Groundwater sampling from bores ~5 cm wide and < 60 m sampled depth

Michael Lloyd Strack

Abstract

This protocol describes a method of sampling groundwater from bore-holes. The method was used in my PhD research on aquifer microbial ecology over two weeks at the Wellington Research Station in New South Wales, Australia. With a little practise, the method can probably be carried out solo by most people, although additional assistance would certainly speed things up. I managed to consistently sample and process groundwater from eight bores a day using this method; your mileage may vary depending on number of workers, distance between bores, and so on.

The sampling protocol describes the use of an inertia pump for bores with an internal diameter of approximately 5 cm and a sampled depth of less than 60 m. It includes the measurement of bore information - such as depth and water table - as well as the use of water meters to measure the pH, dissolved oxygen, temperature and conductivity of groundwater, and of course the collection of the groundwater sample itself.

Separete protocols will be provided for sampling narrow-diameter bores, sampling stygofauna, sampling surface soils, conducting colorimetric analysis of ferrous and sulphide anion concentrations, and further post-processing and analyses of the groundwater samples collected in this protocol.

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Guidelines

- Especially if working in remote areas, it is recommended to carry spare petrol, 4-stroke motor oil, spark plugs and a maintenance kit for the PowerPack PP1 pump. A spare foot valve is also recommended because abrasion against bore casings can wear holes in the housing and, in rare circumstances, they can also fall off.
- A variety of sampling hose lengths can also be useful - a long hose for sampling the deepest wells (the PP1 can sample down to about 60 m) and shorter lengths which are easier to handle and more practical for sampling shallower wells.
- Sometimes bores drilled into well-consolidated fractured rock aquifers are left un-cased. This causes very rapid wear on the foot valve and parts of the sampling hose. It can be prudent to

carry additional spares for this eventuality, and to sample them last if that is an option.
- The Enviroequip Aqua Dipper Pro appears to be a localised rebranding of - or at least substantially similar to - the Heron Water Tape.
- We used the HACH-approved calibration standards for the pH and DO probes but it is sometimes acceptable to use alternatives.
- You will also need a range of replacement and alternative fittings which connect the sampling hose with the flow splitter, and the flow splitter with the flow cells. A well-stocked maintenance kit including various types of tubing, adapters, o-rings, tube clamps, duct tape, a sharp knife, and other such supplies is recommended.
- It's particularly useful to use rather long (>2 m) lengths of tubing for connecting the flow cell with the flow splitter, and also for the flow cell outlet. This allows relatively free movement of the sampling hose and redirection of flow cell outflow to various containers without also having to move the flow cell apparatus itself.
- We used domestic bleach to make up a sodium hypochlorite solution (used to sterilise the sampling equipment). The cheapest domestic bleach is actually preferable, because it tends not to contain surfactants or other chemicals which could leave a residue.
- Larger-volume sample containers may be necessary if your groundwater is particularly low-biomass.
- Make sure the portable cooler is large enough for ice and for the maximum number of samples you expect to collect in a single session.
- Purge water should be stored in containers during sampling so it does not re-enter the groundwater. Some published guidelines (e.g. Sundaram, B. *et al.*, 2009. *Groundwater sampling and analysis: A field guide*) recommend purging at least three bore volumes of water, although pumping should continue until the water meter readings are stable. Knowing this, and with *a priori* knowledge of the dimensions of the bores you plan to sample, you can calculate the container size(s) necessary for storing purge water. You may need to record the volume of purge water at close intervals (e.g. <5 L), so gradation markings are useful.
- The gentler angles of a Y-shaped flow splitter should provide less resistance and more efficient pumping than a T-shaped splitter. Either way, make sure each outlet has an independent flow control valve. Splitters with larger internal diameters will be less prone to clogging.

Before start

- Make sure the sample containers are clean and (preferably) sterile. The Nalgene polypropylene containers we used can be (and were) autoclaved; not all plastics can. The other reason we used these is because the wide mouth makes it easy to scrub biofilm and other dirt off the inside.
- Find a groundwater bore near your institutional laboratory and obtain permission to sample it. Practise the techniques and iron out any kinks before heading out into the field.
- Ensure your equipment - particularly the water meters - are fully functional, calibrated and charged before fieldwork. Test and pack spare batteries, calibration solutions, and so on. It can be impractical to obtain replacements outside of major cities.

Materials

- Sodium Hypochlorite Solution by Contributed by users
- MilliQ Water by Contributed by users
- PowerPack PP1 inertia pump actuator PP1 by Waterra
- LDPE tubing NA by Waterra
- Standard-flow inertial foot valve D-25 by Waterra
- Sheffield flow cell SLF-6CellKit by Waterra
- Aqua Dipper Pro EEQADPRO(60) by Enviroequip
- HQ40D 2-input water meter HQ40D53000000 by Hach Australia
- HQ14D conductivity meter HQ14D53000000 by Hach Australia
- IntelliCAL LDO101 dissolved oxygen probe LDO10101 by Hach Australia
- IntelliCAL CDC401 conductivity probe CDC40101 by Hach Australia
- IntelliCAL PHC101 pH probe PHC10101 by Hach Australia
- Nalgene square wide-mouth 4L PPCO bottle with closure 2122-0010 by Thermo Fisher Scientific Australia
- Ice by Contributed by users
- Cleaning cloths for hose by Contributed by users
- 2-way tap flow splitter by Contributed by users
- Portable cooler by Contributed by users
- Maaloo Outdoor app NA by Maaloo (Oliver Michel)
- Lumia 920 smartphone NA by Nokia Corporation
- Purging containers by Contributed by users
- Torch by Contributed by users
- Marker pens by Contributed by users

Protocol

Record bore details

Step 1.

Record the bore GPS location.

Record bore details

Step 2.

Record any information written on the bore monument or plaque.

Record bore details

Step 3.

Take a photograph of the bore with its surroundings in the background.

Record bore details

Step 4.

Open the bore, remove any monitoring or logging equipment and record the time. This can help monitoring agencies to correct their data for any inaccurate readings.

Record bore details

Step 5.

Record any visual or olfactory observations by examining the open bore hole with your torch and nose.

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Beware spiders, frogs, etc.

Record bore details

Step 6.

Mount the Aqua Dipper Pro.

Record bore details

Step 7.

Using the Aqua Dipper Pro, measure the distance from the mounting position to the ground level.

Record bore details

Step 8.

Using the Aqua Dipper Pro, measure the distance (if any) from the mounting position to the water table.

Record bore details

Step 9.

Using the Aqua Dipper Pro, measure the distance from the mounting position to the bottom of the bore hole.

Record bore details

Step 10.

Remove the Aqua Dipper Pro. Record any observations (visual, olfactory etc.) about groundwater or sediment on the probe and tape.

Record bore details

Step 11.

Store the Aqua Dipper Pro clean & dry.

Preparing for pumping
Step 12.

Mount the PowerPack PP1 securely on the bore monument.

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If no monument is present, then placing the PP1 on the ground and standing firmly on the metal stand during pumping should keep the unit sufficiently stable, though this is potentially hazardous.

Preparing for pumping
Step 13.

If you are aiming to target a particular water-bearing layer and know its depth, you can measure the appropriate height on the sampling hose (starting from the foot valve) using the Aqua Dipper Pro and make a small mark (adding extra height for the bore monument if present). If the water-bearing layer is not artesian then groundwater from this layer will not refill above the depth of that layer, so aim to place the foot-valve approximately 20 cm below the layer's lower bound.

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This a very imperfect means of isolating a particular water-bearing layer, so if accurate separation is necessary then use well packers instead.

Preparing for pumping
Step 14.

Insert the sampling hose (foot-valve end first) down the bore-hole, swabbing the exterior with bleach from a cloth as you go. If the bore is uncased, this may require a fair amount of jiggling and rotation. If you are aiming for a particular water-bearing layer (see previous step), then clamp the hose to the PowerPack PP1 once your mark is level with the bore opening. If not, then lower the hose until the foot-valve hits the bottom of the bore, then draw it up approximately one meter to lift it above any settled sediment before clamping.

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Note that small stones on the bottom of the bore hole can wedge the valve open at this stage; if pumping is inexplicably ineffective then draw the hose out to check. Also be careful to use a sufficiently long hose to avoid dropping it irretrievably down the bore hole. In deeper bores, the total length of hose can be quite heavy (especially when full of water), so be prepared for this.

Preparing for pumping
Step 15.

Assemble the flow cell apparatus with their probes and turn on the (calibrated/tested/charged!) water meters.

Preparing for pumping

Step 16.

Attach the flow cell apparatus to one outlet of the flow splitter. I will refer to this as the 'flow cell outlet'. Turn this flow splitter valve to the CLOSED position and the other flow splitter valve (which I will refer to as the 'open outlet') to the OPEN position.

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As far as possible, place the flow cell and inflow tubing in the shade to protect them from the effects of solar UV and IR radiation, which can affect the water temperature and hydrochemistry readings. Obviously the exposure of the outflow tubing is not a concern.

Preparing for pumping

Step 17.

Arrange your purge storage container(s) within the range of the sampling hose outlet (i.e. the open outlet of the flow splitter) and the flow cell outlet tubing.

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It's helpful to be able to redirect sampling outflow (both from the open outlet and the flow cell outflow tubing) without needing to move the flow cell apparatus itself.

Pumping the groundwater

Step 18.

Double-check everything is prepared and secured.

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The sampling hose will slowly shift and any coils will 'tighten up' during pumping, so it's sensible to arrange the bulk of this hose away from the flow cell and other equipment prior to starting.

Pumping the groundwater

Step 19.

Record the time and start the PowerPack PP1 motor on low throttle.

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Although it is possible to interrupt sampling to stop the PowerPack PP1 and refuel, it's better to top it up before starting.

Pumping the groundwater

Step 20.

Firmly grasp the end of the sampling hose just before the flow splitter and point the open outlet (i.e. the one not connected to the flow cell apparatus) towards the purge container.

Pumping the groundwater

Step 21.

If necessary, increase the throttle on the PowerPack PP1 until groundwater begins to exit the open outlet of the flow splitter into the purge container.

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The sampling hose will twitch and jerk and slowly tighten and shift during this process, so a steady hand is required.

Pumping the groundwater

Step 22.

Observe the characteristics of the groundwater efflux. Usually, there will be a volume of clear water, followed by turbid water which slowly clears.

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While the PowerPack PP1 can achieve very rapid sampling, there are several practical limitations on the maximal flow rate. For example, the pressure pulse can burst flow splitter or flow cell fittings apart. Also, in un-cased bores, the water pressure of groundwater in the bore hole can be the only thing preventing the surrounding geological medium from collapsing into the bore-hole, so slower sampling is necessary to prevent excessive drawdown.

Pumping the groundwater

Step 23.

Once you judge that the groundwater will not clog the flow cells, ensure the flow cell outlet tubing is also directed into the purge container and gently open the flow cell valve in the flow splitter until a steady flow groundwater is passing through the flow cell apparatus.

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Sometimes the pumping pressure can cause fittings to burst apart. To prevent this, try reducing motor throttle, closing the flow cell apparatus outlet valve in the flow splitter a little, and taping fittings in place firmly with duct tape.

Pumping the groundwater
Step 24.

Take the first water meter readings (pH, DO, conductivity and temperature) and record the corresponding amount of groundwater purged. If you are sampling solo, you may need to briefly cease pumping to take these readings.

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The action of the inertia pump creates a slight vacuum effect between surges of sample. This can suck air into the flow splitter which then is surrounded by water and forced into the flow cells as air bubbles. To prevent this, do not orient the flow splitter outlets on a horizontal plane, but rather so that the open outlet is uppermost and the flow cell outlet is underneath. That way any air bubbles will rise to the top and be expelled through the open outlet and into the purge container.

Pumping the groundwater
Step 25.

Repeat step 24 when you have purged half the intended volume.

Pumping the groundwater
Step 26.

Repeat step 24 when you have purged the intended volume.

Pumping the groundwater
Step 27.

If the last two consecutive readings were not within *approximately* 10% of one another, then continue purging in the same volume increments until the readings stabilise.

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In unusual cases, the hydrogeology may be sufficiently complex that the readings do not stabilise within the practical limits of the purging procedure. In that case, you can cease purging and acquire the sample, but be aware that without further characterisation you cannot make strong assumptions about whether it is representative of a particular aquifer.

Pumping the groundwater
Step 28.

Collect your groundwater sample by pumping water into the (cleaned, sterilised) sample container, rinsing and discarding this water, then filling to overflowing (to exclude air) and sealing it tightly.

Cleaning up
Step 29.

Record the sample ID on the sampling container and place it in the portable cooler, on ice, in the dark.

Cleaning up

Step 30.

Record the time pumping ceased.

Cleaning up

Step 31.

Unclamp the sampling hose from the PowerPack PP1 and withdraw it from the bore hole.

Cleaning up

Step 32.

Measure the depth to water table using the Aqua Dipper Pro to calculate the drawdown.

Cleaning up

Step 33.

Remove the probes from the flow cells, rinse with milliQ water, dry and pack away.

Cleaning up

Step 34.

Detach the flow-cell apparatus from the flow splitter and rinse with MilliQ water, dry and pack away.

Cleaning up

Step 35.

Lift the foot-valve end of the sampling hose so the groundwater flows away, then walk along the length of the sampling hose, lifting it as you go, until most of the groundwater has exited the hose.

Cleaning up

Step 36.

Pour approximately 250 mL of bleach into the foot valve and walk this along the hose and out the outlets. Pack the hose away.

Cleaning up

Step 37.

Remove the PowerPack PP1, top up the fuel, and pack away.

Cleaning up

Step 38.

Replace any logging instruments and record the time replaced.

Cleaning up

Step 39.

Close the bore lid and replace the padlock (if present).

Warnings

- Several of the chemicals in this protocol (e.g. bleach, probe calibration standards, petrol) are hazardous to workers and the environment. Read the MDS, conduct a risk assessment, and take appropriate precautions.
- Hearing protection should be worn while operating the PP1 motor.
- Groundwater sampling is 'field work' which comes with its own unique hazards. Follow all necessary procedures and take all appropriate precautions e.g. sun/snake protection, remote area preparedness, and so on. For example, groundwater bores are an attractive habitat for (potentially venomous) spiders.
- Depending on the environment, groundwater itself can harbour hazardous compounds or pathogens. At the very least, take precautions to minimise direct contact or inhalation of aerosolised groundwater.