Discharge Measurement

The resulting tracer breakthrough curve measured downstream arises typically from a background concentration to a constant value called the plateau concentration (Figure 1). Sampling is only permitted after the tracer has fully reached the constant plateau value at the end of the mixing section. One should remember that to obtain the plateau concentration downstream, the duration of pulse injection (T_{pulse}) has to be sufficiently long. The discharge is calculated as:

$$Q = \frac{q_{in}{}^{*}(c_{in} - c_b)}{(c_p - c_b)}$$

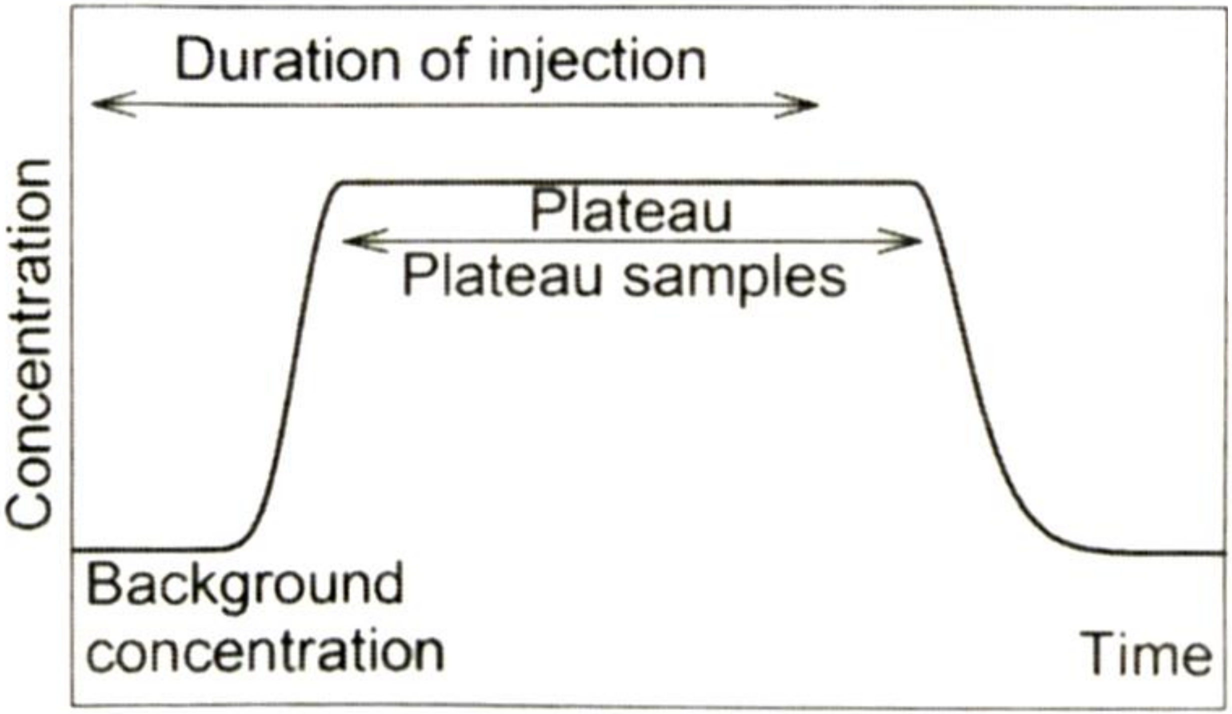
with q_{in} tracer solution inflow rate (l/s)

c_{in} tracer solution concentration (g/l)

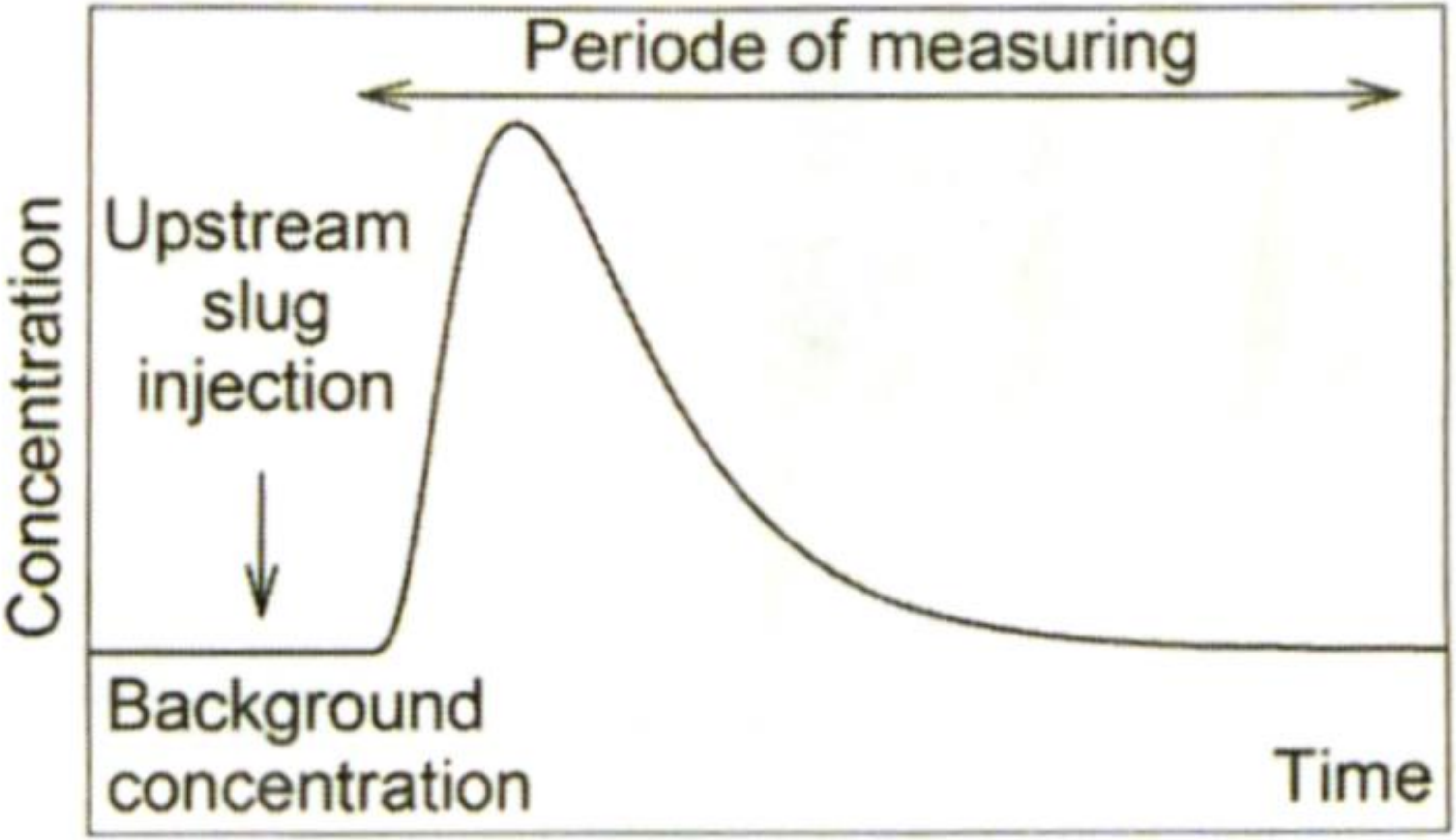
c_p measured sustained 'plateau' concentration (g/l)

c_b background concentration (g/l)

Discharge Measurement



Discharge Measurement



Discharge Measurement

$$Q = \frac{M}{\int_0^\infty (c(t) - c_b)\,dt}$$

with M injected tracer mass (g)

$c(t)$ measured concentration at time, t
c_b background concentration

Discharge Measurement

$$Q = \frac{M}{\int_0^\infty (c(t) - c_b)\, dt}$$

with M injected tracer mass (g)

$c(t)$	measured concentration at time, t
c_b	background concentration

Discharge Measurement

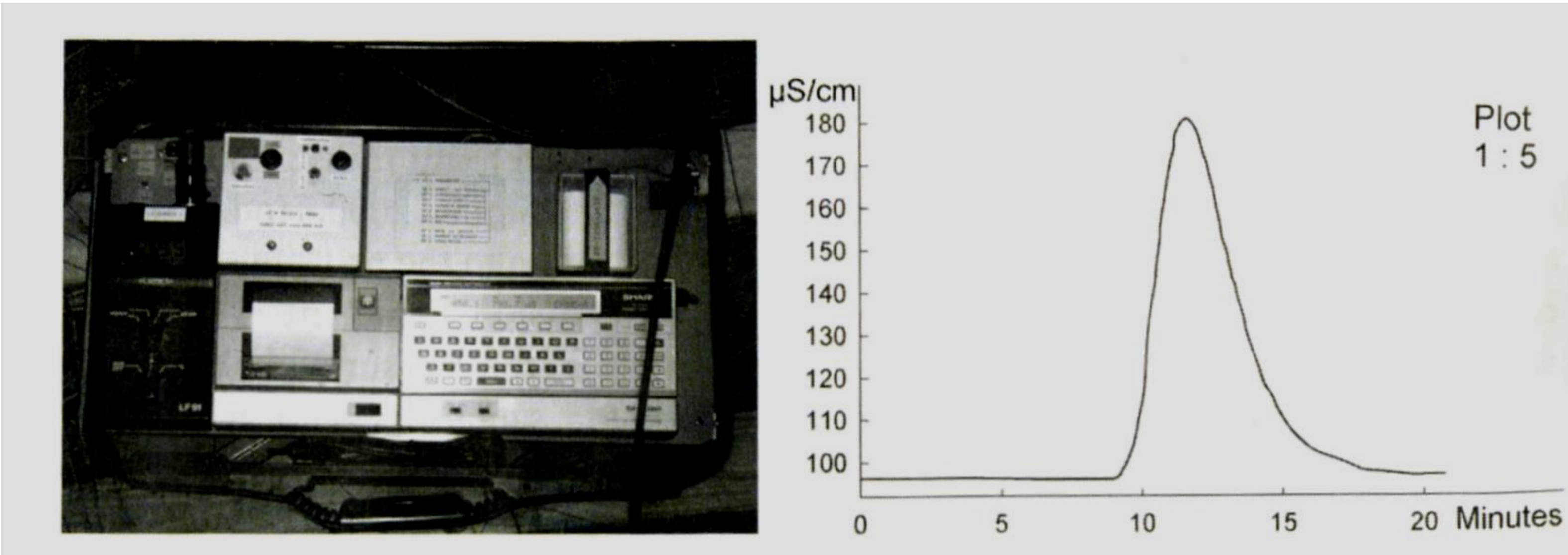
$$Q = \frac{M}{\sum_{i}^{N} (c_i - c_b)^* \Delta t_i}; \quad \text{i} - \text{samples}$$

with c_i	measured concentration at time, t_i
$\Delta t_i = (t_{i+1} - t_i)$	time interval between two collected samples
N	amount of samples

Discharge Measurement

	Advantage	Disadvantage
	Using salt tracer	
Slug injection	– Short measuring time – Direct calculation in situ – May be also achieved with simple techniques – Rather cheap equipment	– Only small discharge measurable – High masses of tracer needed due to usually high background concentrations
Constant rate injection	not recommended for salt tracers	
	Using fluorescent tracer	
Slug injection	– High discharge measurable – Small amount of tracer – Short measuring time	– Accuracy may be affected by sorption effects on suspended load – Accuracy may be affected by sorption effects on suspended load – Analysis in the laboratory if no field fluorometer is available
Constant rate injection	– High discharge measurable – High accuracy – Validation possible by repeat sampling	– Photolytical decay of tracers – Long measuring time – More tracer needed – Higher effort required for preparation of experiment

Discharge Measurement



Discharge Measurement

The experiment was carried out in clear river water using Uranine. As expected, the background concentration (c_b) was zero, as Uranine is not part of chemical compositions of natural waters. The tracer breakthrough was sampled at constant time intervals of exactly $\Delta t = (t_{i+1} - t_i) = 20$ s and analysed in the laboratory (Figure 6.13).

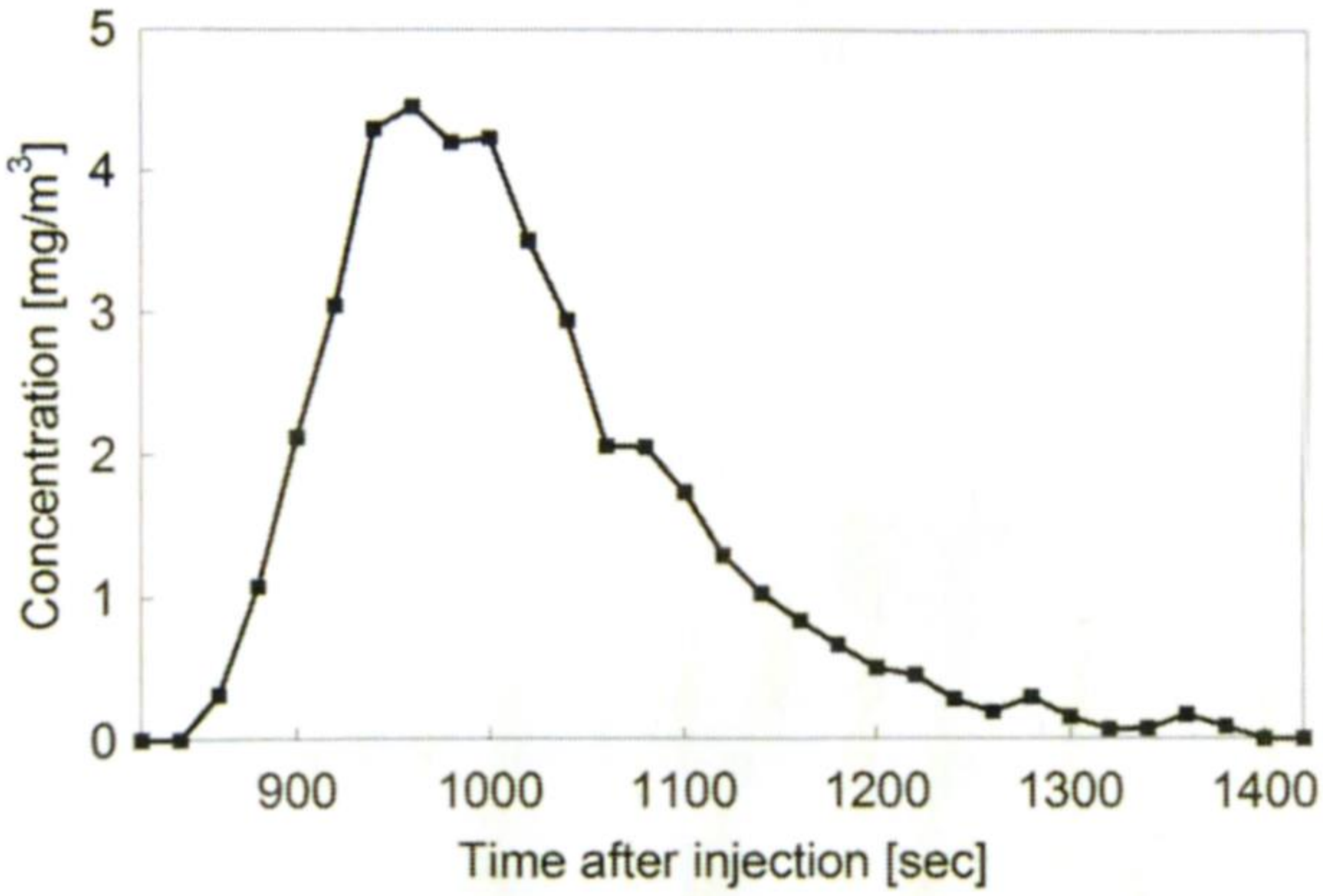
The injected tracer mass was M = 1 g Uranine. Altogether 27 samples were taken. According to Equation (6.9), the discharge is calculated as follows:

$$Q = \frac{M}{\sum_i (c_i \times \Delta t)} = \frac{1000000\,\mu g}{20s \times \sum_i c_i}$$

The sum of all products of measured concentrations ($\Sigma c_i \times \Delta t$) is 843.24 [$\mu$g × s/l], which yields the discharge of:

$$Q = \frac{1000000\,\mu g}{843.24\,\mu g/l/s} = 1186 l/s \approx 1.2\,m^3/s.$$

Discharge Measurement



Hydrograph Separation

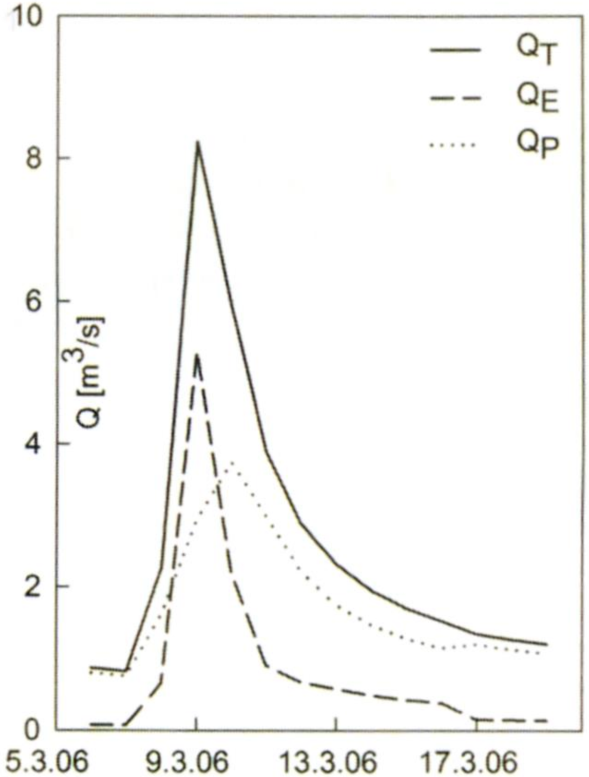


Figure Example for a hydrograph separation in event and pre-event water. Q = discharge and C = $\delta\ ^{18}O$ content of E = Event water, P = Pre-event water.

Hydrograph Separation

	Measured		Calculated	
Date	Q_T [m³/s]	C_T [‰ V-SMOW]	Q_E [m³/s]	Q_P [m³/s]
6/3/2006	0.87	−9.78	0.05	0.82
7/3/2006	0.82	−9.78	0.05	0.77
8/3/2006	2.27	−10.07	0.60	1.67
9/3/2006	8.27	−10.58	5.20	3.07
10/3/2006	5.93	−10.19	2.08	3.85
11/3/2006	3.89	−9.99	0.81	3.08
12/3/2006	2.88	−9.99	0.60	2.28
13/3/2006	2.32	−10.02	0.53	1.79
13/3/2006	1.95	−10.02	0.45	1.50
15/3/2006	1.70	−10.02	0.39	1.31
16/3/2006	1.53	−10.02	0.35	1.18
17/3/2006	1.35	−9.82	0.12	1.23
18/3/2006	1.27	−9.82	0.11	1.16
19/3/2006	1.21	−9.82	0.10	1.11

Hydrograph Separation

Separation of total discharge in event and pre-event water: assumed event water input: $C_E = -11.1‰$, assumed pre-event water (after low-flow period): $C_P = -9.7‰$

$$Q_T = Q_E + Q_P$$

$$Q_T{}^*C_T = Q_E{}^*C_E + Q_P{}^*C_P$$

$$\rightarrow$$

$$Q_E = Q_T \frac{C_T - C_P}{C_E - C_P}$$

$$Q_P = Q_T - Q_E$$

Planing a Tracer Test