.2 Sample Collection Procedures

Guidance Statement 6.2a [BASELINE]: ***Establish groundwater sampling procedures for both routine and special monitoring, and address such items as:***

- ***Sample planning***
- ***DQOs if applicable***
- ***Sample collection methods***
- ***Water-quality indicators to be measured during sampling and their acceptance criteria***
- ***Sample analytes***
- ***Sample holding time(s)***
- ***Required sample volume, container type(s) and preservative(s)***
- ***Number of field quality control samples such as duplicates, matrix spikes, equipment rinsate blanks, and splits***
- ***Qualification and training requirements for sampling personnel***
- ***Management of sampling waste, including well purge water***
- ***Sample handling, labeling, storage, and shipment***
- ***Chain of custody***
- ***Analytical data receipt and review***

The licensee may refer to the *Multi-Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual* (Reference 17) and Regulatory Guide 4.15 (Reference 18 or Reference 19, as appropriate for the site) for guidance on these sampling topics. The reader is also directed to applicable state guidance or permit conditions and the documents listed in Section 12 of this Guideline, "Additional Technical References."

As defined within this Guideline (Section 13), "groundwater" includes all subsurface water, whether in the saturated or vadose zones. Techniques for collecting vadose zone water are available using suction lysimeters. However, in most cases this Guideline does not address sampling of vadose water.

Guidance Statement 6.2b [BASELINE]: ***When sampling in areas where groundwater is contaminated, appropriately control the water purged from a well prior to collection of a sample. Appropriately assess the purge water prior to disposal.***

If groundwater quality in a well has not yet been determined, good sampling technique suggests that purge water should be contained and controlled until the sample is analyzed and an appropriate method for disposal of the water can be established. An action level that would invoke the need for continued containment and control of sample purge water during subsequent sampling should be specified and documented in the sampling procedure. In many cases proper management will consist of containment of the pumped groundwater and disposal through the plant's existing permitted liquid effluent discharge pathway. The licensee should evaluate whether or not a revision to the plant ODCM is required to create a permitted discharge pathway for contaminated groundwater.

6.3 Analyte List

Guidance Statement 6.3a [BASELINE]: ***Select analytes, at a minimum, based on the radionuclides contained in the SSCs that are potential sources of groundwater contamination. Always include tritium and gamma emitting radionuclides. Include in the analyte list both past and present source terms for SSCs of interest, a historical analysis of on-site spills, leaks, or unanalyzed pathways, and a review of positive radionuclide detections in soil, groundwater, and other environmental sample media.***

Tritium is always considered an analyte because of its abundance within primary cooling water and mobility within groundwater systems. Those radionuclides with half lives less than a few days generally are not of interest for groundwater monitoring. Similarly, those radionuclides that are relatively immobile in groundwater may be removed from the analyte list for selected sampling locations.

Although not a radionuclide, boron can be a useful analyte to monitor in groundwater at Pressurized Water Reactor (PWR) nuclear power plants because it is typically added to primary cooling water as a neutron moderator. Therefore, when detected at concentrations greater than background, boron can indicate leaks from primary systems and its presence can be associated with plant-related radionuclides in groundwater. It should be noted that boron may also be found in the environment due to contamination from a nearby fossil fuel plant.

In establishing the analyte list, it cannot be assumed that the relative distribution of radionuclides within in-plant sources is valid for groundwater. For example, although they are always found together in primary cooling water, at some sites Sr-90 has been identified in groundwater without the presence of Cs-137. In all cases, the rationale for the selection and de-selection of analytes should be documented.

The following is a list of analytes used during the decommissioning of Connecticut Yankee (Haddam Neck): H-3, C-14, Mn-54, Fe-55, Co-60, Ni-63, Sr-90, Nb-94, Tc-99, Ag-108m, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239, Pu-241, Am-241 and Cm-243. This list is provided as an example of an analyte list used during one plant's decommissioning, and is not intended to prescribe that which should be used at any other plant. This list does not include short-lived radionuclides that might be appropriate for the analyte list at an operating plant.

Guidance Statement 6.3b [BASELINE]: ***Periodically re-evaluate the list of analytes.***

If analysis for detecting the presence of a radionuclide has been performed on several occasions, and the radionuclide consistently has not been detected, consideration may be given to deleting that radionuclide from the list of analytes. Alternatively, changes in plant processes or detection of contaminants where they previously had not been found may prompt the addition of radionuclides to the list of analytes.

6.4 Minimum Detectable Concentration Requirements and Criteria for Positive Detection

Guidance Statement 6.4 [BASELINE]: ***Establish and document the rationale for establishing the MDCs and the criterion for determining when an analytical result is statistically valid.***

Establishing the MDCs for the analysis of each radionuclide is an element in the DQO process of any sampling campaign. A related element is the criterion for determining when an analytical result is a positive detection. The criterion is based upon the analytical measurement uncertainty, which increases as the MDC decreases. Refer to the MARLAP Manual (Reference 17) for further discussion on these topics.

It should be noted that in some instances, the *a posteriori* MDCs for analyses of samples collected as part of the Radiological Environmental Monitoring Program (REMP) may not be low enough to achieve the DQOs of a groundwater sampling program. It should also be noted that while an existing effluent or 10 CFR Part 61 analyte list may be useful in the initial design of a groundwater protection program analyte list (see Sect. 6.3), the MDCs used for the effluent or Part 61 analyses also may not be low enough to achieve the groundwater sampling DQOs.

6.5 Sample Volume, Container and Preservation Requirements

Guidance Statement 6.5 [BASELINE]: ***Document the rationale and basis used in the determination of minimum sample volume, container type, and preservation requirements for groundwater samples.***

The minimum sample volume, container type, and preservation requirements are based in part on the MDCs and laboratory protocols for the chosen analytical method. Refer to ASTM D5903-96(2006) “Standard Guide for Planning and Preparing for a Groundwater Sampling Event” (Reference 20) and ASTM D6517-00(2005) “Standard Guide for Field Preservation of Ground-Water Samples” (Reference 21) for further discussion on these topics.

If samples are to be split (e.g., with a regulatory agency), sample volumes and the number of containers will need to be adjusted accordingly.

6.6 Sampling Schedule

Guidance Statement 6.6 [BASELINE]: ***Develop a written sampling schedule and sampling plan consistent with the established DQOs or sampling requirements for each sampling point and analyte.***

Sampling points may include monitoring wells, water-supply wells, surface water bodies, springs, foundation drains, storm drains, sumps, leaks at structures or components, and basement floors or walls with groundwater in-seepage.

The frequency of sampling can be based on site objectives, but quarterly sampling is generally a good initial approach. The sampling frequency will be contingent upon site specific conditions, such as soil type, hydraulic gradient, proximity to sources, and the existence of preferential migration pathways. If contaminant concentrations vary seasonally, the cyclic nature of the data may become apparent after a few years of quarterly sampling. Sampling frequency is often reduced after accumulating a few years of data in cases where contaminant concentrations appear to be at equilibrium or trending downward.

If samples are to be split (e.g., with a regulatory agency), the list of analytes and their corresponding MDCs should be established and agreed upon in advance of sample collection. The sampling method, as well as the sample labeling, handling, storage, shipment, and chain-of-custody procedures should all be established and agreed upon prior to collection of the samples. Finally, all parties receiving sample splits should agree prior to sample collection on how to proceed if sufficient sample volume cannot be obtained.

6.7 Validation of Analytical Results

Guidance Statement 6.7 [BASELINE]: ***Establish a consistent documented process to review analytical data. Include such items as:***

- ***Inventory of analytical results to ensure that all data are reported by the analyzing laboratory***
- ***Evaluation of the achieved laboratory MDCs***
- ***Evaluation of laboratory QC/QA data***
- ***Evaluation of any split, duplicate, blank, or spike sample results***
- ***Evaluation to determine whether the acceptance criteria for each category of quality control samples were achieved***

This information may already be included in the DQO documentation. Refer to applicable state guidance and MARLAP (Reference 17) for guidance on data validation methods.

7
EVALUATING SAMPLING AND MONITORING DATA

Each subsection of this chapter constitutes a distinct “Program Element,” and has one or more “Guidance Statements” that provide the specific groundwater protection program actions and attributes. As indicated in the square brackets following each Guidance Statement number, each Guidance Statement in this section is part of the Baseline Program.

The implementation of an effective evaluation process for sampling and monitoring data should, at a minimum, include review and implementation of the Baseline Program elements listed in this section.

7.1 Analytical Data Evaluation

Guidance Statement 7.1 [BASELINE]: ***Validate data, and include a comparison with regulatory criteria, prior to the evaluation of the analytical data.***

This evaluation may include statistical analysis for normality and analytical bias, determination of horizontal and vertical spatial correlations, and time-series plots of contaminant concentrations within sample points to identify temporal trends.

Analytical data for matrices other than groundwater may also be of value in evaluating environmental impacts. These may include measurement of water levels and the chemical or radiological content of surface water, sea water, precipitation, storm water, and building infiltration. Tidal fluctuations may propagate inland through near-shore groundwater and may affect contaminant transport.

It is good practice not to rely upon the result of a single analysis of a groundwater sample when developing a Site Conceptual Model or when making long-term decisions regarding groundwater protection. Results of analysis of several discrete samples from the same monitoring well can vary because of inconsistent sampling technique, limitations of laboratory analytical precision, and temporal variations in groundwater quality. When an unexpected sample result is obtained, additional follow-up sampling should be conducted periodically until the cause is well understood. Compare the data to the trigger levels of the voluntary communication protocol to ensure that reporting is carried out in accordance with the industry groundwater protection initiative (see Section 9).

7.2 Evaluation of Field Water-Quality Indicator Data

<u>Guidance Statement 7.2 [BASELINE]</u>: ***Collect groundwater samples in accordance with applicable governing agency regulations or permit conditions. The following parameters are useful indicators of general water quality and may be measured and evaluated prior to collecting groundwater samples for radiological analysis to ensure that representative samples are obtained:***

- ***Turbidity***
- ***Temperature***
- ***pH***
- ***Oxidation-reduction potential (ORP)***
- ***Specific conductivity***
- ***Dissolved oxygen concentration***

Document all evaluations

In order to determine when a representative sample can be obtained, these indicators of water quality typically are measured periodically prior to collection of a groundwater sample for radiological analysis. If the measurements do not stabilize within specified limits, or if anomalous values of these indicators are measured, they may indicate that the corresponding groundwater sample is not representative of the formation from which it was collected. Accordingly, the significance of the reported analyte concentrations should be evaluated.

Refer to References 16, 22, 23 and 24 for discussions of measurement of field water-quality indicator parameters during groundwater sampling, and for stabilization criteria for the measured parameters.

7.3 Analytical Data Management and Data Quality Assessment

<u>Guidance Statement 7.3a [BASELINE]</u>: ***Include the following items with documented analytical data:***

- ***Sample identification***
- ***Sample location or well identification***
- ***Sample date and time***
- ***Measured concentration for all radionuclides where results have been reported (whether or not above the detection criteria, or positive or negative)***
- ***Measurement uncertainty***
- ***Achieved MDCs***
- ***Records of data validation and verification***

- ***Whether or not any validated analytical results exceed applicable site action levels***
- ***Identification of missing sample results***

Data may be displayed in a variety of formats, such as that provided by computerized visualization software, which can overlay potential plume profiles onto a site map.

Guidance Statement 7.3b [BASELINE]: ***Manage data to ensure that summary results are documented, retained, and readily retrievable.***

The following attributes should be considered for a data management tool:

- Be maintained in a single location and be regularly backed up by the nuclear records department, using the process described in ANI Information Bulletin 80-1A (Reference 2)
- Have database read and write privileges clearly established for various classes of users
- Records of change are maintained if data contained within the database can be altered

7.4 Ambient Concentrations

7.4.1 Background Radionuclide Concentrations

Guidance Statement 7.4.1a [BASELINE]: ***Determine background concentrations of radionuclide analytes.***

The presence in the environment of background concentrations of radionuclides that may also be contaminants at a nuclear power plant presents challenges for the measurement of these analytes. The analytical complications resulting from the presence of *background radioactivity* are distinct from those due to analytical bias. They are also unrelated to false-positive detections of radionuclides that are statistically predictable when analyzing at low environmental levels near the MDC. Appendix A of Reference 3 provides a detailed discussion of these topics.

Radionuclides found in background may be naturally occurring in the environment or may be of anthropogenic origin. Possible sources of background radioactivity in groundwater include the following:

- Minerals in soil and rock
- Cosmogenic processes in the upper atmosphere
- Atmospheric nuclear weapons testing
- Nuclear accidents such as at Chernobyl
- Releases of radionuclides from up-gradient nuclear power plants, hospitals, U.S. Department of Defense facilities, U.S. Department of Energy facilities, or other facilities that are sources of radioactive material
- Releases of radionuclides from up-gradient water treatment plants and landfills (e.g., from radiopharmaceuticals and exit signs)

Useful sources of information for establishing values of background concentrations are data collected at control locations monitored by the licensee's REMP, data provided by government agencies such as the U.S. Nuclear Regulatory Commission, the former U.S. Department of Energy Environmental Measurements Laboratory, the U.S. Environmental Protection Agency, and the U.S. Geological Survey. Data provided by the International Atomic Energy Administration can also be useful.

The following U.S. Geological Survey web link to the "National Water Quality Assessment Report: National Analysis of Trace Elements in Ground Water, Streams, Stream and Reservoir Sediment, and Fish and Clam Tissue Across the United States" provides additional data pertaining to background concentrations of elements in environmental media:

http://water.usgs.gov/nawqa/trace.

The following EPA web site provides guidance on developing screening values for radionuclides in soil:

http://www.epa.gov/superfund/health/contaminants/radiation/radssg.htm

Concentrations less than these screening values can generally be considered background.

Background concentrations of some radionuclides may be lower than the analytical sensitivity levels historically achieved by the site's REMP. In such cases, additional samples may need to be collected and then analyzed at appropriate sensitivities to determine site-specific background concentrations. In other cases, an analyte may not have been included in REMP analyses, and its background will need to be determined through research of references such as those listed earlier in this section, by sample collection from control locations with analysis at the appropriate sensitivities, or by other means.

Guidance Statement 7.4.1b [BASELINE]: ***Evaluate analytical data for Type I errors (false positive detections).***

When measuring at low environmental levels near the MDC, about five percent of analytical results will be false positive if a 2-sigma criterion (95 percent confidence interval) is used to define a positive detection. The 2-sigma criterion results in a statistically-expected 5 percent of false positive results because about 95 percent of samples from a normally distributed population have values within two standard deviations of the population mean. Stated another way, 5 percent of the samples from a normally distributed population have values greater than two standard deviations (2-sigma) of the population mean. If no contamination is present (neglecting analytical bias and background), the mean of the sample population is zero. Therefore, when the result of a radiological analysis of a sample is considered to be a positive detection if it is greater than 2-sigma of the counting error, about 5 percent of the analytical results for samples in a population where no contamination is present will have values greater than 2-sigma, and will be (falsely) defined as positive detections even though no contamination is present. Appendix A of Reference 3 provides a detailed discussion of this topic.

Several rounds of analytical data from a sampling program may be needed to identify Type I errors. Because these errors are randomly distributed, false positive detections of the same analyte typically will be reported in different monitoring wells for different sampling events. When several rounds of sampling data are accumulated and the data set becomes larger over time, the predictable 5 percent false-positive rate becomes more apparent and can be used to confirm the absence of certain radionuclides.

7.4.2 Atmospheric Deposition of Plant-Related Radionuclides

Guidance Statement 7.4.2 [BASELINE]: ***Evaluate and document the significance of atmospheric deposition of plant-related radionuclides.***

Controlled airborne releases from the plant, such as from the ventilation stack, cooling tower, or condenser air ejectors, may result in measurable atmospheric deposition of plant-related radionuclides (including tritium) in the vicinity of the owner-controlled area. Some of this material may accumulate on plant roof surfaces and wash into roof drains during precipitation events. Rain may also wash airborne material onto the soil and building surfaces near the plant. In addition to washout, condensate in AC systems, air exchanged from passive tank vents, and frost accumulation (e.g., on ice condenser containment, cryogenic equipment) have been shown to contain high concentrations of tritium.

The impact of this potential source of groundwater contamination may vary substantially with release periods and meteorological conditions. While this potential source is not likely to be a major contributor to groundwater contamination, operators of at least one nuclear power plant believe that measurable tritium concentrations in groundwater at their site are likely due to the deposition of tritium in airborne effluents (Reference 25). Recognition that atmospheric deposition may be a process actively contributing to observed wide-spread, low-level tritium concentrations in groundwater would be a feasible explanation for the presence of these low-level concentrations when no other potential source can be identified.

The first task in evaluating the impact of this potential source is to measure its occurrence. The effluent from a representative roof drain in a downwind direction from the source could be sampled during selected precipitation events and analyzed for tritium or other radionuclides. Analysis of two or more samples during one rainstorm would provide an indication of the duration and average concentration of the washout for that event. The total activity in the roof drain effluent could then be estimated, knowing the area of the roof and the total precipitation accumulation measured during the storm.

However, it should be recognized that the deposition pattern and quantity of tritium deposition is likely influenced by many variables. Therefore, an attempt to infer detailed information from a few measurements would not be advisable. Rather, sampling in several areas over long periods and/or numerical modeling of atmospheric transport and deposition may be necessary to allow meaningful conclusions to be drawn. This type of robust investigative program could require substantial resources and should be well planned in order to obtain high-quality and reliable information. This program should include collection of radioactive effluent data as well as meteorological data during release and sampling periods. In the colder climates, frozen precipitation should be collected. Further, when sampling liquid precipitation, provisions should be made to prevent sample re-evaporation to the atmosphere.

7.4.3 Plant-Related Liquid Pathways

Guidance Statement 7.4.3 [BASELINE]: ***Where such processes take place, evaluate and document the potential impact from the discharge of cooling water and subsequent re-use in plant systems or on-site drinking water.***

Plants that re-circulate lake, cooling tower, or cooling canal water into which their cooling water has been discharged may measure re-circulated plant-related radionuclides in other plant systems. While this process may not present a risk to health and safety, it creates the potential for release of radionuclides through a pathway that includes the affected plant systems. Release of radionuclides through this mechanism may explain the presence of low-level contamination whose source has not been identified. Although remediation of such low-level contamination may not be warranted, the process producing it should be understood.

7.5 Review and Revision of the Site Conceptual Model

Guidance Statement 7.5a [BASELINE]: ***Periodically evaluate the Site Conceptual Model against the results of the data assessment, and if significant deviations are identified, consider revision of the model.***

Site characterization is an iterative process. Each time new data are developed through such activities as drilling new monitoring wells, sampling soil, testing aquifer parameters, reviewing plant construction records, or periodic groundwater monitoring in the saturated zone, those data should be evaluated in the context of the current Site Conceptual Model. If the data are inconsistent with the conceptual model, the model should be revised to reflect the new data. For example, an increase in contaminant concentrations in an area of the site where they were previously stable would trigger a revision of the model.

Guidance Statement 7.5b [BASELINE]: ***Review the Site Conceptual Model after any of the following:***

- ***Substantial site construction or disturbance of site or near-site property***
- ***Substantial change in on-site or adjacent off-site water use***
- ***Substantial change in the rate of pumping for on-site or nearby off-site wells***

The use of non-potable water for industrial process water or fire suppression may increase over the life of the plant and alter the hydraulic gradient within the plant vicinity. The licensee should anticipate such potential future changes in water use.

Guidance Statement 7.5c [BASELINE]: ***If the Site Conceptual Model is revised, evaluate the need to revise the applicable site licensing basis documents and appropriate site drawings that are part of the plant design basis documentation.***

8 PROGRAM VALIDATION AND REVIEW

Each subsection of this chapter constitutes a distinct "Program Element," and has one or more "Guidance Statements" that provide the specific groundwater protection program actions and attributes. As indicated in the square brackets following each Guidance Statement number, each Guidance Statement in this section is part of the Baseline Program.

The implementation of an effective validation and review program should, at a minimum, include review and implementation of the Baseline Program elements listed in this section.

8.1 Program Inception With Independent Review

Guidance Statement 8.1a [BASELINE]: ***Conduct an independent review when the initial review described in Section 3 of this Guideline has been completed and documented and a Site Conceptual Model has been developed.***

Plants may conduct an independent review with personnel internal or external to the site, provided that the review team members have relevant experience and are not those personnel who conducted the original work. The review should be performed by individuals that collectively have relevant experience in system operations and design, radiation protection, chemistry, and hydrogeology.

This independent review will provide additional assurance that all SSCs and work practices identified during the implementation of Section 3 of this Guideline have been effectively evaluated for the potential of creating groundwater contamination from surface and subsurface sources, and that the Site Conceptual Model is consistent with available information regarding groundwater at the site. The independent review is not envisioned to be a repetition of the detailed review of each SSC and work practice conducted in the development of the program. Rather, the independent review should be a broad overview that assesses whether the rationale for identifying an SSC of interest or work practice of interest is sound and has been appropriately documented, and that of the Site Conceptual Model is consistent with the site's conditions and location.

Guideline Statement 8.1b [BASELINE]: ***An independent program review should be completed following development of the Site Conceptual Model.***

Some plants may choose to conduct the independent review prior to drilling monitoring wells. In this way the decisions regarding the placement of wells, the list of radionuclides to be analyzed, the sampling techniques to be used, and other elements of the groundwater protection program will benefit from the evaluation of the review team. Other plants may choose to conduct the review after a well drilling campaign. It is recommended that the independent program review be completed within two years following development of the Site Conceptual Model. A two-year timeframe should allow adequate planning and budgeting of the groundwater protection program, collection of several rounds of groundwater samples, analysis of the samples, validation of the analytical results, evaluation of the data, and preparation of a comprehensive technical report.

8.2 Revalidation of Potential Sources of Subsurface Contamination

Guidance Statement 8.2a [BASELINE]: ***Establish and document a review cycle for the identification of potential sources of subsurface contamination. Document the rationale for selecting the frequency and methods of reviews. The frequency of the review cycle should not exceed five years.***

The frequency of the review cycle may depend on many factors, including plant construction projects, design changes, operation changes, source-term changes, personnel changes, industry events and lessons learned, and regulatory changes (local, state or federal). One method to identify potential changes in groundwater quality is to include triggers in the site's work control and design processes.

Guidance Statement 8.2b [BASELINE]: ***If site conditions result in a significant change in the potential radiological impact of SSCs or work practices, or if previously unknown spills, leaks, or unanalyzed pathways are identified, a re-evaluation of possibly-affected SSCs and work practices should be performed, as described in Section 3.***

9
COMMUNICATING WITH STAKEHOLDERS AND REGULATORS

Voluntary communications with the NRC and the appropriate state and local officials shall be made in accordance with the "Nuclear Energy Institute (NEI) Industry Groundwater Protection Initiative – Final Guidance Document" (Reference 26). This document also provides criteria for notifications to the NRC in the Annual Radiological Environmental Monitoring Program (REMP) Report, the Annual Radiological Effluent Technical Specification (RETS) Report, and written 30-day reports, as well as through informal communications to NRC, state, and local officials. Many licensees have prepared procedures and protocols to implement these communication protocols.

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POTENTIAL MITIGATING ACTIONS

Listed below are mitigating actions that may be considered for a site with known groundwater contamination. Local, state, or federal agreement is generally needed prior to implementation.

- Repair the leak.
- Remediate the root cause of leakage through a major replacement or design change.
- Address the unanalyzed pathway.
- Remove contaminated soil within the source area.
- Initiate a program of Monitored Natural Attenuation. This approach relies on such naturally-occurring processes as dilution, dispersion, adsorption, and radioactive decay to reduce the concentration of radioactive contaminants over time. A groundwater monitoring program is essential to provide data to demonstrate the effectiveness of this approach. Use of this technique may be appropriate if a contaminant plume is generally in equilibrium, the risk to receptors is low, and contaminant concentrations are low enough so that applicable regulatory criteria can be achieved within a reasonable timeframe. Information regarding the use of monitored natural attenuation can be found at: http://www.epa.gov/oust/directiv/d9200417.htm (Reference 27).
- Pump and treat (or release) near the source area. This approach should be used with caution because of the potential for re-distributing contamination. The groundwater flow domain should be well understood before employing this technique.
- Pump groundwater to intercept the plume before it advances to the site boundary. This approach should be used with caution because of the potential for re-distributing contamination. The groundwater flow domain should be well understood before employing this technique.
- Install grout curtains or sheet piling to create low-permeability boundaries which divert groundwater flow. This technique usually also requires pumping and treating of the intercepted plume.
- Initiate a program of phytoremediation. This technique uses vegetation to transpire groundwater and dissolved contaminants from the shallow subsurface. This technique results in a portion of the contaminant being released to the atmosphere and a portion accumulating in the plant tissue.

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ADDITIONAL TECHNICAL REFERENCES

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ASTM D4210, "Standard Practice for Interlaboratory Quality Control Procedures and a Discussion on Reporting Low-Level Data," ASTM International.

ASTM D4220, "Standard Practice for Preserving and Transporting Soil Samples," ASTM International.

ASTM D4448, "Standard Guide for Sampling Ground-Water Monitoring Wells," ASTM International.

ASTM D4750, "Test Method for Determining Subsurface Liquid Levels in a Borehole of Monitoring Well (Observation Well)," ASTM International.

ASTM D4840, "Standard Guide for Sample Chain-of-Custody Procedures," ASTM International.

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GLOSSARY

Analyte: For the purposes of this guidance document, a radionuclide that is targeted for identification and quantification *in situ* or by laboratory analyses of soil, water or other media. An analyte is a radionuclide that may be identified in liquid effluents, gaseous effluents, or radioactive waste, and in some cases may also be found as part of background radioactivity.

Background Radioactivity: Radioactivity 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 or from past nuclear accidents such as Chernobyl. "Background radioactivity" is not under the control of the licensee, and does not include radioactivity from source, byproduct, or special nuclear materials regulated by the cognizant federal or state agency.

Graded Approach: A defined process for evaluating the significance of potential or actual groundwater contamination. The specific actions recommended for implementation in all groundwater protection programs are identified in this Guideline under the "Baseline Program." At sites with a higher risk contamination situation (e.g., more complex hydrogeology, closer proximity of leak/spill to site boundary, greater amount of contamination), a licensee might use characterization methodologies identified in the "Elevated Program" in this Guideline.

Groundwater: Any subsurface water, whether in the unsaturated or vadose zone, or in the saturated zone of the earth.

Investigation Well: A borehole drilled in the earth and lined, either partially or entirely, with a casing to stabilize and isolate one or more sections of the borehole. The purpose of an investigation well is generally to allow rapid collection, during the drilling process, of soil, groundwater, or soil gas samples for examination and testing. These wells are often installed by the direct-push method and are relatively shallow (no more than about 20 feet [6 m] deep). Investigation wells are typically not used for long-term monitoring (see "monitoring well") and their casings are removed and boreholes sealed after environmental media have been sampled from them.

Monitoring Well: A borehole drilled in the earth and lined, either partially or entirely, with a casing to stabilize and isolate one or more sections of the borehole. Monitoring wells, like investigation wells, are used to collect environmental media for examination and testing. However, unlike investigation wells, monitoring wells are intended to be in service longer (typically years) to allow continued sampling of groundwater or soil gas.

Fate and Transport Numerical Model: A mathematical approximation of a groundwater flow system comprised of a computer code that simultaneously solves multiple differential equations describing the balance of mass, momentum, and energy within the flow domain.

Site Conceptual Model: A unifying hypothesis to describe how a contaminant release may be observed and measured currently in the site environment, and to identify the ultimate fate of the contaminant in the future. The model incorporates what is known about a site's hydrogeology, existing and past site activities that may have resulted in contaminant releases to the environment, the locations of those releases, the contaminants of concern, their fate and transport within the environment, and the receptors of those contaminants.

Subsurface: Below the earth surface.

Surface Water: Water within streams, lakes, reservoirs, discharge canals, cooling towers, retention ponds, water from precipitation events, wetlands, estuaries, and oceans.

Vadose Zone: The subsurface zone where earth materials are not saturated.

A
APPENDIX: LIST OF GUIDANCE STATEMENTS

No.	Program	Guidance Statement
Section 3. Evaluation of Potential Subsurface Releases		
3.1a	Baseline	Spills with the potential to release plant-related radionuclides to the environment, and other subsurface contaminating events, shall be evaluated and documented. Obtain an estimate of the date, location, volume, and quantity of radioactivity for all documented spills. Such information should be filed in the 10 CFR 50.75(g) file, if it is not already there.
3.1b	Baseline	Evaluate any remedial actions taken in response to a spill to determine the quantity of the spill that may have been recovered, and the quantity which remains as a potential ongoing source of groundwater contamination.
3.2.1a	Baseline	A comprehensive evaluation of systems, structures and components (SSCs) that contain or could contain radioactive liquids, whether above or below grade, shall be performed. Only those SSCs that have a credible potential for releasing radioactive liquid to soil or groundwater need be considered in this evaluation. Examples of SSCs of concern include, but are not limited to, radwaste systems, sumps and drains, spent fuel storage pools and leak detection systems, and secondary systems. Identify the SSCs of concern and evaluate their applicable components, their locations, their age, and their current physical condition.
3.2.1b	Baseline	Where possible, sample and analyze the contents of the identified SSCs for plant-related radionuclides. As a minimum, analyze for gamma emitters and tritium.
3.2.1c	Baseline	Use a database or spreadsheet tool for the collection and use of data pertaining to SSCs to ensure that summary results are documented, retained, and readily retrievable.
3.2.2a	Baseline	For each SSC identified in Section 3.2.1, review and summarize the preventive maintenance, surveillance, and inspection programs that are in place to ensure their integrity. Ensure that the preventive maintenance and inspection program includes , at a minimum, a periodic assessment of the below-grade or inaccessible SSCs, and a periodic visual assessment of the above-grade and accessible SSCs.
3.2.2b	Baseline	For those SSCs where inspections and verifications are not being performed, evaluate the need for such activities based on the condition of and the potential likelihood for an inadvertent release posed by the SSC.

No.	Program	Guidance Statement
3.2.3	Baseline	Evaluate the SSCs identified during the implementation of Section 3.2.1 of this guidance document with regard to their potential for leaks to the environment or for the existence of an unanalyzed pathway. Consider the age of the SSC, its current physical condition, its maintenance history, and the results of any leak testing or other means of verifying SSC integrity.
3.3	Baseline	Work practices shall be evaluated to assess their potential for contributing to groundwater contamination. Only those work practices that have a credible potential for causing or allowing the release of radioactive liquid to soil or groundwater need be considered in this evaluation. If groundwater contamination is confirmed, consider former work practices that may no longer be in use. Document the results of this work practice evaluation.
Section 4. Establishing a Site Conceptual Model		
4.1	Baseline	An initial Site Conceptual Model shall be developed.
4.2	Baseline	Examine references such as existing site construction era photos, aerial photos, and engineering drawings that show foundations, pipes, conduits, storm drains, and other SSCs that are located below the water table and that may divert local groundwater and contaminant flow.
4.3a	Baseline	Examine, when available, reports of previous hydrogeologic investigations of the site.
4.3b	Baseline	If monitoring wells were installed during previous hydrogeologic studies of the site and are to be used in a site groundwater protection program, verify that they were constructed in accordance with current standards.
4.4a	Baseline	Identify the source(s) of water that could represent a source of exposure to the public (e.g., drinking water or food/feed irrigation water). Include water sources both on-site and on properties near the utility owner-controlled property. Also identify the uses of such water sources.
4.4b	Baseline	Compile, document, and periodically re-validate the location, depth, use, and yield of water wells and springs at on-site and near-site locations.
4.4c	Baseline	Identify the existence of wetlands or estuaries down-gradient from the site.
4.5	Baseline	Review applicable state and local regulations relating to radioactive contamination of groundwater.

No.	Program	Guidance Statement
4.6.1	Baseline	Evaluate records relating to groundwater elevation. Include in the evaluation such records as site or regional maps that show surface waters and topography, preconstruction boring information, the location, depth, and static water elevation in building sumps and stand-pipes, the location and operating water level in active sumps and supply wells, and the elevation of nearby surface waters, unlined retention ponds, and canals.
4.6.2	Baseline	Evaluate geologic studies that were conducted during the initial siting investigation of the plant.
4.6.3a	Baseline	Review reports and mapping by the U.S. Geological Survey and the State Geological Survey.
4.6.3b	Baseline	Ensure that applicable site licensing basis documents are consistent with the information contained in referenced regional reports.
4.7.2	Baseline	Locate monitoring wells so as to adequately characterize the horizontal groundwater flow.
4.7.3	Elevated	If contamination is detected in the shallow aquifer, then install additional monitoring wells to characterize the vertical extent of the plume and more fully characterize the horizontal extent.
4.7.4	Elevated	If radiological contamination of multiple water-bearing zones is confirmed, conduct aquifer tests in the various strata to determine whether hydraulic connection exists between strata.
4.8.1	Elevated	Consider the use of data-logging pressure transducers to record changes in water level in selected monitoring wells.
4.8.2	Elevated	Characterize the hydraulic characteristics of the groundwater system in greater detail if features such as bedrock or site-specific complexities in stratigraphy have the potential to affect contaminant flow and need further assessment.
4.8.3	Elevated	Consider conducting aquifer testing to estimate the rate of groundwater flow.
4.8.4	Elevated	Hydrophysical testing may be conducted to identify water-bearing fractures and fractured zones within consolidated bedrock formations.
4.9	Elevated	Evaluate the need for a fate and transport numerical model, and develop one if appropriate.

No.	Program	Guidance Statement
Section 5. Locating, Installing, and Testing Groundwater Monitoring Wells		
5.1	Baseline	Consider the establishment and documentation of a Data Quality Objectives (DQO) process for well drilling.
5.2.1a	Baseline	Document monitoring well construction details.
5.2.1b	Baseline	Establish a database for the collection and use of well construction data to ensure that summary results are documented, retained, and readily retrievable.
5.2.2	Baseline	Review the regulations of state and local agencies to identify jurisdictional requirements for drilling groundwater monitoring wells.
5.2.3	Baseline	Locate wells based upon the Site Conceptual Model and the results of the evaluation of each SSC and work practice.
5.2.4	Baseline	Verify that monitoring wells are installed with sufficient diameter to allow proper sampling.
5.3a	Baseline	Install and document monitoring wells under the supervision of a qualified geoscientist/engineer.
5.3b	Baseline	Construct and maintain both investigation wells and monitoring wells in accordance with recognized standards.
5.3c	Baseline	Install both investigation wells and monitoring wells with the appropriate size and depth, with screened intervals within the zones most likely to be impacted by a release from the plant.
5.3d	Baseline	Sample, examine, and log the geologic materials penetrated as both investigation and monitoring wells are drilled.
5.4a	Baseline	Develop and implement a maintenance program for monitoring wells.
5.4b	Baseline	Construct monitoring well surface completions using a licensed well drilling contractor or under the supervision of a qualified geoscientist/engineer.
5.4c	Baseline	Include surface completion inspections for all wells in the site groundwater monitoring program as a formal and documented inspection process.
5.4d	Baseline	Decommission monitoring wells that are no longer useful for their intended purpose in accordance with appropriate standards.

No.	Program	Guidance Statement
Section 6. Establishing a Groundwater Sampling and Analysis Process		
6.1	Baseline	Establish and document Data Quality Objectives (DQOs), or an equivalent strategy, for each sampling campaign in the form of a sample plan or procedure.
6.2a	Baseline	Establish groundwater sampling procedures for both routine and special monitoring, and address such items as: sample planning; DQOs if applicable; sample collection methods; water-quality indicators to be measured during sampling and their acceptance criteria; sample analytes; sample holding time(s); required sample volume, container type(s) and preservative(s); number of field quality control samples such as duplicates, matrix spikes, equipment rinsate blanks, and splits; qualification and training requirements for sampling personnel; management of sampling waste, including well purge water; sample handling, labeling, storage, and shipment; chain of custody; and analytical data receipt and review.
6.2b	Baseline	When sampling in areas where groundwater is contaminated, appropriately control the water purged from a well prior to collection of a sample. Appropriately assess the purge water prior to disposal.
6.3a	Baseline	Select analytes, at a minimum, based on the radionuclides contained in the SSCs that are potential sources of groundwater contamination. Always include tritium and gamma emitting radionuclides. Include in the analyte list both past and present source terms for SSCs of interest, a historical analysis of on-site spills, leaks, or unanalyzed pathways, and a review of positive radionuclide detections in soil, groundwater, and other environmental sample media.
6.3b	Baseline	Periodically re-evaluate the list of analytes.
6.4	Baseline	Establish and document the rationale for establishing the MDCs and the criterion for determining when an analytical result is statistically valid.
6.5	Baseline	Document the rationale and basis used in the determination of minimum sample volume, container type, and preservation requirements for groundwater samples.
6.6	Baseline	Develop a written sampling schedule and sampling plan consistent with the established DQOs or sampling requirements for each sampling point and analyte.
6.7	Baseline	Establish a consistent documented process to review analytical data. Include such items as: inventory of analytical results to ensure that all data are reported by the analyzing laboratory; evaluation of the achieved laboratory MDCs; evaluation of laboratory QC/QA data; evaluation of any split, duplicate, blank, or spike sample results; and evaluation to determine whether the acceptance criteria for each category of quality control samples were achieved.

No.	Program	Guidance Statement
Section 7. Evaluating Sampling and Monitoring Data		
7.1	Baseline	Validate data, and include a comparison with regulatory criteria, prior to the evaluation of the analytical data.
7.2	Baseline	Collect groundwater samples in accordance with applicable governing agency regulations or permit conditions. The following parameters are useful indicators of general water quality and may be measured and evaluated prior to collecting groundwater samples for radiological analysis to ensure that representative samples are obtained: turbidity; temperature; pH; oxidation-reduction potential (ORP); specific conductivity; dissolved oxygen concentration; and document all evaluations.
7.3a	Baseline	Include the following items with documented analytical data: sample identification; sample location or well identification; sample date and time; measured concentration for all radionuclides where results have been reported (whether or not above the detection criteria, or positive or negative); measurement uncertainty; achieved MDCs; records of data validation and verification; whether or not any validated analytical results exceed applicable site action levels; and identification of missing sample results.
7.3b	Baseline	Manage data to ensure that summary results are documented, retained, and readily retrievable.
7.4.1a	Baseline	Determine background concentrations of radionuclide analytes.
7.4.1b	Baseline	Evaluate analytical data for Type I errors (false positive detections).
7.4.2	Baseline	Evaluate and document the significance of atmospheric deposition of plant-related radionuclides.
7.4.3	Baseline	Where such processes take place, evaluate and document the potential impact from the discharge of cooling water and subsequent re-use in plant systems or on-site drinking water.
7.5a	Baseline	Periodically evaluate the Site Conceptual Model against the results of the data assessment, and if significant deviations are identified, consider revision of the model.
7.5b	Baseline	Review the Site Conceptual Model after any of the following: a) Substantial site construction or disturbance of site or near-site property; b) Substantial change in on-site or adjacent off-site water use; and c) Substantial change in the rate of pumping for on-site or nearby off-site wells.

No.	Program	Guidance Statement
7.5c	Baseline	If the Site Conceptual Model is revised, evaluate the need to revise the applicable site licensing basis documents and appropriate site drawings that are part of the plant design basis documentation.
Section 8. Program Validation and Review		
8.1a	Baseline	Conduct an independent review when the initial review described in Section 3 of this Guideline has been completed and documented and a Site Conceptual Model has been developed.
8.1b	Baseline	An independent program review should be completed following development of the Site Conceptual Model.
8.2a	Baseline	Establish and document a review cycle for the identification of potential sources of subsurface contamination. Document the rationale for selecting the frequency and methods of reviews. The frequency of the review cycle should not exceed five years.
8.2b	Baseline	If site conditions result in a significant change in the potential radiological impact of SSCs or work practices, or if previously unknown spills, leaks, or unanalyzed pathways are identified, a re-evaluation of possibly-affected SSCs and work practices should be performed, as described in Section 3.

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