Groundwater is a critical resource sustaining billions globally. The present study addresses a critical gap in understanding how large, heterogeneous aquifers respond to climatic and anthropogenic stresses beyond the conventional demand-versus-recharge framework. Recognizing that apparent groundwater recovery can mask underlying instability, the work introduces the novel concept of “silent groundwater stress”, a hidden a hidden regime of aquifer instability concealing delayed system responses and feedbacks. To diagnose this phenomenon, the study further develops an integrative framework combining empirical time series analysis, physical modeling, and conceptual system dynamics. The mass–spring–damper analogy reveals four universal groundwater response phases and their transitional “early warning” states. These phases are empirically validated over the Ganga Basin, showing that minor recharge declines or sustained pumping can destabilize even seemingly recovering aquifers. Furthermore, the study quantifies resilience using a cross-wavelet coherence framework linking rainfall and groundwater levels, demonstrating that higher coherence corresponds to lower resilience in over-pumped systems. Finally, a regional groundwater model, MODFLOW, is set up over the Ganga Basin to enhance the understanding of system response to changes in pumping. The study develops a basin tailored calibration technique PACIT-F (Physics-cum-Knowledge Assisted Iterative Calibration Framework) that ensures parameter consistency and improves model accuracy by 95%. Collectively, these innovations advance theoretical and practical understanding of groundwater system resilience offering adaptive strategies under climate and human pressures