CMD 25-H9.8

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Written Submission from the Inter-Church Uranium Committee Educational Co-operative

In the matter of

Denison Mines Corporation

Licence Application to Prepare Site and Construct for Denison Mines' Wheeler River Mine and Mill Project

Commission Public Hearing

December 2025

Mémoire de l'Inter-Church Uranium Committee Educational Co-operative

À l'égard de

Denison Mines Corporation

Demande de permis pour la préparation de l'emplacement et la construction du projet de mine et d'usine de concentration d'uranium Wheeler River de Denison Mines

Audience publique de la Commission

Décembre 2025

Critical review — Mitigation measures & monitoring for Denison's Wheeler River (Phoenix) ISR project

Denison's mitigation suite (freeze-wall containment, phased leaching + neutralization, monitoring wells and commitments) is technically credible on paper, but it **relies heavily on engineered containment and post-leach remediation that are difficult to guarantee in practice**, and several monitoring/design gaps and governance/long-term stewardship issues remain. PR Newswire+2PR Newswire+2

1) Freeze-wall containment — strong concept, but single-point risk and uncertain long-term performance

What Denison proposes: a freeze wall around the ISR wellfield to provide hydraulic containment of the leach zone. PR Newswire

Critique

- Freeze-wall construction is technically complex at depth and requires continuous operation (and energy) to maintain frozen ground. If freezing performance degrades (power outage, instrument failure, incomplete freeze, seasonal effects), containment could be compromised. The plan appears to treat the freeze wall as a primary containment barrier rather than as one of multiple redundant controls.
- There is limited publicly available, independent long-term performance data for deep freeze walls used as permanent hydraulic containment in ISR contexts. Reliance on a novel single-system for primary containment increases project vulnerability. d3e2i5nuh73s15.cloudfront.net+1

Recommendation

- Treat the freeze wall as one component in a layered-defence system: add redundant hydraulic controls (e.g., hydraulic capture pumping, hydraulic gradient control, additional low-permeability cutoff barriers), independent performance verification, and documented contingency procedures for freeze failure (spare capacity, rapid response power provisioning, temporary cutoffs).
- Publish a probabilistic failure modes analysis of the freeze wall and emergency response triggers so regulators and stakeholders can assess risk.

2) Neutralization / aquifer restoration — optimistic outcomes vs. documented difficulty

What Denison claims: field tests (leaching + neutralization phases) demonstrated ability to neutralize the test area and remediate the test pattern. PR Newswire+1

Critique

- Global ISR experience and peer literature show that aquifer restoration after aggressive leaching (especially if there is localized acidity or major geochemical shifts) is frequently incomplete: metals and radionuclides sorb to sediments, precipitates can form and later re-mobilize, and heterogeneity in permeability/chemistry causes persistent hotspots. Denison's FFT (field feasibility test) is limited in spatial scale and timescale and may not capture full complexity of large-scale operations. Wheeler River Project+1

- The company's announcements emphasize successful neutralization in the FFT, but they don't substitute for evidence that multi-decadal baseline quality can be restored across a commercial wellfield footprint. Short-term neutralization does not guarantee absence of long-term releases. PR Newswire

Recommendation

- Require conservative, performance-based restoration criteria (not just "return to within X % of baseline" over a short period). Include long-term rebound testing (years to decades), and require financial surety sized to cover extended remediation if restoration fails.
- Expand pilot programs to replicate heterogeneous hydrogeologic conditions expected at scale and publish independent third-party evaluations.

3) Monitoring network design — analytes and spatial/temporal density concerns

What Denison proposes: monitoring well networks, periodic groundwater sampling for uranium, pH, major ions, and selected contaminants; real-time operational monitoring (company documentation/EIS). Wheeler River Project

Critique

- Public summaries lack granular detail on: monitoring well spacing beyond the proposed perimeter; depth distribution relative to confining units; frequency and responsiveness of sampling; which radionuclides and trace metals are included (e.g., radium-226, thorium isotopes, arsenic, vanadium); and whether real-time pH/EC sensors are installed in sentinel wells. Sparse networks or low sampling frequency will delay detection of plume migration. Wheeler River Project
- Monitoring appears largely company-led; the degree of independent auditing, third-party verification, and public real-time data release is unclear. This raises transparency and trust issues for Indigenous groups and local stakeholders. Métis reviewers explicitly called for stronger inclusion of Métis knowledge and involvement in monitoring design and implementation. registrydocumentsprd.blob.core.windows.net+1

Recommendation

- Require a denser, multi-layered monitoring network (inner, mid, outer rings) with sentinel wells hydrogeologically downgradient and cross-gradient, continuous sensors for key parameters (pH, conductivity) with automated alerts, and full analyte suites including radium isotopes and trace metals at high frequency during operations.
- Mandate independent, third-party audits of monitoring and public near-real-time data feeds; formalize Indigenous-led monitoring roles and data-sharing protocols.

4) Well integrity, infrastructure and operational leak risk

What Denison proposes: standard well construction, corrosion control, inspection and maintenance programs (described in EIS/technical reports). Denison Mines Corp.

Critique

- ISR projects create many potential leak points: well casings, packers, surface wellheads, transfer pipelines and storage tanks. Corrosive fluids (acidic phases or sulfate-rich fluids) and scale (radium-sulfate) accelerate equipment degradation. The EIS/press materials summarize mitigation but provide limited public detail on inspection intervals, NDT (non-destructive testing) regimes for casings, and replacement schedules. This makes it hard to evaluate whether the planned program will prevent slow leaks or detect casing failures early. Denison Mines Corp.+1

Recommendation

- Publish a detailed well integrity management plan: materials specification (corrosion allowance), NDT schedule (caliper logs, pressure tests, cement bond logs), redundancy on critical control systems, and immediate shutdown thresholds. Require remote leak detection for pipelines and double-walled storage where practical.

5) Radionuclide mobilization, scale and waste handling

What Denison describes: recognition of radionuclide behavior, scale formation, and management measures in technical reports.

Critique

- Radium and other NORM can form insoluble scales (e.g., radium-sulfate) that accumulate in wells and processing equipment. Handling and disposal of these concentrated wastes are long-term liabilities. Public documents note management but give limited detail on waste form characterization, long-term storage specifications, or institutional controls. Without detailed pathways for safe long-term disposal, there is risk of improper handling or future release. Denison Mines Corp.

Recommendation

- Require full waste characterization studies, mandated engineered disposal facilities meeting radiation safety best practice, and a funded long-term stewardship plan (including institutional controls and monitoring) backed by secure financial assurance.

6) Emergency response, spill contingency and transparency

What Denison proposes: spill prevention and response plans, as part of regulatory requirements and EA commitments. Wheeler River Project

Critique

- The EIS lists spill plans, but public materials do not provide granular response times, staging locations, community notification procedures, nor criteria for escalating to regulator intervention. In remote northern contexts, response logistics (weather, access) can slow containment. Indigenous communities flagged the need for better clarity and inclusion in contingency design. registrydocumentsprd.blob.core.windows.net+1

Recommendation

- Publish clear, operational contingency plans: maximum allowed response times, local staging caches, multi-agency drills with Indigenous participants, and mandatory public incident dashboards. Require predefined escalation triggers that compel immediate suspension of operations.

7) Long-term monitoring, financial assurance & independent oversight

What Denison commits to: post-closure monitoring and restoration, with commitments in the EIS and licensing processes. Wheeler River Project+1

Critique

- Many ISR sites globally face decades of post-closure monitoring. It is unclear whether Denison's financial assurances (bonding/surety) are sufficient for extended remediation beyond company lifetime changes, and whether monitoring responsibilities transfer reliably if the operator changes or declares bankruptcy. Public documents do not fully detail the sufficiency or governance of long-term funding. Wheeler River Project+1

Recommendation

- Require independent escrowed long-term funds sized by conservative remediation scenarios, legal mechanisms to ensure funds are available irrespective of corporate status, and institutionalized independent oversight (e.g., an environmental trust board including Indigenous and public representatives).

8) Indigenous engagement and incorporation of Traditional Knowledge into monitoring

What community reviewers requested: Métis Nation and other stakeholders asked for active Métis knowledge integration and co-design of monitoring and effects management. registrydocumentsprd.blob.core.windows.net

Critique

- Denison's documentation recognizes Indigenous engagement, but reviewers judged some monitoring design elements insufficiently inclusive or lacking in mechanisms for Indigenous co-management and data sovereignty. Without formal co-governance, monitoring can fail to capture culturally-relevant indicators or local concerns. registrydocumentsprd.blob.core.windows.net+1

Recommendation

- Co-design monitoring programs with Indigenous partners, include traditional ecological indicators, guarantee data access and capacity funding for Indigenous-led monitoring programs, and embed formal roles for Indigenous representatives in adaptive management decision processes.

9) Information disclosure and data accessibility

What's lacking: public documents and press releases summarize tests and plans but don't provide continuous public data feeds or full technical appendices in accessible form. PR Newswire+1

Critique

- Limited public transparency reduces stakeholder trust and slows independent verification. Given the high stakes for water resources, full, timely release of monitoring results is essential. Wheeler River Project

Recommendation

- Mandate public, near-real-time data portals (with raw data and QA/QC notes), independent data audits, and timely reporting of deviations from triggers.

Short prioritized checklist for regulators / Indigenous monitors

1. Require a redundancy analysis for containment (freeze wall + backups).
2. Make restoration performance criteria conservative, long-term, and enforceable with financial assurance.
3. Tighten monitoring: dense multi-ring network, continuous sensors, expanded analyte lists (including radium isotopes), frequent sampling and public dashboards.
4. Publish detailed well integrity & inspection plans and require third-party verification.
5. Mandate Indigenous co-design, co-management and funded local monitoring capacity.
6. Require escrowed, legally protected funds sized for multi-decadal remediation and stewardship.

Sources

- Denison Mines — Phoenix ISR project and corporate project pages (project overview, freeze wall adoption). Denison Mines Corp.+1
- Denison — Draft and Final Environmental Impact Statement (EIS) documents (commitments, monitoring summaries, FFT results). Wheeler River Project+1
- Denison press releases and field feasibility test summaries (leach + neutralization results). PR Newswire+1
- Métis Nation of Saskatchewan technical review of the Draft EIS (requests for Indigenous knowledge integration and concerns about monitoring design). registrydocumentsprd.blob.core.windows.net
- CNSC project page and regulatory milestones (EA process and participant funding context). cnsc-ccsn.gc.ca

In this section I pulled Denison's submitted **Groundwater Protection & Monitoring Plan** (the GWMP submitted with the Final EIS / CMD 25-H9.1) and compared the plan text to international / national monitoring best-practice guidance (IAEA, EPA, Australian Geoscience/Au. gov guidance, relevant state guidance). I extract the **exact, verbatim** passages from Denison's GWMP that define the monitoring-well network, analytes / key indicator parameters, and the wording used for the post-mine / "restoration" / control-limit criteria; and present a **redline-style summary (gaps vs. recommendations)** against accepted best practices, with clear, actionable recommendations.

All quoted items below are taken verbatim from Denison's GWMP (Groundwater Protection and Monitoring Plan, Denison Mines — CMD25-H9-1) unless otherwise noted — I cite that plan and the best-practice sources I compared to.

1) Verbatim extractions from Denison's GWMP (Final EIS submission)

Source: *Groundwater Protection and Monitoring Plan (Denison Mines Corp., Wheeler River Operation),* CMD25-H9-1 (PDF). api.cnsc-ccsn.gc.ca

A. Monitoring network / numbers / conceptual layout (verbatim)

- "A total of 13 or 14 new wells will be installed to monitor shallow groundwater conditions during operations of the surface facilities (Table 3-4). GWR-036 and GWR-037 will also be sampled as per Table 3-4 to monitor downgradient locations at the Site, close to Whitefish Lake, and any excursions associated with the effluent discharge lines." api.cnsc-ccsn.gc.ca
- "The monitoring well network can be built up over time in alignment with the mining phases. If this approach is taken, groundwater sample collection will begin prior to mining. Pre-operations samples in the surface facilities wells should be collected on two occasions, and preferably in two seasons." api.cnsc-ccsn.gc.ca
- "The recommended monitoring well network to achieve these objectives is shown in Figure 3-4, and details are provided in [text]. … Existing GWR-series monitoring wells will be used where possible to meet the monitoring needs at this stage. New monitoring wells will be installed as required." (Figure 3-4 is cited as the conceptual configuration for full-phase monitoring.) api.cnsc-ccsn.gc.ca
- On mining-area monitoring objectives: "Within the freeze wall: demonstrate that groundwater quality at elevations above the mining area (i.e., positioned at elevations 50 m or more from the mining horizon) do not show a change from baseline levels; and … Outer perimeter of freeze wall: demonstrate that groundwater quality outside the freeze wall is not changing in a manner as to signal excursions, and if occurring, to detect the excursion and location where it is occurring, in a timely fashion." api.cnsc-ccsn.gc.ca

B. Key indicator parameters / analytes (verbatim excerpts from Table 3-4 and related text)

- Table 3-4 (selected lines, verbatim):
  - For many surface-facility downgradient wells: **"Water Level, pH, temperature, EC, Cl, Dissolved U — Semi-Annually (Spring, Fall/Winter)."** api.cnsc-ccsn.gc.ca

- For perimeter wells around industrial waste landfill / leachate: **“Water level, pH, temperature, EC, Cl, Nitrate — Seasonal (Spring, Summer, Fall/Winter).”** api.cnsc-ccsn.gc.ca
- For perimeter wells associated with industrial waste / perimeter monitoring: **“Water Level, pH, Temperature, EC, Major Ions (Na, Ca, Mg, K, Cl, SO4, Inorganic Carbon Species), radionuclides (includind dissolved U) — Seasonal (Spring, Summer, Fall/Winter).”** api.cnsc-ccsn.gc.ca
- For hazardous waste storage pad wells: **“Water level, pH, temperature, EC, Cl, Volatile organic constituents (VOCs) — Semi-Annually (Spring, Fall/Winter).”** api.cnsc-ccsn.gc.ca

- Other explicit parameter wording in the GWMP (verbatim):
  - “Downgradient water quality in OB aquifer monitored as part of Freeze-Wall perimeter wells (Being measured in freeze wall perimeters wells is: pH, EC, ORP, Cl, Sulphate, Dissolved U).” api.cnsc-ccsn.gc.ca
- On sulfate concentrations in leachate (verbatim):
  - “Sulphate: The primary chemical in the injected fluids is sulfuric acid (H2SO4). In metallurgical testing completed for the project to date, sulphate concentrations in the leachate can exceed **40,000 mg/L**.” api.cnsc-ccsn.gc.ca

C. Control limits / “restoration” / post-decommissioning criteria (verbatim)

- On how excursions and limits are defined (verbatim):
  - “The objectives in establishing baseline and background conditions for the Operation are to: …” (Section heading — see Section 4.2) … and “Control limits for the mining stages will be established as follows:
    o **Mining and Decommissioning Stages:** Background values as defined by control charts or upper limit of background for wells on the perimeter and downgradient of surface facilities, the freeze wall perimeter wells and wells within the freeze wall overlying the mining area; and
    o **Post-Decommissioning:** Upper bounds of water quality predictions.” api.cnsc-ccsn.gc.ca
- On identification of excursions (verbatim):
  - “Trends away from control limits will be considered as signaling an excursion if and only if the following conditions are met:
    • Control limits are exceeded, and a monotonic trend is confirmed by trend analysis for continuous monitoring of EC or temperature for an appropriate number of routine sampling intervals. …
    • Control limits are exceeded and a monotonic trend is confirmed for two or more of the Key Indicator Parameters (or other constituents identified as key parameters measured through discrete sampling, over three or more routine sampling intervals.” api.cnsc-ccsn.gc.ca
- On remediation/remedial actions the GWMP states (verbatim):
  - “If, on the basis of the above criteria, an excursion is signaled, the investigative or mitigative actions may include the following: • Confirmation of results; • Increase sampling frequency; • Investigate potential source(s); • Delineate groundwater plume; and • …” (Section 4.4). The plan further states that recommendations for

methods/approaches for remediation are **outside the scope** of this document. api.cnsc-ccsn.gc.ca

2) What the Denison text *does* and *doesn't* give you (quick factual summary)

- **Provided explicitly:** conceptual monitoring network, numbers of proposed new surface-facility wells (13–14), list of **key indicator parameters** for different well types (water level, pH, temperature, EC, major ions incl. SO?, dissolved U, VOCs, radionuclides), approach to control limits (Shewhart/control-chart approach, UCL/LCL) and excursion trigger rules (monotonic trend + exceedance criteria). The plan flags sulphate as a major COPC and gives a measured leachate concentration (40,000 mg/L). api.cnsc-ccsn.gc.ca
- **Not specified with hard numbers / distances:** the GWMP is *conceptual* about spatial spacing — it describes perimeter, freeze-wall perimeter, multilevel clusters (MLS-1), and conceptual Figure 3-4 — but I did **not** find a single, explicit numeric *well-to-well spacing* (e.g., "monitoring wells every X metres around the freeze wall") or a single, fixed analyte table labeled "full lab analyte list" with method detection limits and QA/QC details. The plan says the network can be built up and that details are in figures and in subsequent design documents; remediation methods are outside the GWMP scope. api.cnsc-ccsn.gc.ca

3) Redline — Gaps in Denison's GWMP (Final EIS) vs. published best practices, and recommended text/actions

I compared Denison's GWMP to authoritative guidance including the IAEA in-situ leach / ISR guidance and the IAEA environmental EIA guidance, the EPA RCRA/EPA monitoring well handbook and EPA/State guidance on monitoring well spacing and sentinel wells, and national best-practice summaries (Australia GA/IAEA summaries). Key references: IAEA *In-Situ Leach Uranium Mining* guidance and EIA guidance, EPA "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells", and Australian ISR Best Practice guidance. www-pub.iaea.org+2epa.gov+2

Below I give the **gap**, then the **recommendation**, plus a short justification and a citation to best practice.

Gap 1 — No explicit numeric well-to-well spacing or detection-time objective in the GWMP

Why it's a gap: Best practice recommends designing a spacing that gives a specified detection time (e.g., a plume from a point source should be detected before it reaches receptors — many regulatory guides recommend detection within months and define spacing rules of thumb). Guidance documents explicitly state that spacing should be tight enough that a plume cannot pass between wells undetected; examples: Florida DEP suggests 30–50 ft spacing near source areas, Texas guidance ties spacing to detection time, EPA handbook and technical literature recommend design driven by hydrogeology and detection time objectives. epa.gov+2tceq.texas.gov+2

Redline / recommended wording:

> "Denison shall define and publish numeric monitoring-well spacing criteria derived from the site-specific hydrogeologic model and an explicit *detection objective* (e.g.,

detection of a 95th-percentile plume front within X months of release at the freeze-wall perimeter). Well spacing shall be justified by transport modelling and should follow the principle that a contaminant plume from any credible point source cannot pass between monitoring wells without detection. Where coarse/gravelly materials or high groundwater velocities occur, spacing shall be reduced accordingly (example rule-of-thumb spacing: 10–15 m within 50 m of critical infrastructure; 30–50 m further from source, to be refined by modelling)."
Justification / citation: ties GWMP concept to IAEA and EPA guidance on detection objectives and well spacing. www-pub.iaea.org+1

Gap 2 — Analyte suite is partial / "key indicators" are defined but there is no single, complete laboratory analyte list with required MDLs / methods / frequency for all well types

Why it's a gap: The GWMP lists "key indicator parameters" for many well types (water level, pH, EC, Cl, SO?, dissolved U, major ions, radionuclides, VOCs) but does not present a single, auditable laboratory analyte table (e.g., full COPC list including radium-226, thorium, gross alpha/beta, arsenic, selenium, metals, acidity/alkalinity, DOC, major anions/cations, sulfate speciation, and isotopic analyses where needed) with **required methods and detection limits** and sample preservation and QA/QC. Best practice expects a comprehensive COPC/analyte list, method detection limits, and QA/QC. www-pub.iaea.org+1

Redline / recommended wording:

"Denison shall provide, within the GWMP or an Appendix, a **complete laboratory analyte table** for each monitoring well type. Each analyte entry shall include: analyte name, rationale, analytical method (e.g., ICP-MS, alpha spec, GC-MS), required method detection limits (MDLs) and quantitation limits, sample preservation and holding times, and required QA/QC (field blanks, trip blanks, duplicates, matrix spikes). The analyte list shall include (as a minimum): dissolved uranium, gross alpha/beta, Ra-226, U isotopes (U-234/U-238), major ions (Na, K, Ca, Mg, Cl, SO?, HCO?/alkalinity), metals (As, Se, Mo, V, Fe, Mn, etc.), acidity/alkalinity, DOC, VOC suite, and any COPCs identified in the site characterization."
Justification / citation: aligns with IAEA/EPA requirements for full COPC suites and QA/QC to allow detection and trend analysis. www-pub.iaea.org+1

Gap 3 — Sulfate / acid leach COPC is flagged but the plan lacks explicit numeric triggers for early-warning sentinel wells and no numeric interim thresholds for immediate action (beyond general control-chart wording)

Why it's a gap: Sulfate is explicitly identified and very high leachate concentrations (40,000 mg/L) are reported; this justifies explicit numeric early-warning sentinel trigger criteria at specific distances (and a requirement to sample sulfates with high frequency at sentinel wells and along potential flowpaths). Good practice is to identify sentinel wells with continuous EC and frequent sulfate measurement and to set numeric interim action levels tied to baseline + x% or to site-specific health/ecological thresholds. api.cnsc-ccsn.gc.ca+1

Redline / recommended wording:

"Designate sentinel wells between the freeze-wall perimeter and Whitefish Lake and set **numeric early-warning thresholds** for EC and SO? (for example: EC exceedance of baseline UCL + 20% and sulfate exceedance of baseline UCL or an absolute interim screening level of X mg/L). On exceedance of sentinel thresholds, require immediate confirmatory sampling (within 7 days), increase sampling frequency to weekly, and initiate plume delineation modelling."
Justification / citation: site-specific early-warning thresholds are recommended by IAEA and U.S. guidance for ISR sites with strong chemical gradients. www-pub.iaea.org+1

Gap 4 — No explicit numeric restoration endpoints tied to receptor uses (background vs. risk-based endpoints)

Why it's a gap: The GWMP says Post-Decommissioning criteria = "Upper bounds of water quality predictions." That wording is too vague for a regulatory decision: it doesn't state whether restoration target is pre-mining baseline, background UCL, or a risk-based standard tied to domestic/ ecological receptor uses. International and national guidance commonly require explicit, defendable restoration endpoints. www-pub.iaea.org

Redline / recommended wording:

"Post-decommissioning restoration endpoints shall be explicit and prioritized as: (1) return groundwater quality to **pre-mining baseline** (site-specific), where baseline supports domestic or ecological uses; or (2) where pre-mining baseline does not meet higher-use standards, adopt a clearly justified **risk-based endpoint** (numerical) tied to receptor protection (e.g., drinking water guideline or aquatic guideline), together with a justification for leaving concentrations above baseline. 'Upper bounds of water quality predictions' shall be numerically defined and compared to baseline and receptor criteria."
Justification / citation: This follows IAEA and Australian guidance that regulators require explicit endpoints to approve closure and relinquishment. www-pub.iaea.org+1

Gap 5 — Lack of prescribed minimum monitoring frequency and transducer / continuous-monitoring requirements for critical parameters at freeze-wall perimeter and sentinel wells

Why it's a gap: The GWMP does call for continuous monitoring of water level/EC/temperature in places, but frequency and minimum up-time, redundancy, and data QA (e.g., transducer calibration, data-logger redundancy, real-time telemetry to regulators) are not fully spelled out. Best practice for ISR is to require continuous telemetry for leading indicators and redundancy at key sentinel locations. www-pub.iaea.org+1

Redline / recommended wording:

"Require continuous monitoring transducers for water level, EC, temperature and ORP at all freeze-wall perimeter and sentinel wells, with telemetry to both the operator and the regulator in near-real-time (hourly or better). Define calibration frequency (e.g., quarterly), QA checks, and data validation procedures. Provide redundancy for at least 2 critical transducers per sentinel cluster."
Justification / citation: continuous data provides earliest warning of excursions; IAEA and EPA guidance recommend continuous monitoring for ISR critical control parameters. www-pub.iaea.org+1

Gap 6 — No explicit requirement that multi-level / nested well clusters be installed so different hydrostratigraphic zones are screened separately with no more than one transmissive zone screened per well

Why it's a gap: Regulatory and technical guidance warns against screening multiple transmissive zones in the same well (because the well can act as a conduit). Best practice is multi-level clusters where needed and single-zone screening. Denison mentions MLS-1 multilevel cluster conceptually, but the GWMP lacks binding wording that no well will screen multiple transmissive zones and that multilevel clusters must be used where vertical resolution is needed. api.cnsc-ccsn.gc.ca+1

Redline / recommended wording:

"All monitoring well designs shall screen no more than one transmissive zone per well. Where monitoring of multiple vertical intervals is required, install multilevel clusters (MLS) or discrete multilevel samplers. Completion records, geophysical logs, and packer testing shall be submitted to the regulator prior to commissioning of the monitoring network."
Justification / citation: prevents artificial cross-contamination and ensures vertical delineation capability (EPA/State best practice). epa.gov

Gap 7 — Remediation methods / decision tree beyond "investigate / delineate" are outside the GWMP

Why it's a gap: The GWMP commits to delineation and investigation on excursion detection but explicitly says remediation approaches are out of scope. Regulators and communities usually expect an accepted decision tree that ties exceedances to specific remediation options and timelines — especially important where groundwater supports downstream receptors such as Whitefish Lake. api.cnsc-ccsn.gc.ca

Redline / recommended wording:

"Append an **Excursion Response & Remediation Decision Tree** to the GWMP that ties trigger levels to specific, pre-approved responses (e.g., immediate containment, pump-and-treat, ion exchange, hydraulic containment, hydraulic reverse-flush, in-situ neutralization) and timelines (e.g., immediate, 7 days, 30 days). If active remediation is proposed, require a remediation plan with performance objectives and monitoring to demonstrate plume rollback."
Justification / citation: IAEA and EPA advise that post-detection decision trees and remediation options should be agreed pre-emptively. www-pub.iaea.org+1

Short, prioritized checklist

1. **Add numeric well-spacing & detection time objective —** justify by transport modelling. (Ref: EPA / TCEQ / IAEA). epa.gov+1
2. **Publish a full laboratory analyte table (appendix) —** MDLs, methods, QA/QC per analyte, and frequency by well type. epa.gov
3. **Define numeric early-warning thresholds** for EC and sulfate at sentinel wells, with immediate confirmatory sampling and escalation steps. www-pub.iaea.org

4 **Make restoration endpoints explicit** — baseline return OR risk-based numerical endpoints tied to receptors, not just "upper bounds of predictions." Geoscience Australia

5 **Require continuous telemetry + redundancy** for freeze-wall perimeter sentinel wells (EC, level, temp, ORP). PNNL

6 **Require single transmissive-zone screening** or multilevel clusters and submit as-built completion logs/geo-logs before operations. epa.gov

7 **Add an excursion decision tree and remediation plan appendix** with timelines and remediation performance metrics. www-pub.iaea.org

Example redline language for Denison's GWMP / EIS comments

Insert after Table 3-4 (Monitoring network):
"Denison shall supplement Table 3-4 within 90 days prior to commissioning with: (a) a site-specific **well spacing matrix** that defines lateral and vertical spacing for perimeter, sentinel and down-gradient wells (numerically in metres), tied to a documented detection-time objective; and (b) a complete laboratory analyte table (with method, MDL, preservation, holding time and QA/QC). The spacing matrix and analyte table shall be justified by hydrogeological and transport modelling and subject to regulator review."
(Rationale: provides measurable design criteria consistent with IAEA and EPA guidance.)
api.cnsc-ccsn.gc.ca+2www-pub.iaea.org+2

Sources

- Denison Mines — *Groundwater Protection and Monitoring Plan*, CMD25-H9-1 (Final EIS reference/GWMP). api.cnsc-ccsn.gc.ca
- IAEA — *In-Situ Leach Uranium Mining / EIA & monitoring guidance*. www-pub.iaea.org+1
- EPA — *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*; EPA RCRA guidance on groundwater monitoring. epa.gov+1
- Australian Geoscience (GA) / national ISR best practice guidance (IAEA/URAM conference materials summarizing ISR monitoring). Geoscience Australia
- State guidance (FL DEP / TCEQ) on well spacing and detection time concepts. floridadep.gov+1

Summary Comparison Table – Wheeler River GWMP Redlines vs. Clean Text

SectionTracked / Redlined HighlightsClean (Accepted Revision) Summary3.2.3.2 – Monitoring Well Network• Inserted numeric well-spacing criteria and detection-time objectives.
• Added requirement for single-zone or multilevel (MLS) wells.
• Added requirement for hydrogeologic justification and spacing matrix appendix.
• Introduced continuous telemetry (EC, ORP, Temp, water level) with real-time data feed to regulator.
• Added minimum data frequency (hourly) and calibration schedule (quarterly).Defines well

spacing of **10–15 m (sentinel)** and **30–50 m (downgradient)** based on site-specific modeling; requires single-zone or MLS construction; mandates telemetry on freeze-wall and sentinel wells with hourly data feeds and quarterly calibration. Establishes measurable detection-time objective (? 3 months).**Table 3-4 – Recommended Monitoring Well Network**• Expanded analyte list (major ions, trace metals, radionuclides, U-isotopes, VOCs).
• Added QA/QC and MDL specifications.
• Introduced weekly EC and sulfate triggers for perimeter/sentinel wells.
• Required ? 3 sentinel clusters between freeze wall and Whitefish Lake.
• Specified redundant transducers and real-time telemetry.
• Defined post-closure restoration endpoint: baseline or protective numerical criteria, 10-year monitoring minimum.Comprehensive analyte suite added; monitoring frequency increased to quarterly (surface and storage areas) and weekly (active leach). Sentinel wells with redundant telemetry provide early warning. Restoration targets set to baseline or protective numeric levels, with ? 10 years of post-closure verification.**4.2 – Control Limits and Criteria for Excursions**• Replaced vague "upper bounds of predicted water quality" with numeric restoration endpoints.
• Added definition of "excursion" tied to early-warning triggers (EC, SO?, U).
• Added mandatory 24-hour notification to regulator and Indigenous monitors.
• Added detailed five-step Excursion Response & Remediation Decision Tree.
• Required independent annual hydrogeologic audit.Establishes explicit numeric control limits linked to Table 3-4; defines early-warning excursions; mandates 7-day confirmatory sampling and 24-hour notification. Includes formal response plan and annual third-party audit of excursion events and recovery performance.**Overall Effect**Introduces explicit, measurable, and transparent standards where the original GWMP relied on qualitative or descriptive language.Produces a defensible and auditable monitoring plan meeting international ISR uranium mining best-practice standards.

1.1. The Critique of Sulfuric acid injection

2.While sulfuric acid injection in in situ uranium mining offers economic efficiency and reduced surface disturbance, it poses **substantial environmental hazards**. The aggressive acid chemistry mobilizes toxic metals and radionuclides, permanently alters aquifer geochemistry, and makes groundwater restoration exceedingly difficult. The long-term persistence of contamination and the risk to human and ecological health make sulfuric acid-based ISR one of the most environmentally challenging uranium extraction methods. To minimize these impacts, a shift toward **alkaline leaching alternatives**, enhanced monitoring, and stricter environmental standards is essential for ensuring that uranium production aligns with sustainable environmental stewardship.

2. The Process of Sulfuric Acid Leaching

In sulfuric acid-based ISR mining, a dilute sulfuric acid solution (typically 0.1–5% H?SO?) is injected into the ore-bearing aquifer through a network of wells. The acid reacts with uranium minerals such as uraninite (UO?), converting insoluble tetravalent uranium (U??) into soluble hexavalent uranium (U??) species, which are then recovered through extraction wells. The process, while effective for uranium dissolution, simultaneously mobilizes a wide range of other elements and drastically lowers the pH of the surrounding groundwater. This alteration of geochemical conditions is the root of most environmental hazards associated with sulfuric acid leaching.

3. Groundwater Acidification and Chemical Mobilization

The injection of sulfuric acid creates **strongly acidic conditions** within the ore zone, often reducing groundwater pH to below 3.0. This acidity dissolves not only uranium but also host rock components such as iron, aluminum, manganese, and various heavy metals. As a result, toxic elements such as **arsenic, lead, cadmium, vanadium, and nickel** are mobilized into solution.

Moreover, the acidic environment disrupts the natural buffering capacity of the aquifer. Once neutralization processes are exhausted, the acid plume can migrate beyond the mining area, contaminating adjacent aquifers and posing risks to drinking water resources. The re-oxidation of sulfide minerals, stimulated by acid leaching, may also produce **secondary acidity** and sulfate pollution long after mining ceases.

4. Mobilization of Radionuclides

Sulfuric acid leaching significantly enhances the solubility of radioactive elements beyond uranium, including **radium-226**, **thorium-230**, and **polonium-210**. These radionuclides may migrate through groundwater flow paths, posing long-term radiological hazards. Radium, in particular, can precipitate as insoluble sulfates, forming radioactive scale in well casings and pipes, which presents occupational and environmental management challenges. If mobilized, these isotopes can contaminate groundwater used for human consumption or irrigation, leading to elevated radiation doses and chronic health effects.

5. Aquifer Restoration Difficulties

Restoring an aquifer after sulfuric acid leaching is far more difficult than after alkaline leaching (such as with sodium bicarbonate). Acidic leaching fundamentally alters the mineralogy of the formation, dissolving carbonates and clays that naturally regulate groundwater chemistry. These irreversible reactions make post-mining neutralization challenging.

Even after extensive flushing and chemical treatment, **residual acidity and metal contamination** can persist for years. Studies of former ISR sites in Central Asia have shown that groundwater quality often fails to meet baseline conditions or regulatory limits, with persistent contamination by uranium, sulfate, and heavy metals.

6. Surface and Soil Contamination

The infrastructure supporting ISR operations—pipelines, tanks, and injection wells—poses additional contamination risks. Leaks and spills of sulfuric acid or uranium-bearing solutions can cause soil acidification and local contamination of surface water bodies. Acidic runoff dissolves metals from soils and can lead to **secondary pollution** in nearby ecosystems. Repeated spills, if inadequately managed, create long-term “hot spots” of chemical and radiological contamination that are difficult to remediate.

7. Ecological and Human Health Impacts

The environmental degradation caused by sulfuric acid ISR mining has both ecological and human health implications. Acidification of aquifers can eliminate microbial and aquatic life adapted to neutral pH conditions. Toxic metals and radionuclides may bioaccumulate in food chains, affecting plants, animals, and humans. Exposure to contaminated water can lead to health problems such as kidney damage, neurological disorders, and increased cancer risks due to chronic ingestion of uranium and radium isotopes.

In arid regions—where ISR is most common—the reliance on groundwater for drinking and agriculture amplifies these risks, potentially affecting entire communities.

8. Long-Term Radiochemical Risks

Even after site closure, the altered geochemical conditions can sustain contamination for decades. Acidified zones can continue to release metals and radionuclides through slow desorption and redox cycling. The persistence of acidic and sulfate-rich waters may cause ongoing degradation of water quality and increase the mobility of uranium decay products. Without continuous monitoring and long-term remediation, these risks can evolve into **permanent environmental legacies**.

9. Regulatory and Management Implications

Given the high potential for environmental damage, sulfuric acid-based ISR operations require rigorous regulatory control. Effective management should include:

- **Baseline hydrogeological characterization** before leaching begins.
- **Real-time monitoring** of groundwater chemistry and hydraulic gradients.
- **Strict containment measures** to prevent acid plume migration.
- **Post-mining restoration plans** with performance-based criteria rather than time-based ones.
- **Public transparency** regarding monitoring data and environmental incidents.

In regions with weak regulatory enforcement, such as parts of Central Asia, long-term contamination has already been documented, underscoring the need for stronger international oversight and environmental governance.

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In situ uranium mining poses several **environmental hazards**, particularly concerning groundwater and ecosystem health.

Here’s a breakdown of the main environmental risks:

1. Groundwater Contamination

- **Primary hazard:** In situ mining involves injecting a leaching solution (usually containing oxygen and bicarbonate, or sometimes acid) into underground uranium-bearing formations to dissolve uranium.
- This process can:
  - Mobilize **heavy metals** (e.g., arsenic, selenium, lead, vanadium, molybdenum).
  - Introduce **radioactive elements** (radium-226, radon, thorium) into groundwater.
  - Spread these contaminants **beyond the mining zone** if the leaching fluids migrate due to pressure differences, natural fractures, or poorly sealed wells.
- **Result:** Long-term risk to aquifers that supply drinking or irrigation water.

2. Aquifer Restoration Challenges

- After mining, companies must try to **restore groundwater** to its original quality — but this is **technically difficult and rarely fully successful**.
- Residual contamination (especially metals and radionuclides) often persists in the pore water or rock matrix.
- **Restoration methods** (e.g., flushing, reverse osmosis) can take years and still fail to meet regulatory standards.

3. Surface Spills and Leaks

- **Pipelines** and **storage tanks** used to transport leaching solutions and uranium-bearing fluids can leak.
- Accidental spills contaminate **surface soils and waterways** with radioactive and toxic substances.
- Such incidents have occurred at ISR sites in the U.S., Kazakhstan, and Australia.

4. Wastewater and Solid Waste

- Even though ISL minimizes mine tailings, it still produces:
  - **Liquid wastes** from water treatment and uranium recovery.
  - **Solid residues** containing radioactive materials.
- These must be properly managed to prevent **leaching into the environment**.

5. Ecosystem Impacts

- Surface disturbance is smaller than conventional mining, but still includes:
  - **Well pad construction**, **roads**, and **processing facilities**, which can disrupt local habitats.
  - **Dust and noise** affecting wildlife.

- In arid or ecologically sensitive regions, this can harm **flora and fauna** dependent on groundwater.

6. Long-Term Radiological Risks

- Even after site closure, **residual radioactivity** in the groundwater or rock can pose long-term environmental and health risks if migration continues.

7. Regulatory and Monitoring Issues

- Inadequate **long-term monitoring** or **regulatory enforcement** can exacerbate impacts.
- If companies abandon or inadequately restore sites, contamination can persist for decades.

In summary:

Hazard TypeMain Risks Groundwater contaminationMobilization of radionuclides and heavy metalsAquifer restoration failurePersistent contamination after closureSpills and leaksSurface and subsurface pollutionWaste generationRadioactive residues and wastewaterHabitat disturbanceLocal ecosystem damageLong-term radiological risksOngoing migration of radionuclides