accelerates vertical seepage, leading to peat and sulfur oxidation that leads to contaminant mobilization. Swamp hydrology and chemistry, therefore, may respond not only to surface water fluctuations but also to subsurface pressure gradients.

4.5 Management considerations

Our findings provide a new understanding of hydraulic connectivity between the Okefenokee Swamp and the Floridan Aquifer, which should inform future water resource management and environmental protection in the region. For instance, proposals for heavy mineral sand mining near Trail Ridge or large-scale groundwater pumping in the vicinity should be evaluated with the knowledge that the swamp is not an isolated “bathtub,” but rather a leaky reservoir intimately linked to the Floridan Aquifer. A stress to one will affect the other. Previous environmental assessments may have underestimated swamp vulnerability by assuming the confining layer prevents any aquifer-surface water interaction. Our data suggest any activity that lowers Floridan Aquifer levels (such as pumping) could induce greater vertical flow from the swamp, potentially dewatering it. Conversely, extreme high water in the swamp (e.g., after hurricanes) will recharge the aquifer significantly, which could be beneficial for aquifer storage. This interplay should be incorporated into hydrologic models and management plans. In quantitative terms, the swamp’s leakage could represent on the order of 5–15% of annual rainfall (~50–150 mm/yr out of ~1300 mm/yr) if our flux estimates are scaled across the swamp – a non-trivial quantity that should be factored into water budgets.

4.6 Uncertainties and future work

While our study demonstrates vertical hydraulic connectivity, there remain uncertainties regarding the spatial variability and controls of the leakage. It is still unclear whether exchange is dominantly diffuse and uniform or concentrated along preferential flowpaths—perhaps beneath prairie depressions, forested slough margins, or reactivated tectonic features. Recharge studies elsewhere show that such distinctions are often climate- and geology-dependent: as Cuthbert et al (2019) observed across sub-Saharan Africa, humid settings tend toward diffuse infiltration through soils, whereas semi-arid landscapes rely increasingly on focused recharge via ephemeral surface flows and topographic lows.

Our 2025 isotope results already hint at analogous heterogeneity here—some wells showing markedly higher swamp fractions than others—suggesting that vertical connectivity may be organized around localized “hot spots” of permeability rather than a spatially uniform leak. Mapping the confining layer’s integrity using geophysical methods or exploratory borings could help identify such zones of focused exchange.