British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Groundwater – meltwater interaction in a proglacial aquifer

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**Groundwater plays a significant role in the hydrology of active glacial catchments. Evidence from SE Iceland shows a high permeability, high storage proglacial floodplain aquifer, in parts of which groundwater is closely coupled with glacial meltwater.**

## The Virkisjökull sandur aquifer

The Virkisjökull sandur (glacial floodplain) aquifer is formed of sediment outwash from the Virkisjökull glacier, which drains the Vatnajökull icecap in SE Iceland. Virkisjökull has been in retreat since the 1990s, with increasing retreat rates since 2007.

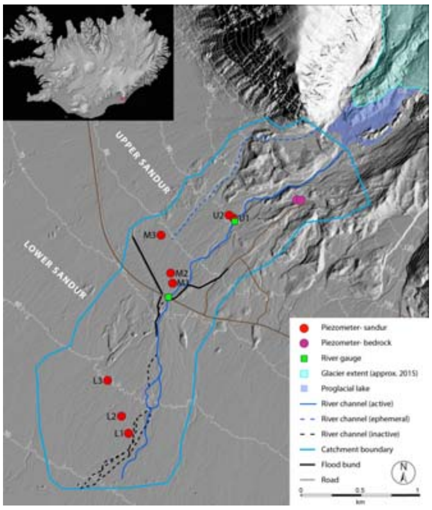
Geophysical evidence shows two aquifer layers: a shallow, lower density layer that thickens from ~20–30 m at its upper (near-glacier) edge to ~50–70 m in the lower sandur; and a deeper, higher density layer. The shallow sandur layer comprises loosely consolidated, moderately to poorly sorted, dominantly medium- to coarse-grained glaciofluvial sand, gravel and cobbles.

The Virkisá river flows across the sandur aquifer, draining all glacial meltwater and virtually all precipitation that falls on the glacier and its adjacent hillslopes and proglacial moraines.

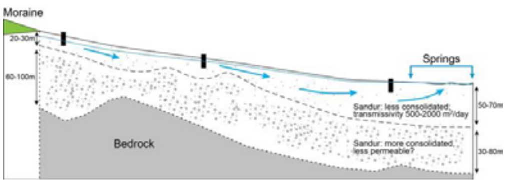
Drilling an investigation borehole on the sandur aquifer

Test pumping borehole by Virkisá river in upper sandur

Virkisá river in upper sandur



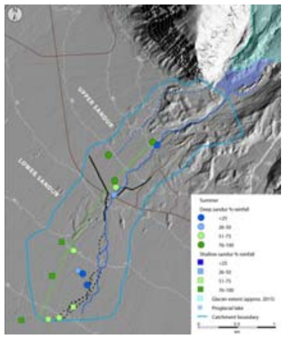

Virkisjökull sandur aquifer, showing location of the Virkisá river, groundwater investigation piezometers and river gauges




Schematic cross section illustrating 3D hydrogeology of Virkisjökull sandur aquifer , showing piezometer transects and indicative flow lines

## Stable isotopes and hydrochemistry

Stable isotope and chemical composition and temperature of ground- and surface waters vary significantly across the aquifer. Near the river, groundwater shows many signals of glacial meltwater: colder; more depleted in $\delta^{18}O$ and $\delta^{2}H$; and lower concentrations of SEC and $HCO_3$. Further from the river, groundwater has higher temperatures and concentrations of SEC and $HCO_3$ and less depleted stable isotopic composition. Mixing models indicate that groundwater close to the river is recharged dominantly by meltwater, particularly in summer; but that further from the river groundwater recharge is predominantly from local precipitation.



Mean proportion of $\delta^{2}H$ in groundwater derived from local precipitation in summer (May-Sept)

## Hydrogeology

The shallow sandur aquifer has high permeability (~30-300 m/d) and transmissivity (~200-2000 m²/d). Estimated groundwater storage in the aquifer is equivalent to at least ~25% of total annual flow in the Virkisá river.

The main groundwater flow direction is from upper to lower sandur, with a secondary flow direction from the catchment edge towards the river. Mean annual groundwater flow volumes are equivalent to 10-20% of annual river flow. Estimated recharge from local precipitation is high and is a strong control on groundwater levels across most of the aquifer – except close to the river – with high winter precipitation driving higher groundwater levels than in summer.

In the upper sandur, groundwater levels near the river are up to ~1 m lower than adjacent river stage, a difference that reduces down-sandur. From ~2 km down-sandur, groundwater levels are higher than river stage for much of the year, particularly in winter. These head gradients drive river recharge to groundwater in the upper sandur, most strongly in summer; and extensive groundwater discharge via springs and baseflow to the river channel across the lower sandur throughout the year, but most strongly in winter.

## Groundwater-meltwater interaction

The recharge of glacial meltwater from river to sandur aquifer forms a zone extending 20-500 m away from the river, in which groundwater level fluctuations, temperature and chemistry are more strongly influenced by glacial meltwater than by local precipitation. In the aquifer closest to the river at least 75% of groundwater is derived from meltwater recharge. Beyond this zone, there is little evidence for meltwater influence on groundwater.

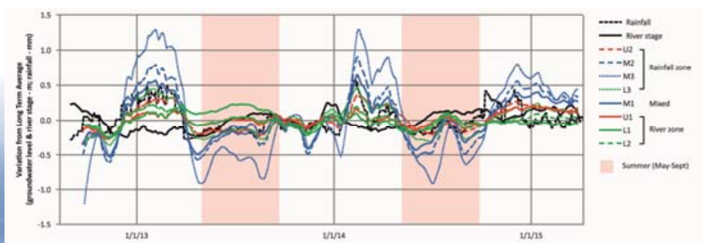
Groundwater flows are a significant contributor to river flow via springs and baseflow to the river, particularly across the lower sandur. These flows are perennial, but highest in winter. Recently published stable isotope data (MacDonald et al. 2016) indicate that groundwater discharge to the Virkisá river makes up at least 15-20% of river flows during winter.

## What about the future?

Glacial melt is predicted to increase in Iceland, which will initially increase summer meltwater flows, and potentially increase the extent of the zone of river influence on groundwater. Eventually, if glacial retreat is total, meltwater flows will decrease.

Winter precipitation and snow melt are predicted to increase, with a corresponding likely increase in winter recharge to the sandur aquifer. This could increase winter groundwater discharge via springs and baseflow to the Virkisá river.

A combination of decreasing meltwater flows and increasing winter and total precipitation is likely to increase the significance of groundwater storage in the sandur aquifer as a water resource and of groundwater discharge in maintaining environmental surface water flows.




Deviation of groundwater level, river stage and rainfall from their long term average

Groundwater discharging via a spring on the lower sandur

Groundwater discharge to river channel on the lower sandur

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