

Role of Bedrock Flow to Hillslope-Riparian Linkage in Forested Headwater Catchment

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Background

Constructing the hydrochemical models...
The chemistry of each subsurface source links to the streamwater chemistry

In Many Studies...

- Geographic-Sources of the streamflow
 - Throughfall
 - Soil water in Hillslope zone
 - Groundwater in Riparian zone
- Hillslope zone is the largest part of the catchment
- However, the chemical signature of the hillslope was not apparent in the stream
- Riparian zone is important for the hydrology and hydrochemistry (e.g., McGlynn et al., 1999; Gilliam, 1994)

⇒ Riparian Control

Bedrock Groundwater...

Bedrock flow is the dominant component of the baseflow (Walker Branch, USA) (Mulholland, 1993)

⇒ What is the role of Bedrock Groundwater?

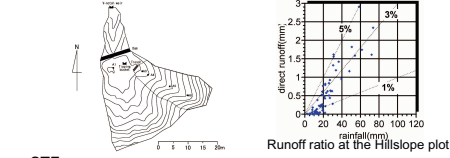


Kiryu Catchment

Hillslope Plot

Matsuzawa Catchment

Estimation of Bedrock Seepage: Water Budget at Hillslope plot



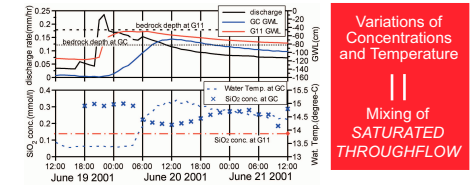
STF RUNOFF FROM THE HILLSLOPE PLOT WAS EPHEMERAL
RUNOFF RATIO WAS RARELY EXCEEDED 5%
ANNUAL EVAPOTRANSPIRATION IN KIRYU CATCHMENT IS 46% OF THE TOTAL RAINFALL (1972-2001)

$$R = Q + E + \Delta S + BS$$

100 5 46 0 49

Bedrock Seepage is CONSIDERABLE!!

Short-term SiO₂ variations during a rainstorm

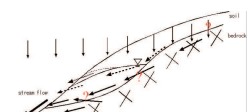


Variations of Concentrations and Temperature
Mixing of SATURATED THROUGHFLOW

STF OCCURRED AT G11 ⇒⇒⇒ GWL AT GC STARTED RISING
STF HAD LOW SiO₂ CONCENTRATION
CONC. DECLINED WHEN GWL APPROACHED THE BEDROCK DEPTH.
NOT WHEN THE GROUNDWATER LEVELS STARTED RISING
GROUNDWATER TEMP. ROSE SUDDENLY AT THE SAME TIME
SOIL TEMP. IS HIGHER NEAR THE SURFACE IN SUMMER

Objective

Linkage between Hillslope zone and Riparian zone is not well understood (Hooper, 2001)

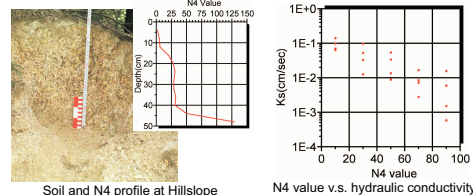


How much water infiltrate to bedrock?
Dynamics of Bedrock Groundwater?

WE CONSIDER THE ROLE OF BEDROCK GROUNDWATER ALONG THE HYDROLOGICAL AND HYDROCHEMICAL PROCESSES

Bedrock in this study...

N4 values in excess of 100 were defined as bedrock
N4 VALUE: THE NUMBER OF BLOWS REQUIRED FOR A 4-CM PENETRATION BY A CONE PENETROMETER WITH A CONE DIAMETER OF 9.5 MM, A WEIGHT OF 1.17 KG, AND FALL DISTANCE OF 20 CM

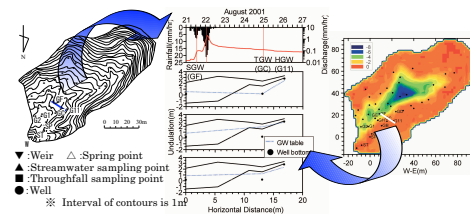


Soil and N4 profile at Hillslope

N4 value v.s. hydraulic conductivity

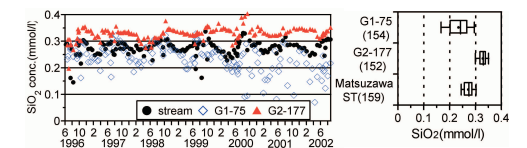
Bedrock in this study is PERMEABLE!!

Water movement from Hillslope to Groundwater body



SATURATED THROUGHFLOW GENERATED AT HILLSLOPE ZONE
GWL AT GC WAS RAISED OVER THE BEDROCK DEPTH
AND THE WATER MOVED TOWARD GF IN SGW
GROUNDWATER EXISTED WITHIN THE BEDROCK EVEN AFTER RAINFALL

SGW-Stream: Seasonal variations of SiO₂ concentration



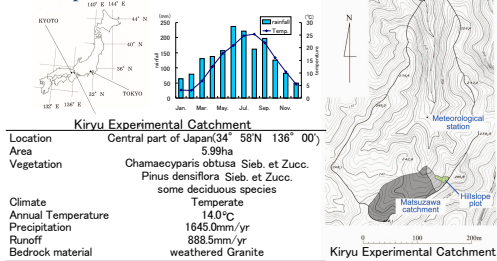
◇ SGW shallow (G1-75): Low concentrations, Large variations
▲ SGW deep (G2-177): High concentrations, Small variations
● Stream: Intermediate of G1-75 and G2-177, Large variations

In Riparian Zone...

SGW shallow layer: Large effects of Saturated Throughflow
SGW deep layer: Large effects of Bedrock Groundwater

Mixing → STREAM

Site Description

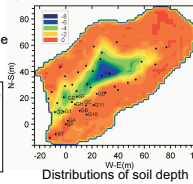


The classification of groundwater zone

Groundwater zone is grouped into three types depending on response of the GWLs to rainstorms (Ohte et al. 1995)

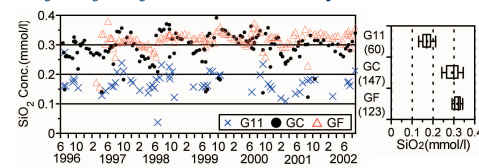
- 1. Saturated zone (SGW)**
Located around the spring point and groundwater always exist
- 2. Unsaturated hillslope zone (HGW)**
Located in upland hillslope and saturated throughflow occurred on the soil-bedrock interface only during rainstorms.
- 3. Transient saturated zone (TGW)**
Located at the edge of Saturated zone and saturated when Saturated zone enlarged with rainstorms.

SGW (blue-lime green) = Riparian zone
HGW (orange-red) = Hillslope zone
TGW (yellow-orange) = Linkage???



Distributions of soil depth

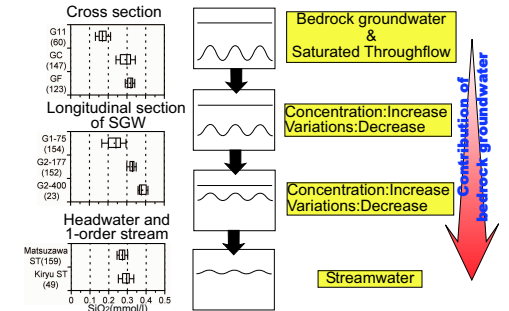
HGW-TGW-SGW: Seasonal variations of SiO₂ concentration



× HGW (G11): Low concentrations, Large variations
● TGW (GC): Intermediate of G11 and GF, Large variations
▲ SGW (GF): High concentrations, Small variations

With the Water Movement...
Concentration: Increase
Seasonality: Unchanged (Max. = September, Min. = March)
Variations: Decrease

Effects of Bedrock Groundwater on Streamwater



Observations

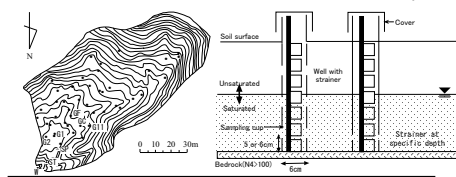
- at Hillslope plot...
 - generation of saturated throughflow (STF) at soil-bedrock interface
 - runoff rate of STF from the trench
- ⇒ Estimate the bedrock seepage at the hillslope zone

- at Headwater catchment (Matsuzawa Catchment)...
 - groundwater dynamics from the hillslope zone to the stream via the riparian zone
 - groundwater levels and chemistry

⇒ Examine the role of bedrock groundwater at each zone using SiO₂ tracer

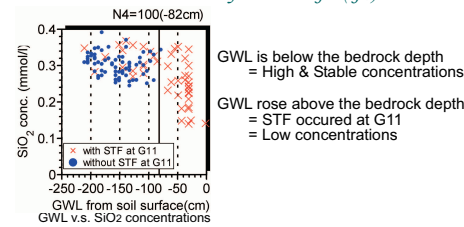
Observation Wells

Some wells are selected for discussion in this study



Point	Zone	Soil depth (cm)	Well depth (cm)	Comment
G11	HGW	40	49	Hillslope zone
GC	TGW	84	217	Drilled into the Bedrock!
GF	SGW	356	200	Center of SGW
G1-75	SGW Shallow Layer	468	75	Riparian zone
G2-177	SGW Deep Layer	448	177	Riparian zone

Vertical distributions of SiO₂ at TGW (GC)



N4=100(-82cm)
GWL is below the bedrock depth = High & Stable concentrations
GWL rose above the bedrock depth = STF occurred at G11 = Low concentrations

Bedrock groundwater: High conc. / Small variations
Saturated throughflow: Low conc. / Large variations
Vertical distributions below and above the bedrock

Conclusions

