On Monitoring Water in Extreme Droughts

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Introduction – Timely, Accurate Hydrological Information is Critical

Nothing focuses attention on the vital importance of water and the value of water monitoring as much an extended drought. The stakes are high. Every drop counts. Extreme droughts draw attention to shortcomings in our knowledge of exactly how much water is available at all points in the supply chain.

As a result, droughts provide the best time to request public funding … for the much needed investments in water monitoring programmes required to fill critical gaps in hydrological information. Additional funding for establishing new gauging stations and modernising water monitoring capability enables the production of timely, accurate environmental insight. It enables the production of highly impactful water data that are relevant, reliable and trustworthy.

Droughts therefore present an opportunity to change the course of history. While new investments in water monitoring will not prevent droughts and floods from occurring in the future, information realised from these investments can substantially reduce the economic, social and environmental impacts of future extreme hydrological events.

This paper examines the importance of monitoring during extreme droughts and concludes with recommendations for how to make the most of new data investments.

Making History – Monitoring Low Flow Extremes

July 2015 was the hottest month in recorded history according to the National Oceanic and Atmospheric Administration (NOAA). The Clausius Clapeyron relation tells us that the moisture holding capacity of the atmosphere is non-linear with temperature. Over global land surfaces, the July average temperature was almost a degree higher that the 20th century average. This translates into an additional capacity of about one gram of water per kilogram of air. This means in July 2015 the atmosphere had the capacity to suck up about 10% more water than ever before. The net result is that many regions were dryer than they have ever been.

The 2015 droughts in California, Puerto Rico, North Korea, Sao Paolo, and India are climatologically driven events. However, these and other droughts of recent times have almost certainly been aggravated by water overuse, misuse and abuse. Additional water monitoring is needed so that society can adapt to a changing climate. An attractive alternative to the drought scenarios around the world is one in which monitoring is in place and provides:

- water supply statistics (so that planning and policies strategically prevent overuse);
- real-time data (to inform adaptive management practices to prevent misuse); and
- strategically located high-resolution hydrological information (to prevent abuse).

While it is alarming to learn that one third of global aquifers are under stress, one might reasonably expect to see equal proportions at 'normal', 'above,'and 'below' at any given time as a result of decadal-scale climate processes constantly re-arranging global water distribution. Our problem is that we do not have enough data to characterise what these patterns are, so we cannot plan for the likelihood, intensity and duration of these excursions. We also need more data to characterise the nature of groundwater/surface water interactions during all phases, including both surplus and deficit. The past is no longer a reliable predictor of the future.

With more water resource extremes, the new normal does not look like the old average anymore. Adaptation to the new normal first requires characterisation of the new normal. New policies, planning, drought management strategies and agricultural best practices all need to be informed by how much water there is, where and when.

This is not the last excursion from our comfort zone that the climate is going to take us on.

There will be more droughts and more floods in more places. We need to be better prepared for both extremes. The climate is changing and we cannot predict with 100% certainty what those changes will bring. The influence of greenhouse gases on the climate is well explained in both theory and empirical evidence. What is not so well understood is how to plan for these influences on water distribution in the absence of useful hydrological information.

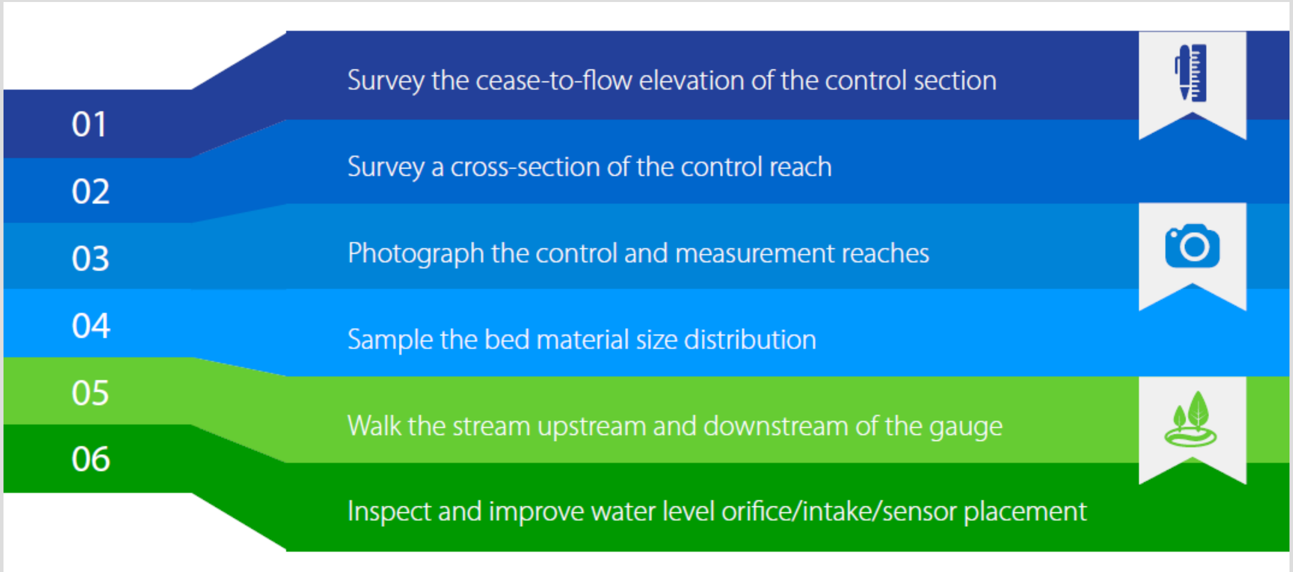
Additional investment in monitoring is needed so that society can adapt to change. Funding is needed to ensure that monitoring can adapt to our changing needs. We control the data legacy that will guide society through more extremes.

What will our legacy be? It Is All about the Data – Illuminating Our Water Options

Extreme droughts in many regions of the world are creating an opportunity for Civil Engineers to record a historic event. Low flow measurements being made during extreme conditions will inform hydrological science and watershed management decades into the future. In distant times, end-users of the data may have questions about the reliability and accuracy of the data. There may be gaps in the data. The time to answer those questions is now, while we are in the field. The time to invest in water monitoring is now, to address critical data gaps.

Extreme low flow is a good time to be extremely careful in field procedures and documentation. A lot can go wrong with the measurement of small flow. There may not be sufficient channel width to sample channel depth with sufficient resolution. There may not be sufficient depth to sample the velocity profile with sufficient resolution. There might not be sufficient velocity for an accurate velocity measurement. There may be current angles, or even reverse flow, but the force of the current may be insufficient to accurately measure direction of flow. There might not be enough cross-sectional area to get a representative velocity field for ADCP measurements. The control feature may not be sensitive to very small changes in stage. Small rearrangements of the stream bed may result in large effects on the stage-discharge relation. To make matters more complicated, high stream temperature and slow velocity are favourable to the growth of aquatic vegetation on the control.

Low flow measurement, however, provides an excellent opportunity to be especially thorough in procedures and documentation. There is no better time to:



As Civil Engineers are recording some of the lowest flows in the past century, it is an excellent time to conduct replicate gaugings. Changing equipment and/or initial point for soundings provides a wealth of information that is helpful for accurate calibration of the low end of the rating curve. In the time it would take to do one high flow gauging it may be possible to do several low flow gaugings.

Water data are complex. Water data are context sensitive.

Streamflow, its constituents (e.g. sediment, solutes), properties (e.g. temperature) and behaviours (e.g. velocity) integrate local, regional, and global processes in non-linear ways that often defy upscaling. Environmental intelligence must therefore become smart enough to be able to consume data complete with its meaningful context. This means that, as a water monitoring community, we must give careful thought to our metadata management. Environmental intelligence will need the exposure of Long Tail data to fill critical data voids. However, the burden of even minimal metadata management is a causal factor for many data sources to go dark. We need to develop a viable metadata payload for our data that is sufficient to address emerging roles for our data and that is so easy to implement that data hoarding will become a relic of the past.

Seven Best Practices for Monitoring Water during Droughts

During extreme droughts, every drop of water matters. Hydrological data availability, accuracy, and timeliness are more important than ever before. Extended droughts thus present an opportunity to revisit and adjust our industry best practices.

01 Increase Station Density to Better Characterise Spatial Variability

Many water monitoring networks are optimised for the ‘normal’ flow condition. There will typically be one gauge per basin at a given scale of interest. During times of drought, however, this density is insufficient to resolve important differences in water supply and demand from upstream catchment areas. In other words, when water is scarce, all scales become of interest. Low flow is a very good time for synoptic-scale monitoring to collect a snapshot of many sub-catchments to characterise the spatial distribution of flow. Any identified anomalies in runoff (i.e. flow per unit area) are good candidates for locating new permanent gauges.

02 Track Meteorological & Other Parameters to Better Understand Variability

It is one thing to have data that demonstrates that different catchment areas have different response characteristics; it is another thing to explain these differences. Air temperature, snowpack, precipitation and soil moisture sensors provide an ability to reconcile basin inputs with outputs. These parameters have value not only in closing the water balance but also in providing great value for improving the management and limiting the impacts of droughts. For example, forest fire frequency, magnitude and severity are all affected by hydrological drought and better information about temperature, precipitation and soil moisture provide essential guidance for forest management.

03 Reduce Uncertainties with More Measurements

Low flow conditions are an excellent time to validate measurements by replication with a change in initial point for soundings and/or change in technology to better characterise sources of uncertainty in low flow measurements. Returning to the gauge to repeat measurements even for a relatively small change in stage can reduce the uncertainty at the low end of the rating curve. If the stream is approaching zero flow then frequent site visits can greatly reduce the uncertainty of the cease-to-flow elevation.

04 Anticipate Future Questions with Well-Documented Answers

You cannot fully anticipate the impact of your measurements on any number of different water management objectives. However, you can anticipate that your observations will add great value to an improved understanding of the impacts of drought and the implications for future droughts. Therefore, you need to be the eyes of future investigators. This is a good time to be verbose in commenting on your observations. If the gauge is dry, is there any standing water in the channel? What is the condition of that water, are they any creatures taking refuge in the pools? What is the condition of the exposed streambed? Predict what the relevant questions may be based on your knowledge of locally important issues and concerns, and then document the answers accordingly.

05 Monitor Water Quality

Water quality is never more important than when water is in short supply. Low flow streamflow may be from deep underground sources laden with minerals, which may make the water unsuitable for certain uses. In the absence of storm-cycle driven flushing events and with high rates of evaporative loss nutrient concentrations may build up. High nutrient concentrations combined with high water temperatures can result in toxic algal blooms and/or pathologically low dissolved oxygen levels. Lack of refuge from high water temperatures can be lethal to resident fish populations. Reporting on water quantity alone cannot convey whether the water is fit for its intended use.

06 Monitor Groundwater

Extended drought conditions are a good time to coordinate groundwater and surface water monitoring. Surface water flow will be largely dominated by groundwater deposits, and the extent of the interaction between groundwater and surface water is essential to the wise management of water resources during times of drought.

07 Streamline Data Sharing

Do not assume that the only stakeholders who can find value in your data during drought are the same ones who use the data during high flow conditions. New uses for the data are discovered that create great social, economic, or environmental benefit when water data are openly shared and made publicly accessible. Extended drought conditions are a good time to:

• modernise gauges with real-time telemetry;
• set up automated preliminary data processing;
• publish data directly to the World Wide Web.

There Is No Better Time Than Now!

Water monitoring is an under-appreciated public service that is essential for wise and sustainable management of a largely under-appreciated common pool resource. The only time when the value of water is fully appreciated is during times when our freedom to access an unlimited supply of high quality water is at risk. It is when attention is highly focused on the value of water that requests for needed investments in water monitoring capability are most likely to be successful.

Sustainable and secure water supply management requires sustainable and secure water monitoring. One factor often lost in crisis-motivated spending is that monitoring, by its very nature, requires funding distributed over a long time frame. This essential truth is difficult to reconcile with funding motivated by urgent requirements. There is often a poor return on investment if funding exceeds short-term capacity to hire and train Civil Engineers and build new stream gauges but is insufficient to provide for ongoing salary, operations, and maintenance costs long after the crisis ends. Investments in monitoring made when new funding is available should focus on the long-term view.

Strategic improvements in the relevance, reliability, and accessibility of water data will systematically increase the influence of the data in forming public policy. Visibility of the true nature of water supply variability in time and space raises public awareness of the importance of water monitoring for water supply management. It is by improvements in social awareness that sustainable, long-term investments in monitoring can be achieved.

Water Stress – Make Stream Gauges Not War

The World Resources Institute used an ensemble of climate models and socio-economic scenarios to rank future water stress globally. Notwithstanding the uncertainties inherent in the methodology, the results align with intuition; countries with a trend toward greater water demand than supply are setting themselves up for water stress. Tragically, many of the countries at the head of the list are already experiencing strife and turmoil and the study does not shy away from making an explicit connection.

Climate change is a challenge that we must learn to adapt to; chronic mismanagement of water resources is not. The surest path to change course from water overuse, misuse, abuse to a secure and sustainable water future is to ensure that decisions are well-informed by relevant, timely and trustworthy hydrological information.

There is an unfortunate negative feedback loop between civil strife and water management. Water resources monitoring and the subsequent development of sustainable water infrastructure does not happen during times of war. The result is that conflict has no hope of resolving the underlying issues. To paraphrase a 1960's slogan – 'make stream gauges not war'.

The problem is global, not regional. While some countries are failing to make the needed investments to monitor and manage their water resources to enable sustainable development, the impact of these strategies will not be locally contained. There is already a migration crisis which is a warning of the flood of climate refugees we can expect over the coming decades. Water rich regions of the world can either choose to ignore the preconditions for social failure in water stressed regions of the world or they can be proactive and take steps to help develop needed water monitoring and sustainable water infrastructure. What is our responsibility for global water security and how can we better live up to that responsibility?

Conclusion– Monitor Water Before Every Drop Counts

We can hope that the next major drought will not re-occur until the currently depleted groundwater resources have been fully replenished to provide water supply insurance that has been heavily depended on for recent water demand. However, we need to consider that some of the water present in many aquifers was likely sourced as meltwater from the last ice age. Given the time-scales involved, such hope may be little more than wishful thinking.

We do have options. We can systematically reduce overuse, misuse and abuse of our water resources today. We can strategically improve our water storage and distribution systems to improve our renewable storages to reduce, or even eliminate, our dependence on unsustainable water sources.

Much can be achieved with almost immediate effect at relatively low cost whereas some projects will require years of planning and enormous capital investments. The most efficient path to a desirable water future is paved with data. Improvements in water monitoring today will guide critical decisions along the way with reliable and trustworthy hydrological information.