A Indian Institute of Science, Bangalore
and IBM White Paper

Rain to Drain

A roadmap to gaining control over water resource management using information management and predictive analytics

Introduction

This white paper addresses how Information Technology (IT) can play a part in better management of water distribution system, its assets and water quality for large water boards and bodies. It lays out a roadmap that water boards can use to create systems that can monitor, administer and manage increasingly complex water distribution systems which are under a lot of stress because of high demand growth.

Water challenges in India

India is facing a serious problem of natural resource scarcity, especially that of water in view of population growth and economic development. The per capita fresh water availability which was 5,177 cubic meter per annum in 1951 has reduced to 1,820 cubic meter per annum in 20011. In fact, it is predicted that by 2025, the per capita annual average fresh water availability will be 1,340 cubic meter approximately1. Per capita water availability of less than 1,700 cubic meters is termed as a “water stressed” condition. It is also expected to decline to as low as 1,140 cubic meters in 2050. This is driven by several factors including:

- Increasing population
- Growing economy
- Large agricultural sector
- Unclear laws
- Heavy industrial and human pollution

A number of areas need to be worked on to alleviate the water problem[3]:

- Increasing water availability through infrastructure investments such as increasing storage capacity to take advantage of the bountiful rainfall in most parts of the nation.
- Investment in water distribution systems both for upgrading old infrastructure as well building new distribution.
- Pollution control to ensure that sewage and industrial effluents are treated before discharge into rivers.
- Appropriate regulation and unifying disparate bodies in charge of different facets of water supply.

However our focus will be on utilizing the nation’s strength in IT, to enable stressed organizations and water boards regain control over their resources and to vest back the intelligent decision making powers back into the hands of the administrators and subject matter experts by providing them accurate information and the tools to control their complex systems. This paper studies Bangalore’s situation and attempts to develop a roadmap for Bangalore’s water body.

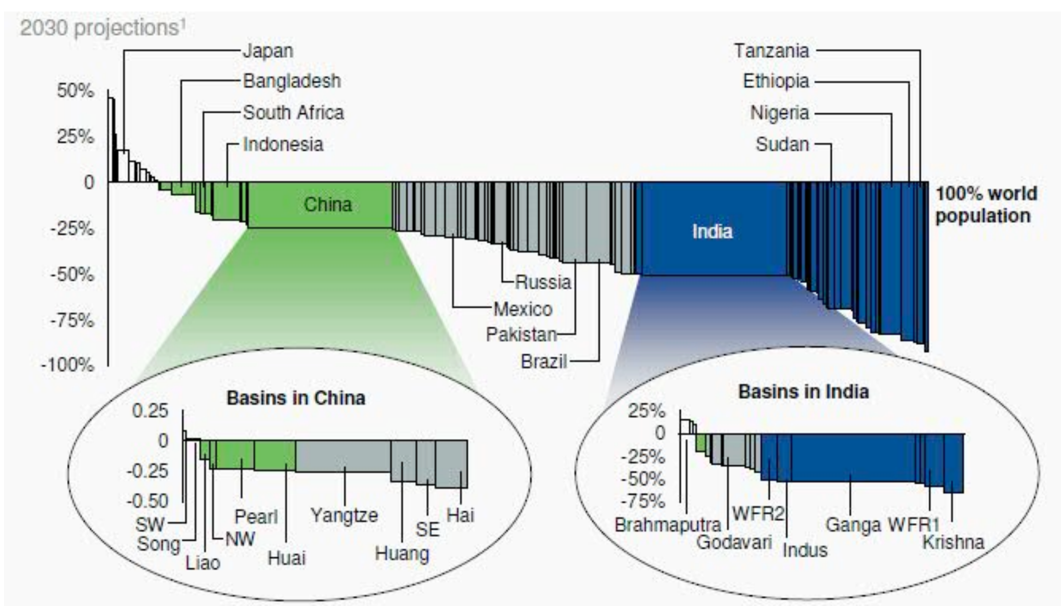

Figure 1: Water deficit projected in 2030 assuming technological innovations are frozen at 2010 levels, Source: OECD workshop 2010[2]

Bangalore city

Bangalore is a thriving metropolis in the heart of the Deccan plateau in India with a population that has grown from 5.4 million in 2000 to 8.4 million in 2010. This phenomenal growth has been triggered by the growth in the IT industry in India and Bangalore in particular. This unprecedented growth has put a tremendous amount of pressure on basic infrastructure inside the city including water supply. Bangalore Water Supply and Sewage Board (BWSSB) supplies water to nearly 800 sq kms of the city and outlying areas under its jurisdiction, see figure 2.

The city's population was supplied water from the Arkavati river by the water supply scheme commissioned in Hessaraghatta in 1896. The original capacity was 36 million liters per day (MLD) and was augmented in 1962 by a pumped transmission system of 149 MLD in T K Halli in 1962. Since 1974, brisk additions to water supply have been commissioned through pumped systems of Cauvery river at T K Halli at roughly 10 year cadence (four pumped transmission systems with capacities of 135, 135, 270, 270 MLD). The total capacity of the BWSSB is currently approximately at 900 MLD and is on the verge of being augmented by a massive 500 MLD middle of 2012. In addition to this nearly 200,000 borewells are being operated by BWSSB and private parties all over Bangalore. The water supply situation is Bangalore is still in

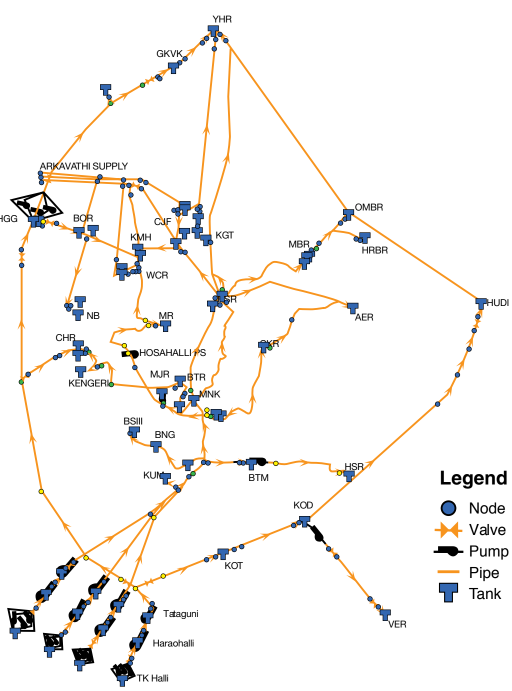

Figure 2: Bangalore Water Transmission System

the red despite the massive infrastructure build up, mostly because of the growth in the city and continuous incorporation of outlying areas into BWSSB's service zones.5 To add to that water supply is extremely expensive because BWSSB has to pump the water from T K Halli to the city which is a distance of nearly 70 kms and an altitude of nearly 400m. Pumps at T K Halli, Harohalli and Tataguni are working 24x7 to ensure that water is continuously fed to the city. Despite all this any zone within the city gets water once every other day and for a few hours each.

Each transmission system consists of a water treatment plant. Within the water treatment plant is a Parshalls Flume for measurement of rate of flow and a filtration plant for improving the quality of the water to drinking standards through chlorination. This water resides briefly in a temporary reservoir that can hold upto approximately 1 hour worth of water supply. Water from the reservoir is pumped by 3 to 6 centrifugal hydraulic pumps to the next stage gaining roughly 100m in altitude and requiring head to be restored. The final (3rd) stage of pumps will feed the water into the distribution system made up of several elevated service reservoirs (ESR) and overhead tanks (OHT) through large balancing reservoirs. Water from ESRs and OHTs is then fed into the rest of the distribution system.

Bangalore water supply challenges

BWSSB's biggest challenge is that demand is far greater than supply. Hence the highest priority is to keep the pumps running all the time and feeding as much water as available from Cauvery into the city. An equally high priority is to ensure that of the water available to be supplied, distribution is as equitable as humanly possible. Like all old water boards, BWSSB has a large amount of assets that are past useful life but accessing them for replacement or modification in the middle of the city is a difficult task. Leakage and theft account nearly 40-50% of the water supplied to the city also called NRW (non-revenue water). Anecdotally NRW for Bangalore is in line with cities of similar size and asset age. Energy bills arising from pumping the water from T K Halli to the city which is nearly 400m of altitude difference is very large and accounts for nearly 60-70% of the net expenses. Fortunately the board relies on subsidized energy tariff rates provided by the government, but rising energy costs does put a tremendous pressure on the board and government to rein in costs.

Management of assets is done manually. Data such as input power and output pressure relating to pumps is entered in log books by hand. Management of assets is done by engineers and technicians on the ground. Records are kept in detail but hard to access outside the specific location. Engineers keep in touch with each other by texting and calling over mobile phones. In the past 5 years, due to the foresight of one of the BWSSB's chairman, the board has begun to develop a geographic information system (GIS) for all its fixed assets such as pipes, valves, sewers, manholes and drainpipes. The best estimate is that the database is about 60-70% accurate. Accessing the pipes is still a complicated job because the GIS system shows approximate location of pipes along roads not latitude – longitude per critical junction or turn. So any maintenance or adding capacity requires a lot of work on field and engineers have to make decisions at the site based on data available.

BWSSB is like many boards in India and other growth markets. Clearly at the top of the priority is to **add capacity** to feed a burgeoning and increasingly affluent population. But **running operations** is becoming a very big challenge. Engineers employed nearly 30-40 years ago are on the brink of retirement and with it a lot of working knowledge will be going away. Energy costs and management of the distribution system are two of the biggest operational challenges for BWSSB. As it installs new capacity it is demanding that the contractors install SCADA (supervisory control and data acquisition) systems that can feed real time data to an operations center. However, the challenge is how does BWSSB build a plan that allows gradual integration of the legacy systems with the newer systems and provide a single integrated view of the water distribution system. Some challenges are similar to other international water bodies, while others are unique to Bangalore and growth markets.

Water systems in North America

Most North American water systems are better instrumented which makes the goal of integration relatively easier. North American systems are generally well metered. Each consumer or household has a separate water meter. In Bangalore as in much of India, meters are by building or ward. Since systems in developed nations are well instrumented and integrated, the focus is on higher level functions such as optimizing pump schedules to reduce energy costs by using differential energy tariff rates and pumping water during off peak hours.
In developed nations, labour rates are very high and contribute towards a large fraction of operation budgets. Thus optimizing work plans and schedules yields large bottom line benefits.
By contrast, cheaper labour in India makes optimizing crew orders a less rewarding area for water boards. Work crew management is a more hands on task. The point is that growth markets like India and developed markets like the US have different challenges and problem statements. IT solutions for water management need to comprehend these differences.

Water management information system

Exposed to the IT revolution, both at home and through interactions with other governmental and semi-governmental agencies, engineers in the boards have begun to feel the need for an integrated water management system with the full comprehension that all parts of the current system are not ideally suited for immediate integration. A comprehensive water management system should integrate every component from the raw water input up to the endpoint. An engineer managing the system should have a clear view of which pumps are working, how much water each pump is transmitting, water supply in each of the individual parts of the distribution system, position and status of each valve, levels of water in each reservoir or tank and the quality of water at each point in the system.

Indian Institute of Science, Bangalore and IBM have been working closely with BWSSB and envision an information management system that will form the backbone for monitoring, administering and managing water supply networks for cities and states like Bangalore. A comprehensive information management system with appropriate dashboards will provide the visualization capability to engineers in BWSSB and move the control point from junior operators to more experienced engineers. Armed with such a system, water boards will regain the control over the complex distribution systems that have resulted from unplanned urban sprawls. Regaining control will lead to better decision making and proactive management which is vital in the coming years as pressures on water supply are bound to grow.

Platform

At the core of the information management system, must be a suitable platform that allows models, applications, user interfaces, and database to communicate with each other seamlessly. Further addition, deletion and modification of applications should be modular, not requiring complete overhaul of the platform. Domain models are required to model the transmission and distribution system. Models should be based on industry standards and modular in nature so that modifying components within the model is easy.

A core engine must have the following capabilities. See figure 3.

- Allow rules for alerts or alarms to be defined based on business needs. Generate alerts or alarms when these rules are breached. An example of an alarm is a pump breaking down which results in a SMS (short message service) being sent to operations engineers.
- Manage movement of data between various applications and interfaces.
- Able to interface with OPC (Object Linking and Embedding for Process Control) compliant SCADA systems.
- Support various applications and APIs (Application Programming Interface).

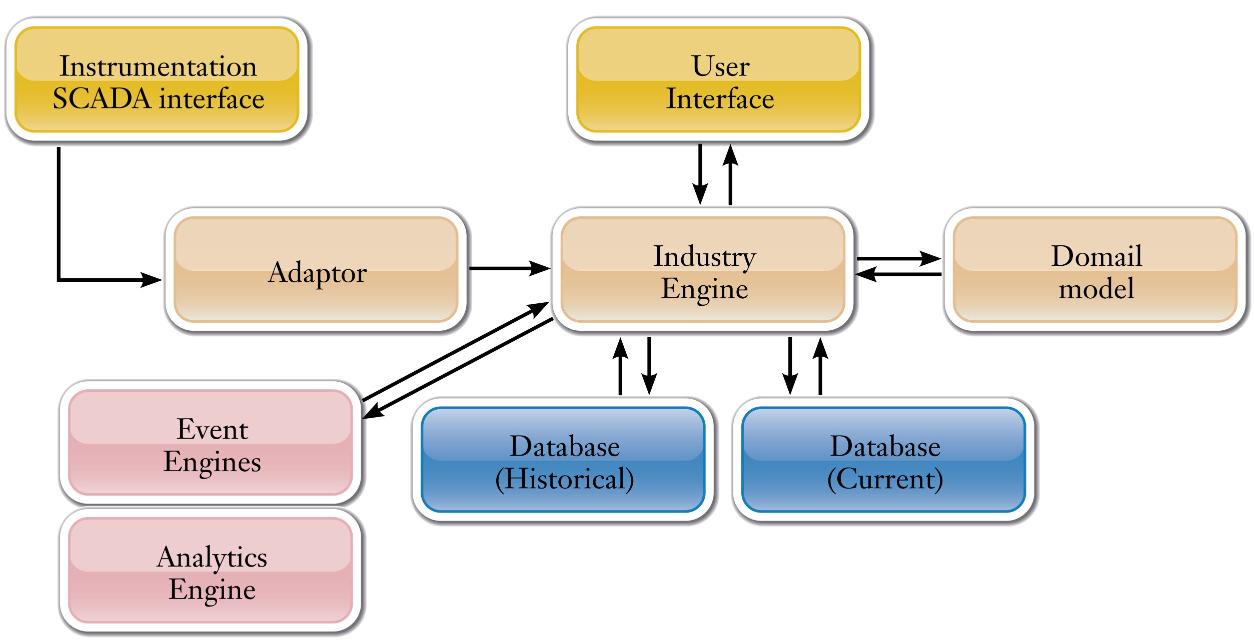

Figure 3: Architecture of an information management system to handle water systems

Domain model:

A hierarchical domain model should encompass all critical parts of the water management system such as transmission, distribution, sewage and drainage. It should contain data regarding water quantity and quality at each critical node and operating performance indicators for each asset as a time series. An example of performance indicator could be input power and output pressure and flow at each pump.

User Interface:

Web based user interface (UI) is the most visible manifestation of the management system. It should have easy to navigate and have easy to drill down capabilities. An "operational dashboard" such as that provided by the IBM Intelligent Operations Center (IOC) which presents a unified view of Intelligent Water functions should be the heart of the UI. It is the "control center" or "command center" for all users. See Figure 4. A good dashboard should contain:

- A geospatial representation of the water distribution system.
- Key health or performance indicators to represent status of each asset. Example pressure or flow rate of water flowing through a section of the pipe.
- Ability to access historical data for each asset.
- Customizable alarms or alerts.
- Collaboration tools such as bulletin boards for communication between users.
- Role based access: different users have different privileges and access to data based on their role.

Sensors and Instrumentation:

Instrumenting the water transmission and distribution system[4] is a key enabler to leveraging the water management system. Sensors and instrumentation provide real time data that is required for reporting live the status of each asset in the network.

- Transducers for pump motors
- Pressure and flow meters for all pumps
- Stress sensors (wall stress sensors) for pipe lines
- Identify air lock using multiphase flow meter
- Chlorine sensors and turbidity monitoring for water quality

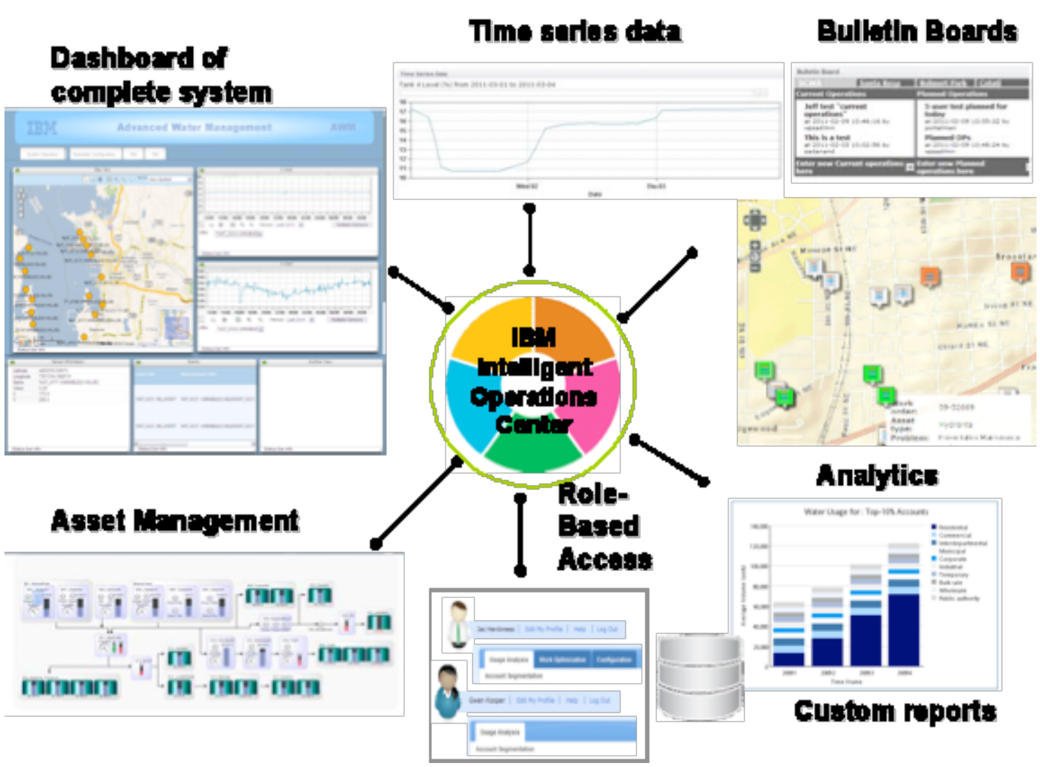

Figure 4: Features of IBM's Information Operation Center for Water

For those cases, where wiring of the sensors and instruments turn out to be impractical, wireless mode of data transmission directly to the digitization platform using suitable RF (Radio frequency) transceivers would be preferred.

Advanced capabilities:

The real benefit for water board starts accruing when the information management system is operational, data is streaming in from various points, and new capabilities are added at a fraction of effort and cost that leverage real time data in ways that wasn't conceivable before. The predictive analytic capabilities of these new generation systems enable you to predict and prevent service disruption. Here are a few examples:

- Integrating sewage network for a more holistic view.
- Analytics to reduce energy costs by optimizing pump scheduling and output pressure.
- Analytics to service assets such as pumps before they breakdown.
- Analytics to determine which assets can be refurbished for increasing operational efficiency and reducing energy costs.
- Hydraulic models to direct valve settings for equitable water supply to all zones.
- Hydraulic models and algorithms to detect possible points of leakage or theft.
- Hydraulic models to direct valve settings for alternate routing of water for contingencies.
- Analytics to assess whether replacement cost of aged equipment pays back in reduced energy costs and reduced service costs.
- Root causing which sections of the distribution network is causing contamination and reduction in water quality.
- Detecting defective water meters.
- Integrating billing and water usage for a better compliance and optimizing revenues.

Roadmap for water boards in India

IBM proposes the following information management roadmap for water bodies in India and developing countries. See Figure 5:

- Creation of an information management system that is **easy to modify and upgrade**. Able to accept data through an OPC compliant SCADA system, which is a well accepted industry standard.
- Start with a single part of the system such as part of a transmission system and then slowly expand to include the entire distribution system.
- Integrate sewage system in parts.
- Focus on basic management capabilities and instrumentation to begin with. Focus on **monitoring, administrating and information availability**.
- Use analytics and hydraulic modeling to move up the ladder of capabilities such as equitable supply, NRW detection, energy management, contingency planning, water quality issue detection.
- Extend to include other facets such as billing/revenue, costs, project construction, crew management under a single umbrella.
- Build towards an intelligent infrastructure that allows for pro-active management of a complex distribution system and readies the board for an eventual national inter-basin water exchange.

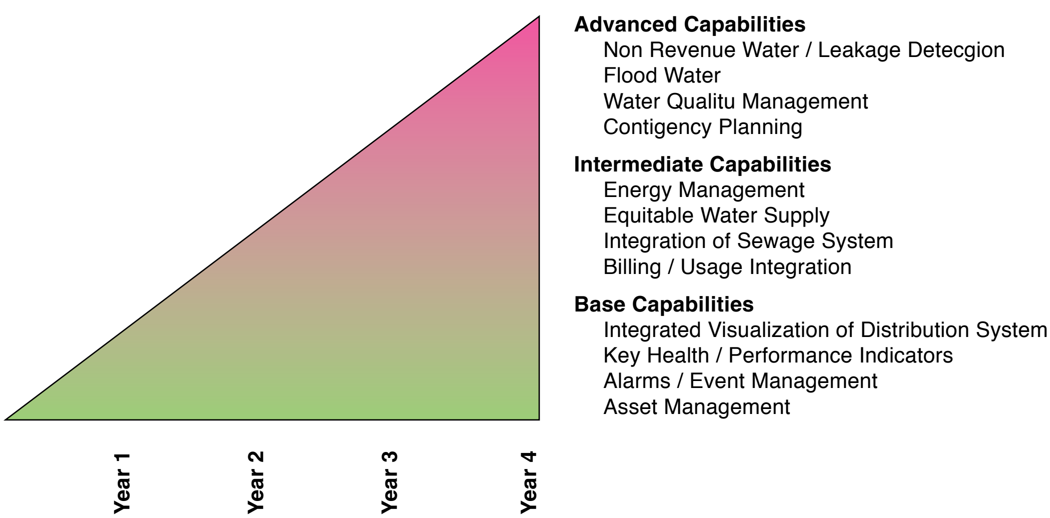

Figure 5: Roadmap for an integrated water and sewage management system for water boards

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