04:15 pm

Session 1.01. - Part B

Room:
R1 Dischma

Topic:
1.01. Karst hydrogeology: Flow systems and modelling approaches

Form of presentation:
Oral

Duration:
105 Minutes

04:15 pm

109134: Enhancing the Understanding and Remediation of Saltwater Intrusion in Grand Bahama's Karst Aquifer: A Modeling Approach

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In 2019, Hurricane Dorian profoundly impacted the Bahamas. Due to a large storm surge induced by the Hurricane, 40% of the freshwater aquifers on Grand Bahama became salinized as saltwater infiltrated through the thin overlying soil into the karst aquifer. This rapid saltwater intrusion was facilitated by the numerous fractures and conduits in the Lucayan Limestones prevalent in the area.

Today, Grand Bahama relies on desalination using a reverse osmosis system (RO) to produce its drinking water. However, this method remains highly unsustainable in terms of both costs and energy consumption. Therefore this work aims to improve the understanding of the hydrogeology and the saltwater intrusion into the freshwater lenses in such complex geological and hydrological conditions with the help of groundwater modeling, in order to reduce dependency on the RO and return to potable water supply from the aquifers (freshwater lenses).

A groundwater model using MODFLOW and the 3-dimensional variable density groundwater flow package SEAWAT was set up. In this model the two lithological layers, Lucayan Limestones and the underlying dolomites, were subdivided into 15 layers to enhance vertical resolution in the model simulations. Due to limited available data, alternative methods were required to model the random distribution of karst conduits. A Gaussian Model was used to simulate these features as accurately as possible. This approach involved identifying random points across the island and assigning them different hydraulic conductivity values compared to their surroundings.

After setting up the model, it can be used to support the planning and implementation of groundwater abstraction wells (for drinking water use) and injection wells for artificial groundwater recharge. The latter has the potential to support natural remediation of aquifers beneath Grand Bahama, as a measure of managed aquifer recharge aimed at mitigating saltwater contamination of freshwater lenses.

04:30 pm

109154: Groundwater vulnerability assessment as a tool for understanding karst flow systems and prediction of spring yield - case example of a karst spring in Western Serbia

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Modelling approaches in karst hydrogeology imply a high degree of schematization, uncertainty and subjectivity due to the specific nature of karst systems. The need to protect groundwater, especially in karst, has resulted in increasing application of methods for assessing groundwater vulnerability. Vulnerability methods specially developed for karst could assess filtration conditions, anisotropy, specific infiltration, and temporal variability, enabling better characterization and understanding of the karst systems. A recently developed method is the Time Dependent Model (TDM method), where vulnerability is based on the simulation of groundwater flow through unsaturated and saturated zones and expressed through groundwater travel time.
The study demonstrates the utilization of TDM method to simulate the yield of karst springs. This procedure includes creating spatial maps for each rain event, which, in addition to GIS software, requires using Python or similar programming language to automate the entire process. The spatial calculation of recharge using the TDM method enables the creation of maps of the recharge rate for each rainy day. At the same time, calculating groundwater travel times enables obtaining information on the arrival date of infiltrated water from each part of the catchment to the spring. Summing up all the amounts of water that reach the spring on a particular day, a hydrogram of the spring discharge is obtained. The comparison of the calculated and measured spring discharges implies adjusting the TDM method's input parameters, enabling a better simulation and understanding of the entire karst system.
This approach was successfully applied to a karst spring in Western Serbia. The results show that vulnerability maps have great potential in modelling karst systems and simulating karst processes. The conducted research also validates the vulnerability map, which was previously considered the main disadvantage when these methods are applied.

04:45 pm

107696: Dam leakage potential and mechanism related to karst genesis in limestone bedrocks

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Increased leakage at dam sites due to the dissolution widening of fractures in the sub-surface soluble rocks, i.e., karst genesis, poses a great threat to the longevity of dam structures. The high hydraulic gradient caused by the impounded water may significantly accelerate karst genesis and lead to a dramatic leakage increase. Previous numerical modeling studies of karstification and leakage at dam sites do not consider the effect of vertical temperature variation within the formation. Here, we incorporate the temperature effects on dissolution and fluid flow parameters into karst genesis modeling to assess leakage potential. Results show that the temperature effect may cause calcite precipitation/dissolution when water flows downward and then upwards when bypassing the grout curtain. The precipitation-induced aperture reduction impedes the movement of the dissolution front and may even alter its direction. As a result, the breakthrough may be delayed, depending on the dissolution pathways induced by the initial aperture contrast between bedding planes and joints (anisotropy) and the heterogeneity of fracture network geometry. This paper provides important implications for the engineering design of dam site construction to reduce leakage risk and improve dam longevity.

05:00 pm

107778: The Karst Vadose Zone as an Important Water Storage System

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Recent field and modelling investigations have shown the karst vadose zone to act as an important factor in the assessment of available water resources, particularly in regions, characterised by thick unsaturated zones. In particular, in semi-arid regions of the Eastern Mediterranean, very wet years have shown to have prolonged effects of elevated groundwater discharge as well as elevated groundwater levels, compared to long-term average hydraulic conditions.
The above prolonged storage effects can generally be attributed either to delayed groundwater discharge or the sustained infiltration processes in the matrix of the vadose zone.
The research focussed on the analysis of the geohydrological processes in the field, i.e. the analysis of spring discharge and groundwater hydrograph records, both for humid-temperate as well as semi-arid conditions, the analysis of water tracers (Krypton an T/He; trace organics) as well as the coupled modelling of saturated / unsaturated flow, employing a double-continuum approach (HydroGeoSphere).
Our findings show that in less maturely karstified aquifer systems, the contribution of delayed seepage from the vadose zone can reach up to 40% of total spring discharge which is of particular importance for regions with prolonged drought periods, expected for semi-arid environments. The analysis of the tracer information allowed the discrimination of the source of the delayed discharge, in particular Krypton tracer analysis demonstrated the extended residence time of infiltrating water in the vadose zone. The quantification of the partitioning between rapid recharge and slow vadose seepage proved to be a challenge.