Focusing on the Essentials

Integrated Monitoring and Analysis of Water Resources

SHARACHCHANDRA LELE, VEENA SRINIVASAN

Welcoming the debate on the assumptions underpinning water resource monitoring in India triggered by the Mihir Shah Committee report, the authors suggest that the proposed National Water Commission should focus on providing integrated data and science to help water managers and policymakers, avoiding getting directly involved in planning or regulation.

Sharachchandra Lele (*slele@atree.org*) is a senior fellow and Veena Srinivasan (*veena.srinivasan@atree.org*) is a fellow at the Centre for Environment and Development, Bengaluru.

The term "integrated water resource management" has been popular in water resource management circles for several decades now. The concept, in principle, is about recognising the manner in which water moves and thereby links all manner of users—upstream with downstream, surface with ground, domestic with non-domestic, and so on—and managing water in a way that recognises these linkages. Achieving this laudable goal has, however, been difficult for a variety of reasons, including the fact that these linkages—especially the link between surface water and groundwater—are hardly recognised in the way we monitor, analyse, and present information on water resources.

The move in 2015 by the Ministry of Water Resources to set up a committee

> to recommend suitable re-orientation and re-structuring of CWC [Central Water Commission] and CGWB [Central Ground Water Board] and assess the capacity requirements of CWC and CGWB to discharge all functions as envisaged for integrated water resource management

was a welcome and long overdue one. The report of the committee (hereafter, Shah Committee) provides a comprehensive overview of the challenges facing India's water sector. Its core recommendation is the creation of a National Water Commission (NWC) that will monitor, plan, promote, incentivise, manage, and regulate water resources (quantity and quality) in the country.

Less Is More

This is an ambitious idea, to say the least. Constitutionally, water is a state subject in India. The central government may provide information, funding or training, but its powers in terms of actual water management or regulation of water use are limited to addressing interstate water disputes, shipping and navigation of national waterways, and tidal waters (Cullet 2007). Even where the centre has passed laws, such as the Water (Prevention and Control of Pollution) Act that relates to water pollution, the agencies who enforce the law—in this case, the pollution control boards—are set up by and answerable to the state governments. The CGWB, which has powers to regulate and grant consent for the industrial pumping of groundwater in notified areas, is somewhat of an anomaly here, but its powers are still fairly limited.

The current mandates of the CWC and CGWB reflect this constitutional arrangement. While the CWC provides technical approval of surface water projects when asked for, and post facto evaluations of their performance, the primary activity of both agencies is providing data and analysis on water resources through monitoring of surface flows and groundwater levels, flood forecasting and groundwater resource estimation, reservoir sedimentation studies and dam design, and associated basic research and training. And the primary focus is on water quantity, given that the Central Pollution Control Board is statutorily mandated to provide guidance in the area of water pollution.

Given this jurisdictional context and core competencies, we believe that it would be legally and practically advisable that any national-level agency created by merging the CWC and CGWB focuses on information provision, analysis, and associated research and training to enable other actors at various scales to carry out integrated surface-ground water management for achieving the goals of equitable and sustainable water use. We believe this mandate is narrow enough to be realistic while challenging enough, as it focuses attention on how to achieve the core objective of the merger—providing a holistic understanding of surface and ground water in the river basins of the country.

Case for Integration

Historically, the CWC's surface water hydrologists have been civil engineers, who took river "yield" as consisting of surface run-off and base flow (most visible as flow that appears in streams even after the rains have stopped). The assumption—not an unrealistic one 50 years ago—was that these flows were "natural," influenced only by how much rain falls in a given year and the land cover in a catchment. And the engineers' focus was on building dams to harness these flows for hydropower or to divert them for irrigation, or occasionally to contain them when excessive. Little attention was paid to where base flow came from, and even less to how human actions other than building dams, such as changing vegetation and extraction of groundwater, might affect it.

On the other hand, the CGWB's groundwater hydrologists have been largely hydrogeologists, who for many decades focused on groundwater prospecting to promote its "development" (that is, extraction), and therefore on recharge (water entering the aquifer) rather than on discharge (water exiting the aquifer into the stream). Even when the idea of regulation for "sustainable use" was introduced, groundwater was treated as a "separate" resource. So they defined groundwater as "overexploited only if extraction exceeded recharge, forgetting that extraction comes at the cost of base flow in the river.

But if one looks at the complete water cycle, one realises the limitations of both perspectives. Broadly speaking, precipitation (including rain and snow) ends up either as surface run-off or infiltrates the soil. Plants then suck up/transpire some water, while the infiltrated water percolates through the soil till it reaches (recharges) the water table. This water table is always dynamic—rising in the monsoon when most of the recharge takes place, and falling in the post-monsoon period as groundwater becomes base flow, either into streams and rivers, or at coasts, directly into the ocean. The net result is that all precipitation that enters the "system" (the river basin) exits in only one of two ways—evapo-transpiration (ET; from plants, bare soil, or waterbodies), or outflow to the oceans (surface or subsurface) (Lele and Srinivasan 2015).

Human actions may be in the form of direct abstraction or indirect modification of the links, but the net effect is always to change the partitioning between evapo-transpiration and ocean outflow (and sometimes water quality). Hydropower dams may store water, increasing evaporative losses and slowing the movement to the oceans. Irrigation dams may increase net evapo-transpiration as semi-arid regions get irrigated. Urban use is largely non-consumptive, and most (~80%) of the water may come back to the river (but often in a highly polluted form). As all uses generate some return flows, water may get used multiple times before it reaches the oceans. Moreover, "use" happens not only when plants transpire or human beings consume water, but also by aquatic life in streams, lakes, rivers and estuaries.

Similarly, deforestation upstream may reduce evapo-transpiration, and the compaction of soils often associated with it may also reduce infiltration, thereby increasing surface flows to the ocean. Groundwater pumping and its use for irrigation in upstream areas will, on the other hand, reduce base flows and therefore ocean outflows. Indeed, today, most Indian rivers have hardly any outflows to the ocean—an indication of how human use of water has intensified (that is, evapo-transpiration has increased) in these basins. As the Shah Committee report says, "The single most important factor explaining the drying up of post-monsoon flows in India's peninsular rivers is the over-extraction of groundwater" (Srinivasan et al 2015).

A holistic consideration of the water cycle thus demands making a normative shift. One would have to give up the notion of "utilisable potential," which is virtually all the water that was flowing out to the oceans when the river basin was pristine, as an objective concept (WRISD 2015). Because, in one sense, no water is simply "available" for human use. All new consumptive use reduces flows in the rivers and out to the ocean, depriving other life forms in some fashion. Equally, one would have to abandon the idea of "net annual ground water availability" as an objective concept and groundwater "development" as a phrase because, again, groundwater is not simply "available" for "development"[1]—any consumptive use of groundwater reduces base flows, which affects someone downstream.

The goal of integrated water management then becomes fair allocation of water across all uses and users—an allocation that has to be socially determined. And the goal of integrated water monitoring and analysis then becomes providing inputs that inform these allocation decisions by elucidating the ultimate fate of water in the form of evapo-transpiration and ocean outflows, and the intermediate links, including the changes introduced by human actions and use at multiple scales.

Integrated Monitoring and Analysis

This changed paradigm translates into a new approach to monitoring and analysis, the ultimate objective of which will have to be to generate (and constantly refine and update) a detailed "water balance" or "water budget" at multiple socially relevant scales—from gram panchayat-size micro-watersheds to the whole river basin, and across all uses—domestic, agricultural, industrial, and in-stream. And analysing and predicting the effects actively proposed large water projects as well as dispersed water-relevant actions—urbanisation, groundwater pumping, land use change, and so on—and, of course, climate change have on this water balance.

This approach requires significant changes to and augmentation of the variables to be monitored and the analyses to be taken up. While the Shah Committee has flagged several of these (for instance, aquifer mapping),[2] others include:

(i) Direct measurements of groundwater pumping: Unlike surface water, investments in groundwater abstraction structures are made by individuals. Therefore government records on these are poor and estimates of the quantum extracted very approximate. Preliminary comparisons suggest there are order-of-magnitude discrepancies in groundwater-irrigated areas between the official data and independent estimates from satellite imagery or field measurements (Heller et al 2012). Serious investments in simply quantifying groundwater abstraction are needed.

(ii) Direct measurement of consumptive use: Evapo-transpiration is the fate of most of the precipitation in a basin, but current estimates of this variable are based on very scattered and limited direct measurements of a few vegetation types, with the rest being based on crop-coefficient values determined from the global literature. Given the tremendous diversity and dynamism of Indian agriculture and also forests and grasslands, and the intensity of use in almost all basins, a massive programme on direct measurement of actual evapo-transpiration under different crops, irrigation systems, and uncultivated vegetation types is essential.

(iii) Low-flow impacts on aquatic life: Hydro-ecology has been a neglected dimension of our monitoring systems. The impacts of low flows on aquatic ecosystems, including fisheries but also other organisms, needs to be much better understood.

(iv) Multiple stressor disaggregation: Rather than simply presenting data on river flows, it would be valuable to disaggregate the impacts of upstream diversion/dams from those of land use change or changes in groundwater use, large-scale watershed development, and climate change.

(v) Imports: Often, CWC gauging stations are located downstream of rapidly urbanising areas or highly irrigated areas, which may import water across watershed boundaries and create additional return flows. Separating urban return flows and agricultural return flows from run-off and base flows is essential.

(vi) Recharge estimation: Rigorous estimation of recharge from primary measurements of all other parameters, including soil moisture and evapo-transpiration, is essential if one is to understand the effects of human actions on our aquifers.

(vii) Changing water cycle or non-stationarity: Neither the CWC nor CGWB currently present in-depth analyses of the trends in the data they collect. For instance, the CWC often presents "average" water resource availability or "basin yield." The tendency is to assume stationarity in conditions, when the water cycle is actually changing for a variety of reasons—dams, diversions, land use changes, groundwater pumping, and climate change. Teasing out the effects of these changes must be a high priority for the integrated agency.

(viii) Monitoring network density: Whether it is observation wells, stream gauging stations, or weather stations, the current monitoring network suffers from low density, poor quality (especially of state-run stations), and fragmentation (lack of sharing of data between state and centre, and across agencies). Significant expansion, quality control, and integration across agencies are essential.

In other words, the NWC would focus not on evaluating the design of new dams by states or estimating the potential for groundwater development, but on generating a scientifically rigorous and fine-grained understanding of the relationship between different human interventions and their multiple consequences, with the added effects of climate change woven in.

Integrated Understanding

The Shah Committee has rightly emphasised the importance of an interdisciplinary approach and therefore a multi-disciplinary leadership. Even keeping in mind the narrower, more "hydrological" mandate that we are proposing, we believe that the data and science generated by the NWC must be informed by and must speak to the social and ecological dimensions of water use. Consequently, the multidisciplinary body proposed by the Shah Committee could be seen as a high-level advisory committee that guides and evaluates the direction and rigour of the NWC's work on a regular basis. The organisation itself should have a single head, a director-general, who would be an openly recruited world-class scientist with managerial experience, who can demonstrate an understanding of and commitment to socially-relevant integrated water monitoring and analysis.

But perhaps the biggest challenge that will have to be confronted is one of breaking disciplinary barriers within the staff. The divides between surface and groundwater hydrology, between engineering and geology, or between eco-hydrologists and conventional hydrologists all run deep. Organising divisions of the NWC along traditional lines—for example, river rejuvenation versus aquifer mapping versus water quality, as currently proposed—will not help bridge these divides. The only way they are likely to be overcome is to start with some "crisis" basins as the foci, and constitute teams around each such basin that are charged with developing a joint "product," such as a spatially disaggregated water balance model, and generating series of analyses of different scenarios that will feed into the planning processes in that basin. This would include forecasting trends under climatic, demographic, and economic uncertainty to enable more adaptive water resource management. This exercise would not only generate valuable insights for the focal basins, but also generate a joint understanding of the kind of integrated monitoring and analysis protocols that may be required in general.

In conclusion, the Shah Committee report has triggered an important and long overdue debate on the normative and scientific assumptions underpinning water resource monitoring in India. Both the fragmentation across disciplines and the separation of missions from ground realities are significant, as highlighted in the report. Taking a cue from the United States Geological Survey (USGS), which defines its mission as producing "science for a changing world," without getting directly involved in planning or regulation, the NWC could fruitfully focus on integrated data and science for helping water managers and policymakers in an intensely contested and changing water landscape.

NOTES

1 See http://www.cgwb.gov.in/faq.html.

2 And also flagged the need for complete data transparency, which we shall not repeat here.

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