# Real-time monitoring of water level at low-cost

F. Cherqui [1,2,3]*, R. James[2], P. Poelsma[2], C. Szota[2], M. J. Burns[2], T.D. Fletcher[2] & J.-L. Bertrand-Krajewski[1]

[1] *Univ. Lyon, INSA Lyon, DEEP EA 7429, F-69621, Villeurbanne cedex, France*
[2] *School of Ecosystem and Forest Sciences, The University of Melbourne, Burnley, VIC 3121, Australia*
[3] *Univ. Lyon, Université Claude Bernard Lyon-1, F-69622 Villeurbanne, France*

**Corresponding author email: fcherqui@gmail.com*

## Highlights

- Water-level is a key parameter for the operation of water infrastructure.
- A novel open-source water level monitoring system is proposed, costing under $100 AUD.
- The system can be used in different configurations with a maximum absolute error of 2 cm.
- Insights on low-cost monitoring system development are provided.

## Introduction

Managing water infrastructure such as stormwater control measures (SCMs) requires monitoring in order to anticipate failures and maintenance requirements (Cherqui *et al.*, 2019). However, high costs and complexity of traditional monitoring may be major barriers to SCM asset management and thus to SCM adoption (Cossais *et al.*, 2017). This paper suggests that the costs of monitoring for maintenance can be drastically reduced, making pro-active management of assets more viable. Cost is not the only benefit from recent technological development regarding sensors and open-source hardware. The paper presents a water level monitoring system that provides real-time data, and which is already deployed in the field. The paper also discusses key elements of design related to low-cost monitoring systems. The proposed system is open-source: more details and the code are available here: https://mind4stormwater.org/monitoring-systems/waterlevel1/.

## How to build a low-cost monitoring system?

**Monitoring specifications and choice of the sensor**

The proposed system aims to monitor the water level in constructed stormwater wetlands to inform operation and maintenance. The objective is to minimize the costs of design, construction, installation, data management and monitoring system maintenance. The sensor is used to monitor a maximum water level range of 1.9 m and an accuracy of 2 cm which is considered acceptable for this application. The system has to provide real-time data to raise alerts (high / low water level, low-battery level, absence of new data).

To reduce cleaning needs, the sensor is not in contact with the water. This constraint drastically limits the choice as it eliminates many systems (Morris and Langari, 2012). Among the different contact-less sensors, the ultrasonic sensor JSN-SRT04 has been chosen because (i) it is one of the most common sensors, (ii) it is water proof, (iii) it is easy to install, and (iv) it provides an expected accuracy within a compatible range of measure (Cherqui *et al.*, 2020).

The fact that a sensor is very commonly used is very important because it is mass produced and consequently very low cost and reliable (<$7 AUD for the JSN-SRT04), but also a large community of users and potentially a high number of open-source projects and extensive knowledge to aid deployment and troubleshooting.

**Power management and communication**

Power management and communication are key elements of the system. To avoid frequent site visits, the system needs to be self-powered. Low power management is a frequently discussed topic and can involve a variety of hardware or software solutions. Easy-to-implement solutions include decreasing the measurement time, increasing the sleep time between measurements, and decreasing the communication consumption.

LPWAN (low-power wide-area network) communication facilitates minimum energy consumption and maximum range for communication, when compared to cellular (GSM) communication. These solutions are however often one-way communication, with a limited bandwidth (Mekki *et al.*, 2019), which is acceptable for the present project (no image or video to be sent). Based on the existing coverage, the LoRaWAN technology is used where available (no subscription fees) or alternatively, Sigfox (subscription fees).

**Optimal measurement cycle**

Each measurement cycle can be broken down in two phases: an active phase and a sleeping phase. The active phase consists in the initialisation (powering of the sensors), the measurement, the communication of data, and a termination (power down of the sensors). During the sleeping phase, the system consumes as little energy as possible until the next active phase. The number of cycles per hour represents a trade-off between power management (more measures means more energy consumption), communication constraints (LPWAN often limits the number of messages per day) and the monitoring requirement. In the present case, a message is sent every 15 minutes.

The duration of the measurement phase is very important because of its high-energy consumption. It is again a trade-off between the quality of the measurement (improved when using the median of *n* measurements) and the total measurement duration (*n* times the duration for one measurement). This trade-off is highly depending on the sensor chosen and the measurement performance expected.

**Testing the sensor and the measurement procedure**

A testing bench has been developed to test various water level sensors (Cherqui *et al.*, 2020). It consists of a 2 m high water column equipped with a reference PLS pressure sensor (OTT, 2020) and a pump to automatically change the water level. The OTT reference sensor costs approximately $1500 AUD, has an accuracy of +2 mm and the measurements are verified with several manual readings during the experiment. The water level is decreased from 1.90 m to 0 m with steps of less than 0.03 m. For each step, the water level is measured with the reference sensor and 1,000 ultrasonic measurements. The air temperature and relative humidity are also monitored. The calculation of the distance is based on the duration between transmitting sound waves and receiving the echo using the speed of sound according to the air temperature and the air relative humidity (Panda *et al.*, 2016). According to the results, the precision of the ultrasonic sensor is below 6 mm. It has thus been decided to calculate the median of 25 measurements (maximum measurement duration of less than 2 seconds). The total active cycle lasts less than 15 seconds: initialisation, measurements (distance, air temperature, air relative humidity and battery voltage), communication and termination. The system is thus active less than 2% of the time when using a 15-minute time step.

**Field installation**

The system is encapsulated in a 100 mm pipe in order to provide a cheap water-proof case and make it less noticeable, with the aim of reducing the risk of vandalism. The enclosure also allows easy removal/replacement without changing its location. Figure 1 presents the system deployed on site. The system runs on three AA rechargeable batteries and a 0.5 W solar panel.

**Figure 1.** System installed on the field (on the left of the pole) and photos of the encapsulation system made for easy fixing and removal without changing the location of the sensor.

## Performance of the system

Data can be accessed in real time using the online platform [http://mind4stormwater.online](http://mind4stormwater.online). The first system deployed in the field has been running for more than a month and has provided continuous time series. Figure 2 presents the water level and battery voltage (peaks of voltage are due to the solar panel). According to initial tests without the solar panel, the system can run more than two weeks without sun.

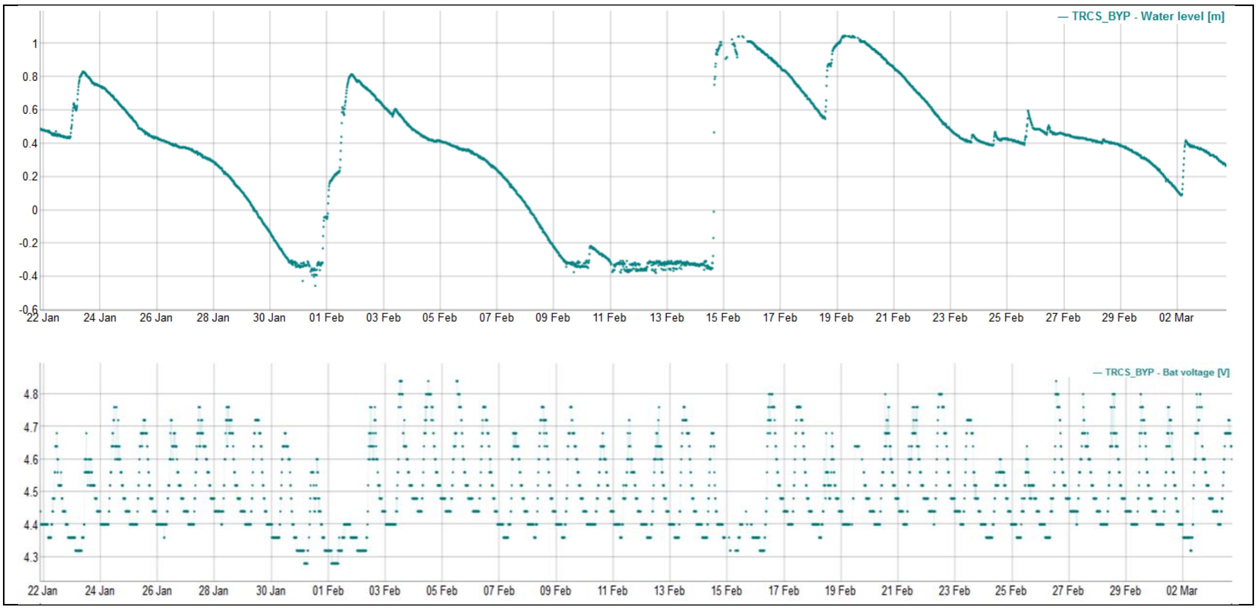


**Figure 2.** Water level [m] and battery voltage [V]. The real time data is available here: [http://mind4stormwater.online](http://mind4stormwater.online). The water level can be negative when it is below 0 m on the gauge.

## Conclusions and future work

A low-cost water level monitoring system has been successfully deployed under real in situ conditions. Key design elements are i) choice of the sensor, ii) measurement cycle, iii) power management, and iv) communication. Other low-cost systems have already been built, showing the flexibility provided by DIY development of monitoring systems and open-source material. More info on [https://mind4stormwater.org](https://mind4stormwater.org).

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