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Environmental Solutions

Application Note
YSI Systems & Services • XA00183

Five Steps to a Stormwater Monitoring System

Storm drain outflows

Design of a stormwater monitoring system can seem daunting when one looks closely at local, state, and federal regulations and the complex set of requirements that they may carry. The task of stormwater monitoring can be eased by following five basic steps outlined here. These steps can lead to a foundational system design, and one can work with a system integrator to build in additional features to reach even more specific goals. The integrator may also perform installation, data collection, and analyses becoming a trusted partner that relieves the programmatic burdens for stretched-thin personnel and budgets.

In other words, instead of top-down design that is driven by difficult-to-understand regulations, this bottoms-up approach might be an easier place for your organization to start.

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Organizations set up stormwater monitoring systems for a variety of reasons. Some of the most common are:

- **MS4s** — Support of a Municipal Separate Storm Sewer System (MS4s) program
- Detection of point-source discharges, such as from industrial facilities or construction activities
- Evaluating non-point-source pollution of waterways, such as nutrient runoff in agricultural watersheds
- **EPA** — Application for or compliance with an EPA National Pollutant Discharge Elimination System (NPDES) permit
- **TMDLs** — Development and monitoring of Total Maximum Daily Loads (TMDLs) for Section 303(d)-listed water bodies[1]

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[1] Section 303(d) of the Clean Water Act, administered by the U.S. EPA. More information is available at https://www.epa.gov/tmdl/overview-identifying-and-restoring-impaired-waters-under-section-303d-cwa , accessed 30 March 2021.

Let YSI solve stormwater monitoring for you.

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Aerial view of flooded river

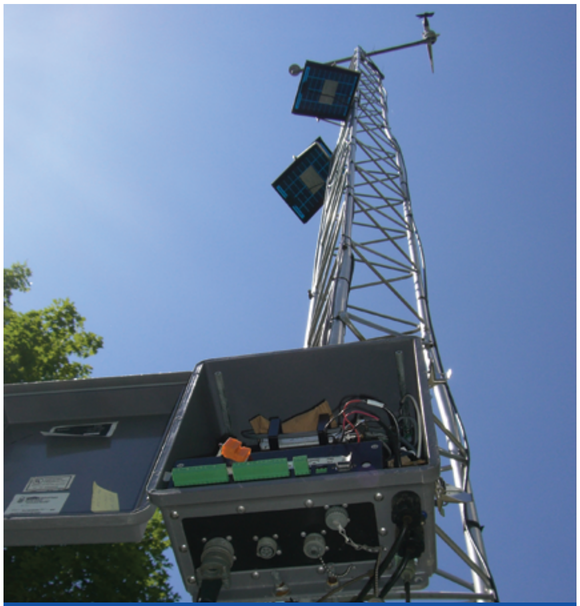
Step 1: Define What To Measure

Do you want to know rainfall, water level, flow, flux, discharge…or all of these? Are there also water quality parameters or specific pollutants of interest? This must be decided to make choices about the most common sensors used in stormwater monitoring, which are briefly described below.

Weather Sensors

Precipitation and water level are incorporated into almost all stormwater monitoring systems. The standard tool used for precipitation is a tipping bucket rain gauge, but in recent years all-in-one "weather stations" have become affordable and highly reliable, and relatively easy to integrate into a larger system. A weather station can measure wind speed and direction, air temperature, humidity and precipitation, and barometric pressure in a single device. In all cases, it is critical to stably mount the device in a way that measurements will not be interfered with by the immediate surroundings (such as a wall that can act as a wind break).

Another consideration is to collect your weather data from a freely available source, like local meteorologists or the National Weather Service. Depending upon the geographical resolution of measurement required, software platforms may allow one to ingest the data of others rather than measure these parameters on site, which can save time and money.



Meteorological evaluation tower featuring a YSI Data Logger and meteorological sensors.

Road closure from flooding. Notice the staff gauge (arrow), a useful tool for drivers.

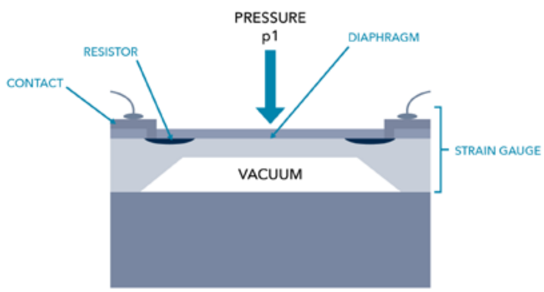
Water Level

Water level is the one parameter that every stormwater system should measure, and in some instances it is the only parameter of interest. Three of the most common water level sensors are:

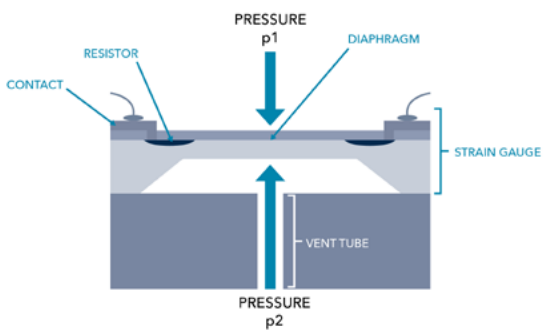
Pressure Transducers

Compact and reliable, a submersible pressure transducer (PT) may be the most widely used water level sensor there is. PTs are great for sites where water is almost always present, but must be kept free of debris and sediment to function best. Note that the pressure on the transducer is not only a function of water depth, but also a function of the barometric pressure at the water's surface and the density of the water. These can have a significant impact during a storm, when barometric pressure can vary greatly, road salts or other runoff can impact water density, and the depths measured might be relatively shallow (less than 10 m). A vented PT is strongly advised to enable automated barometric compensation, and salinity compensation might be obtained with water quality sensors if necessary. This necessity will be driven by the desired accuracy of the depth measurement.

Non-vented pressure transducer



Vented pressure transducer



Vented vs. Non-vented PTs
p1 = water pressure, p2 = air pressure

A complete stormwater solution featuring the Amazon Bubbler and WaterLOG Storm 3 Data Logger at a monitoring station in Texas.

Bubblers

Fundamentally a bubbler is as simple as it sounds. An air compressor pushes air through a tube called the orifice line, which has one end submerged in the water. The deeper the water above the exit orifice, the more pressure required to push a bubble out. Internal calibration of the bubbler translates that pressure to a water depth. In spite of their simplicity, well-built, factory-calibrated bubblers are astonishingly accurate, and have the added benefit that they don't get damaged or stop working when the exit orifice is no longer submerged. Bubblers are great for sites that might go dry in between storm events, especially if operators will not return to the site frequently. Another advantage is that, with a properly secured orifice line, bubblers operate well in turbulent waters. When properly set up and maintained, bubblers can last in the field for decades.

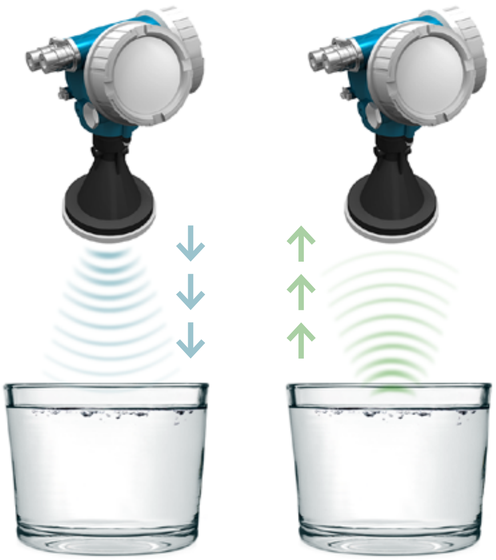
Learn More:
YSI.com/Amazon

The Amazon Bubbler is user programmable from 30 to 120 bubbles per minute.

Permanent HydroMet monitoring systems such as mast-mounted, metal walk-in sheds or constructed walkways and platforms, offer a secure option for long-term monitoring. The metal gauge house, riverbank installation, and bridge mounted NEMA-4X rated enclosure above is an example of a custom designed HydroMet system.

Radar

Radar is the chief representative of "non-contact" water level sensors, which also include ultrasonic, camera and laser-based sensors. Radars use the time-of-flight principle to measure distance to a target, in this case the water's surface. The radar emits an electromagnetic signal of a specific frequency, and the signal is reflected on the water's surface and received by the radar's sensor. The time of flight to signal receipt is used to calculate the distance. Like bubblers, radars handle high-flow and turbulent conditions well. A big advantage of radar is that there isn't much in the way of construction required to mount one on a culvert or bridge, and there are no concerns related to fouling, sediment, or blockage. Once in place, radars, like bubblers, operate for years and are highly accurate.



The radar sensor makes multiple distance measurements, averages the results and converts the measurement data into Water Level.

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Measuring flow can support TMDL calculations that are required by some NPDES permits.

Water Flow

It is often of interest to not just measure water level, but also to understand water flow. Stormwater channels can vary from concrete channels to natural streams, and the right flow sensors are chosen based on the deployment site characteristics. Measurement of flow may be accomplished with very low-cost flow meters, or traditional methods that use a primary device such as a weir or flume paired with a secondary device such as a level sensor. The paired devices can provide information for calculation of flow.

The best technology for hands-off flow measurements, and which conveniently also supplies level measurements, is an acoustic Doppler profiler. It's important that the instrument can measure velocity without interference from the low levels of suspended solids that are common in stormwaters. The sensor should be capable of measuring the majority of the flow profile cross section and should adapt to rapidly changing water levels. Beware of technologies that don't recognize the entire cross-sectional flow profile during velocity measurements—this can have a significant impact on the measurement error. It is recommended to consult with an experienced product specialist when selecting and deploying Doppler technologies to assure the most accurate flow measurements.

SonTek IQ Acoustic Doppler Profiler based open channel/non-full pipe flow meter being installed in a typical stormwater culvert.

Water Quality

Finally, if one wants to understand discharge of a pollutant such as nitrate or a heavy metal, it is valuable to deploy a water quality sensor along with a flow sensor. Pairing water quality and flow will allow one to calculate the flux of that analyte and ultimately the loading, or the total amount of the analyte delivered over time. This is highly relevant when nutrient loading as a consequence of stormwater runoff is evaluated, for instance.

In some cases a deployed sensor may not provide a direct measurement of the analyte of concern.

For example, conductivity is a good surrogate for road salt runoff or deicing fluids used on airport tarmacs. Oxidation/Reduction Potential (ORP) is a good surrogate for heavy metal contamination. However, the actual deicers or metals may still be best measured in a laboratory. In fact for some NPDES permits or TMDL monitoring a laboratory analysis is a requirement, even if there is a deployable sensor technology that provides direct or indirect measurement of the analyte.

Such a scenario is why the next step is so important.

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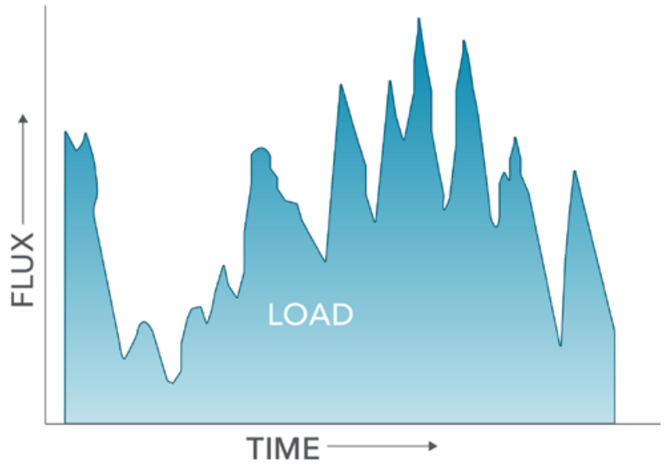


The ProSample automatic sampler can collect samples when alerted by the Amazon bubbler that water levels in this discharge pond are above a specified threshold.

Step 2: Define The Sampling Regimen

It is possible that precipitation, level, and/or flow is all that is of interest, or that a water quality sensor deployed with a flow monitor, as described above, will enable one to get any necessary information about flux and loading of a pollutant. In these cases the sampling regimen may simply be "no sampling."

In some cases, the regulatory agency may require analysis by a defined laboratory method and that will usually require collection of samples. Since it is not usually ideal to deploy personnel to collect samples during a storm an automatic sampler, or "autosampler," is often used.

Autosamplers can be programmed to collect at specific times, or in response to specific conditions. Autosamplers can collect multiple times time points into one single bottle (composite sampling), such as collecting a sample every hour after the start of an event. The composite sample can be analyzed later, in effect obtaining an "average" measurement over the course of the storm event.

Autosamplers can alternatively collect discrete samples. For example, instead of collecting hourly samples into a composite bottle, 24 individual hourly samples can be collected into 24 bottles. Either sampling mode (discrete or composite) can be used to look for anything from coliforms to nutrients to road salt, as well as emerging contaminants that are very hard to track through any available sensor technologies.

It is very common to pair a water quality or water level sensor with an autosampler to trigger sample collection. For example, if road salt runoff is being monitored with conductivity, things other than road salt might lead to a change in conductivity. Thus, one might use conductivity as the trigger that tells the automated sampler when/how to collect a sample, but then the sample would be taken to a laboratory for more specific analysis.

There are scenarios where even an autosampler may not suffice, and manual samples will have to be collected. For example, volatile organic compounds (VOCs) are sometimes analyzed by laboratory methods that require sample collection in a specific type of sealable vial. Autosamplers might not be able provide the proper containment. If the analyte of interest is temperature-sensitive a refrigerated sampler can be used which will store the material until it can be collected by an operator. For stormwater monitoring, however, the portability and lower power requirements of a non-refrigerated sampler are usually both sufficient and preferred.

The water quality or water level trigger approach also affords for one of the most important features of a stormwater monitoring system, discussed for Step 3.

Learn More:
YSI.com/ProSample

Step 3: Define Notification Requirements

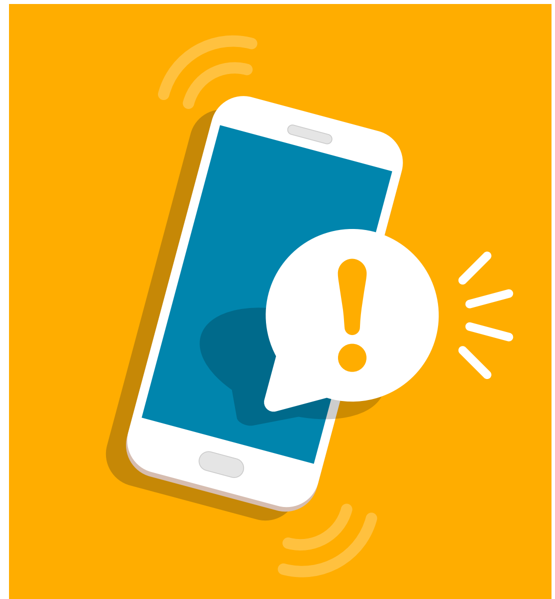
In the simplest of systems, the data are logged by the sensors and manually downloaded after an event. This requires site visits so operators often piggyback data downloads with routine maintenance visits or collection of samples. This perfectly acceptable approach does fail, however, to take advantage of one of the greatest benefits of a modern stormwater monitoring system: the ability to receive alerts and notifications directly to a mobile device.

Many users feel it is beyond their reach, either technically or financially, to set up an automated alert system. However automated alerts are more accessible than ever, particularly when working with an experienced integrator. Alerts can be received by anyone ranging from a single technician to the public, and via email, RSS feeds, texts, and even into mobile applications like Google's WAZE. Alerts can regard any aspect of interest, such as:

Rising waters that make it unsafe for safe passage of ships under a bridge

GPS-defined locations of flooded roads

Detection of a pollutant in excess of a defined threshold



Alerts can be received by anyone via email, RSS feeds, texts, and even into mobile applications like Google's WAZE.

What one wants to know, who is supposed to know it, and when and where they want to see it, will all define the logging, telemetry and data platform of a system.

Ideally one would have 24/7 eyes on the data through a mobile phone and only visit the monitoring system for maintenance purposes. The most common approach is for an integrated system to have a central datalogger that collects data from multiple sensors, and which transmits the data via cellular networks into a cloud-based data platform that is readable on either a mobile device or desktop. The same platform is typically the source of user-defined alert criteria that can also include actionable escalation protocols.

However one size does not fit all when it comes to logging and telemetry. While the user defines the sensors and sampling regimen, along with the what/who/when and where for notifications, the integrator can assist in choosing the type of datalogger, the means of telemetry, and the platform into which the data will be sent. Datalogger choice will be driven by the numbers and types of sensors, autosamplers, or other instruments that must connect to it. The telemetry choices most often are driven by location. Cellular networks are by far the most common means of telemetry, but in highly remote areas it might be necessary to use a satellite radio, or even a line-of-sight radio system to facilitate transmission. Finally, it must be decided whether the data are to be sent to an online, browser-based platform or a local network or system. As security of online platforms has improved, this has become the landing point of choice for the majority of stormwater monitoring systems.

IoT sensors are emerging that can independently transmit data into browser-based platforms or mobile apps that can be accessed on phones, removing the datalogger altogether. For stormwater monitoring, however, redundancy is advised wherever possible: for telemetry, for logging, and especially for the next step, which is about power.

YSI's field services crew finalizing the installation of complete stormwater site in North Carolina.

Step 4: Review The Power Budget

Now that you have considered what you want to measure, what your sampling regimen is, and how data will be telemetered, it is critically important to take a step back and look at the power consumption of all this gear before you buy it. This is another area where working with an experienced integrator can be quite helpful; they will likely have power budget calculators they routinely employ.

Loss of power during a storm is a common occurrence, and a stormwater monitoring system should not rely on mains power unless there is a backup generator or battery. In outdoor environments this is not always feasible. Further, when one starts adding sensors, samplers, and telemetry, power demands increase. It is important when choosing these features to calculate the power budget for the complete system, and to choose the power source(s) and backups accordingly.

Most systems are sufficiently powered by a solar-recharged 12 V battery. It is important to routinely clean solar panels, and also to keep track of battery voltage either through telemetered data or routine visits. It is also important to make sure that sufficient sunlight will reach the panels under non-storm conditions. High-power-demand systems may require additional batteries, and it is also prudent to use sensors that can be powered by their own internal batteries should system power fail.

With the final system design in mind, the protection of this investment should be taken into consideration next.

This portable water quality stormwater site in Kansas features a solar panel and is capable of collecting data, telemetry, water quality, MET, or flow in rugged applications.

Step 5: Secure The Equipment

There is more than one way to interpret what is meant by the phrase "secure the equipment." The first regards proper installation, such as when placing a radar on a bridge, or a Doppler device in an open flow stormwater pipe. The radar must be able to withstand the elements not just during the storm, but also during periods of high or low temperatures, high humidity, or whatever other weather risks may occur in an area. A Doppler device has to be secured so that high flows during a storm don't carry it off. Proper installation of not just the sensors but of all system components is paramount to successfully getting through a storm event with both equipment and data intact.

YSI field technicians installing protective casings for an EXO water quality sonde and discrete water sampler suction line.

However, "secure the equipment" also refers to protection against vandalism. When planning a stormwater monitoring system, it is important to consider whether simple choices can be made that make the equipment difficult for vandals to reach it. Sensors, dataloggers, and power systems should be in locked containers, and sometimes even fake warnings are put on them to deter vandals.

For both interpretations of security, working with experienced system integrators is highly valuable. Often the job of integrators is thought of as putting together the system components, but certainly one of the greatest benefits is their ability to assess a site and the safest and most secure ways the equipment can be placed there.

Choose the Right Partners

The five steps above will help almost anyone get started with the design of a stormwater monitoring system. A complete program however is another matter. One must consider how systems will be integrated, installed, and maintained, and also what the requirements will be to analyze and manage the data. The personnel burden can be significant and many organizations opt to work with a system integrator and full service provider to best execute on a stormwater monitoring program. This can lead to advanced decision support, such as aggregating information so that leaders can make decisions on when to alert the public to a dangerous flooding situation, for instance. YSI excels at bringing together complete programs through our Integrated Systems and Services team.

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