Journal of African Earth Sciences 121 (2016) 154–167

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

Hydrologic interconnection between the volcanic aquifer and springs, Lake Tana basin on the Upper Blue Nile

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A R T I C L E I N F O

Article history:
Received 14 February 2016
Received in revised form
20 May 2016
Accepted 23 May 2016
Available online 25 May 2016

Keywords:
Groundwater
Ethiopia
Stable isotopes
Hydrochemistry
Spring water
Gilgel Abay

A B S T R A C T

Hydrochemical and stable isotope ($\delta^{18}O$, $\delta^{2}H$) data were used to identify the recharge sources of major springs and the hydraulic interconnection between the volcanic aquifer and springs in the Gilgel Abay catchment and adjacent areas. The hydrochemical data analysis showed that all water samples of springs and shallow wells have freshwater chemistry, $Ca-HCO_3$ to $Ca-Mg-HCO_3$ types. This is mainly controlled by dissolution/hydrolysis of silicate minerals. The analyzed stable isotope data indicate that springs water, except Dengel Mesk, Kurt Bahir and Bility springs, and well waters, except Dangila well, fall close to the LMWL. This clearly shows that the infiltrated rainwater did not undergo much evaporation and $\delta^{18}O$ values for spring water and groundwater are nearly equal to the value of Ethiopian summer rainfall, which is −2.5‰. Therefore, generally both stable isotope and hydrochemical data show the recharge source to springs and shallow groundwater is primarily from precipitation. Furthermore, data suggest that rock-water interaction has remained relatively limited, pointing to relatively short residence times, and local recharge rather than regional recharge.

1. Introduction

The Quaternary basalts, which are found in and around Bahir Dar are fractured and highly vesicular. The transmissivity value of Quaternary basalts varies within the range of 100–200 m^2/day (BCEOM, 1999) and is high compared to the basalts of the Trap Series with transmissivity of 1–32 m^2/day (SMEC, 2008). This shows that the Quaternary basaltic aquifer is highly porous and fractured. Three or more major springs which discharge from these highly fractured basalts are situated approximately 8 km west of Bahir Dar. The discharge is > 120 l/sec at Areke spring and about 60 l/sec from Lomi springs (Admasu, 2010) (Fig. 1). The study done by Alemayehu and Kebede (2011) reported that the discharge of Areke spring is 165 l/sec and Lomi can yield about 58 l/sec, while Tropics Consulting Engineer's (2009) estimated Areke and Lomi spring with a discharge of 210 l/sec and 90 l/sec respectively during the month of March. The major discharge discrepancy in different studies is due to the diffuse nature of the springs and their emergence at the contact of the flat and small undulating volcanic hills, which is not suitable for measurement.

The Lake Tana basin in the Upper Blue Nile Basin is a source of fresh water for the fast growing and expanding metropolitan city of Bahir Dar, and other cities in the basin and for irrigation water. Abstracted water comes both from springs and groundwater wells. Groundwater accounts for about 71% of the public utility water supply for the city of Bahir Dar (Tropics Consulting Engineer's, 2009), excluding groundwater abstracted by individually owned shallow and deep wells. According to the same study done by Tropics Consulting Engineer's (2009), the current abstraction from Areke spring is about 51% of its estimated discharge. The rest of the water is leaving the site as an overflow and drains into the Infranz River downstream. Likewise, Lomi spring is also the source of the current water supply of the town. About 41% of the available spring discharge drains as excess overflow to the Infranz River together with the overflow from the Areke spring.

Previous studies done in the Blue Nile Basin have shown that high discharge springs elsewhere in the basin emerge at the foot of the shield volcanoes that are characterized by large networks of deep-running tectonic discontinuities (Alemayehu and Kebede, 2011). In the same paper, the hypothesis is expressed that Areke,

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http://dx.doi.org/10.1016/j.jafrearsci.2016.05.015
1464-343X/

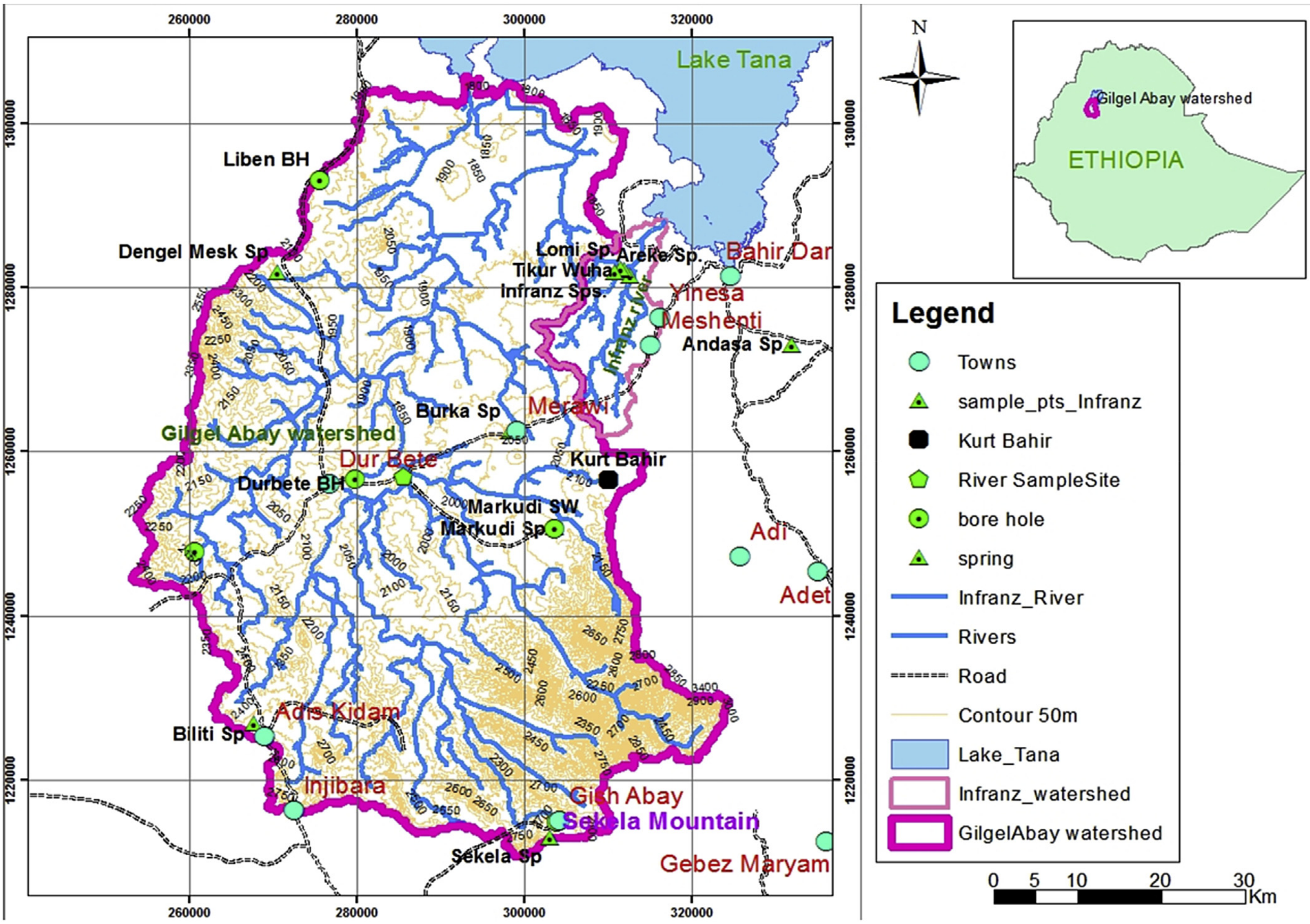

Fig. 1. Location map and sampling points of the study area.

Lomi, Merawi (Burka), and Andasa (Tikurit) (Fig. 1) also emerge at the foot of the shield massif volcanoes, and are also regionally recharged through the Tertiary basalts. However, Tropics Consulting Engineer's (2009) reported that the springs emerge from the vesicular Quaternary Basaltic Formation at the geomorphology where the local slope break has intercepted the shallow groundwater.

2. Objectives of the study

Although interest in water of the regional volcanic aquifer is high in the Lake Tana basin, data on the quality and quantity of water are relatively scarce because of limited work done and relatively few wells penetrating the volcanic aquifer. Some studies show that the springs at the foot of the mountains in the Upper Blue Nile Basin are recharged from volcanic massifs due to delayed flow as a regional source (Kebede et al., 2005; Alemayehu and Kebede, 2011). However, this conclusion is only based on limited data. The high discharge springs, namely: Areke, Lomi, Tikur wuha and others around Bahir Dar, Andasa (Tikurit) spring, and Merawi (Burka) springs are not well studied, and it remains unclear whether they are regionally or locally sourced, because of the limited set of physical and chemical characteristics.

Both contrasting hypotheses for this study were, whether the high discharge springs are regionally or locally recharged. At one hand, and according to some former studies (Kebede et al., 2005; Alemayehu and Kebede, 2011), the high discharge springs may be recharged from a distance at Sekela mountain volcanic flanks, as rainfall infiltrates into the Tertiary basalt, circulates at depth and flows to low-altitude aquifer zones, interconnected with the top Quaternary volcanic aquifer system in the lowlands and finally discharges at the major springs as a mixture of regional and local sources. On the other hand, these major springs might be recharged from local sources from the relatively pervious Quaternary basaltic aquifer system in the lowlands as rainfall infiltrates. Chemical and isotope techniques have been used to conclude about these two alternatives.

Based on the local geology, drilled boreholes and topography, a geological cross section which shows the conceptual groundwater flow model was developed for the study area (Fig. 2). The conceptual model is drawn from S–N along the regional flow direction following spring discharge areas.

This study was conducted to identify the hydrological interconnection of the springs with the surrounding regional and local volcanic aquifer systems, specifically in the southern part of the Lake Tana basin, in the Gilgel Abay catchment and surroundings (Fig. 1). The results of this study will advance the knowledge of water sources for the major springs and volcanic aquifer system and location of its discharge zones. In general, this study will give clues about the flow system and recharge zone of the springs within the Lake Tana basin and explains on how to make them sustainable as most of them are sources of water supply.