From Rain through River Catchment to Aquifer: The Flow of Water through the Wairau Hydrologic System

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BIBLIOGRAPHIC REFERENCE

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Dissolved reactive phosphorus (DRP) and potassium (Figure 4.17c–d) show elevated concentrations only in groundwater with MRTs greater than one year. Concentrations in younger waters represent river water concentrations. Increasing concentrations with increasing MRT indicate geogenic sources, leaching from the soils and aquifer materials.

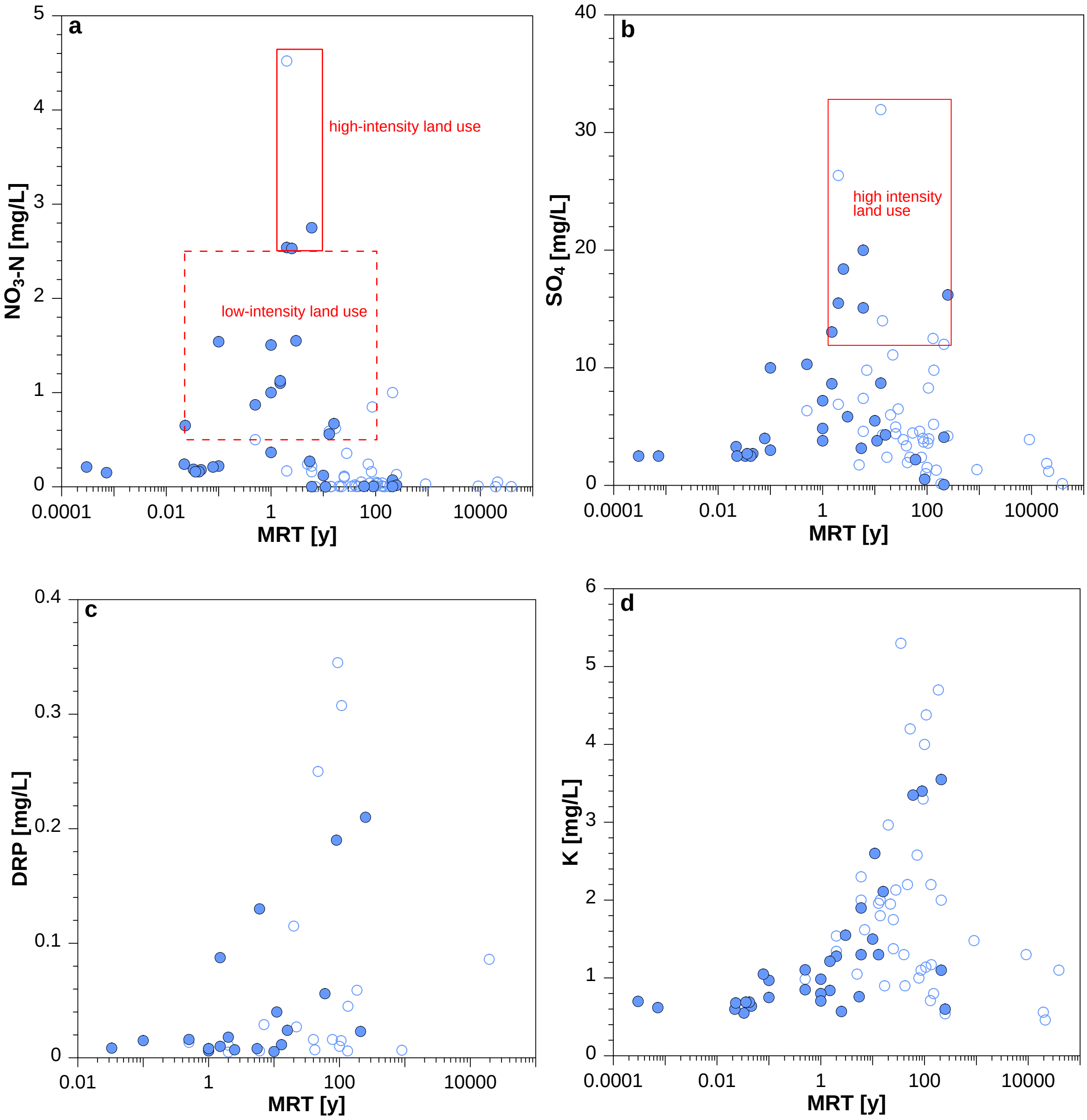

Figure 4.17 Nitrate (NO_3-N), sulphate (SO_4), dissolved reactive phosphorus (DRP) and potassium (K) concentrations versus MRT for the Wairau Plain groundwater. Red boxes indicating thresholds for low- and high-intensity land use are based on Morgenstern and Daughney (2012). This hydrochemistry data originates from various sources over time – solid blue circles indicate more robust recent data.

Overall, the groundwater data covering the last 140 years in Figure 4.17 allows robust identification of the impacts of land-use activities on groundwater quality in the Wairau Plain. About half of the young waters have elevated nitrate concentrations to cause environmental issues. No legacy nitrate load was identified, but the sample number is very low. Approximately 20% of the samples also show elevated SO_4 concentrations of up to 30 mg/L, which appear to also be related to high-intensity land use – SO_4 and NO_3-N are strongly correlated. DRP and potassium are elevated only in older groundwater, indicating geogenic sources. For spatial distributions of agricultural contamination, see Section 4.2.4.

4.2.3 Hydrochemistry Evolution

Figure 4.2 shows hydrochemical parameters that are part of minerals and usually leached from the aquifer material, therefore showing increasing concentrations with groundwater age. In the Wairau Plain groundwaters, all of these parameters show increasing concentrations with groundwater age. However, this data, across the entire Wairau Valley, including various geologic formations, shows only weak correlations between concentration and age, limiting their potential as an indicator of groundwater age and residence time. The best correlations are observed in groundwaters with MRTs < 100 years, likely because these represent the groundwaters from formations originating from similar evolutionary processes. In other areas of New Zealand, silica and dissolved reactive phosphorus (Figure 4.17) show stronger correlation between concentration and age, with greater potential to use these correlations as indicators of groundwater age (e.g. Morgenstern et al. 2015).

To identify hydrochemistry trends that were observed by Taylor et al. (1992) in the confined aquifer relative to distance to the confinement boundary, we marked the data from sites within the central flow path in the Wairau Aquifer with red inner circles in order to show the data from the formations that went through similar evolutionary processes and are hydraulically connected (Figure 4.18). Note that the transition from the unconfined Holocene gravels to the confined Pleistocene gravels is at about MRT = 1 year (Figure 4.4). Where reasonable correlations were obtained, these are shown by the red power fit curves together with their parameters.

Reasonable evolutionary hydrochemistry trends were observed along the central flow path throughout the Wairau Valley for Mg, Na and HCO_3. For SiO_2, a reasonable fit is observed only for the Pleistocene gravels, also found by Taylor et al. (1992). The relatively poor correlation of Si concentration with MRT ($R^2 = 0.5$), compared to other aquifers of New Zealand, may be a result of the narrow concentration range where relative measurement errors between the data become large.

None of these hydrochemistry parameters show elevated concentrations in the most recently recharged groundwater. Some of these parameters, for example, Mg, Ca and Na, are part of fertilisers and lime, and could therefore be indicative of impacts of high-intensity land use on groundwater quality. However, for the Wairau Aquifer, such an impact may not be detectable because, up to MRT = 1 year, the locally recharging groundwater is highly diluted by river-recharged water and, for MRT > 1 year, the aquifer is confined.

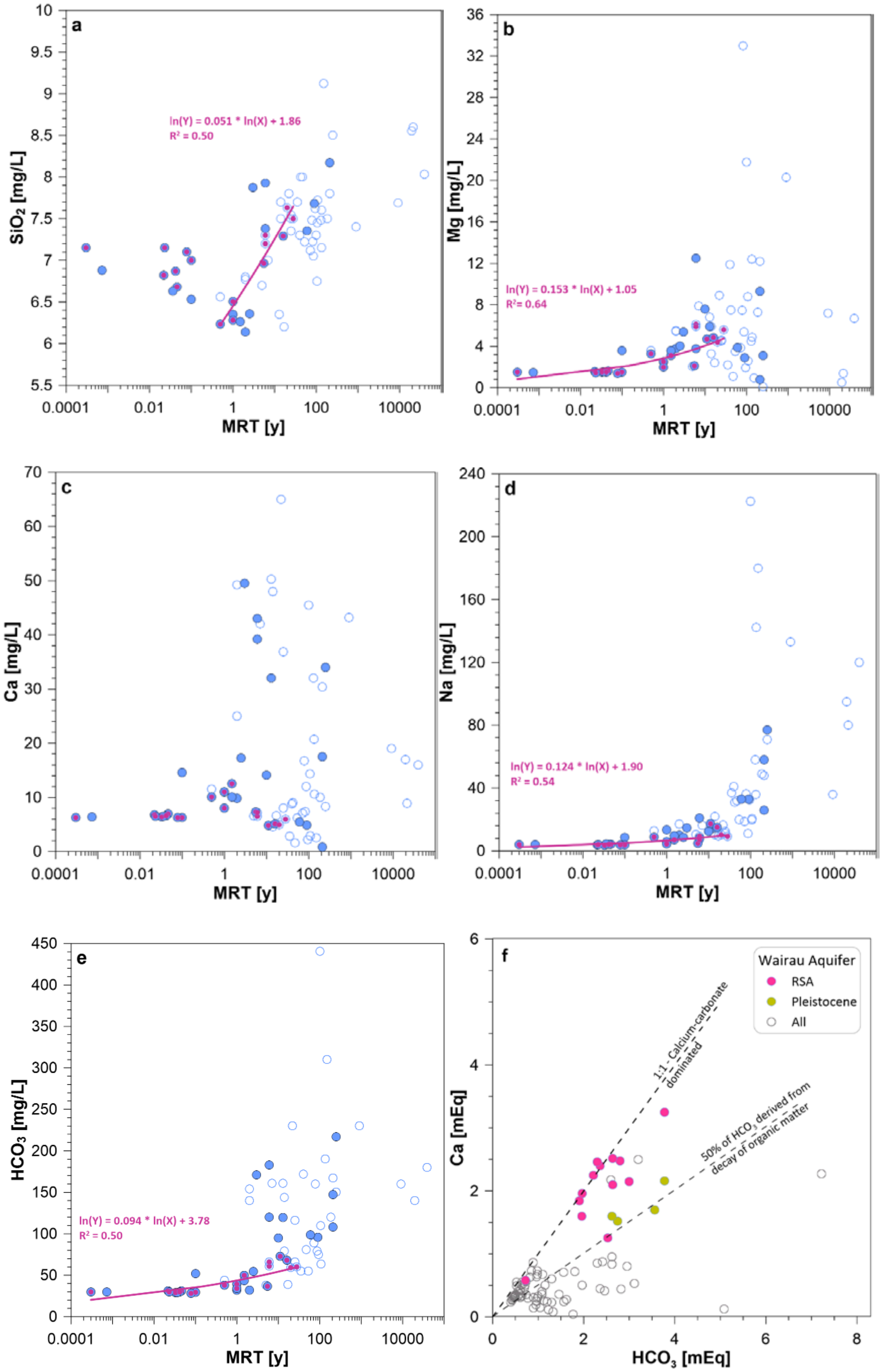

Figure 4.18 Silica (SiO_2), magnesium (Mg), calcium (Ca), sodium (Na) and bicarbonate (HCO_3) concentrations versus MRT for the Wairau Plain groundwater. This hydrochemistry data originates from various sources over time – solid blue circles indicate more robust recent data. Groundwater samples with red inner circles are from the central flow line; from formations that went through similar evolutionary processes and are hydraulically connected. f) shows Ca versus HCO_3 on a milli-equivalent basis.

4.2.4 Spatial Distribution of Selected Chemistry Parameters

In this section, examples of spatial distributions of chemistry parameters are shown that can inform recharge sources and flow patterns for the Wairau Plain groundwater system.

4.2.4.1 Chloride

Chloride (Cl) is a conservative tracer, without significant sources and sinks in the aquifer, and can be used to track natural flow patterns. Inland rain is characterised by significantly lower Cl concentrations compared to local coastal rain. Low Cl in groundwater therefore indicates recharge from inland rivers.

Low Cl concentrations in the Wairau Fan and in its confined extension to the coast (Figure 4.19 – dark green symbols) indicate without ambiguity that this groundwater has been recharged from the Wairau River, including the groundwater in the centre of the valley near the coast. Active groundwater flow there indicates that the Wairau Aquifer in the centre of the valley consists of gravels with high hydraulic conductivity up to the coast, also indicated by the evidence that these groundwaters are relatively young (Figure 4.4). The shallow wells in the vicinity of Omaka River contain water recharged from inland rivers.

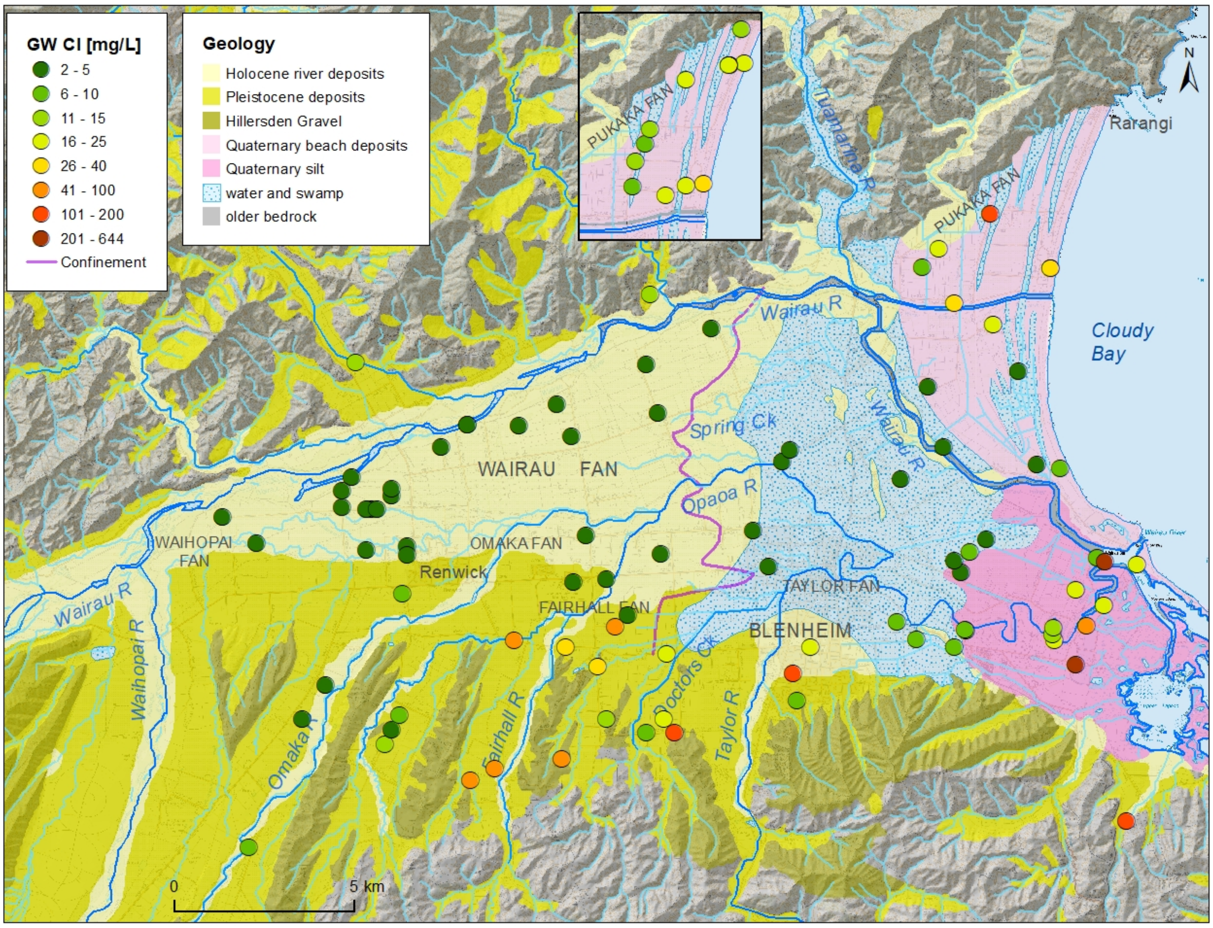

Figure 4.19 Spatial distribution of chloride (Cl) in the Wairau Plain groundwaters. The insert on the top shows Cl for the Rarangi Shallow Aquifer, while the main figure shows the Cl only in the confined aquifer in this area.

Groundwaters in the northern and southern parts of the coastal deposits are elevated in Cl, indicating coastal rain recharge, or connate water for the deeper wells with old water. The same applies to the wells in the Pleistocene deposits south of the Wairau Fan and north of the Wairau River. The elevated Cl concentration in the shallow wells of the Rarangi Shallow

Aquifer (Figure 4.19 insert) indicate local coastal rain recharge, with decreasing concentration with distance from the coast. Low-Cl water in the centre of the valley indicates that this part of the aquifer is connected to the Wairau Fan.

4.2.4.2 Nitrate

Nitrate (NO_3-N) is the most pervasive agricultural contaminant in New Zealand's groundwaters. Figure 4.20 shows that NO_3-N concentrations in the Wairau Plain groundwater are relatively low. NO_3-N contamination is not a major problem in Wairau Plain aquifers, with only moderate mixed and dairy farming land use until the late 1980s. Because land-use activities using NO_3-N are relatively uniform throughout the Wairau Plain, the NO_3-N distribution in the Wairau Plain is useful as an indicator of the recharge contribution from local rain versus river water. The Wairau River, discharging mainly from a pristine catchment, contains very little NO_3-N, approximately 0.1–0.2 mg/L NO_3-N.

Only the deeper and older highly anoxic groundwaters in the coastal deposits and in the Pleistocene deposits south of the Wairau Fan contain lower NO_3-N concentrations than those of the river, close to zero, due to complete denitrification reactions in these highly anoxic environments.

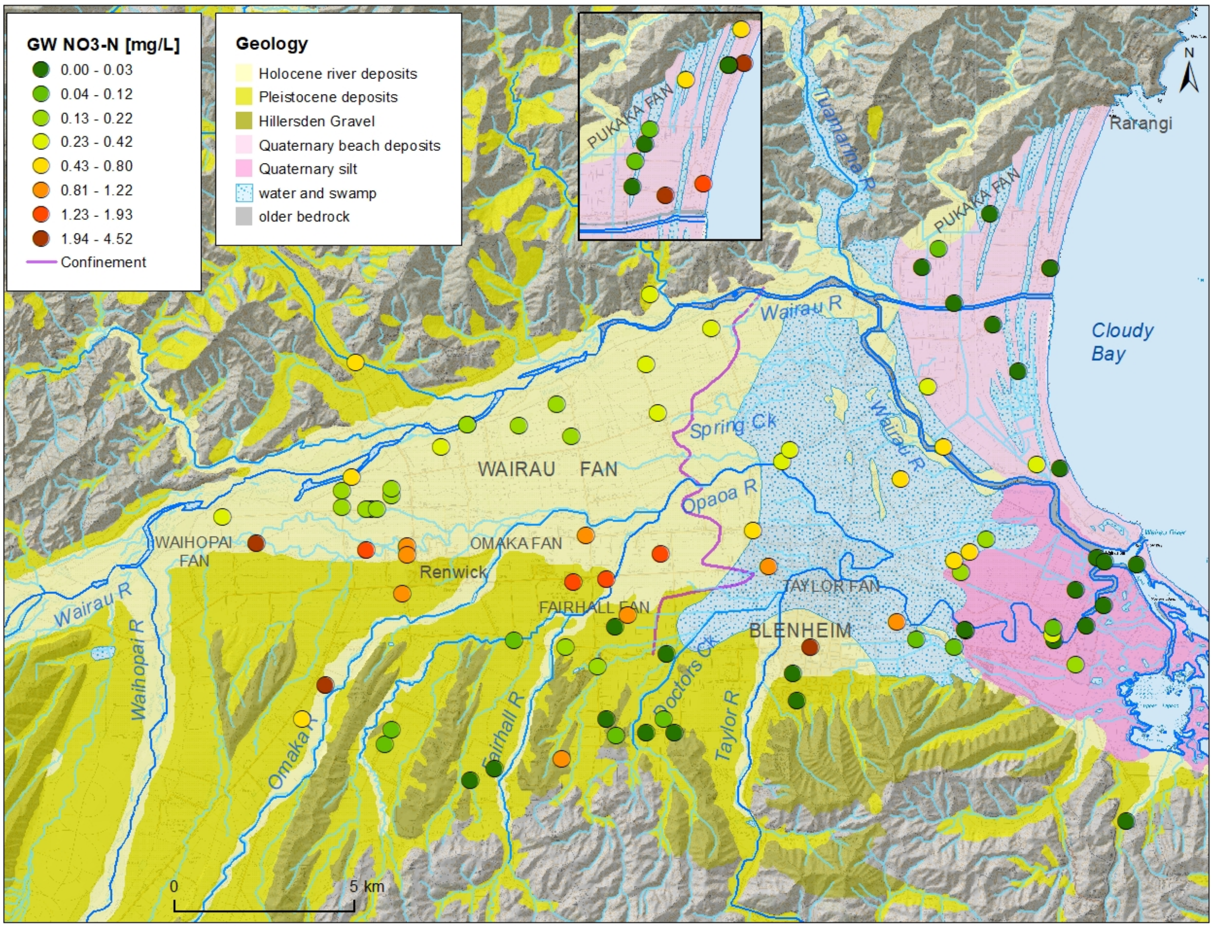

Figure 4.20 Spatial distribution of nitrate (NO_3-N) in the Wairau Plain groundwaters. The insert on the top shows NO_3-N for the Rarangi Shallow Aquifer, while the main figure shows the NO_3-N only in the confined aquifer in this area.