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Local assessment of the risk on groundwater resources related to unconventional hydrocarbon development

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A study was carried out in the Haldimand sector of Gaspé, Québec, Canada, to assess the potential link between a tight sandstone petroleum reservoir, whose potential is being evaluated, and the shallow fractured rock aquifer system. Petroleum exploration operations are taking place in the forested core of a hilly 40 km2 peninsula by the sea (up to 200 m amsl). Houses located on the periphery of the peninsula use wells for their water supply. This study served as a test case for a new framework proposed specifically to regulate oil and gas exploration and production activities. Significant concerns have been voiced in Quebec about such relatively new activities in the past few years. The study thus also aimed to provide a sound scientific perspective on the actual risk to groundwater resources related to oil and gas industry upstream activities. The study was based on the compilation of existing hydrogeological, geological and petroleum exploration data and on a field characterization. The field work involved 1) the installation of 17 observation wells and their hydraulic testing, including two fully-cored wells, 2) groundwater and surface water sampling in observation wells and more than 70 residential wells within a 2 km radius of a proposed new drill pad, and 3) geophysical logging of the open-hole observation wells. On all samples, chemical analyses involved major and minor inorganics, a wide range of organics, dissolved light hydrocarbon gases and CH4 isotopes, where present. More specialized analyses were done on observation wells (stable isotopes, tritium, 13C and 14C, noble gases, CFCs and SF6, organic acids). The hydrogeological conditions were then defined on the basis of existing and newly acquired data. Fracturing was found to control groundwater flow which is more intense in the upper 15 m of the rock aquifer. Recharge occurs on topographic highs where the rock is not covered by a low permeability glacial till, as found almost everywhere. Hydrogeochemical conditions were defined on the basis of a multivariate analysis of 16 chemical parameters. Quite wide variations in geochemistry were encountered, with evolved groundwater types affected by cation exchange or mixing with sea water. Groundwater residence time can thus be quite long, which may be due to the relatively high porosity (5-10%) of the rock. Methane is of mixed origin and preferentially associated with evolved water types. SALTFLOW, a variable-density flow and mass transport simulator, was used to represent the peninsula as well as the adjacent highlands in a 2D vertical section model. The interaction of the highland and peninsula recharge leads to nested flow systems with converging-diverging flow conditions under the peninsula, with a relatively shallow active flow zone. The observed and simulated conditions support a conceptual model that can be used to infer the level of risk for groundwater quality related to oil and gas industry activities.