J. Ind. Geophys. Union, 28(4) (2024), 282-288

Investigation of groundwater flow regime using electrical resistivity tomography in a watershed of the Lesser Himalaya

Pallavi Banerjee Chattopadhyay[1]*, Ravi S. Dubey[1], Roshani Singh[1], Swagat Kar[1,2], Praveen Kumar[1] and Satwik Bhattacharya[3]

[1]*Department of Earth Sciences, Indian Institute of Technology Roorkee-247667, U.K., India*
[2]*Defence Geoinformàtics Research Establishment, DRDO, Chandigarh -160030, India*
[3]*Department of Geography, Banaras Hindu University, Varanasi-221005, UP, India*
*Corresponding author: cpallavi@es.iitr.ac.in

ABSTRACT

The hydrogeological pattern in the Himalayan region is highly variable due to diverse lithology, complex hydrogeological formations, and dynamic tectonic activities. This variability underscores the critical need to delineate groundwater flow along steep hillslopes under climate change scenarios to assess the sustainability of water resources in the hilly region. However, reliable flow evaluation demands robust subsurface evidence to better explain groundwater flow towards the stream or springs. The Electrical Resistivity Tomography (ERT) technique is a scanner that provides subsurface information based on subsurface distribution of geo-electrical properties to delineate the hill-slope scale hydrological processes. The study aimed to assess the feasibility of employing resistivity imaging to gain insight into the geological composition and hydrological behavior in the complex hilly Aglar watershed the of Uttarakhand region in Himalayan mountain belt of India. The geoelectrical survey employed the 2D electrical resistivity imaging technique with the Wenner-Schlumberger configuration with 48 electrodes. Apparent resistivity was collected in the field and inverted to true resistivity along the hill slopes. The imaging lines delineated variations in subsurface composition and preferential flow through unsaturated sap rock (fractured bedrock with weathering) in hillslope. The findings of this study offer valuable insights into the subsurface characteristics of the most permeable pathways that control groundwater resource availability and flow along the slopes of the watershed. The hard rock is exposed on the northern slope, and the southern slopes are less steep with fractured and weathered formations, facilitating strategic management and sustainable development in the Himalayan region.

Keywords: Aglar watershed (Uttarakhand), Hillslope hydrology, Electrical Resistivity Tomography (ERT), Preferential subsurface flow path, Water resources management, Himalyan region.

INTRODUCTION

Efforts have been made to study the dynamics of natural water resources and preferential flow through preferred pathways in the Himalayas and other mountainous regions worldwide (Stewart et al., 1967; Narayan et al., 1991, Singh, 1999). Hydrological modeling has witnessed significant advancements in the past two decades, driven by improvements in computational power, the widespread availability of distributed hydrological observations, and a deeper understanding of hydrological system dynamics and physics. (Zhang et al., 2024). These advancements have facilitated the incorporation of higher levels of complexity into hydrological models, marking a transition from lumped conceptual models towards semi-distributed and distributed physics-based models (Van Nostrand et al., 1966; Banerjee and Singh, 2011).

Numerous studies have demonstrated an understanding of the preferential flow path and its impact on the ecosystem (Beven and Germann, 2013; Chattopadhyay and Singh, 2013; Chattopadhyay and Rangarajan, 2014). Studying the preferential flow path is scientifically very important, but it is too complex to solve on an experimental and theoretical basis. Therefore, understanding the preferential flow, which is responsible for runoff generation processes in hilly terrains, demands a field survey approach to systematically test the influence of geological formation. In the context of this study, we conducted 2D resistivity surveys employing the Wenner-Schlumberger configuration, known for its moderate sensitivity to vertical and horizontal resistivity variations. The lower resistivity zone indicates localized flow paths at a faster rate, serving as preferential flow paths. This is highly relevant for subsurface runoff generation, bypassing the consolidated matrix (Weiler, 2017; Singh et al., 2022).

Electrical resistivity surveys have long been employed to explore the electrical properties of rocks and subsurface materials (Singh et al., 2022). ERT (Electrical Resistivity Tomography) measurements can be used to monitor subsurface hydrological processes by providing detailed images of the subsurface resistivity distribution. This technique is particularly useful for identifying and tracking changes in moisture content, groundwater flow, and the movement of contaminants (Chattopadhyay et al., 2015). For example, ERT can help detect water infiltration into the soil, monitor aquifers' recharge and discharge areas, and assess the impact of hydrological events such as flooding or drought on subsurface water distribution. By offering real-time data, ERT aids in better understanding and managing water resources and hydrological systems (Banerjee et al., 2008, 2011, 2012). Electrical resistivity tomography is a well-known technique to monitor subsurface moisture and saturation (Nguyen et al., 2009). The widespread adoption of computer-based technologies in the 1970s catalyzed the evolution of geoelectrical and resistivity research. Present-