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Topical Collection: Advancements in hydrogeological knowledge of Haiti for recovery and development

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Abstract

Haiti's groundwater resources are poorly understood and scarcely researched, despite their importance as the principal source for water supply. The knowledge gap and its role of inhibiting informed relief, recovery and investments in development are described, along with an update on progress towards the UN Sustainable Development Goals. This essay leads a topical collection of seven articles that advance hydrogeological knowledge of Haiti. Additional data, research and monitoring are identified as urgently needed for the nation's sustainable development.

Keywords Water security · Groundwater development · Groundwater management · Groundwater and society · Haiti

Introduction

Water security plays a critical role in human wellbeing and supports societal development and stability. However, population growth and sectoral competition (domestic, industrial and agriculture) are combining with climate change and variability to undermine water security in locations across the Global South. These conditions are further exacerbated by natural disaster risks and locations experiencing political and/or economic upheaval. These factors are relevant to Haiti and have hampered the development of sustainable water, sanitation and hygiene (WASH) practices.

Groundwater is regarded as an important component of water security in contexts of drought, hazards and conflict (LaVanchy et al. 2021) and is deemed strategically important to securing equitable access to clean water and sanitation as outlined in the UN Sustainable Development Goals (SDGs). Investments in hydrological knowledge and supporting water management strategies are needed to ensure adequate water supply and public health justice for vulnerable populations.

Groundwater is one of Haiti's most important resources (Adamson et al. 2016). It has helped shape development over the country's history and is the primary source of water for a present population that exceeds 11.4 million and its volatile and fragile economy. Population growth, land-use changes, climate change, lack of governance and inadequate sanitation, waste and water management are some of the factors increasing pressure on Haiti's groundwater resources (Balthazard-Accou et al. 2017; Hedges et al. 2018; Adamson et al. 2016).

Despite the importance of groundwater in Haiti, insufficient knowledge and data are available to guide planning, policy and management. The dearth is partly due to endemic and cyclical socioeconomic and political instability, which has inhibited public works investments and development of professional and academic capacity. Haiti's post-independence

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(1804) double debt to France contributed to education receiving < 1% of the national budget in the mid-nineteenth century (Porter et al. 2022). Haiti's public works department was not established until 73 years after independence and employed only two architects and six engineers for the whole country. Haiti still lacks country-wide intermediate- to small-scale geological mapping, whereas other Caribbean nations have benefited from such maps for many decades.

Progress in hydrogeological understanding has been further hampered in recent decades by the diminishing pool of educated and experienced local experts. Today, groundwater knowledge is held and furthered by only a few local hydrogeologists and international practitioners; thus, rebuilding local capacity is sorely needed. Coordination with Haitian government agencies, universities, and municipalities has been limited, partly because of the large number of actors in the WASH sector (Gelting et al. 2013). This has also contributed to data scarcity despite development investments, as information from many actors is frequently not captured and retained within Haiti.

Frequent natural disasters have further undermined water security across Haiti. In a little over a decade, Haiti experienced two major earthquakes (2010 and 2021), a major hurricane (Matthew in 2018) that caused damage equal to 1/3 of its gross domestic product and a 2-year drought (2015–2016) that devastated food production. The 12 January 2010 earthquake (Mw 7.0) prompted unprecedented international attention and investment in Haiti. At the time of the earthquake only 62% of the population had basic access to water (JMP 2021). A separate disaster of a cholera outbreak later in 2010 resulted in 820,000 cases and > 10,000 deaths (MSPP 2020). Available groundwater data and knowledge from the early to mid-twentieth century and the 1980s were scarce and outdated and were found inadequate to support the necessary scale of WASH efforts for response and recovery from these disasters.

Despite the momentum, pledges and investments following the earthquake and cholera outbreak, only a small improvement in water access resulted. According to data from the WHO and UNICEF Joint Monitoring Programme (JMP), 4.5% of the total population (including population growth) gained basic water access between 2010 and 2020 (bringing the total to 66.7%). In addition, less of the population had access to piped water on premises in 2020 than in 2010 (JMP 2021). It should be noted that the JMP datasets compare between Millennium Development Goal (MGD) and SDG indicators, and the latter replaced the former in 2015.

Access to safe, and reliable water is a critical foundation for recovery from natural disasters and progress in sustainable development, however, current knowledge and research gaps are expansive in Haiti. There remains an urgent need to characterize and monitor Haiti's groundwater resources and an equally urgent need to disseminate knowledge to support decision-making and investments in the country. In this context, the Inter-American Development Bank facilitated an organic initiative to bring together some of Haiti's experienced and passionate researchers to publish recent studies and investigations in a peer-reviewed forum with open public access. The authors advocate prioritization of research and data acquisition through instrumentation and monitoring to address important knowledge and data gaps and that results of future work be made publicly available. Practitioners and funding entities have an important responsibility to disseminate research findings to enable the strengthening of policy and governance to manage the resources amidst the growing water security risks and vulnerabilities.

Topical Collection content

The seven articles in this collection contribute data and knowledge for many of Haiti's important and diverse aquifer systems (Fig. 1). Interpretations and results expressed in the papers are based on limited datasets and are set to be strengthened as research advances and supplemental data become available. The articles target a broad audience to support wider interest, policy integration, application and opportunity for continued research and monitoring.

Miner et al. (2022b) present data mining and reconnaissance results from Tunnel Diquini and Source Mariani, two of Haiti's largest water supplies that flow from the Massif de la Selle bedrock aquifer system in the metropolitan region of Port-au-Prince. The findings support insights into what may be considered one of Haiti's most important and least studied aquifer systems. Adamson et al. (2022b) synthesize and analyze piezometric, stream flow, stable isotope and chloride data to evaluate river infiltration recharge to the Plaine du Cul-de-Sac and Plaine de Leogane alluvial aquifers. The results advance the conceptual understanding of the aquifers and the importance of the Massif de la Selle mountain block and its watersheds for recharge to the alluvial aquifers. Gourcy et al. (2022) set forth a database of all known stable isotope data in Haiti to support and strengthen future hydrogeological studies. The data were broadly analyzed to identify important data gaps and demonstrate the value of isotope data as a cost-effective means to support characterization of Haiti's aquifer systems. Arnaud et al. (2022) present a regional-scale groundwater flow model for the Plaine du Nord-Massacre shallow alluvial aquifer to support sustainable agricultural development. The effort compiled an important volume of data with insights on surface water and groundwater flow, water balance and vulnerabilities and noted important data gaps to strengthen the conceptual model and improve modeling efforts. Miner et al. (2022a) focus further on a subsection of this coastal aquifer in the area of Cap-Haitien by applying gravity and electromagnetic geophysical methods to assess alluvial thickness and evaluate the potential for deep groundwater to augment growing demand within the region. Wampler (2022) explains the spatial distribution of karst aquifers and their vulnerability to contamination. He provides a snapshot of water quality data to assess karst aquifer contamination in several areas of the country and

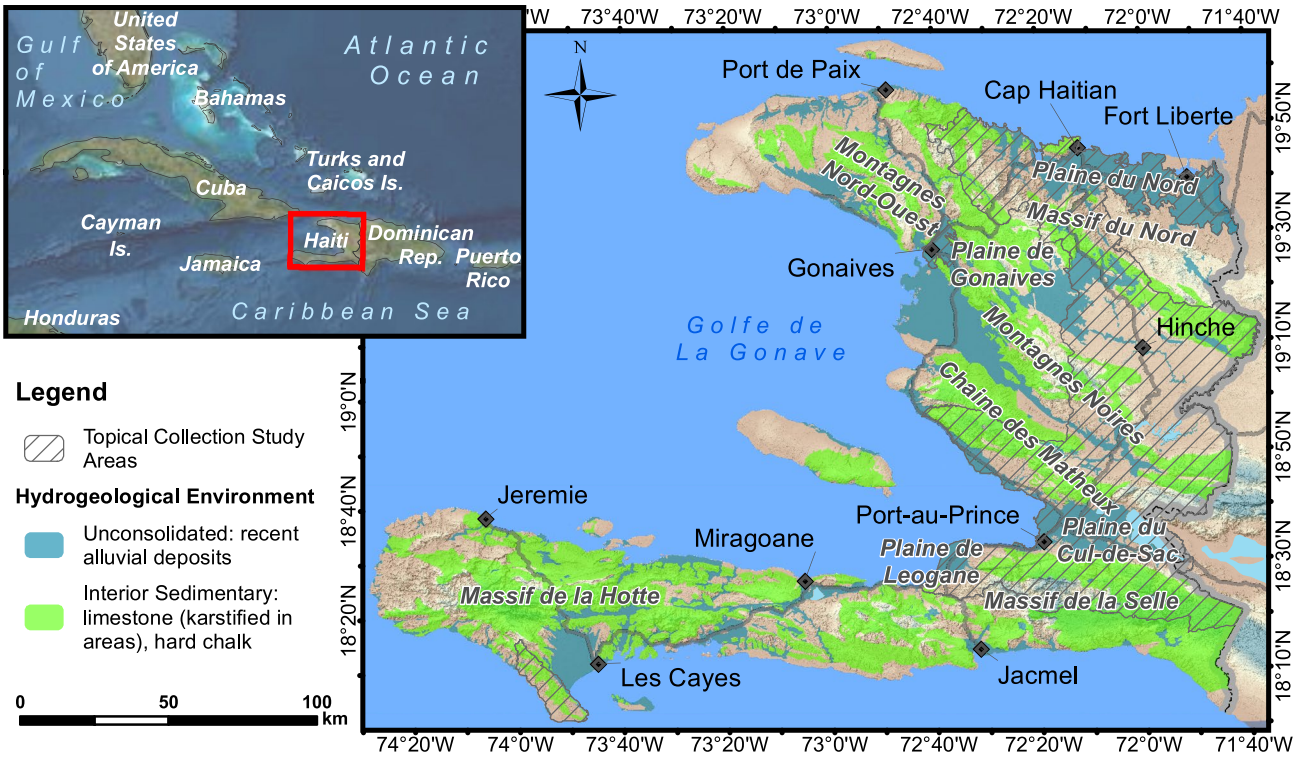

Fig. 1 Map of Haiti showing the distribution of primary bedrock and alluvial aquifer systems and the study areas represented in the topical collection

presents relevant water treatment technologies to enable safe drinking water in vulnerable areas. Adamson et al. (2022a) apply a data synthesis effort, coupled with a reconnaissance mission, to advance a conceptual hydrogeological model for the Plaine de Gonaïves aquifer system. The results were supported by a volume of drilling records, historical datasets and recent stable isotope, hydrochemistry and flow data.

Summary of findings

Five articles document four of Haiti's largest alluvial aquifers, which are among the largest in the Antilles. Unconsolidated alluvium blankets over 25% of the country and the associated aquifers encompass population centers and agricultural regions, making them the most exploited resources (Adamson et al. 2016). Their coastal setting and hydrogeological characteristics make them vulnerable to diverse impacts that are discussed in the papers. The model of Plaine du Nord presented by Arnaud et al. (2022) shows clearly that under drought conditions, as observed in 2016, the risk of saline intrusion inevitably increases in areas where the groundwater is unsustainably exploited. The topical collection emphasizes the critical importance of governance and management with the hope that these articles and future studies will facilitate informed and effective management of Haiti's alluvial aquifers. For example, Arnaud et al. (2022) indicates that groundwater withdrawals may have to be managed more intensively under drought conditions to avoid saline intrusion and potential associated longer-term damage to aquifer water quality.

Many of Haiti's alluvial aquifers do not receive significant quantities of recharge from direct precipitation, in part because of their low elevations and high evapotranspiration (Adamson et al. 2022b; Adamson et al. 2022a; Arnaud et al. 2022). Infiltration of rivers and inflow from mountain bedrock aquifers are interpreted as key sources of recharge for the Plaine du Nord, Plaine du Cul-de-Sac, Plaine de Leogane and Plaine de Gonaïves, and perhaps other alluvial aquifers in Haiti. The understanding of temporal recharge dynamics is improved through these papers, which show the importance of larger precipitation events and El Niño Southern Oscillation (ENSO) climatic cycles for both the bedrock and alluvial aquifer systems. Groundwater storage, flow dynamics and water quality in the alluvial aquifers have a close relation to the river systems that have carved out and infilled the basins (Adamson et al. 2022b; Arnaud et al. 2022). The cost-efficient geophysical methods outlined by Miner et al. (2022a) can be applied to improve characterization of the alluvial basins and guide groundwater modeling and development. Such methods are of particular interest given the lack of well-drilling records available in Haiti.

As discussed by Adamson et al. (2022a), Miner et al. (2022a) and Wampler (2022), mountain bedrock aquifers are very important and are referred to as Haiti's "mountains of water" because of their high recharge rates, storage capacity and abundant springs. These include the Massif de la Selle, Massif de la Hotte, Chaine des Matheux, Montagnes Noires and Montagnes Nord-Ouest.

The discontinuous carbonate and karst bedrock aquifers absorb most of the country's recharge and feed thousands of springs and hundreds of water systems throughout the country. The above-cited research indicates the aquifers receive disproportionate recharge from larger precipitation events and provide important storage that buffers drought impacts. As previously noted, many alluvial aquifers rely upon the bedrock aquifers and their watersheds for a majority of recharge. The alluvial and bedrock aquifers are vulnerable to contamination, climate change and land use changes, including widespread deforestation, as outlined by the authors in this collection. The management and protection of Haiti's aquifers and their watersheds is an important takeaway that is necessary to protect the quantity and quality of existing spring supplies and the downstream alluvial aquifers, and therefore the health of those who use these water sources.

Closing

Haiti has alluvial and bedrock aquifers that serve a critical foundation for recovery and development; however, the lack of local capacity, data and knowledge to inform planning, investments and management are prohibitive. This collection is an effort towards "making the invisible visible" as it relates to Haiti's groundwater resources. Increased visibility and knowledge of groundwater will strengthen continuing research, encourage critical monitoring and lead to the advancement of governance and management to protect and sustain Haiti's most important resource. While the future of Haiti remains uncertain, investing in water security strengthens the prospects of recovery, stability and socioeconomic development.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Disclaimer The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the US Centers for Disease Control and Prevention.

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