TRIFINIO: Transboundary Aquifer Systems in the Upper Lempa River Basin, El Salvador, Guatemala and Honduras, in Central America

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ABSTRACT

The Trinacional Commission for the Trifinio Plan is managed by the respective national deputy presidents and works under the slogan 'Water without borders', recognizing the importance of water resources for these three countries. This study includes homogenization of existing geological descriptions of different geological units in the Trifinio region. Physical and chemical parameters were measured in the field for about 140 samples. Geoelectrical campaigns were carried out in selected areas to reveal information about the location and hydraulical properties of the principal aquifers. Thus, the first hydrogeological map of the Trifinio region was generated with a scale of 1:100 000. The preliminary results have shown the chemical and isotopic similarities between most surface waters and groundwaters, suggesting both a fast dynamic for most systems and the relevance of local sources of recharge. The precipitation presents a high temporal variation in deuterium (-105.60 ‰ $\leq \delta 2H$ 21.66 ‰) and oxygen-18 (-14.76 ‰ $\leq \delta 18O \leq$ 1.37 ‰), due to the combined effects of amount and altitude. Also, a strong seasonally effect can be found. Tritium was determined in 29 samples from wells, springs, rivers and lakes from El Salvador. Observed maximum activity was of 2.09 UT and a minimum of 0.00 UT. Tritium concentration in precipitation shows a tendency to decrease their activity to background noise. The results indicate that at least four samples showed no Tritium activity, which could be interpreted as water corresponding to intermediate and regional flows where the Tritium in the system has disappeared. 20 samples showed an activity greater than 1 TU reaching even 2.09 UT. Taking into account that the natural concentration of tritium when it enters the hydrogeological system is of approximately 4 UT, the trend observed at the Ilopango Station (outside the Trifinio region) and the half-life of tritium (12.3 years), there is a significant component of young water (less than 12 years) in the majority of the sites.

Key words: Trifinio, Transboundary Aquifers, Isotope Hydrology, Lempa River.

1. INTRODUCTION

In 1998, the governments of El Salvador, Guatemala and Honduras in Central America established the "Comisión Trinacional del Plan Trifinio" a platform to promote a sustainable development of water resources in this environmentally valuable and sensitive transboundary area. This commission is managed by the respective national deputy presidents and works under the slogan 'Water without borders', recognizing the importance of water resources for these three countries. Its strategy for development of Trifinio highlights water as the resource with the greatest impact on life, society, food production and the environment. The principal research objectives of the study are twofold: first, to assess the dominant types of recharge and stream-aquifer fluxes, and second, to compile and complete the hydrogeological information of the three countries in a transboundary hydrogeological map.

With International Atomic Energy Agency (IAEA) assistance through the project: "Sustainable Development of the environment and water resources in the Upper Lempa River Basin" (RLA/8/038) between 2006 and 2008, the studies were coordinated by the commission and implemented by more than 30 professionals representing national counterparts from the following institutions: Honduras: ENEE, DEFOMIN, and SNM. El Salvador: SNET-MARN, CEL, ANDA, UES and MAG. Guatemala: INSIVUMEH.

2. STUDY AREA

The Trifinio (Figure 1) area has over 4343 km^2; of which El Salvador occupies about 29.5%, Honduras 11.6% and Guatemala 58.9%.

The Trifinio region is one of the most complex regions from an geological point of view. The geological formations extend from the volcano-sedimentary Complex "Complejo Espinal" from the Jurassic age up to lava and pyroclastic rocks of the Ipala graben from the Pliocene to the Holocene and are related to the volcanism behind the volcanic arc (BVF), these structures have a major effect on the existence of aquifers in the region.

3. METHODOLOGY

The initial work included homogenization of existing geological descriptions of different geological units in the Trifinio region. Due to the limited amount of hydrological information available at the begin of the study, the first phases of the project consisted of several field work campaigns between 2006 and 2008, aimed at creating and updating a comprehensive inventory of water points - mostly springs, dug wells and drilled wells. Physical and chemical parameters were measured in the field for about 140 samples, representing surface waters and about 110 groundwater samples. Geoelectrical campaigns were carried out in selected areas to reveal information about the location and hydraulical properties of the principal aquifers. Complementary hydrogeological mapping was conducted in areas with sparse information available. Additionally, precipitation, surface and groundwater samples were collected for analysis of environmental isotopes and about 244 $\delta^{18}O$ and $\delta^{2}H$ analyses were carried out at the stable isotope laboratory in El Salvador. The results were synthesized in preliminary conceptual models of stream-aquifer interactions in the principal zones and contributed to the finalization of the transboundary hydrogeological map.

4. RESULTS AND DISCUSSION

The first hydrogeological map of the Trifinio region with a scale of 1:100 000, is presented in figure 2. The map indicates three main hydrogeological: units:
a) Porous media aquifers: Thirteen units were identified and mapped in fluvial valleys and terraces. These units are mostly formed by alluvial sediments transported by rivers, or are result of landslides. Sedimentary units reach thicknesses ranging from 30 m to 80 m and have a very heterogeneous grain size distribution, mostly formed by fragments of igneous rocks. Hydrochemical and isotope data confirmed the meteoric origin of these locally recharged waters with fast dynamics. The dominant hydrochemical feature of these waters is calcium bicarbonate with low mineralization (250 –600 µS/cm). Nitrate levels are above the drinking water limit at only a few locations. **b) Fractured aquifers**: This hydrogeological unit type is formed by volcanic rocks affected by intense fracturing, mainly in the western part of the Trifinio region (Guatemala). Groundwater usually manifests itself in the form of large springs. The dominant hydrochemical type of these waters is also calcium bicarbonate with low mineralization (300–600 µS/cm). Stable isotopes provided estimation of the recharge area altitude of various springs. **c) Low porosity fractured rocks:** These units (approximately 10) extend over most of the Trifinio region, especially in the eastern part. Despite a moderate fracturing, these volcanic rocks demonstrate poor conditions for groundwater flow. The local population nonetheless exploits most of the existing springs. These waters show a more complex geochemical evolution, with electrical conductivity reaching values of up to 1200 µS/cm and chemical facies ranging from calcium bicarbonate to calcium bicarbonate/chloride. Environmental isotopes revealed that most of these waters also derive from local recharge.

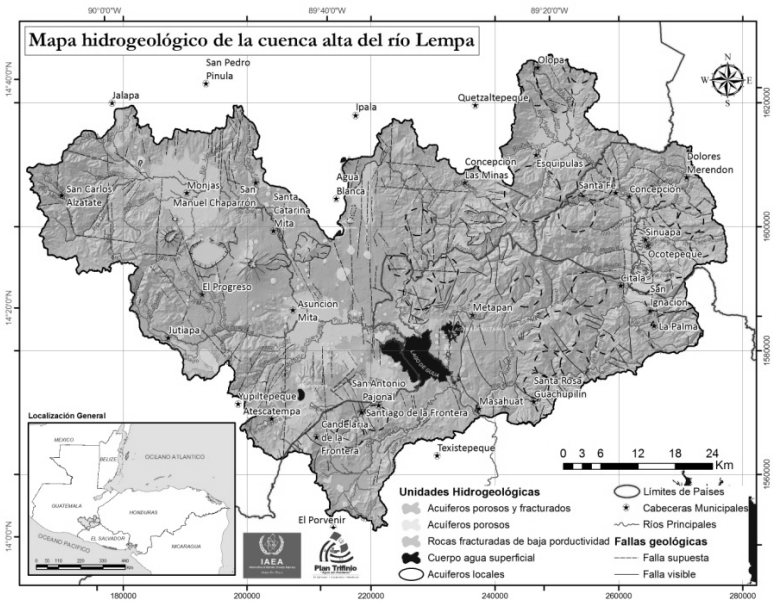

Figure 2. Hydrogeological map of Upper Lempa River Basin.

As a synthesis, the hydrogeology of Trifinio is characterized by the importance of significant fracture systems, which create deep circulation of groundwater in certain areas, and the existence of both local and regional flow systems. Tritium isotope indicated groundwaters with various degree of admixture of recent waters to waters probably recharged several decades ago. Chemical and isotopic similarities between most surface waters and groundwaters, however, suggest a dominantly fast dynamic for most systems and a high relevance of local sources of recharge via isolated aquifers.

Conceptual flow models demonstrate that the main discharge points takes place through springs and other structures in valleys. Isotopically enriched groundwater was observed in the zones of Güija and Metapán, suggesting a recharge of evaporated water from the adjacent lakes. This can be seen in Figure 3, which shows a Craig diagram with the local meteoric line and δ^2H $\delta^{18}O$ results of all samples of surface and groundwater.

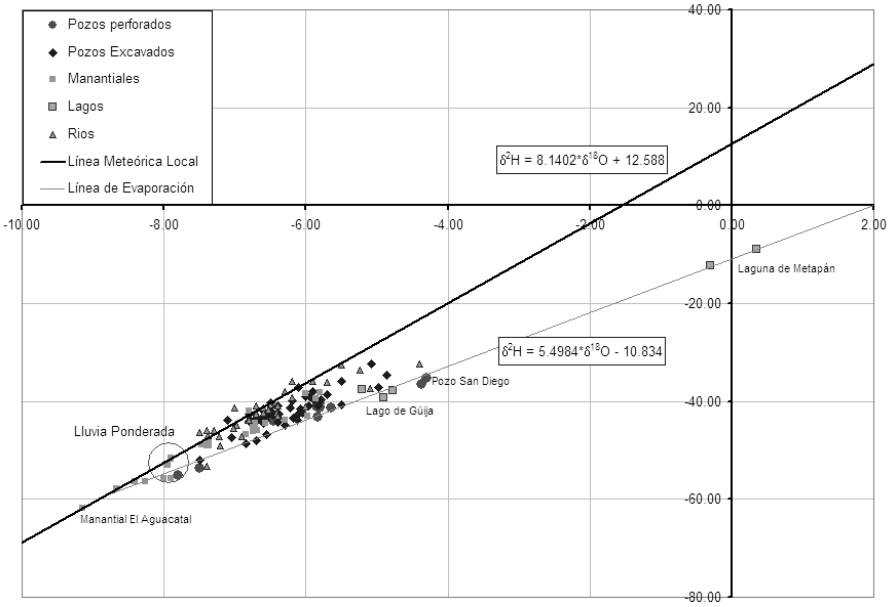

Figure 3. Isotopic composition of δ^2H $\delta^{18}O$ in groundwater and surface waters

More pronounced stream-aquifer interactions possibly with spatial or temporal shifts between aquifer recharge and discharge from and to streams was observed in certain valleys (for example the zone of Nueva Ocotepeque in Honduras). Additional work on a possible interaction with deeper groundwaters is in progress.

5. CONCLUSIONS

It can be concluded that the Trifinio is a highly dynamical shallow hydrogeological system with a dominance of rapid circulation between aquifers, springs and streams, and a portion of fractured aquifers with potential hydraulic communication via deeper regional flow systems yet to be better understood. The rapid recharge and discharge imply a high degree of vulnerability through

contamination fluxes and must be considered in local and regional water management plans of the Upper Rio Lempa basin. Current work is focusing on the assessment of vulnerability of selected larger transboundary porous aquifers, such as Nueva Ocotepeque or Guija-Metapán, and their interactions with the fractured aquifers. The preliminary results have shown the chemical and isotopic similarities between most surface waters and groundwaters, suggesting both a fast dynamic for most systems and the relevance of local sources of recharge. Most of the identified shallow aquifers are isolated and the base flow of the Upper Lempa River is maintained through discharge by these aquifers, mainly located in the eastern zone (Olopa-Ocotepeque-La Palma).

The Metapan lagoon and Lake Güija behave as discharge areas for the groundwater flow system in the Trifinio region, this behaviour was deduced from the piezometric heads and the hydrogeochemical characteristics of the surface and groundwater. The isotopic signature of both water bodies is enriched by evaporation, but this phenomenon has a stronger impact in the Metapan lagoon as in Lake Guija since the lagoon is relatively shallow. It was also estimated that the Metapan Lagoon discharges into the Lake Güija through a barrier of highly fractured and scoriaceous lava forms that separates them, and also because the Metapan lagoon has a higher elevation.

Even though the former mentioned surface water bodies behave as regional discharge areas, the direction of the groundwater flow could be locally reversed by the pumping of deep wells, as is the case of the San Diego well, which is located less than one mile from the Metapán lagoon, which could be extracting waters that are a mixture of local and regional flows and water of the lagoons. The precipitation presents a high temporal variation in deuterium (-105.60 ‰ $\leq \delta^2H$ 21.66 ‰) and oxygen-18 (-14.76 ‰ $\leq \delta^{18}O \leq$ 1.37 ‰), due to the combined effects of amount and altitude. Also, a strong seasonally effect can be found.

Tritium was determined in 29 samples from wells, springs, rivers and lakes from El Salvador. Observed maximum activity was of 2.09 UT and a minimum of 0.00 UT. Tritium concentration in precipitation shows a tendency to decrease their activity to background noise. According to Tritium data from precipitated water monitored at the Ilopango Station of El Salvador during the period 1968-1981(outside the Trifinio region), Tritium shows and exponential and asymptotic behaviour toward the values 4.0 to 4.5 UT. The results indicate that at least four samples showed no Tritium activity, which could be interpreted as water corresponding to intermediate and regional flows where the Tritium in the system has disappeared. 20 samples showed an activity greater than 1 TU reaching even 2.09 UT. Taking into account that the natural concentration of tritium when it enters the hydrogeological system is of approximately 4 UT, the trend observed at the Ilopango Station and the half-life of tritium (12.3 years), there is a significant component of young water (less than 12 years) in the majority of the sites. In order to give a accurate estimation of groundwater age on the Trifinio region d14C or CFC studies should be carry out.

5. ACKNOWLEDGEMENTS

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