Groundwater

Technology Spotlight/ Technology Editor / Chris Lowry

Making the Invisible Audible: A Simple Sound-Emitting Water Level Meter

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Introduction

“Groundwater: Making the invisible visible” is the theme of the World Water Day 2022 and the title of the corresponding UN World Water Development Report (United Nations 2022). It describes our dilemma quite well: Groundwater is of vital importance, but being hidden, it is out of sight and out of mind. Hence, current efforts aim at increasing the awareness for this undervalued resource.

Apart from a better formal education, community science (citizen science) holds great potential to improve this situation. In such projects, not only valuable scientific data can be gathered, but participatory data collection also allows the community to become more informed about groundwater and may eventually lead to a better protection of this important resource (Little et al. 2016; Speir et al. 2021). Groundwater community science has indeed gained some momentum over the past years, but corresponding efforts are still relatively rare (Speir et al. 2021), particularly in comparison to projects focusing on surface water (United Nations 2022). While this could in part be due to the above-mentioned groundwater visibility issue, also access to relevant technology can be critical (Speir et al. 2021) and probably plays a role as well.

Arguably the most common tool to measure groundwater levels is the electric water level tape. The underlying principle is straightforward. Upon water contact, an electrical circuit is closed at the probe tip, which triggers a light and/or buzzer at the tape reel. Nevertheless, these water level tapes usually cost several hundred U.S. dollars (Michelsen 2021). While such a price seems reasonable in a professional context, purchasing multiple devices for a community science project may be possible in some cases (Little et al. 2016 bought 40 tapes for their volunteers), but is often prohibitively expensive. Fortunately, there are low-tech alternatives.

Low-Tech Toolbox: Self-Contained Probes for Groundwater Level Measurements

Over time, a number of simple devices have been developed to measure groundwater levels. These low-cost probes have in common that they are self-contained, that is, they can be attached to an ordinary measuring tape. One of the simplest tools is the plopper (also known as popper), a cylinder with a concave bottom that emits a “plop” sound when impacting on the water surface. Ploppers are commercially available, but can also be improvised (Figure 1a). A more sophisticated variation is the well whistle (literal translation of the German *Brunnenpfeife*; Figure 1b), a development from 1901 by the company Spohr (Frankfurt, Germany; Spohr 2022). The thin cylindrical pipe features a whistle at its upper end, so the air that is pushed out upon partial immersion in water creates a whistling sound. Circumferential grooves (in 1-cm intervals) collect water when immersed and thus document to what extent the pipe was submerged, allowing for a rather precise reading. Later, researchers also developed acoustic probes that emitted a sound when the water closed an electrical circuit (Schrale and Brandwyk 1979; Henszey 1991) and shared construction details like circuit diagrams, encouraging others to rebuild their devices. Groundwater Relief (2022), by contrast, harnessed a different principle. Their commercially available Pocket Dipper (Figure 1c) produces a high-pitched sound when switched on and the sound is dampened when the device makes water contact. Apart from these acoustic probes, the light-based one reported by Michelsen (2021) is worth mentioning (Figure 1d). Here, an LED bait, usually used

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Received December 2022, accepted December 2022.

doi: 10.1111/gwat.13287

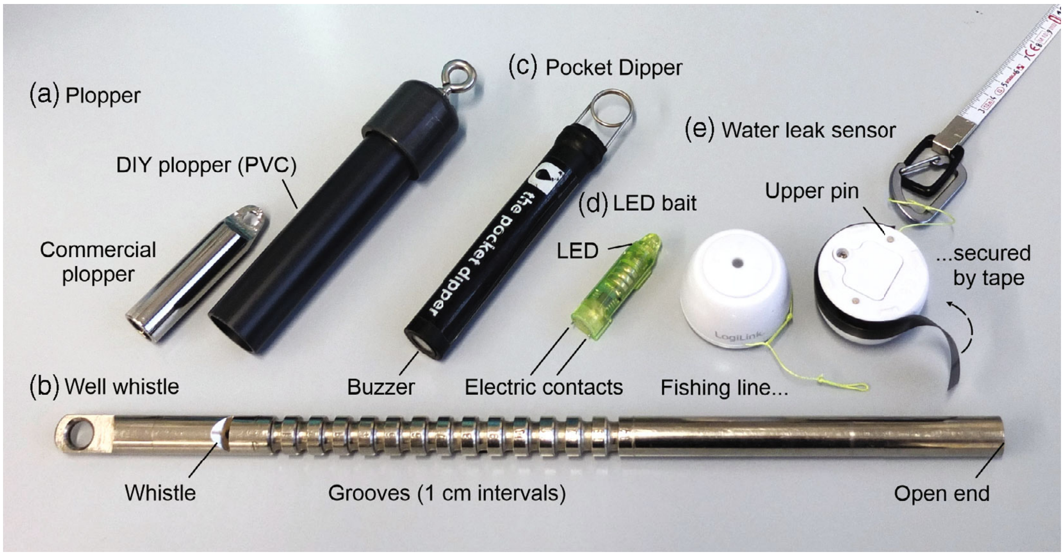

Figure 1. Selection of self-contained probes that can be attached to a measuring tape for groundwater level measurements. (a) Plopper (commercial and DIY version), (b) well whistle, (c) Pocket Dipper, (d) LED bait, and (e) water leak sensor (top and bottom view). Some electrical tape keeps the fishing line sling in place (in a production-related groove).

for fishing, is fixed to a measuring tape and starts flashing upon water contact.

As the Pocket Dipper and the LED bait solution are relatively new, their popularity is hard to evaluate, but the classic plopper and the well whistle are commercially available and apparently still in use (the latter especially in German-speaking countries). The electric acoustic probes by Schrale and Brandwyk (1979) and Henszey (1991), however, seem to have gained only limited popularity—despite their do-it-yourself (DIY) character. Or *because* of their DIY character?

Repurposing an Off-the-Shelf Water Leak Sensor

Commercially available water leak sensors, attached to a measuring tape, may offer a convenient low-threshold way to improvise a low-cost water level meter—without deciphering circuit diagrams and firing up a soldering iron. These sensors are small battery-powered units that are usually placed under dishwashers or washing machines to detect leaks automatically. Leaking water causes an electrical contact between two metal pins at the bottom of the device, triggering a high-pitched alarm.

To test this concept, a LogiLink SC0105 water leak detector was utilized (Figure 1e; currently <10 USD). The device has a diameter of 45 mm and is 33 mm high, and works with three LR44 button cell batteries. Upon water contact, it emits a loud alarm sound, which is, given our intended purpose, appropriately annoying.

The unit is, to a certain degree, waterproof (Ingress Protection Code IP65). Nevertheless, adhesive tape was used to cover the battery compartment at the bottom and an opening at the top. Then, the leak sensor was attached to an ordinary measuring tape with a fishing line sling (WFT 67KG Strong, Dyneema, diameter 0.39 mm; Figure 1e). The latter was placed in a production-related groove, where it was secured with electrical tape. This way of vertical mounting outperformed a horizontal orientation, which frequently led to water drops collecting at the bottom, causing a short circuit even after removal from the water.

Laboratory experiments showed that the leak detector floats on water, taking an upright position with its sound-emitting top part pointing up. Additionally, the tests revealed that the alarm mechanism also works at low electrical conductivity values of down to about 5 µS/cm.

Field Tests and Comparison with Other Self-Contained Probes

To check the field applicability of the water leak sensor, it was tested in several observation wells, together with other self-contained probes (Figure 1, Table 1). The wells showed water levels of 28.19, 36.81, 46.97, 62.93, and 87.05 m below top of casing and have diameters between 10 and 15 cm. They are all located in forests and during the tests, there was very little wind, resulting in a quiet test environment.

In terms of measurable water levels, the probes showed variable performances. While all devices could be easily operated at a water level of 28.19 m below top of casing, some models were less convenient to use beyond that depth. When working with the (very compact) commercial plopper and the Pocket Dipper, for instance, the acoustic signal became relatively subtle. Interestingly, the flashing of the LED bait could not be seen in the well with a water level of 36.81 m, but was visible in the well with a water level of 46.97 m. This shows that LED brightness is not the limiting factor in this depth range, but rather borehole straightness.

Table 1
Comparison of Tested Self-Contained Low-Tech Probes for Groundwater Level Measurements

	Commercial Plopper	DIY Plopper[1]	Well Whistle	Pocket Dipper	LED Bait	Water Leak Sensor
Manufacturer	Eijkelkamp	DIY	Spohr	Groundwater Relief	No-name product	LogiLink
Price (USD)[2]	30	<7	100	60	<7	<10
Signal type	Acoustic	Acoustic	Acoustic	Acoustic	Visual	Acoustic
Size (mm)[3]	Ø 17 × 70	Ø 33 × 157	Ø 15 × 370	Ø 21 × 145	Ø 15 × 54	Ø 45 × 33
Battery	No battery	No battery	No battery	Not exchangeable	Not exchangeable	Exchangeable (3 × LR44)
Test at well with water level of ...[4]						
28.19 m	+	+	+	+	+	+
36.81 m	(+)	+	+	(+)	−	+
46.97 m	(+)	+	+	(+)	+	+
62.93 m	(+)	+	(+)	(+)	−	+
87.05 m	−	(+)	−	−	−	+
Precision (m)	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01
Disadvantages	Strong impact on water surface required	Strong impact on water surface required	Often several trials needed to constrain level (groove drying)	Remaining drop may dampen sound	Remaining drop may cause short circuit; unobstructed view required	Less robust than other devices; larger diameter
Advantages	Robust; very compact; no battery	Robust; compact; no battery; low-cost; easy to build	Robust; compact; no battery	Compact	Robust; very compact; low-cost consumer product	Large depth range; low-cost consumer product

Notes: +, Convenient use; (+), use possible, but with difficulties; −, use not possible.
[1] Made from PVC pipe and end cap.
[2] Approximate price in the author's home country at the time of writing (converted to USD).
[3] Diameter (Ø) and length.
[4] Water levels given in meters below top of casing.

With increasing depth, most devices became unusable. In the deepest well, showing a water level of 87.05 m, only the DIY plopper and the water leak sensor could be used—the former with some difficulties, the latter with ease.

During the field tests, instrument precisions were estimated. These estimates were similar (±0.01 m), but associated efforts differed among the devices. The plopper and the well whistle, for example, require a relatively strong impact on the water surface to produce an audible sound and hence usually require several attempts to constrain the water level. In the case of the well whistle, the user has to remove the device from the well to inspect (and dry) the grooves. The Pocket Dipper, LED bait, and water leak sensor, by contrast, can be slowly moved up and down to locate the water level precisely, similar to an electric water level tape. However, it is worth mentioning that the former two occasionally collect a water drop at the bottom (causing a short circuit) that has to be shaken off. As the water leak sensor did not show this phenomenon, and emits a well-audible sound, it was very convenient to use.

Discussion and Outlook

Somewhat untypical for this column, the presented water leak sensor itself is neither novel, nor high-tech. Yet, repurposing this simple consumer-grade device yielded a relatively compact, fully functional, and low-cost water level meter that can be used over a wide range of depths to water. It thus complements available water level meters relying on self-contained probes.

Since the tested model requires some space in the well (approximately 50 by 50 mm), one may be tempted to rebuild the sensor with a more compact and streamlined design. However, the very fact that the sensor is available as an off-the-shelf consumer product, and does not require soldering, represents a clear advantage for many potential users, both professional and nonprofessional.

The approach outlined in this (Low-)Technology Spotlight may represent a viable option for a number of users without access to an electric water level tape. Examples include participants in school or community science projects, (private) well owners, and possibly also hydrogeologists with limited resources. Hence, this simple low-cost solution has the potential to contribute to improved groundwater literacy among the general public and to support groundwater monitoring efforts.

Acknowledgments

I thank Gunnar Lorenzen for the fruitful discussion that led to the presented leak sensor-based water level meter. Open Access funding enabled and organized by Projekt DEAL.

Author's Note

The author does not have any conflicts of interest or financial disclosures to report.

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