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Optimizing Aquifer Thermal Energy Storage in the Mannville Aquifer through Well Spacing Strategies

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Summary

Heating and cooling of residential buildings account for a major share of global energy demand and are traditionally supplied by non-renewable sources such as natural gas, resulting in significant greenhouse gas emissions. Thermal energy storage (TES) offers a sustainable alternative by storing excess renewable or waste heat during periods of high availability and delivering it during peak demand. Among TES technologies, aquifer thermal energy storage (ATES) and borehole thermal energy storage (BTES) are widely used, with ATES often providing superior performance due to the higher volumetric heat capacity of groundwater and its suitability for large-scale applications.

ATES systems are generally classified as low-temperature (≤ 25 °C) or high-temperature (≥ 50 °C). While LT-ATES has been successfully deployed for decades, advances in system design and operational strategies have recently improved the feasibility of HT-ATES by reducing risks such as clogging, mineral precipitation, and corrosion.

Building on previous work involving solar-assisted heat injection into shallow aquifers, this study evaluates the Mannville Aquifer in the Western Canadian Sedimentary Basin as a candidate for large-scale ATES. The work examines how well-configuration strategies, including doublet spacing and a single-well alternating injection-production mode, affect thermal plume migration, breakthrough timing, and long-term heat-recovery performance.

Methodology and Modeling Workflow

This study assesses the feasibility and performance of solar-assisted aquifer thermal energy storage within the Mannville Aquifer of the Western Canadian Sedimentary Basin. Geological and hydrogeological properties for the model domain were derived from regional stratigraphic data, core analyses, and groundwater-flow information for the Regina area. The aquifer was represented as a laterally extensive sandstone unit at approximately 850 m depth, with boundary conditions reflecting the observed southwest-to-northeast regional flow regime.

A numerical reservoir model was developed to simulate heat injection, storage, and recovery under seasonal operating conditions. The heating-demand profile for the simulation was based on the load characteristics of the Kisik Towers at the University of Regina, providing a realistic annual injection-production schedule. Thermal and hydraulic parameters, including porosity, permeability, thermal conductivity, and specific heat capacity, were assigned using available regional datasets and literature values for Mannville Group sandstones.

Two categories of well-configuration scenarios were evaluated. The first involved doublet systems with varying injection-production spacing to quantify the influence of well separation on thermal plume migration, and recovery efficiency. The second examined a single-well configuration that alternates between injection and production on a seasonal basis, allowing assessment of its operational viability and sensitivity to cycling frequency. Model outputs included temperature distribution, plume evolution, cumulative recovered heat, and long-term system performance over multi-year operation.

Results and Conclusions

Simulation results show that well configuration has a significant influence on thermal plume behavior and long-term heat-recovery performance in the Mannville Aquifer. In previous modeling, a doublet system with 400 m spacing resulted in thermal plume migration towards the production well after approximately 14 years, although a substantial portion of the stored heat remained untapped. The expanded analysis confirms that well spacing strongly governs both thermal plume evolution and recovery efficiency. Larger separations delay plume arrival but reducing the fraction of recoverable energy.

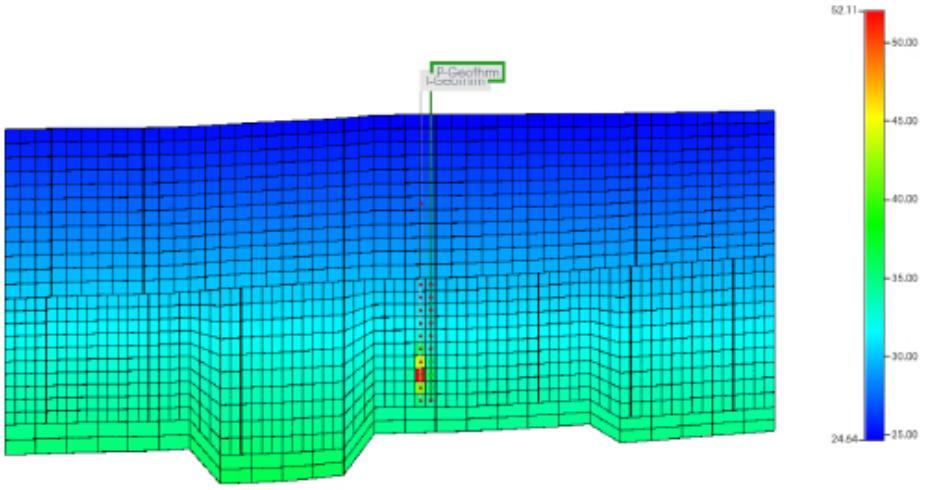


Figure 1. Thermal plume evolution relative to well placement after 14 years of solar-energy injection

The single-well alternating injection-production configuration demonstrates potential as a simplified ATES design, particularly for sites where surface infrastructure constraints limit well count. However, the performance of a single-well storage requires further investigation.

Overall, shallow aquifers such as Mannville exhibit favorable characteristics for large-scale ATES deployment in the Regina region. The results underscore the importance of optimizing well placement and operational strategies to maximize long-term heat recovery and ensure sustainable system performance.

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