Monitoring, measurement, and verification principles and objectives for CO_2 sequestration projects

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Alberta

Monitoring, Measurement and Verification Principles and Objectives for CO_2 Sequestration Projects

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MMV Principles and Objectives

What is a Monitoring, Measurement, and Verification Plan?

Monitoring and measurement are surveillance activities necessary for ensuring the safe and reliable operation of a CO_2 sequestration project. Verification refers to the comparison of measured and predicted performance, which is also known as conformance. The purpose of monitoring, measurement, and verification (MMV) is to address health, safety and environmental risks, evaluate sequestration performance and provide evidence that the site is suitable for closure. MMV is central to CO_2 sequestration risk management.

An MMV plan sets out the monitoring, measurement and verification activities that a project proponent will undertake for the term of the evaluation permit or carbon sequestration lease. MMV plans are developed by the project operator in response to the risks identified, and to enable that regulatory requirements be met and conditions specified in project approvals be satisfied.

Sufficient data must be collected regarding the behavior of the sequestered CO_2 for several purposes. Measurement and monitoring of the injection facilities, geological sequestration site and surrounding environment provide assurance that CO_2 is confined to the storage complex (containment). Verification refers to the comparison of measured and predicted performance and is used to ensure sequestration sites are operating as predicted and permitted (conformance).

Key Principles

- Regulatory compliance
- Project-specific
- Site-specific, but also addresses potential regional impacts
- Risk-based
- Fit-for-purpose
- Adaptive, with elaboration through successive project stages
- Provide timely warning of CO_2 stream containment and conformance anomalies in order to take appropriate action
- Monitorability in every domain of review (geosphere, hydrosphere, biosphere, and atmosphere)
- Transparency
- Best available technologies economically achievable (BATEA) - based on sound science and engineering

Objectives

At All Project Stages:

- Meet all regulatory requirements set out in legislation and regulation, and meet the expectations of the Regulator as described in directives, bulletins, project approvals and other sources.
- Accurately assess site-specific risks and plan to manage them
  - Must identify all potential adverse events, assess and quantify the likelihood and potential consequences of their occurrence, and inform project risk management activities.
  - Particular areas of concern for CO_2 sequestration include assessment of the potential for:
    - Existence of faults, (known/unknown) wells and other zones of weaknesses (e.g. Karstic features) that may exist within the area of interest of the storage complex. This will require an understanding of aspects of cap rock integrity tied to distribution, thickness, and lithological/mineralogical properties.
    - Generating induced seismicity.
    - Altering regional groundwater flow/pressure/chemistry regimes.
    - Impacts from CO_2 plume or pressure front on other users of local and regional scale subsurface pore space, including other carbon capture and storage (CCS) operators, oil and gas, minerals, disposal, geothermal, storage, etc.
    - Affecting non-saline groundwater.

    - Adverse impacts to public in the event of a release event. MMV information will be used to define Emergency Planning Zones and inform Emergency Response Plans, as described in Directive 071: Emergency Preparedness and Response Requirements for the Petroleum Industry.
- Address health, safety and environmental risks, evaluate sequestration performance and provide evidence for long term safety and security of storage complex
  - Potential environmental impacts from CCS operations must be identified in the MMV Plan and addressed through mitigation measures and compliance assurance activities.
  - The storage complex is the succession of geological formations that contribute to providing secure long term sequestration of CO_2. It may include one or more seals and one or more zones that have the potential to sequester CO_2.
- Protect fresh groundwater systems
  - As part of ensuring there are no adverse impacts to the environment, a shallow groundwater monitoring program (above the Base of Groundwater Protection (BGWP)) should be developed in collaboration with the regulator.
    - This program would establish baseline data for non-saline aquifers, establish that the project will not degrade existing water quality, reduce the risk to the Government of Alberta upon transfer of liability, and help to ensure public and environmental safety.
    - The plan could comprise, but not be limited to, industry monitoring wells and domestic monitoring wells where appropriate.
- Monitor and minimize impacts on adjacent saline groundwater systems and other pore space users, including other CCS, oil and gas, minerals, disposal, geothermal, storage, etc.
  - Minimize the potential for generating induced seismicity hazards
- An induced seismicity hazard assessment, monitoring, and mitigation program must be included as a key component of the MMV Plan.
- Set out the MMV activities that a project proponent/lessee will undertake while the plan is in effect
- Operate in compliance with the plan and keep it up to date
  - Per section 16(1) of the Carbon Sequestration Tenure Regulation, an MMV plan will expire on the earlier of the 3rd anniversary of its approval date or the date that the lease is renewed. A lessee must submit a new MMV plan for approval no fewer than 90 days before its expiry date.
  - Per section 17(1) of the Carbon Sequestration Tenure Regulation, a lessee must not conduct any operations or activities under a carbon sequestration lease unless an MMV has been approved and is in effect for the lease, and the lessee complies with the approved plan.
- Collect sufficient data needed to:
  - Provide evidence of conformance of CO_2 stream and affected fluids within the storage complex.
  - Provide assurance of geological containment of CO_2 stream and affected fluids within the storage complex.
  - Provide evidence of no significant adverse effects to other pore space users within hydraulically connected saline formations.
  - Provide evidence that there are no significant adverse effects of CO_2 injection on health, the environment or other resources.
  - Provide evidence of the amount of CO_2 sequestered and to support permanent reduction of greenhouse gases as described in the Quantification Protocol for the Capture of CO_2 and Storage in Deep Saline Aquifers.
  - Verify and update models and simulations annually, and use the results to continually inform capacity estimates and conformance verification.
- Monitor threats to containment identified in the project risk assessment and where loss of containment is confirmed, trigger appropriate mitigation and/or remediation activities.

Pre-injection (for Evaluation Permit):

- Analyze the likelihood that operations/activities under the permit will interfere with other mineral recovery operations
  - This is a required element of an MMV plan for an Evaluation Permit, as set out in section 7 of the Carbon Sequestration Tenure Regulation.
- Establish anticipated CO_2 storage resource estimates based on the best available public data prior to conducting the evaluation.
- Establish whether the storage complex is a hydrodynamically open or closed system. If an open system, hydrodynamics and spill points must be addressed to support containment assurance.
- Set out the site characterization activities that will be conducted and how these results will inform project risk assessment.

- Information may include:
  - An overview of how information will be gathered and timeline.
  - Plans to assess monitorability.
  - A discussion of the initial risk assessment, as well as plans to undertake a more detailed risk assessment in support of carbon sequestration lease application.
  - A legacy well risk assessment that takes into account the selected locations for injection wells and the possible need to upgrade some legacy wells to modern abandonment standards for CO_2 containment.

Pre-injection (for Sequestration Lease):

- Analyze the likelihood that operations/activities under the lease will interfere with other mineral recovery operations, based on the geological interpretations and calculations the lessee is required to submit to the Regulator pursuant to Directive 065 (Resources Applications for Oil and Gas Reservoirs) in its application for approval of the injection scheme under the Oil and Gas Conservation Act.
  - This is a required element of an MMV plan for a Sequestration Lease, as set out in section 15 of the Carbon Sequestration Tenure Regulation.
- Incorporate additional monitoring and baseline data requirements identified by the regulator during permitting and approval into the MMV plan.
- Identify monitoring tasks.
- Screen, evaluate and select monitoring technologies.
- Provide the rationale for selection of monitoring technologies.
  - Selected technologies must be able to detect early warning signs of any unexpected loss of containment. This will be updated if the results of the baseline assessment indicated a need for more-specific monitoring technologies.
- Propose a monitoring schedule.
- Provide a detailed legacy well assessment that takes into account the selected locations for injection wells.
- Establish appropriate baselines for the selected monitoring technologies
  - Baselines are needed so that anomalous readings for the selected parameter(s) (e.g. pH, CO_2 concentrations) can be identified and response methodologies employed and/or technologies used to provide evidence that the anomalies are not the result of a release from the storage complex.
  - Data must be collected for an appropriate period of time to establish a statistical basis for variations in data.
  - Some of the baseline data may be compiled during site selection through a review of existing data from oil and gas exploration and production activities, or may be newly gathered data.
- Develop models and execute simulations to evaluate and predict the behavior of the storage complex, and inform the project risk assessment using:
  - Reservoir simulation for historical and predictive flow modelling, including of the plume.
  - Geological and geomechanical modelling to assess injectivity and containment (including caprock integrity, stress regime, fault and fracture characteristics, and activation of pre-existing faults and fractures).
- Ensure that the monitoring technologies looking at key project risks have the necessary resolution to establish thresholds for action (“trigger events”).

During Operation/Injection:

- Conduct monitoring to:
  - Demonstrate compliance with legislation (regulations, standards, directives), applications and approvals.
  - Monitor for trigger events and, if detected, employ associated operating procedures in response.
- Compile monitoring results to:
  - Meet the requirement under the section 17(2) of the Carbon Sequestration Tenure Regulation to present an annual report to the Minister of Energy on the findings and observations from MMV activities conducted for carbon sequestration lease holders.
  - Inform and update the project risk assessment.
  - Inform and optimize project operations.
  - Trigger investigation of non-conformance and mitigation and/or remediation activities as required.
  - Support the receipt of offset credits.
  - Update simulations and models so actual and predicted behavior can be compared and the MMV plan can be updated as necessary.
  - Validate model predictive capability throughout the injection period.

- Monitoring technologies are evaluated on a regular basis to:
  - Ensure effectiveness of each technology for the designated task as compared to expectations in the MMV plan.
  - Ensure overlapping technologies are complementary and providing the spectrum of results needed to evaluate sequestration performance.
  - Evaluate technologies in use against advancements so new monitoring techniques are deployed when warranted.
- The MMV plan is periodically renewed and ongoing dialogue is held with the regulator to ensure:
  - Time-sensitive data are collected when available and to the extent required.
  - Simulations and models incorporate actual results to allow comparison of actual and predicted behavior, and evolve as required to illustrate sequestration performance at closure.

During Closure Period:

- Continue to monitor all wells and facilities and perform all closure activities in accordance with the regulations.
  - Selected monitoring activities continue to demonstrate sequestration performance and compliance with legislation (regulations, standards, directives), applications and approvals.
  - This includes demonstrating compliance with section 119 of the Mines and Minerals Act, abandonment of all wells and facilities in accordance with the requirements under the Oil and Gas Conservation Act and under Part 9 of the Mines and Minerals Act, compliance with the reclamation requirements under the Environmental Protection and Enhancement Act, showing that the closure period specified in the regulations has passed, and that the conditions specified in the regulations have been met.
  - Provide evidence to support the issuance of a closure certificate (i.e. meet the requirements of section 120(3) of the Mines and Minerals Act, including providing evidence that the captured carbon dioxide is behaving in a stable and predictable manner, with no significant risk of future leakage out of the storage complex).
- Provided information to the regulator when requested regarding appropriate MMV techniques that could be used in the post-closure period.
- Arrangements are made between the regulator and project operator for the transfer of any MMV monitoring equipment that the regulator requests to be left in place at the point of closure that will not compromise long-term integrity of well abandonments.

Additional Monitoring, Measurement, and Verification Resources

For more information on MMV plans, please see these documents:

Alberta Department of Energy, 2013, Carbon Capture & Storage: Summary Report of the Regulatory Framework Assessment. https://open.alberta.ca/dataset/9781460105641/resource/ecab392b-4757-4351-a157-9d5aebededcd0

U.S. Department of Energy, 2017, Best practices—monitoring, verification, and accounting (MVA) for geologic storage projects: 2017 Revised Edition, DOE/NETL-2017/1847. https://www.netl.doe.gov/sites/default/files/2018-10/BPM-MVA-2012.pdf

Plains CO_2 Reduction (PCOR) Partnership, 2018, Best Practices Manual – Monitoring for CO_2 Storage. https://undeerc.org/pcor/assets/PDFs/PCOR-BPM-Monitoring-for-CO2-Storage.pdf

Canadian Standards Association, 2012, CSA Group Z741-12 Geologic storage of carbon dioxide: Mississauga, Ontario, October.

International Organization for Standardization, 2017, ISO 27914 Carbon dioxide capture, transportation and geological storage — Geological storage.