HUB TECH IA

Deliverable report 51

AI and IAGEN Application Use Case

Environmental Risk Assessment in Water Management in Vaca Dead, Neuquén

I. Introduction

The Vaca Muerta formation represents one of the largest reserves of non-metallic hydrocarbons. most significant conventional ones worldwide, positioning Argentina as a key player in the global energy landscape. Its development is considered a national strategic priority, with projections pointing to self-sufficiency energy and significant export revenues, which could transform the country's economy.

However, this expansion of hydrocarbon activity poses challenges. complex environmental issues, particularly in water resources management, which require extensive attention to ensure long-term sustainability. This report delves into the environmental problems associated with water management. Water in Vaca Muerta, analyzes the limitations of conventional monitoring practices and explores the transformative potential of artificial intelligence (AI) to improve environmental monitoring and protection in this region crucial.

In this context, AI applied to the analysis of geospatial, hydrological and operational data offers an unprecedented opportunity to strengthen the assessment of environmental risks and optimize real-time decision-making.

The specific use case of AI in the evaluation of
risks and regulatory compliance of water management in Vaca Muerta,
describing the identified challenges, AI-based solutions, benefits
obtainable and recommendations for their effective implementation.

II. Opportunities to improve environmental water management through AI

Artificial intelligence offers a significant opportunity to transform the
environmental management of water in Vaca Muerte, allowing a shift from an approach
reactive to proactive and preventative. By analyzing large volumes of data in real time,
AI can generate early warnings and actionable insights,
facilitating the detection and correction of deviations before they escalate to
major problems.

1. Intelligent Geospatial Analysis: Using GeoAI (AI-powered GIS) techniques, models
are trained to identify patterns and changes in images.
satellites that could indicate environmental activities or impacts.

This system can be useful for mapping the annual expansion of wells and
estimate their water consumption, even though industrial data was scarce.

2. Sensor monitoring and IoT with anomaly detection: in Vaca fields
Dead already operating multiple sensors: flow and pressure meters in heads
well, pressure sensors in pipelines, pH meters and conductivity meters in plants
water treatment, weather stations, etc.

AI leverages these real-time data streams by applying *machine learning* techniques to
detect anomalies or subtle deviations that might otherwise go unnoticed. For example,
an anomaly detection model (such as isolation forests or *autoencoders* trained on
normal patterns) can identify atypical increases in the electrical conductivity of
groundwater.
monitored near a well, which would suggest incipient contamination.

Similarly, a trained LSTM (long short-term memory) neural network
with historical series of injection pressure in sink wells could predict

anomalous variations that indicate a possible failure in the integrity of the well (pipe cracks, for example). When an alert is triggered, the system notifies immediately to those responsible so that they can investigate and take preventive measures before a major incident (such as a leak into the aquifer).

3. Predictive models and trend detection: beyond warning about real-time anomalies, AI can uncover long-term trends that help in planning and prevention. Supervised learning algorithms can Analyze historical data on operations and environmental outcomes to predict areas or times of greatest risk.

A model might indicate that certain patterns (such as high fracture density in an area with geological faults near the river) correlate with a higher probability of micro-seisms or leaks, allowing the company to strengthen
monitoring there. Likewise, AI can optimize water management itself: through optimization and reinforcement learning techniques, it can
recommend frac water reuse strategies or optimal sink injection times to minimize impacts (e.g., avoid injecting during river floods to avoid adding stress to the basin). These models incorporate multiple variables (climate, operation, geological characteristics) to
advise on operational decisions that keep production within parameters safe and sustainable.

4. Integrated platforms and smart dashboards: the practical application of the above is usually embodied in digital platforms that integrate all the flows of data and AI algorithms, presenting clear information to users.

In this way, environmental engineers and managers can visualize on a dashboard unified the environmental status of the entire site: levels of each pool of waste, downstream surface water quality, treatment plant performance, etc., with AI-calculated indicators that simplify complexity.
For example, a *dashboard* could display a “water compliance index” for each operational area, calculated based on metrics such as percentage of water reused, quality deviation vs. standard, alerts attended to, etc.

Technically, applied AI includes a range of methods: algorithms of
Anomaly detection (statistical and *machine learning),* Convolutional Neural Networks (CNN) for satellite image analysis, Time series models for forecasting (e.g. Facebook's *Prophet* or LSTM), and
Supervised machine learning for event classification (normal vs. incident). These tools run on data infrastructures that can be *cloud* or hybrid, since they handle satellite or

Real-time IoT streams demand scalability.

Additionally, data physics models (digital twins) can be incorporated that simulate water flow and the dispersion of subsurface contaminants, calibrated with AI based on real data, to predict how a pollutant could spread if a leak occurs in a certain geological stratum.

In short, AI acts as a "digital environmental guardian" in Vaca Muerta: constantly absorbs scattered and complex data, and applies intelligence to reveal what the human eye or traditional methods do not detect in time. This allows those responsible to react quickly to any signs of alarm and adjust the operation to avoid damage. Let's now look at the benefits specific benefits that this AI application provides, both operational and strategic.

III. Comparison with traditional methods and key improvements of AI

The adoption of AI in environmental management marks a paradigm shift with respect to to traditional methods. Below, both approaches are compared in Critical points, highlighting the improvements that AI brings:

- Monitoring coverage: Traditionally, surveillance relied on scheduled inspections and spot sampling (e.g., personnel walking around locations with checklists, or taking water samples monthly).
  Large areas were left without direct observation for days or weeks. With AI, monitoring is continuous and omnipresent.
- Speed of detection and reaction: previously it could happen that a problem was detect only in the next round of inspection or when someone notices a

visible change (dead fish, oil slick, etc.). That delay allowed a small incident to turn into a disaster. Now, AI accelerates
drastically improves detection. For example, an anomalous change in a sensor triggers an immediate alarm to the control center. Instead of days, the response starts in minutes.

- Accuracy and volume of data analyzed: manual methods are prone to human error and limited in the amount of data they can process. An analyst may miss subtle correlations or trends when reviewing spreadsheets or charts. AI, on the other hand, handles large volumes of data heterogeneous data with high precision, finding needles in haystacks information. For example, you can correlate years of weather data, operational and water quality to discover a pattern that indicates risk growing in a certain area, something practically impossible to achieve without automation.

  Integration of multiple variables: traditionally, each department managed his part: production focused on extracted volumes, environment in water quality, maintenance of equipment pressure, etc., with systems poorly communicated. This makes it difficult to see *the whole picture.* AI facilitates a integrated vision, combining variables from different disciplines in its models. For example, a model may simultaneously consider the rate of a well's fracture, the proximity of that well to an aquifer, and the tendency for microseisms in the area to determine the alert level. This integration Multidimensionality is a key improvement, as environmental impacts are often the result of a convergence of factors (not a single one in isolation).

- Adaptability and continuous improvement: Traditional methods are often based on fixed procedures (static checklists, preset thresholds in alarms). AI, especially with machine learning, adapts with the changing needs of the user. time. As it collects more data, the system “learns” and refines its models, becoming more accurate and reducing false alarms. For example, if an algorithm initially generates some false pollution alerts (which then it is found that they were not), it will adjust its parameters to fine-tune itself. In other words, AI brings about almost autonomous continuous improvement.

- Human resources and monitoring costs: With AI, many routine tasks are automated, freeing up professionals for higher-value activities. (interpret results, design solutions). It is not about replacing the human, but to enhance it: an analyst can now monitor 100 wells at a time simultaneously from a dashboard, a task unthinkable without AI. This reduces costs operational, since the company can operate with smaller teams but more specialized, supported by intelligent tools.

In short, AI outperforms traditional methods in range, speed, accuracy, overall intelligibility and efficiency. It should be noted that classic approaches (field inspections, audits) still have their place, especially for validations and to complement AI findings. In fact, a synergy Optimal AI occurs when AI is used to focus human efforts where really matter. For example, instead of sampling 50 water sites randomly, technicians can—guided by AI—sample the 5 sites that the model identifies as most likely to cause problems. In this way, they are combined the best of both worlds: the tireless analytical capability of AI and the judgment and human experience in final decision-making. This complementarity boosts environmental care standards to levels previously unattainable.

IV. AI Agents and Agentic Workflows. The Evolution of Generative AI.

1. Concept of IAGEN agents

In recent years, generative artificial intelligence (GAI) has revolutionized the way we interact with technology, enabling the development of systems capable of generating content, answering complex questions, and assisting with high-demand cognitive tasks.

Generative Artificial Intelligence (GENI) is a branch of artificial intelligence which focuses on creating new content, such as models, images, code or text, from existing data. This technology uses advanced algorithms to

Analyze large amounts of information, identify patterns, and generate content new and original that is often indistinguishable from that created by humans.

From this capability, a new technological architecture emerges: IAGen-powered agents. These agents are not simple conversational interfaces, but autonomous systems that can interpret instructions, make decisions, perform tasks and learn from their interactions with the environment.

An IAGen agent combines large language models with components additional features such as external tools, memory, planning and execution autonomous. This allows them to operate in complex environments, with the ability to break down objectives into steps, coordinate multiple actions, interact with digital systems (such as databases, APIs, or documents), and adapt to changes in context in real time. These qualities distinguish them from traditional chatbots, and open up a spectrum of more sophisticated and customizable.

At the organizational level, these agents are being used to automate processes, generate data analysis, assist in decision making and improve the user experience, both internally and externally. For example, they can take on human resources, legal, financial or logistical tasks, and even, linked to the technical areas of production processes, acting as assistants intelligent devices that collaborate with human teams. This ability to integrate knowledge and execute tasks autonomously transforms the way organizations can scale their operations without losing quality or control.

In addition, agentic workflows—structures where multiple agents collaborate with each other to solve complex problems—allow responsibilities to be distributed between different agent profiles, each with specific functions. This generates Hybrid work environments where humans and agents coexist, optimizing time, costs, and results. The ability to connect agents with tools such as Google Drive, CRMs or document management platforms further expands their capabilities.

The development of IAGen-powered agents represents a crucial step towards a new era of intelligent automation.

Among the benefits of authentic workflows powered by generative AI models is the ability to automate processes
complete, end-to-end production systems, and even add value from the leveraging the skills of language models based on these
technologies.

However, its implementation also poses technical, ethical and
legal, from responsible design to human oversight. Therefore,
Understanding its architecture, its operational logic and its potential impacts is essential for its effective and safe adoption in various contexts
professionals.

2. IAGEN-driven Agents a.
Workflow design proposal

IAGEN Agent: Environmental Guardian for Water Management in Vaca Muerta

Main features of the agent:

Multi-Source Continuous Monitoring

- Real-time integration of:
    - IoT sensors (pressure, flow, pH, conductivity)
    - Satellite images (Sentinel, Landsat)
    - Climate and operational data
- Application of LSTM networks and anomaly detection models.

Predictive Risk Analysis

- Prediction of water risk events (leaks, micro-earthquakes, pollution) using models trained with historical data and geological.

- Preventive evaluation of sensitive areas before expanding operations.

Simulations with Generative Models

- Generation of scenarios and simulations (digital twins) of propagation of pollutants in the event of incidents.

- Simulation of response plans and their environmental/operational impact.

Automatic Report Generation

- Creation of regulatory, internal and public reports using NLP (such as ChatGPT) with data traceability.

- Production of indexes such as:

    - Water compliance index

    - Environmental risk score by location

    - Recycling level and water efficiency

Integrated Smart Dashboard

- Clear visualization for management, environmental engineers and auditors.

- Early warnings, automatic recommendations, and comparative analysis between operational areas.

Transparency and Community Communication Module

- Publication of selected data in a user-friendly format stakeholders and communities (e.g. open environmental observatory).

- Automatic translation into citizen language.

b. Implementation phases

Phase 1 - Pilot:

- Selection of a high activity block.

- Installation of additional sensors.

- Initial training of the model with historical data.

Phase 2 - Modular Scaling:

- Expansion to more blocks.

- Integration of dashboards and reporting modules.

Phase 3 - Transparency & Regulation:

- Integration with regulatory entities.

- Publication of selected indicators.

- Legal validation of data generated by AI.

V. Direct benefits in operational and strategic terms

Implementing AI in water environmental risk assessment offers benefits immediate and tangible benefits for companies' operations and strategy energetic:

- Early detection of incidents: an intelligent system can identify anomalous changes (in water quality, pressures, etc.) in minutes, allowing a leak or spill to be contained before it spreads. This This contrasts with traditional detection, which could take days to complete. next inspection. Timely response minimizes environmental impact and avoids prolonged production interruptions.

- Automated regulatory compliance: AI acts as a watchdog continuous compliance with limits and conditions of permits environmental. For example, it verifies 24/7 that discharges or injections remain within legal parameters (volumes, concentrations). Any potential non-compliance generates proactive internal alerts to course correction or notify authorities if necessary. This reduces the risk of sanctions and improves relations with regulators, demonstrating a responsible approach.

- Operational optimization and cost savings: By analyzing patterns, AI can optimize water use – for example, by recommending increasing the rate of Flowback water recycling when it detects availability, or adjusting water truck logistics to minimize trips. It also helps focus monitoring resources where they are most needed (rather than uniform sampling everywhere). This translates into operational efficiencies: less water waste, lower treatment and transportation costs, and more effective use of technical staff (who dedicate less time to time to manual data review tasks).

- Improved strategic decision-making: Having intelligently processed data allows managers to make informed decisions. evidence-based. For example, if the AI system shows that a certain area has increasing water risk indicators, the company can prioritize investments in environmental infrastructure there (such as reinforcing pool liners or improving treatment plants) before scaling up production. At a broader level, the trends identified (such as water consumption per well, reuse efficiency, etc.) feed into sustainable field planning and even communication strategies with stakeholders, by being able to show improved environmental performance metrics thanks to AI.

- Transparency and trust: an AI-supported monitoring system can generate clear automatic reports, with traceable and objective data, on the environmental performance. Share some of this information with authorities and even with the community (e.g. through open environmental observatories) improves transparency. Stakeholders see that everything is monitored in real time and that the company adopts technology tip to ensure environmental safety, which increases confidence public and reduces social tensions related to water.

VI. Challenges in AI implementation and strategies to overcome them

While the advantages are clear, the incorporation of AI into environmental management Vaca Muerta faces a series of challenges that must be addressed with strategies suitable:

- Data quality and availability: AI is only as good as the data it collects. analyzes. An initial obstacle is the availability of reliable data and sufficient. In Vaca Muerta, much operational and environmental information is confidential or not centralized.

Strategy: Establish data-sharing agreements between companies and regulators, under protocols that guarantee confidentiality where appropriate, but allow the algorithms to be fed with essential data. Leverage public and third-party *datasets :* satellite images (Sentinel, Landsat) freely accessible, climate data from the Meteorological Service, provincial water reports, etc.

In parallel, invest in the IoT instrumentation needed to fill gaps (installing additional sensors at critical points, groundwater monitoring stations, etc.). An initial stage of the project should focus on
Create an integrated and clean data repository, applying validation and debugging techniques (elimination of spurious outliers, sensor calibration).

- Technical skills and organizational culture: implementing AI requires staff with knowledge in data science, geospatial analysis and handling of digital tools. There may be resistance from certain traditional technicians who rely more on “the way it’s always been done.”

  Strategy: Promote a training and cultural change program.
  Start with demo workshops showing success stories (e.g., how AI detected an anomaly that would have escaped).

  Form multidisciplinary teams that combine environmental experts with data scientists, so that they can develop solutions together (this facilitates acceptance, seeing AI as an ally and not as an imposed black box).

  Additionally, sponsorship from senior management communicating the vision of “Sustainable digital transformation” will help overcome resistance and motivate adoption. Celebrating small, early wins (e.g., “The AI system helped us avoid a spill last week”) reinforces confidence.
  of the team in the tool.

- Cost and technological infrastructure: the implementation of sensors, networks of communication, analysis platforms and specialized personnel represents a significant initial investment. Some smaller operators could see it as a cost that is difficult to assume.

  Strategy: Emphasize return on investment (ROI): Economically model how much it would cost to *not* have the system (large spill cleanup costs, fines, production losses) versus the investment in preventing it.
  Most likely, preventing just *one* serious event with AI already pays off for the system. complete. In addition, investments can be staggered: start with a
  A limited pilot project (e.g., in a highly active Vaca Muerta block) to demonstrate the value, then gradually scale up. Relying on *cloud* infrastructure can reduce initial costs, avoiding the purchase of
  expensive servers – instead, use cloud services and pay only for them the necessary use.

- Technical challenges (integration and maintenance): Integrating such diverse data (satellites, field sensors, databases from different companies) is not trivial. Issues may arise with format compatibility, connectivity, and other factors.
  in remote areas without signal, or need to calibrate models to conditions unique locations in Vaca Muerta.

  Strategy: Adopt open standards and modular architecture. For example, use formats like JSON/CSV for IoT data, OGC standards for geodata, well-documented APIs for different systems to connect.

- Plan a pilot test period where the models are adjusted locally and the system is fine-tuned before full implementation.
  It is also key to plan for ongoing maintenance: updating AI models based on new conditions (e.g., new chemicals introduced into fracturing fluids will need to be incorporated into the detection patterns) and supporting technician to the teams.

- Regulatory and legal aspects: currently, environmental regulations Neuquina establishes what monitoring to do and how often, but perhaps does not yet explicitly consider the use of AI. There could be uncertainty on whether automatically generated data is accepted in audits or trials.

  Strategy: work collaboratively with regulatory authorities from The beginning. Include the provincial environmental agency in the design of the AI system, so that its needs (reports, formats) are covered. Promote regulatory updates that incorporate the possibility of AI-assisted continuous monitoring as a valid complement. For example, that an annual water quality report may include sensor data in continuously analyzed by AI, and that this is recognized as compliance equivalent to or greater than X manual samplings. In terms of liability legal, ensure traceability of data and decisions: every important alert should keep a record of what triggered it, so that it can be explained if necessary (this helps with explainability, making AI more transparent and defensible).

- Cybersecurity and confidentiality: by digitizing the environmental operation, opens the risk of cyberattacks or unauthorized access to data sensitive. Sabotage of the AI system could, in the worst case, disable critical alerts.

  Strategy: implement robust cybersecurity measures from the design stage, such as encryption of data in transit and at rest, strong authentication for access to platforms, segmentation of industrial networks, etc. Perform Regular security audits and contingency plans (e.g., if the AI system goes down, have local backup alarms at critical sites).

  Regarding confidentiality, clearly define what data is for internal use vs. what data is shared externally (e.g., with the community). Public data can be anonymized or aggregated to avoid exposing Competitive information. In short, protecting the system against risks computer scientists will ensure that trust in AI is maintained and that its operation is uninterrupted.

Recommendation: Short-term investment in implementation teams AI agents in technology and training

Investment in proof of concept and pilot testing is required. The focus here is on be the training of talent to implement, since a trend is verified cost reduction in systems that allow “no code” and “low code”. For the first stage, it is also recommended to use teams with experience in designing and implementing AI agents. Finally, it is key Form an in-house team to support and appropriate a culture agentic that redefines human-machine interaction.

In conclusion, the effective integration of AI into Vaca Muerta's water management It requires a strategic vision and execution in stages, taking care of both the aspects technical, human and organizational. It is not just about buying a software, but to transform the way of operating towards a data-driven culture and prevention. The above recommendations offer a roadmap for travel that path, minimizing risks and maximizing the probability of success.

VII. Conclusion

The application of artificial intelligence in environmental water management in Vaca Muerta represents a strategic opportunity to advance towards an industry more sustainable, efficient and transparent energy. Through the combined use of IoT sensors, geospatial analysis, predictive models, and intelligent agents generative, it is possible to transform environmental monitoring from a reactive approach to a preventive and proactive one.

This transformation not only allows risks to be detected earlier and more accurately, but also optimizes resources, complies with regulations in a automated and strengthen trust with regulators and communities. AI does not

not only replaces human oversight, but enhances it, allowing for more informed and faster responses to potential incidents.

However, to achieve successful implementation, it is necessary to address technical, cultural, regulatory and infrastructure challenges with planning by stages, initial investment in training and adoption of a culture oriented towards Data intelligence. The evolution toward smart water management in Vaca Death is not only possible, but urgent, and requires leadership, collaboration multisectoral and commitment to responsible innovation.

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