

Estimates of Residence Time and Related Variations in Quality of Ground Water Beneath Submarine Base Bangor and Vicinity, Kitsap County, Washington

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ABSTRACT

Estimates of residence time of ground water beneath Submarine Base Bangor and vicinity ranged from less than 50 to 4,550 years before present, based on analysis of the environmental tracers tritium, chlorofluorocarbons (CFCs), and carbon-14 (^{14}C), in 33 ground-water samples collected from wells tapping the ground-water system. The concentrations of multiple environmental tracers tritium, CFCs, and ^{14}C were used to classify ground water as modern (recharged after 1953), pre-modern (recharged prior to 1953), or indeterminate. Estimates of the residence time of pre-modern ground water were based on evaluation of ^{14}C of dissolved inorganic carbon present in ground water using geochemical mass-transfer modeling to account for the interactions of the carbon in ground water with carbon of the aquifer sediments.

Ground-water samples were obtained from two extensive aquifers and from permeable interbeds within the thick confining unit separating the sampled aquifers. Estimates of ground-water residence time for all ground-water samples from the shallow aquifer were less than 45 years and were classified as modern. Estimates of the residence time of ground water in the permeable interbeds within the confining unit ranged from modern to 4,200 years and

varied spatially. Near the recharge area, residence times in the permeable interbeds typically were less than 800 years, whereas near the discharge area residence times were in excess of several thousand years. In the deeper aquifers, estimates of ground-water residence times typically were several thousand years but ranged from modern to 4,550 years. These estimates of ground-water residence time based on ^{14}C were often larger than estimates of ground-water residence time developed by particle-tracking analysis using a ground-water flow model. There were large uncertainties—on the order of 1,000-2,000 years—in the estimates based on ^{14}C . Modern ground-water tracers found in some samples from large-capacity production wells screened in the deeper aquifer may be the result of preferential ground-water pathways or induced downward flow caused by pumping stress.

Spatial variations in water quality were used to develop a conceptual model of chemical evolution of ground water. Stable isotope ratios of deuterium and oxygen-18 in the 33 ground-water samples were similar, indicating similar climatic conditions and source of precipitation recharge for all of the sampled ground water. Oxidation of organic matter and mineral dissolution increased the concentrations of dissolved inorganic carbon and common ions in downgradient ground waters. However, the largest concentrations were not found near areas of ground-water discharge, but at intermediate locations where organic carbon concentrations were greatest. Dissolved methane, derived from microbial methanogenesis, was present in some ground waters. Methanogenesis resulted in substantial alteration of the carbon isotopic composition of ground water.

The NETPATH geochemical model code was used to model mass-transfers of carbon affecting the ^{14}C estimate of ground-water residence time. Carbon sources in ground water include dispersed particulate organic matter present in the confining unit separating the two aquifers and methane present in some ground water. Carbonate minerals were not observed in the lithologic material of the ground-water system but may be present, because they have been found in the bedrock of stream drainages that contribute sediment to the study area.

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