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SUSTAINABLE DEVELOPMENT OF WIND ENERGY IN HYDROLOGICALLY SENSITIVE LANDSCAPES: THE "DALBE" CASE STUDY

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Introduction

Wind farm construction in forested areas requires detailed hydrological investigations because forest ecosystems regulate water balance differently from open or agricultural lands. In Latvia, annual precipitation (~703 mm) exceeds evapotranspiration (~458 mm); only 35% becomes surface runoff, meaning most precipitation infiltrates or evaporates. About 47% of Latvia's forests have been historically drained, making them hydrologically sensitive. Without careful assessment, wind park construction can cause local flooding, groundwater fluctuations, soil erosion, and infrastructure damage.Forest hydrological processes (infiltration, evapotranspiration, groundwater recharge, runoff regulation) differ from other environments. Forest soils absorb large water amounts due to porosity, providing sustained baseflow even in dry periods. Canopy interception and evapotranspiration return up to 65% of precipitation to the atmosphere. Forest litter and vegetation regulate flow, reducing flood peaks and erosion. Construction risks include reduced infiltration and soil compaction, altered surface flow from roads and turbine foundations, and groundwater drainage changes from excavation. Heavy machinery compacts soil, reduces porosity, and leads to water stagnation or erosion. Therefore, hydrological assessment is essential for sustainable project design, helping identify sensitive zones and plan drainage and mitigation measures.

Materials and Methods

The "Dalbe" wind park lies in the central Zemgale Lowland (3–8 m a.s.l.), between the Medaine, Baložu Canal, and Birziņa rivers. Terrain is flat (slope < 0.5 ‰). Soils consist of sand–loam layers over glacial sands, enabling high infiltration. Climate is moderately humid (mean +6.2 °C; 590–680 mm precipitation).

Five groundwater monitoring wells (DAL1–DAL5) were installed to 2 m depth using PVC pipes with Micro-Diver sensors logging at 30-min intervals.

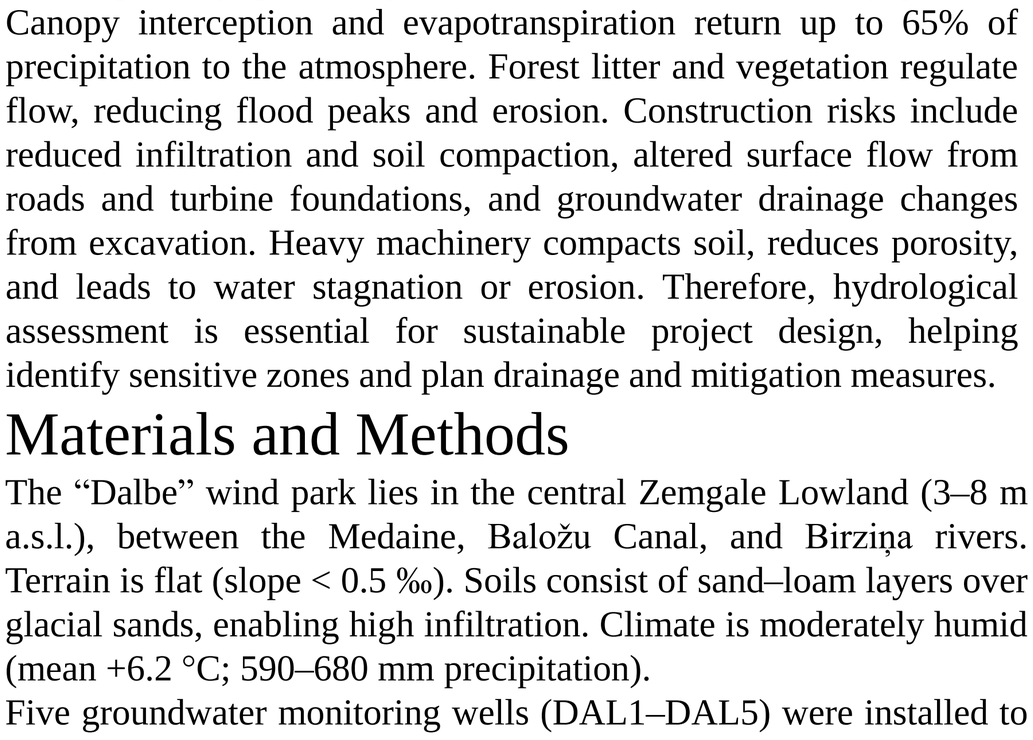

Figure 1. Location of study site where wind turbines are shown in blue and monitoring wells in red.

Results and Discussions

Impact assessment used a high-resolution (1 × 1 m) 3D surface model and conceptual hydrological model METQ to simulate surface and groundwater flow under different construction scenarios. Input data included daily temperature, precipitation, and humidity from Jelgava, Bauska, and Lielpeči meteorological stations (2015–2024).Model structure accounted for snow accumulation and melt, evapotranspiration, infiltration, soil moisture, and multi-layer runoff components (surface Q_1, shallow Q_2, deep Q_3). Water balance equations determined changes in groundwater level (Δh) and runoff distribution.Three scenarios were compared:Baseline: natural conditions.Scenario 1: turbine foundations with 0.5 m perimeter depressions. Scenario 2: inclusion of 2 m drainage trenches.Results showed that $\Delta h \leq 1.9$ m under foundations, fading to < 0.01 m within 25–50 m radius. Thus, all effects are strictly local.

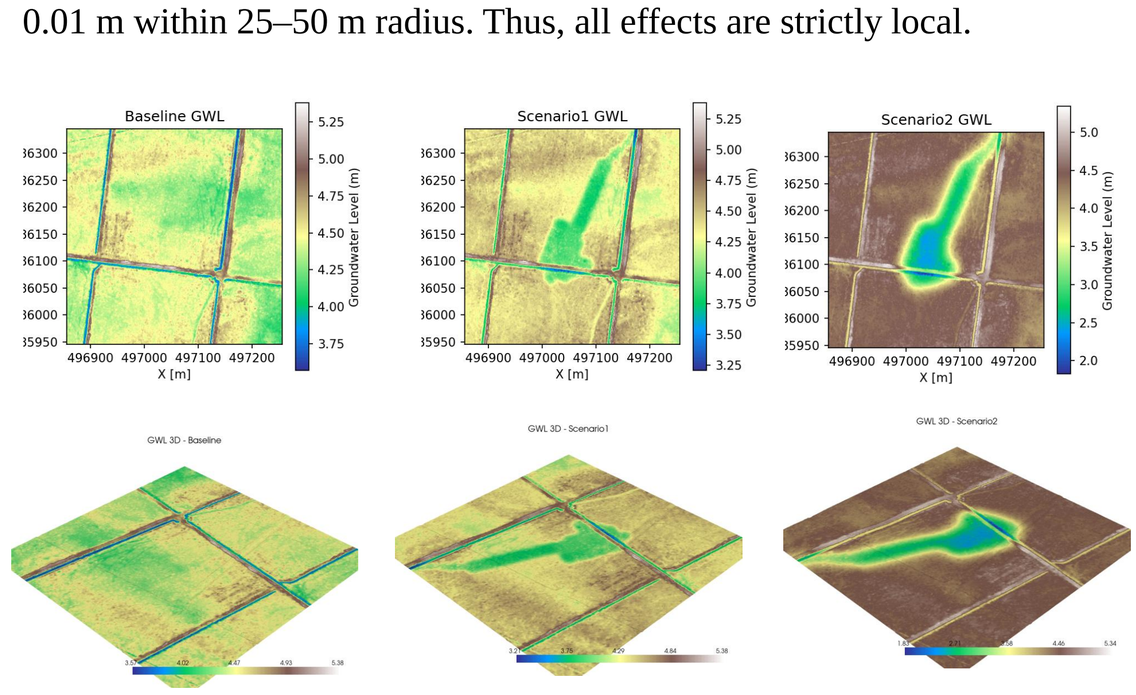

Figure 2. Modelled Groundwater Response under Two Ditch Depth Scenarios

Conclusion

Mitigation Measures:

- Install dual sedimentation–filtration systems (detention > 48 h; infiltration $k \approx 1 \times 10^{-3}$ m s^{-1}).
- Cover slopes > 3% with fiber mats and grass seeding; apply biodegradable mulch to reduce erosion by 80%.
- Maintain original ditch elevations during reconstruction; avoid deepening near sensitive habitats.Schedule heavy earthworks in summer low-flow season (July–September).
- Design access roads on embankments without drainage ditches near wetlands or biotopes.

Continuous groundwater monitoring during and after construction.

Groundwater regime alterations remain within 45 m buffer zones; no regional effects expected.Predicted surface runoff increase ≤ 0.05 m^3 s^{-1} (below ⅓ of drainage capacity).With mitigation, no significant hydrological impact on Natura 2000 habitats.The "Dalbe" wind park is classified as medium-impact, environmentally acceptable under proposed management measures.