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Estimating renewable water flux from landscape features

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Water level fluctuations are not always an indicator of ground water recharge or discharge. Fluctuations occurring over a period of decades can be attributed to naturally occurring climatic changes or anthropogenic activities including land use changes, pumping, irrigation and other engineering modifications. When long-term ground water extraction exceeds recharge, impacts on the natural hydrodynamics of the ground water system, including decreases in the hydrologic unit storage and hydraulic head, may occur. If extraction limitations are set, these ground water units can still take decades to centuries to recover. The complexity of vadose zone, ground water and surface water interactions presents hydrological research challenges for the development of operational hierarchies and up-scaling from reaches to watersheds. Multiple techniques for quantifying ground and surface water exchanges, specifically Geographic Information System (GIS) technology, numerical models and statistical analyses must be applied to overcome these challenges. These techniques promote a multidisciplinary and multi-scale approach to addressing hydrologic system research. By using watershed boundaries as a quantification unit and applying the three types of flow systems resulting from Laplace equation solutions (Tóth, 1963), regional, intermediate and local systems could be addressed. Multivariate exploratory data analysis techniques were used to establish watershed interconnections based on the spatio-temporal structure of annual, seasonal, monthly and minimal monthly runoff. The analysis of an initial dataset of 129 watersheds spanning the State of Minnesota, USA, and split into three varying time periods, resulted in five hydrologic regimes with either a positive, negative or absence of trend in annual stream discharge. At a given point on the earth's surface, a combination of different layers, each representing fundamental landscape components, yields unique features related to hydrologic response. Using this system-based approach, identifying the watersheds within each regime and using the characteristic data for that watershed set, the structure of connections can be determined and the quantitative influence that terrestrial landscape characteristics have on the renewable flux of the system could be established. Since water balance characteristics vary spatially and temporally, applying this regionalization method to first identify hydrologic regimes and then identify the response associated with specific characteristics, the influence of environmental changes could also be estimated for un-gauged watersheds. Quantifying the spatial impact of environmental change on the natural flux of the system is critical for moving from proverbial "protection" or "environmental improvement" to sustainability of water resources.