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Spring monitoring manual for volunteers

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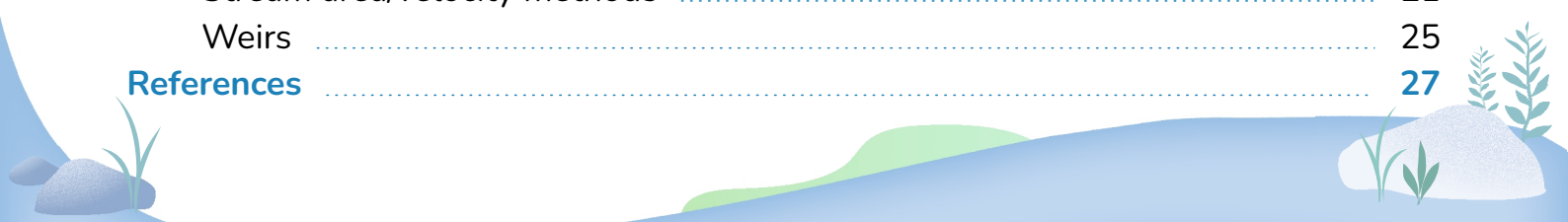
Web application:
allikad.info



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Why volunteer monitoring of springs?

The aim of volunteer monitoring is to help scientists and governmental institutions to collect new information about springs and spring water quality. The data obtained this way help to manage and protect springs. Without your participation, this would not be possible!

Why to study springs?

Clean water is becoming an increasingly scarce resource around the world. We have to consider the fact that the most of the water (~97%) on Earth is saline, and liquid freshwater comprises only about 0.8% of the total amount of water on Earth. Most of the freshwater occurs in the form of groundwater. Springs are natural outflows of groundwater - hence an important part of the water cycle. In Estonia and Latvia, the situation with water resources is still quite good, but climate change and increasingly intensive human activities (for example, using pesticides and fertilizers in agriculture, ditching, mining etc) are leaving their mark on the availability and quality of our water.

Though spring flows are small compared to rivers and lakes, by studying their temperature and water chemistry springs serve as a window into the earth - their properties reflect the flow path and the geologic setting of the aquifer feeding the spring. This makes springs especially convenient and an easy observation location for the health of the aquifer.

Springs produce some of the most pristine freshwater and have been used as the main water source during the troubled times. Artesian springs have high reliability of water flow and no seasonal variations.

Since ancient times, springs have been important sources of water and sacred places. People have a deep-rooted belief in the sacredness of the springs and local legends often speak about the healing effects of spring water. Numerous legends about the value of springs as a life-savers during the wartime or droughts go back thousands of years.

In Estonia and Latvia, we still do not know how many springs we have and there is very scarce or no information on the composition of spring water. In the 1930s, it was estimated that there were around 4,500 springs in Estonia; later, it has been assumed

that we could have as many as 15,000 springs. Today, there are just under 1,500 sources in national databases.

The wellbeing of groundwater and the springs as natural water sources has a huge impact on our daily lives - not only through the price of tap water - but we also need confirmation that spring water is clean and can be used in the future in the event of a drought or other emergency. Currently we do not know very well which residues of pesticides, nutrients or bacteria may have contaminated the springs. To maintain the water quality, protection of the springs and their catchment zone has to be ensured and monitoring of water quality has to be conducted regularly.

What is a spring?

A spring is a place where groundwater naturally flows out of the ground - sometimes only a trickle, sometimes temporarily after a rain event or as a perennial flow. Groundwater forms aquifers, which are underground water reservoirs. A spring is the result of an aquifer being filled to the point that the water overflows onto the land surface.

In general, there are two types of springs with many sub-types:

- **Gravity springs (descending springs, hillslope springs)** - emerge under unconfined conditions where the water table intersects the land surface. The water moves through the ground until it reaches a layer it can't penetrate and starts flowing horizontally until it reaches an opening and water comes out as a spring. Gravity springs are usually found along hillsides or on sandy or gravelly slopes. Gravity springs commonly form a spring run without a pool.
- **Artesian springs (rising springs, ascending springs)** - discharge under pressure due to confined conditions in the underlying aquifer. The pressure inside the confined aquifer (due to being confined between impermeable formations) is higher than the pressure outside the aquifer, so the water moves in that direction, preferably to converging to joints or faults perforating the upper confined layer. Artesian springs often discharge into a pool, in the bottom of which spring boils occur.

How to submit spring monitoring data?

All obtained monitoring data must be submitted through the web-based map application allikad.info. In order to use this application for adding new springs or new observations, you have to register and logged in. You can use allikad.info on site, using your smartphone or phablet, or fill the forms later at home with the help of a PC.



How to find springs?

Open our map application and look for the **📍 MARKERS**. Those are possible spring locations which need confirmation. Somebody has to go there, find the spring and mark it on the map.

Out in nature, there are several possibilities to find springs.

- Many small water streams are starting from the spring. Very good place for looking for springs is river valleys and all small streams joining with the main river.
- During the wintertime, especially when there is some snow and temperature is below zero, look for the open water. If some small stream or creek or pool of water is unfrozen, it will indicate that spring water is flowing into it. Each spring retains almost the same temperature regardless of the season.
- Quite often areas with lush vegetation growth are marking springs, especially if they are in valleys and lower areas. So look for the small green spots, where flowers, shrubberies and trees are thriving.
- Animal tracks are leading quite often also to a natural spring. So look for animal footprints and activities (grass burrows, mud holes etc).



How to recognise springs?

Not every natural pool of water is spring and not every stream starts from the spring. To make sure that the source of this water is groundwater, reached on the surface naturally, you have to look for pieces of evidence and try to answer some questions.

1. Is there any piece of evidence that at least in certain time of the year it has outflow?
2. Is the springwater significantly warmer or cooler than air temperature (depending on the season)? (Springwater is quite often about 7-10 degrees).
3. It does not freeze in winter when the temperature has been below zero for a reasonable amount of time.



How to describe a spring?

While describing a spring, one should pay attention to and describe the the following aspects:

- Is there outflow from the spring?
- Does the spring form a pool or does it flow out from the surface as a small stream?
- If it forms a small stream, then does it have a single outflow point, several discrete outflow points, or there are no discrete outflow points, but the water seeps to the surface diffusely from a larger area?
- If the spring forms a pool, then are there "boiling" spots in the bottom of the pool. If yes, then how many?
- What is the bottom substrate of the spring? Is it sand, mud, etc., are there glittering flakes in the bottom of the spring? Are there any porous lime concretions (tufa) at the bottom of the spring?

- Are there plants growing inside the spring, or in the case of diffuse seepage, on the spring area? If yes, can you name the species? Are there algae growing in the spring?
- Is there any ochre (slimy brown iron-rich sediment) in the spring?
- What do the surroundings of the spring look like? Is the spring situated in a forest, mire, on a field, grassland, in a ditch, in a settlement, etc.?
- Is the spring in a natural condition, or is it surrounded by a concrete, wooden, etc., harness?
- Are there man-made objects inside the spring or around the spring - e.g. money, trash, a cup?
- How accessible is the spring? Does a path lead to the spring, or it requires an effort to reach the spring? Is there any infrastructure for visitors around the spring?
- Is the spring accessible to everyone, or is it located in a closed territory or inside a yard area?



How to photograph springs?

Every photograph is a record of a particular site at a particular time. Any picture tells a story, but to get a good monitoring photo you have to consider some important points discussed below.

Ground-based photo monitoring is a fast, simple, and effective way to determine relatively slow changes in nature. They will build up into a valuable record. Photo monitoring may be divided into two directions:

1. **comparison photos**, whereby a photograph is used to compare a known condition or to estimate some parameter (e.g. water level);
2. **repeat photographs**, whereby several pictures are taken of the exact same location over time to detect change. Comparing recent photographs with older ones provides valuable historical evidence, the photos will show landscape, vegetation, shoreline, human influence etc.

So in short photo monitoring can help to:

- record changes over time
- relate these changes to climate/environment/anthropogenic changes
- document the extent and severity of extreme events
- develop a benchmark against which future changes can be measured
- show up a problem when it is still small
- developing a better understanding of cause and effect

When taking pictures keep in mind some basic rules:

- More is not necessarily better.
- If possible take photos on a cloudy but bright day. This allows a clearer picture without too many shadows.
- If available, look at previous photos of the same spring to ensure that the new photo will be framed the same way as the older ones (if possible use the same angle).
- To ensure that the location of photos is the same, use a particular tree or some other easily recognisable item for a guide.
- Take photos of the spring from different directions and make sure that surrounding landscape and vegetation is also visible.
- Photos of an area can show changes over time. If previous photos were taken just a few days ago and are of good quality, it's no point to add new exactly similar photos.



How to evaluate spring water properties?

How to characterize the spring water quality?

To characterize the spring water without analytical instruments, one's own perception can already say much about the water - feel the temperature with your hand, taste the water, smell it and describe what you can perceive.

Try to feel the temperature of the water. Is it noticeably different from air temperature?

For water tasting we suggest to use a scale suggested by The U.S. Geological Survey (USGS):

- Tastes fine, no complaints
- Metallic, like iron or rust
- Earthy or mouldy
- Smells and tastes like rotten eggs
- Tastes sweet

Smell the water and describe the odour.

Describe the colour and turbidity of the water - is it clean or muddy, has specific colour etc.

If you have a container or bottle with you (made of transparent, colorless material), fill it with water and place it in front of white sheet of paper. Describe the color.

How to measure spring water quality?

For spring water quality monitoring the approach can be either temporal or spatial. For getting high quality time series from one spring, the measurement cycle should be once a month or at least once in every season. For getting an overview of the general water quality in the region, even one measurement campaign from every spring in the vicinity is a viable option.

Depending on the availability of the equipment (measuring devices, testing kits etc) and your skills, there is a wide range of possibilities to conduct water quality measurements. Easiest and more widely available is temperature.

Do you have any means for measurements?

- Water temperature (thermometer, electronic temperature meter)
- pH (pH-meter, colorimetric test, strip test kit)
- Electrical conductivity and specific conductance (conductivity meter)
- Total dissolved solids (conductivity meter)
- Dissolved oxygen (electronic oximeter, colorimetric test)
- Redox potential (multiparameter water quality sensor)
- Alkalinity (alkalinity titration kit)
- Nitrates (nitrates titration kit, strip test kit)

Water temperature

Importance

Water temperature is one of the most important characteristics of spring water. Groundwater usually features a year-round water temperature (6-9 °C; median 8.8 °C) similar to the annual air temperature. In winter, the groundwater temperature is usually higher compared to the air temperature, and in summer, when the surface water temperature follows the daily average air temperature, groundwater temperature is noticeably lower. This makes water temperature a versatile indicator for detecting

groundwater discharge. In spring and autumn, there is a transitional period when the surface water and groundwater temperatures are similar to mean daily air temperature.

Water temperature affects:

- The solubility of oxygen and other essential dissolved gases crucial for life in water. The solubility of dissolved oxygen decreases with increasing water temperature;
- Chemical reactions. The rate of chemical reactions increases with increasing water temperature. A relevant example of this is the temperature dependence of the electrical conductivity of water;
- Temperature affects biological processes, such as metabolism, growth, and reproduction. Aquatic species usually have a limited habitable temperature interval.

How to measure?

Water temperature reading can be obtained by using a calibrated alcohol-filled thermometer or an electronic temperature meter. The measurement should be carried out in flowing water as close to the spring resurgence as possible. A string tied to the thermometer can be used if the water is out of reach. Immerse the thermometer in the flowing water and wait until the reading stabilizes. It may take several minutes, depending on the type of device you are using. At first, it should be at least three minutes. The temperature reading can change quickly once the thermometer is out of the water, especially if the air temperature is significantly different from the water temperature, thus, write down the reading quickly. The preferred practice is to obtain the temperature reading while the thermometer or probe is still in the water. If this is not possible, use a beaker or a bucket filled with the sample water to obtain a reading away from the spring (as quickly as possible). After the first measurement, take two more with one minute intervals and write down the average of the three measurements.



pH

Importance

pH is a measure of the logarithmic concentration of hydrogen (H^+) and hydroxide (OH^-) ions which are expressed in the acidity or alkalinity of the water. The acid and base balance of water will influence the speciation and mobility of minerals/ions, thus, affecting most geochemical and biochemical processes that take place in water. Aquatic species commonly have a narrow tolerance range in pH. Low (<6.5) and high (>8.0) pH environments might be stressful to the majority of aquatic life. However, some ecosystems have adapted to extreme conditions, for example the ones that inhabit acidic bogs and alkaline fens. The pH in groundwater may range from pH 6 to 9, while it commonly averages at pH of 7.7.

How to measure?

pH is commonly measured using a hand-held pH-meter in logarithmic pH units (scale pH 0-14). The measurement should be carried out in flowing water as close to the spring resurgence as possible. Like in the case of measuring water temperature and dissolved oxygen, the pH sensor needs to be immersed in flowing water long enough to ensure the stabilization of the reading. Obtain a reading while the pH probe is still immersed in the water. If this is not possible, use a beaker or a bucket filled with the sample water to obtain a reading away from the spring (as quickly as possible). pH sensors generally have a limited lifetime and are susceptible to calibration drift, thus, they must be calibrated on a daily basis. If a pH-meter is not available, a colorimetric test or a strip test kit would be a viable alternative.



Electrical conductivity and specific conductance

Importance

Electrical conductivity (EC) is a measurement of the ability of water to carry an electrical current, which is primarily dependent on the amount of dissolved ions in the water. EC is highly dependent on the temperature of the water, thus, a temperature compensated (default is 25 °C) parameter, also known as **specific conductance** (SEC), is typically used for the comparability of the measurements. SEC may provide insight into the origin of the water. Rainwater and the water in bogs usually feature a low SEC (10-250 µS/cm) while the SEC of groundwater in shallow aquifers usually falls between 400 to 800 µS/cm, with the median and average of 550 and 650 µS/cm, respectively. The SEC of groundwater in the deeper aquifers and seawater may range from 1000 to more than 10000 µS/cm. Unexpectedly high SEC reading in surface water or groundwater may be a sign of pollution.

How to measure?

EC and SEC are measured using a hand-held conductivity meter (expressed in µS/cm). Most modern conductivity meters automatically provide a SEC value based on the EC and temperature measurement. If your device does not automatically provide the SEC value, it can be calculated manually by determining the EC and temperature of water and using a default temperature coefficient of 1.91%. SEC can be calculated as follows:

$$\text{SEC (25°C)} = \text{EC} / (1 + 0,0191 \times (T - 25)),$$

where $1 + 0,01191$ is the temperature coefficient and T is the measured water temperature.

The measurement should be carried out in flowing water as close to the spring resurgence as possible. Obtain a reading while the probe is still immersed in the water. If this is not possible, use a beaker or a bucket filled with the sample water to obtain a reading away from the spring (as quickly as possible).

The meter should be kept clean, have fresh batteries, and calibrated on a regular basis following the manufacturer's recommendation. Although generally more robust parameters than pH, for example, the same routine should be followed when measuring EC and SEC.

Total dissolved solids

Importance

As the ability of water to carry an electrical current is primarily dependent on the amount of dissolved ions, SEC can be used to estimate the **total dissolved solids** (TDS) content in the water (expressed in mg/l). TDS is mainly made up of inorganic salts formed from the major cations found in water (Ca^{2+} , Mg^{2+} , Na^+ , and K^+), the complementary anions (HCO_3^- , SO_4^{2-} , and Cl^-), and any neutral or uncharged compounds like dissolved silica (H_4SiO_4), including colloids and even organic matter. Shallow groundwater usually features a TDS in the range of 300 to 600 mg/l, while mineral water featuring TDS above 2000 mg/l, can be found in deeper aquifers.

How to measure?

TDS is measured by using a hand-held conductivity meter in mg/l. Most modern conductivity meters automatically provide a TDS reading based on the EC and temperature measurement. Although there is generally a strong linear relationship between EC and TDS, solutions with the same EC reading but with different prevailing dissolved ionic species will feature a slightly different TDS concentration due to the difference in molecular weights. Thus, a conversion factor in the range from 0.55-0.8 is used depending on the composition. However, we suggest using a conversion factor of **0.65** as it is the most commonly used factor for freshwater. TDS is calculated from the SEC as follows:

$$\text{TDS} = \text{SEC} \times 0,65$$

The measurement should be carried out in flowing water as close to the spring resurgence as possible. Obtain a reading while the probe is still immersed in the water. If this is not possible, use a beaker or a bucket filled with the sample water to obtain a reading away from the spring (as quickly as possible).

The meter should be kept clean, have fresh batteries, and calibrated on a regular basis following the manufacturer's recommendation.

Dissolved oxygen

Importance

Dissolved oxygen (DO) is a measure of how much free oxygen is dissolved in the water. DO in water primarily originates from the atmosphere and photosynthesis. DO is vital for living aquatic organisms. DO concentration in water regulates the valence state and mobility of trace metals, as well as constrains the bacterial metabolism of dissolved organic species. DO is often considered to be absent in the saturated zone of the aquifer due to bacterial reduction, giving way to the reduction of nitrate, mobilization of manganese and iron (e.g. redox ladder). Thus, DO can be an indicator for identifying groundwater originating from the saturated zone. However, some DO is not rare in shallow groundwater, especially in shallow karst aquifers, where the flow is rapid and turbulent. Commonly the DO concentration and the percent of air saturation in shallow groundwater ranges from 0.3 to 3.5 mg/l and 3 to 17 %, respectively.

How to measure?

DO is commonly measured by using an electronic oximeter with either an electrochemical or optical sensor. Most modern oximeters report both the DO concentration in mg/l or ppm and the percent of air saturation. The measurement should be carried out in flowing water as close to the spring resurgence as possible. Obtain a reading while the probe is still immersed in the water. If this is not possible, use a beaker or a bucket filled with the sample water to obtain a reading away from the spring (as quickly as possible). Like in the case of measuring pH, the DO sensor needs to be submerged in flowing water long enough to ensure the stabilization of the reading. DO sensors generally have a limited lifetime and are susceptible to calibration drift, thus, they must be calibrated on a daily basis.

If an oximeter is not available, a colorimetric test is a viable alternative. The indigo carmine and the rhodazine D method are the two approved colorimetric methods. Both use colorimetric reagents that react and change color when they react with oxygen in the water. The DO concentration is determined with a spectrophotometer, colorimeter or a simple comparator.

Redox potential

Importance

Redox potential (ORP) is a measure of the oxidizing or reducing potential of a water environment. Just like pH describes the hydrogen activity, ORP characterizes the electron activity, which controls many crucial redox processes in water (e.g. nitrification, iron and sulfate reduction etc.). ORP is directly related to the amount of DO in the water, as well as other oxidants that function similarly to oxygen. For example, ORP of less than -100 mV indicates the water environment is anaerobic, while values greater than 100 mV indicate aerobic conditions. As an example, arsenic and manganese are more likely to be mobile and present in toxic concentrations in anoxic groundwater, while concentrations of uranium, selenium, and nitrate are likely to exceed threshold levels in oxic groundwater.

How to measure?

ORP is measured by using a multiparameter water quality meter also featuring a pH sensor or a combined pH/ORP sensor (expressed in mV). The measurement should be carried out in flowing water as close to the spring resurgence as possible. Obtain a reading while the probe is still immersed in the water. If this is not possible, use a beaker or a bucket filled with the sample water to obtain a reading away from the spring (as quickly as possible). Like in the case of measuring pH, the ORP or pH/ORP sensor needs to be submerged in flowing water long enough to ensure the stabilization of the reading. Just like pH sensors, ORP or pH/ORP sensors generally have a limited lifetime and are susceptible to calibration drift, thus, they must be calibrated on a daily basis.



Alkalinity

Importance

Alkalinity refers to the capacity of water to neutralize acid. In uncontaminated groundwater, alkalinity is primarily a measure of dissolved HCO_3^- ion (if $\text{pH} > 4,5$) and CO_3^{2-} ion (if $\text{pH} > 8,3$) concentrations. Alkalinity is often referred to as the buffering capacity of a water body, a measure of the ability to neutralize acids and bases, and thereby maintain a stable pH which is vital for the dependent ecosystem. This is because CO_3^{2-} and HCO_3^- ions can neutralize two and one hydrogen ions present in water.

In groundwater, the alkalinity comes mostly from the dissolution of carbonate minerals. HCO_3^- concentrations in groundwater commonly range from 150 to 350 mg/l.

How to measure?

Alkalinity is measured by collecting a water sample, and measuring the amount of acid needed to bring the sample down to a pH of 4.2 (pH indicator methyl orange endpoint). At this pH all the alkaline compounds in the sample are "used up". The result is reported as mg/l of CaCO_3 . By multiplying the result by 1.22, you get the HCO_3^- concentration of the water. We recommend to use one of the many easy-to-handle commercial alkalinity titration kits available, for example: MACHERY-NAGEL VISOCOLOR HE Alkalinity AL 7, Hach AL-AP, Hach AL-DT or similar. The sample should be obtained from flowing water as close to the spring resurgence as possible. Use a pre-washed/rinsed (using the sample water) bottle, syringe, beaker or a bucket to collect the sample water to carry out the titration. The titration procedure should be performed as soon as possible.



Nitrates

Importance

Nitrogen is an important nutrient to all living things. Although naturally occurring in groundwater in low concentrations, intensifying human activities, in particular the excessive fertilizer use in agriculture, has led to the widespread pollution of groundwater with nitrogen compounds. Nitrate is the most commonly occurring form of nitrogen, mobile in aerobic groundwater. In anoxic conditions nitrate is reduced to nitrogen gas. Excess nitrate concentrations in groundwater cause eutrophication in dependent ecosystems, which in turn may lead to oxygen depletion and the consequent death of fish and small aquatic animals. Long-term consumption of drinking water with high nitrate concentrations may also be harmful to humans, especially for infants. Nitrate concentrations in groundwater normally range up to about 10 mg/l, while in agricultural areas it may well exceed 50 mg/l.

How to measure?

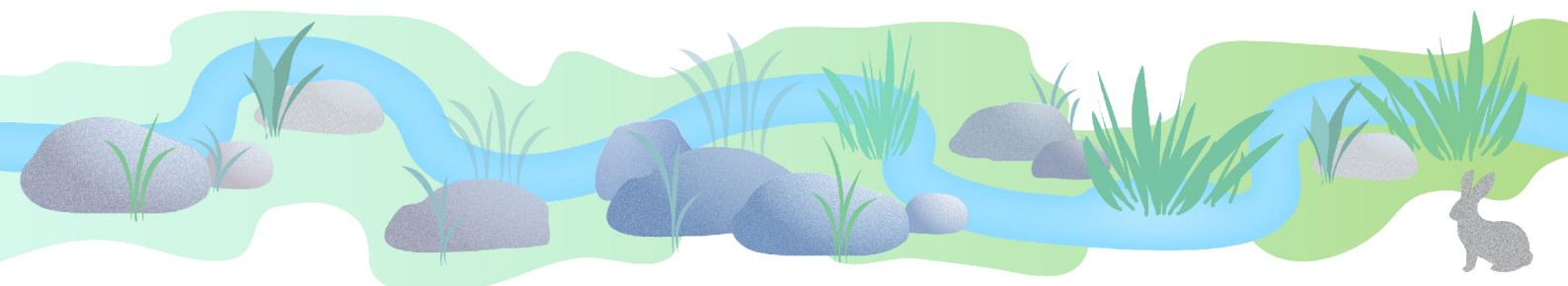
In field conditions, nitrate concentration is commonly measured using a colorimetric test kit implementing the cadmium reduction method. We recommend using one of the many easy-to-handle commercial test kits available, for example: Hach NI-11, NI-12 or similar. The sample should be obtained from flowing water as close to the spring resurgence as possible. Use a pre-washed/rinsed (using the sample water) bottle, syringe, beaker or a bucket to collect the sample water to carry out the analysis. In case you want to analyze the sample later in the laboratory, collect the sample in a bottle. Until the analysis, keep the bottle in a cold box in the field or in a refrigerator indoors at 4°C. Conduct the analysis within 48 hours from sampling.



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How to measure spring discharge?

Measuring spring discharge (stream flow) is crucial for understanding the functioning of an aquifer and the availability of groundwater resources. Moreover, the continuity of flow is crucial for maintaining a water supply for the human population, or sustaining groundwater dependent ecosystems. The amount of water discharged from a spring is expected to vary seasonally, thus, in order to get a detailed overview of the dynamics of groundwater flow, it is necessary to carry out measurements in all seasons.

Spring discharge is a function of water volume and velocity, e.g. it is the volume of water that flows through a certain area (cross-section of the flow channel) in a specific unit of time. Discharge is commonly expressed in cubic meters per second (m^3/s) or liters per second (l/s). Field conditions are rarely ideal for discharge measurements. Moreover, as discharge may vary seasonally, the measurement may require a situation-based approach.



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Volumetric method

Equipment: stopwatch (phone) for measuring time, larger container with a known volume (e.g. 10 l bucket).

If the spring is small and outflow is clearly distinguishable, it may be possible to dam the spring and collect the flowing water into the container or bucket. In some cases, when people are using the spring water it may be already dammed in some way and the possibility to collect the water is easily available. This way you can conduct direct volumetric measurement. In this case discharge (Q , l/s) can be calculated as follows:

$$Q = \frac{V}{T}$$

Where V (l) is the volume of the container and T (s) is the time it took filling the container.



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Stream area/velocity methods

Equipment: stopwatch (phone) for measuring time, measuring tape, floater.

For springs with larger water flow (higher discharge magnitude, ~10 l/sek and more) the simplest method for finding spring discharge is to use a floating object (stick, apple, pine cone, etc.) to measure stream velocity. This method works best in streams with a clearly distinguishable shoreline, clean streambed and calm water. If there is too much wind and the surface of the water is rough, the float may not travel at the normal speed.

Stick (float) method with low accuracy

For finding spring discharge (Q) you need to measure time (T , in seconds) required for the stick to float downstreams from one cross-section to another, distance between cross-sections (S , in meters), average depth (D_{average} , in meters) and width (W , in meters) of the stream channel.

1. First step is to find a suitable section of the stream channel for conducting the water velocity measurements. Stream stretch chosen for the measurement should be as straight (no bends) as possible and preferably with a clearly distinguishable shoreline and at least 10 cm deep. Minimal distance between measurement transects is 3 meters, more is better. It is suggested to use full numbers (3 m, 4 m, 5 m etc). Streambed should be even and without rocks, vegetation etc if possible.
2. Use measuring tape or other means to measure and mark locations of the two transects - use rope and draw it perpendicularly over the stream. Or use some sticks or stones to make markings on the shore.
3. Measure the width of the stream (W , in meters) between transects in a number of places. Calculate the average value (W_{average} , in meters).
4. Measure the water depth (D , in m) of the stream at several points along its width. Take half of the deepest measurement as an approximation of the average depth (D_{average}).

5. For stream velocity (v , in m/sek) you have to measure time (T , in seconds) required for the stick to float downstreams from one cross-section to another. Stick must be placed or thrown to the water at least one meter upstream in order to let it stabilise and to have some reaction time to start the timer.
6. It is important to replicate flow measurements in order to get trustworthy mean value. Ideal would be to conduct at least 3-6 measurements. Calculate the average value (T_{average} , in sek).
7. Calculate velocity (v) by dividing the distance between cross-sections (S) by average time (T_{average}).

$$v = \frac{S}{T}$$

8. To calculate the water discharge (Q , in l/s) multiply the average water velocity (v) by the average width (W_{average}) and by the average depth (D_{average}):

$$Q = v \times W_{\text{average}} \times D_{\text{average}} \times 1000$$

Stick (float) method with medium accuracy

Calculating spring discharge (Q , in l/sek) from this method involves solving an equation that examines the relationship among several measurable variables including stream cross-sectional area, stream length, and water velocity according to the following equation:

$$Q = 1000 \times \frac{A_{\text{average}} \times S \times C}{T}$$

Where: A_{average} is the average cross-sectional area of the stream (stream width multiplied by average water depth).

S is length of the stream reach measured (usually at least 3 meters).

C is a correction factor for stream bed coarseness. This allows you to correct for the fact that water at the surface travels faster than near the stream bottom due to resistance from gravel, cobble, etc. Multiplying the surface velocity by a correction coefficient decreases the value and gives a better measure of the stream's overall velocity. (0.8 for rocky-bottom streams or 0.9 for muddy-bottom streams).

T is time, in seconds, for the float to travel the length (S) between two cross-sections.

1. First step is to find a suitable section of the stream channel for conducting the water velocity measurements. Stream stretch chosen for the measurement should be as straight (no bends) as possible and preferably with a clearly distinguishable shoreline and at least 10 cm deep. Minimal distance between measurement transects is 3 meters. It is suggested to use full numbers (3 m, 4 m, 5 m etc). Streambed should be even and without rocks, vegetation etc if possible.
2. Use measuring tape or other means to mark locations of the two transects - use rope and draw it perpendicularly over the stream. Or use some sticks or stones to make markings on the shore.
3. Measure the width of the stream (W) along the both transects.

4. For calculating the average cross-sectional area (A) needed for the equation, you have to find average water depth (D_{average}) for both transects. Split each transect into four equal intervals and conduct water depth (D) measurement at each interval point (three points in total).
5. To calculate average depth (D_{average}) for each transect, divide the sum of the three depth measurements by factor of 4. Dividing by 4 is needed for taking into account also the shoreline depth, which is zero:

$$D_{\text{average}} = \frac{D_1 + D_2 + D_3}{4}$$

6. Average cross-sectional area (A_{average}) is the average area of both transects:

$$A_{\text{average}} = \frac{(W1 \times D1_{\text{average}}) + (W2 \times D2_{\text{average}})}{2}$$

7. For stream velocity (m/sek) you have to measure time (T , in seconds) required for the stick to float downstreams from one cross-section to another. Stick must be thrown to the water at least one meter upstream in order to let it stabilise and to keep yourself reaction time to start the timer.
8. It is important to replicate flow measurements in order to get trustworthy mean value. Ideal would be to conduct at least 3-6 measurements.

Weirs

Equipment: portable weir plate, measuring tape.

Weirs are sharp-crested, overflow structures that are placed across open channels in a way to dam the flow and guide it over the crest of the weir. The discharge is determined by measuring the head upstream of the weir, which is then used to derive the discharge value from a head-discharge relationship function. If spring discharge is low (<50 l/s) and the flow takes place in a well-defined channel, a portable weir may be used for quick measurement. Such a weir can be easily made out of a thin sheet of steel, aluminum, fiberglass or plastic. Here the use of a 90° V-notch weir is described based on *Van den Bosch et al. (1993)*.

Install the weir plate in the channel and wait until stable flow over the crest is achieved (**Figure**). Make sure the plate dams the whole cross-section of flow. The water level is then measured upstream of the weir in the dam pool using a gauge to determine the head (**H**), e. g. the height difference between the upstream water level and the crotch of the crest (see **Figure**). To measure the elevation of the crotch, use a simple carpenter's bubble level. The water level should be measured upstream of the weir at a distance from the weir of at least four times the determined head (see **Figure**). The determined head is used to derive the discharge (**Q**) from **Table** (next page).

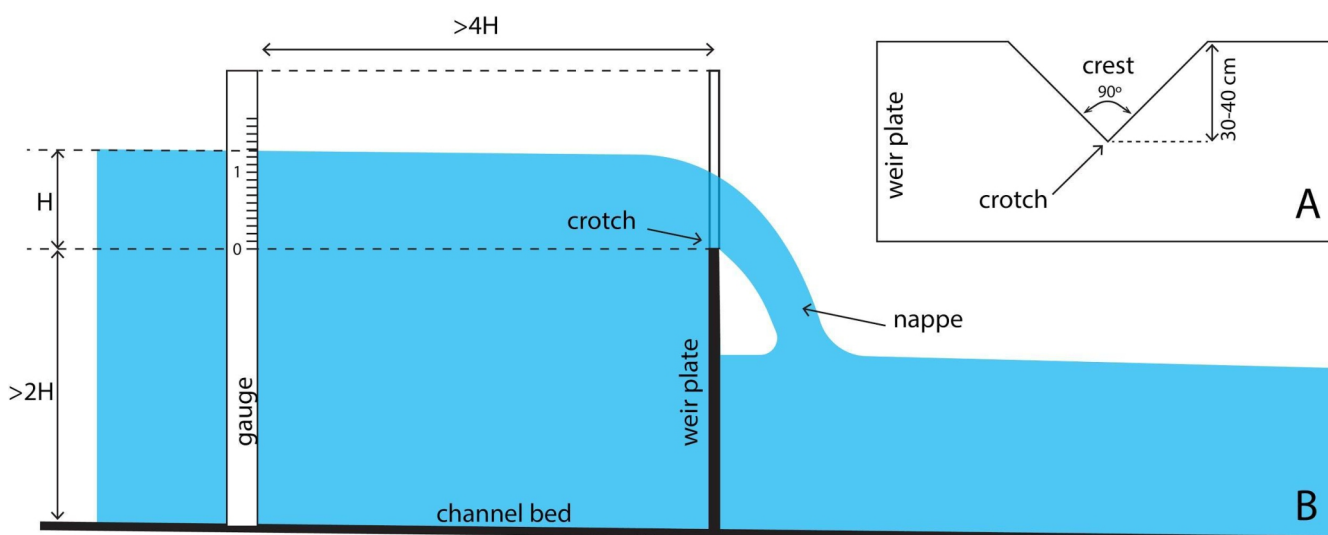


Figure. The cross-sectional view of a weir plate (**B**).
The use of a 90° V-notch weir (**A**).

Table. Discharge-head relationship for a 90° V-notch weir.

H (cm)	Q (l/s)	H (cm)	Q (l/s)	H (cm)	Q (l/s)
1	0	11	5.5	21	27.9
2	0.1	12	6.8	22	31.3
3	0.2	13	8.3	23	35.0
4	0.4	14	10	24	38.9
5	0.8	15	12	25	43.1
6	1.2	16	14	26	47.5
7	1.8	17	16	27	52.2
8	2.5	18	19	28	57.1
9	3.3	19	22	29	62.3
10	4.3	20	24	30	67.8



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