

Optimization of Groundwater Protection Initiatives (GPI) for Nuclear Power Plant Decommissioning

Young Il Na, Suk Bon Yoon

Korea Hydro & Nuclear Power Central Research Institute (CRI), 70, 1312-gil, Yuseong-daero, Yuseong-gu, Daejeon, 34101, Republic of Korea

*Corresponding author: gangwoo.ryu@khnp.co.kr

***Keywords :** Decommissioning, Groundwater Protection, EPRI Report

1. Introduction

During the permanent shutdown and decommissioning phase of a nuclear power plant, groundwater monitoring is more than an environmental surveillance activity; it is a key engineering metric that drives cost and schedule. EPRI Ground Water Protection Guidelines for Nuclear Power Plants (Report 3002029324, [1]) and Groundwater Monitoring Guidance for Decommissioning Planning (Report 3002008167, [2]) delivers a life-of-plant framework for establishing, operating, and transitioning a groundwater-protection program from full power operation through safe-shutdown, decommissioning, and final site release. This abstract summarizes the nine-step methodology defined in the guidelines and highlights key technical and programmatic elements.

2. Materials & Methods

2.1 Methods

The EPRI Ground-Water Protection (GWEP) Guidelines prescribe a nine-step, risk-driven methodology that guides a nuclear-power-plant (NPP) operator from the first day of commercial operation through safe-shutdown, de-commissioning, and final site release. Each step is linked to a specific set of deliverables, decision points, and regulatory checkpoints. The sequence is intentionally iterative; information gathered in later steps is fed back to earlier phases to refine the Site Conceptual Model (SCM) and the overall monitoring program. The table below, which originally served as a concise checklist, is now unpacked into a narrative that explains the purpose of each activity, the technical work required, and the typical outputs that must be documented.

Phase A – Initial Evaluation

1. Historical Release Review – Collect every documented event that could have introduced radionuclides to the subsurface: fuel-pool leaks, waste-water spills, pipe-ruptures, storm-water overflows, and any “near-miss” incidents.

2. SSC Inventory – Develop a master list of all on-site SSCs that contain, transport, or process radioactive material. For each SSC record: location,

operating pressure/temperature, containment design, and any past modifications.

3. Work-Practice Risk Assessment – Evaluate operating procedures, maintenance practices, and human-factor controls that influence the likelihood of accidental releases.

Phase B - Development of the Site Conceptual Model (SCM)

1. Cartographic and As Built Data Integration – Assemble high resolution aerial photographs, GIS based plant layout drawings, and as built schematics of underground utilities. Georeferenced these layers to a common coordinate system.

2. Hydro-geologic Data Synthesis – Collate all available borehole logs, hydraulic-conductivity measurements, aquifer-test results, and regional groundwater-flow studies. Where data are missing, plan targeted investigation.

3. Receptor Identification – Define on-site receptors and off-site receptors municipal wells, surface-water bodies, protected eco-systems. Map regulatory limits for each receptor.

4. Hydraulic-Flow and Transport Hypotheses – Draft conceptual diagrams that illustrate: The groundwater flow characteristics should be analyzed considering seasonal variations between wet and dry seasons, and equipotential line maps (water table maps) should be established. Based on these findings, groundwater modeling must be performed, incorporating the transport characteristics of radionuclides.

Phase C – Monitoring Well Network Design

1. Sentinel Well Placement– Locate wells directly down gradient of each high PI SSC, within the same hydraulic capture zone identified in the SCM. Depth selection follows the vertical hydraulic gradient: shallow wells for unconfined aquifers, deeper wells for confined or semi confined units.

2. Perimeter Well Placement – Install a ring of wells around the plant’s outer boundary to monitor any off site migration. The spacing is typically 0.5–1 km, adjusted for aquifer transmissivity and regulatory expectations.

3. DQO-Driven Drilling Specification – Define the Data-Quality-Objective (DQO) for each well: minimum screened interval, required pumping rate,

acceptable deviation from the target depth, and logging requirements.

4. Well-Construction Quality Assurance – Specify casing material, annular seal design, and surface-completion details to prevent short circuiting between aquifer layers.

Phase D – Sampling & Analysis Plan

1. Analyte List Development – Core radionuclides (^3H , ^{90}Sr , ^{137}Cs , ^{60}Co) are sampled at every well on the routine schedule. “Hard to detect” isotopes (Pu-239/240, Am-241) are sampled on a quarterly or semi-annual basis, depending on historical presence.
2. Minimum Detectable Concentration (MDC) Definition – Set MDC values at least one order of magnitude lower than the applicable regulatory limit (e.g., MDC for tritium = 0.1 Bq/L when the limit is 1 Bq/L). This ensures that any upward trend can be identified well before the limit is approached.
3. Sampling Frequency Matrix – Routine quarterly sampling for sentinel wells and semi annual for perimeter wells. For example, after a high-water-table event, a known spill, or a significant maintenance activity sampling at increased frequency (weekly to daily) for the full radionuclide suite.
4. Laboratory Accreditation & QA/QC – Contract only labs that hold ISO-17025 accreditation for the required radionuclide analyses. Include field blanks, trip blanks, duplicate samples, and matrix spikes in the sampling protocol.

Phase E – Data Management, Evaluation & Trend Analysis

1. Data Validation– Apply automated scripts to flag outliers, missing values, and results that fall below MDC. Cross check field parameters (temperature, specific conductance, pH) against expected ranges for the aquifer.
2. Baseline Establishment– Use the first 12–18 months of validated data to define statistical baselines (mean $\pm$ 2 sigma) for each analyte at each well.
3. Trend Detection – Deploy non parametric statistical tests to identify monotonic trends. For tritium, evaluate whether the apparent half life decay aligns with natural decay or indicates dilution/mixing.
4. Early Warning Triggers – Pre define thresholds. For example, 50 % of the regulatory limit or a statistically significant upward trend persisting for two consecutive sampling events. That automatically initiate an investigation and, if necessary, a spill response activation.

2.2 Benefits

Demonstrates compliance with regulator and international expectations; facilitates License Termination Plan (LTP) approvals. And Early identification of deep aquifer pathways as seen in the Yankee Rowe case prevents costly schedule extensions and drilling overruns. Systematic source ranking and targeted sentinel wells concentrate monitoring resources where they yield the greatest risk mitigation. Transparent, periodic reporting and rapid leak response actions improve public confidence and reduce the likelihood of petition driven regulatory delays.

3. Conclusion

Compared to these standards, the groundwater monitoring systems at domestic nuclear power plants are deficient in many respects. The integrated monitoring system described in the EPRI research reports is not a quick-fix solution, but rather a long-term roadmap that matures incrementally through data accumulation, technological advancement, and regulatory improvement. While the current lack of empirical cases has hindered the implementation of decisive measures, it is imperative to gradually enhance the system to preemptively prevent potential damages, such as delays in decommissioning schedules or increases in costs resulting from monitoring failures.

REFERENCES

- [1] EPRI Technical Report (3002029324) – “Groundwater Protection Guidelines for Nuclear Power Plants”
- [2] EPRI Technical Report (3002008167) – “Groundwater Monitoring Guidance for Decommissioning Planning”