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# ASSET INTEGRITY MANAGEMENT FOR UNDERGROUND NATURAL GAS STORAGE FACILITIES

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## Background

Several drivers have triggered renewed interest in the Oil and Gas (O&G) Industry for Asset Integrity Management (AIM). These include in particular:

- Implementation of strengthened risk management and control policies, aimed at avoiding occurrence of catastrophic events.
- Continuous evolution of the regulatory framework towards increased safety and decreased environmental footprint.
- Growing awareness of communication and Company image issues.
- Increased pressure on CAPEX and OPEX.

Revisited best practices, translated into new norms and standards have been issued as part of the response to the above concerns.

The UGS industry, which largely follows trends in the O&G, from which it borrows most of its subsurface techniques, has specificities of its own:

- UGS facilities are an essential link of the supply chain and must achieve accident free operation and utmost availability, reliability, operability, flexibility and sustainability. On the other hand, a majority of these facilities were constructed more than 30 years ago and the pool is ageing. UGS asset lifetime is expected to extend beyond 50 years and the first of the worldwide close to 700 natural gas UGS facilities (a converted depleted field in Ontario, Canada) celebrates this year its 100th anniversary.
- The UGS industry is a mature, midstream and infrastructure related "niche-activity", with limited financial resource as compared to the O&G upstream. It is currently fighting to keep costs down in a sluggish, very competitive price and performance driven market while being committed to meet high safety standards and is thus looking for cost and purpose efficient solutions.
- UGS facilities are designed and built for secure, long term operation involving cyclic injection and withdrawal phases and -at least- seasonal turnover of the working gas inventory, resulting in the production wells and the storage space being submitted to demanding alternate pressure and temperature load changes and particularly high flowrates.
- Most UGS facilities are located onshore, and are under close scrutiny of regulatory bodies and neighboring communities, entailing requirement for detailed monitoring, reporting and transparent communication with all the stakeholders.

## Aims

There is thus a need in the UGS industry for Asset Integrity Management Systems (AIMS) tailored to its objectives and constraints and combining E&P best practices with UGS specific approaches and experience feedback.

## Methods

The AIM methodology proposed addresses technical lifecycle analysis, operational, environmental and organizational issues and consists of an integrated, adaptative workflow encompassing:

- The comprehensive collection and subsequent organization in adapted data bases of construction data (end-of-wells reports and well barrier schematics, caverns, reservoir) and of the subsurface operating rules
- The organization of the collection of:
    - The operating and monitoring data specified in the facility monitoring plan.
    - The maintenance records specified in the facility maintenance plan; and
    - The occasional specific controls implemented, such as e.g.:
        - for the wells: corrosion logs, performance tests, annulus tests in case of sustained annulus pressure;
        - for salt caverns: periodical bottom tags, sonars under gas and caverns re-certification (including in case of maximum operating pressure increase(1)), microseismic and subsidence monitoring.
        - for reservoirs: flowmeter, bottomhole pressure and temperature measurements or fluids sampling runs

(1) A new method consisting of Helium re-testing of salt caverns under gas is currently under development

- The evaluation, interpretation and diagnostic of the data collected, using ad hoc studies and modeling, aimed at assessing the current status of the asset, at updating its performance envelope, at evaluating its remaining lifetime (impact of corrosion for the wells, sandface completion damage, caverns closure, etc…), at designing optimized repair options as needed and at identifying potential for performance improvement. This includes in particular:

  - For the wells: the identification of critical safety elements (critical well barrier components), and of corrosion and failure mechanisms; then, based on the above, the definition of alarms and of trigger levels. Studies based on Finite Elements Modelling may be called on as required to evaluate the criticity of local well defects detected by corrosion logs. If deemed necessary, repair options –or well abandonment- are investigated.
  - For salt caverns: inventory checks and prediction of the evolution of caverns parameters to support optimized operation strategy based on thermodynamic simulation; assessment of the caverns stability, closure and tightness and re-assessment of the maximum allowable rate of pressure change - an important performance driver- using coupled thermo-geomechanical models.
  - For reservoirs: the assessment of the evolution of the completion and of the near well performance, based on well tests interpretation and modeling.

- A multi-criteria risk and value based evaluation of each well's criticity allowing prioritization of maintenance, inspections and repairs, and offering opportunity for savings (e.g.pooling of well repairs) and minimized downtime through coordinated interventions enabled by communication and coordination between all stakeholders (clients, dispatcher, grid operator, etc…).

- The organization of an up-to-date reference documentation including:

  - Active watch for norms, standards, best practices and company policies
  - Asset Integrity Management Plan (wells, cavern or reservoir)
  - Monitoring & maintenance plans
  - Responsibility assignment matrix (e.g. RACI matrix: Responsible; Accountable; Consulted; Informed)
  - Risk registers & contingency plans, procedures for management of abnormal events
  - Key Performance Indicators
  - Audits and continuous improvement
  - Lessons learnt

The tools supporting the workflow include data bases, spreadsheet and an adaptative, pragmatic toolbox including proprietary and/or commercial softwares.

Typical workflows proposed for respectively Wells (WIMS) and Salt Caverns (CIMS) Integrity Management are displayed here-below.

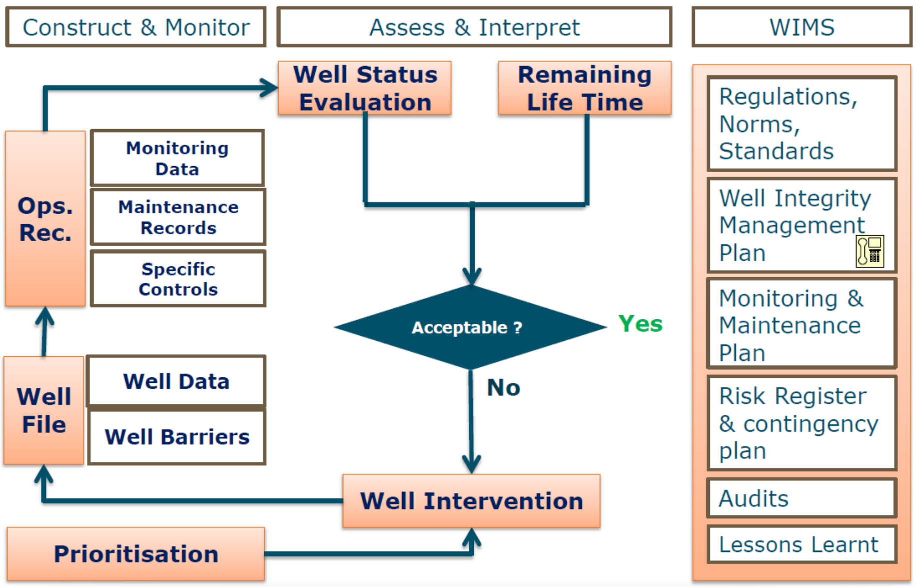


**Figure 1. Workflow for Well Integrity Management**

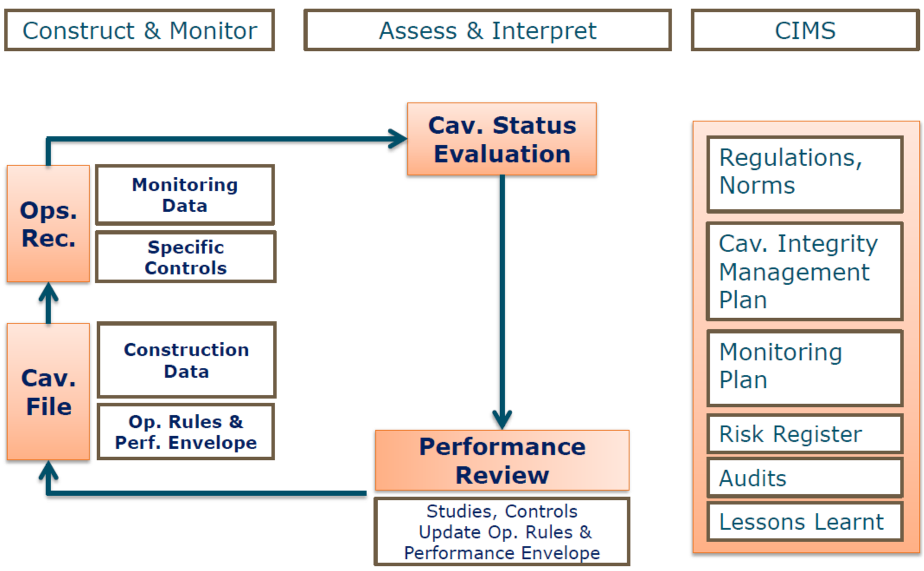


**Figure 2. Workflow for Natural Gas Salt Caverns Integrity Management**

## Results

An AIMS can be developped both for new and for existing UGS facilities, either as a one shot drive or progressively. Main benefits derive principally from application of a structured methodology and from development of the resulting comprehensive, reliable, easilly accessible and shared facility documentation, covering all aspects of the subsurface, both "as built" and updated. They include:

- Enhanced overall safety through:
  - Early detection of abnormal events
  - Reliable characterization of the current status of the asset
  - Early identification of risk of failure (well failure matrix) and evaluation of consequences, thus facilitating contingency planning and emergency response
  - Prediction of the evolution of the operating envelope
  - Enhanced risk management, and in case of crisis, efficient, shared, unified communication support for all stakeholders.
- Optimized performance of the asset throughout its lifetime…and optimized lifetime.
- Improved availability and reliability as a result of shift from reactive to look-ahead risk and value based, planned preventive maintenance focussing on prioritization of controls and repairs and on optimization of repair operations. This approach combined with communication and coordination with all stakeholders at all stages of the process, contributes substantial savings and reduced downtime
- Enhancement of the site operation through a continuous learning and improvement process, including in particular:
  - Compliance with best practices and regulatory framework
  - Strengthened site organization through formal assignation of Roles & Responsibilities
  - Efficient collection and dissemination of lessons learnt

## Conclusions

To put it in a nutshell, introduction of a robust AIMS allows to kill two birds with one stone: achieving increased safety and risk control through a sound methodology and increased value through optimized performance and lifetime of the asset.