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Chapter 1

Informatics, Logistics and Governance in Water Treatment Processes

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http://dx.doi.org/10.5772/83753

1. Introduction

Increasing demands of water for diverse uses of domestic, agricultural, and industrial consumption, both in quantity and quality, pose tremendous pressure on the need of well-articulated management approaches. Such approaches are expected to address several challenges such as limited supplies, deteriorated quality of available and produced water, conflicting interests of public stakeholders and groups, adverse environmental and ecological impacts, climate changes, etc. Large number of these approaches exist and still evolve and develop for different purpose including data management, operation and governance, conjunctive management of water and energy, asset management, and intelligent systems in water treatment process.

Planning and execution of water treatment processes involve a coordinated effort from different stakeholders. This involves collection of data (water availability data, water demand data, demographic data, water quality data, land use data etc.), identification of appropriate authority for their sources and development of effective communication to these authorities. Logistics involved in establishment of water treatment plants vary from country to country and depend on the country's socio-political systems. For any city or town, municipality or city council authority is generally responsible for execution of water treatment plants, however their approval process may involve several stakeholders. Government system of any country significantly affects selection of water treatment processes (desalination plant, surface water treatment plant, groundwater treatment and selection of alternative water sources such as stormwater, rainwater and treated greywater). Collection of treatment plants' performance monitoring data is essential for execution of similar projects. Now-a-days, climate change and their impacts on freshwater availability is a matter of great concern to water professionals. Scientific researches throughout the world anticipate reduction of water availability. Water treatment and water supply schemes require significant amount of energy (electricity) while water is essential for energy and electricity production. This paradox is widely known as “water energy nexus”. It is also known as “climate, water and energy nexus”. Significant progress has been made on uses of intelligent systems in real time monitoring of water quality and water treatment processes. All of these issues can generally be considered as advanced management issues in water treatment and management.

This chapter discusses a number of management approaches associated with different aspects. First, it discusses the data requirements for water treatment and water supply scheme. The management approaches are mostly tailored and oriented to achieve the scheme of Integrated Urban Water Management (IUWM). Second, the chapter discusses the governance in water treatment and water supply scheme. Water governance is defined as the political, social, economic and administrative systems developed to manage water resource and to deliver needed societal water services. Suitable water governance for some sector depends on the societal and environmental conditions prevailing in that sector. Efficient governance system leads to efficient operation of the water system and adequate benefit of the technologies applied in this system. Different classes of water governance, mainly public, public-private, and private systems, are discussed and evaluated. Third, the chapter discusses the joined management of water and energy resources practiced in many cases, known as water energy nexus. Finally, intelligent systems in water treatment process is addressed.

2. Data requirements

Because of rapidly increasing population, tremendous pressure on water quantity and quality is generally observed across all aspects of urban water cycle. Urban water cycle includes water supply, wastewater, stormwater, groundwater and aquatic ecosystems (Fletcher et al., 2008). Water treatment and water supply cannot be considered as an individual component of urban water cycle, rather this is connected to other components. For example collection, storage, treatment and distribution of stormwater for non-potable domestic consumptions (toilet flushing, gardening) may affect groundwater recharge and water quantity and quality in the downstream of streams. Therefore it is important to manage these interactions between different urban water cycle components. The term Integrated Urban Water Management (IUWM) indicates management of individual water cycle component in an integrated way. Availability of appropriate database is the prerequisite for reliable integrated management of individual water cycle components (water treatment, stormwater, wastewater etc.). Monitoring is a fundamental part for water treatment processes and monitoring data is also important for adaptive management of water projects.

Water treatment process is a component of water supply scheme. Components of water supply scheme are collection of raw water, conveyance of raw (untreated) water, supply reservoir, treatment plant, transportation of treated water, distribution system and finally water consumers. Water treatment process is linked with other components of water supply scheme. Water supply scheme is intrinsically related with other components of IUWM. Wastewater may enter into the water supply scheme through leakage on water reticulation

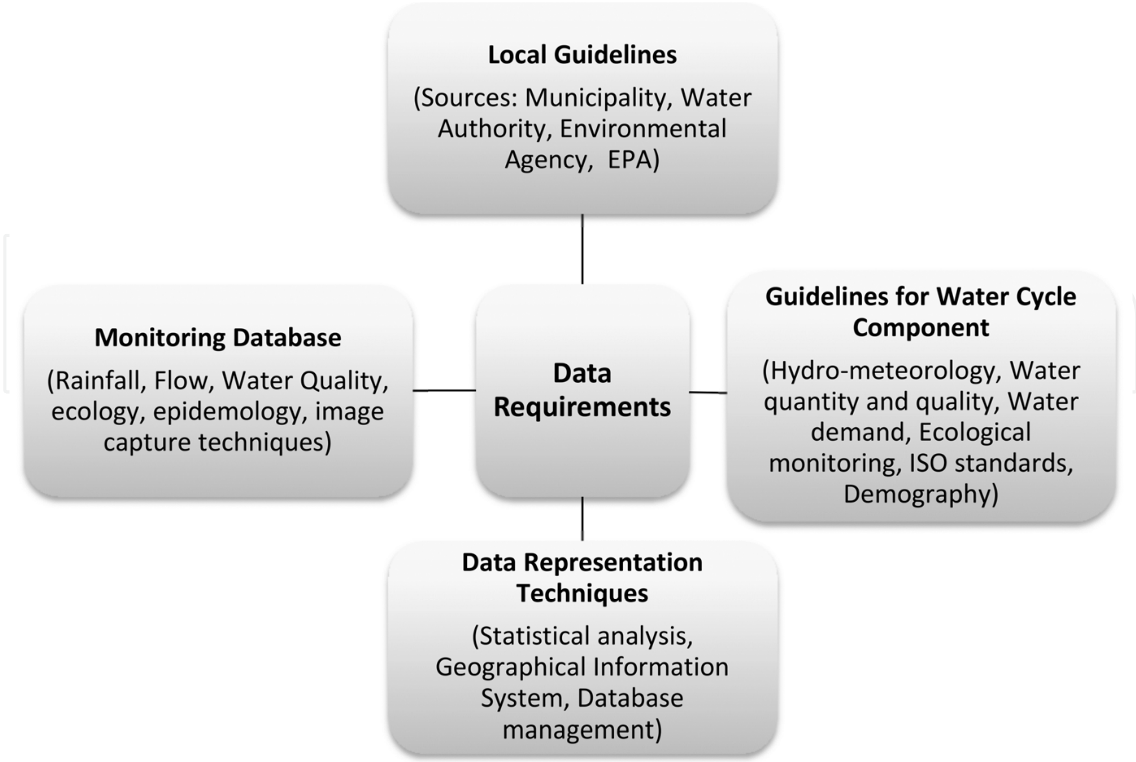

Figure 1. Data requirements guidelines for water treatment processes as a component of integrated urban water management (based on Fletcher et al., 2008)

pipes. More uses of treated water generate more greywater and wastewater. Monitoring of water quality data is an intrinsic property of water supply scheme. Different agencies may collect and store data on various individual components of IUWM. Therefore data exchange between agencies is significantly important for promoting the IUWM concepts. A guideline for data requirements for an integrated urban water scheme is shown in Figure 1 (Fletcher et al., 2008).

Uncertainty is generally involved in monitoring programs. An ideal monitoring program should consists of monitoring data, results and/or predictions from these data analyses and analysis of uncertainty involve in data and predicted results. Uncertainty arises from two sources, bias errors such as systematic error from erroneous sensor calibration and random error from natural processes and equipment measurement variations. When uncertainty level is more than allowable limit, the monitoring programs need to be redesigned.

3. Governance in water

As of now, water sector is driven by investments in technological innovations and development of infrastructures. The goal of such investments is to allow access of large number of people to water supply. However, there are many cases where infrastructures are not operated in an effective manner. In such cases, benefits from appropriate technologies are not fully utilized. This is because of lack of good governance in water management. According to Global Water Partnership (2003), governance can be defined as the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and to deliver water services to different levels of society. There are two main values on which good governance rests, inclusiveness (ensures that all members of the group receive equal treatment) and accountability (ensures that those in authority answer to the group they serve if things go wrong and are credited when things go well) (Tropp, 2007).

There are four competing approaches on how water in different processes should be governed; these are [1] Water (drainage, sanitation, recycling, and reuse) seen as an economic good or commodity, with IWRM focus, [2] Water (and sanitation) seen as a human right and a social good and can be complementary to other approaches, [3] water (drainage and ecological sanitation seen as a socio-ecological good, also can be seen as a h, and human right as well as the right of other living beings and ecosystems, [4] water (and sometimes sanitation) seen as a sector. It is important to realize that for water governance of a city how the territorial dimension of water governance is dealt with and from which perspective. In particular, thre groups here should be distinguished; [1] those mainly looking at water from outside the cities, [2] those mainly looking at water from within the cities, and [3] those mainly looking at water from a multi-scalar perspective combining the global and regional scale with the city, its territory, and the neighborhoods within the cities and vice-versa (Miranda et al., 2011) .

Governance processes determine decision making about selection of water source, water storage, regulation of extraction from aquifers, regulation of discharges, and allocation between competing end users including allocations for environmental flow. For example, choice between a desalination plant and a large dam is an issue of water governance. Good water governance is significantly linked to strong policy, legal, and regulatory frameworks; effective implementing organizations; community involvement to improve water governance; and appropriate investments. Good governance ensures appropriate linkages and processes between and within organizations and social groups involved in decision-making, both horizontally across sectors and between urban and rural areas, and vertically from local to international (Rogers and Hall, 2003). Water governance includes private sector and civil society in addition to the government. The differences between conventional and emerging concept of water governance is given in Table 1. Many decision-makers and water managers are currently not prepared enough to deal with new forms of governance issues. The new concept of water governance involves conflict mediation, mobilization of communities, partnership formation, managing processes of stakeholder dialogue and participation. Generation of knowledge and capacity building in water governance is therefore necessary.

There are mainly three forms of governance arrangements. These are public, public-private and private governance. In **public governance** system, government takes on all of the responsibilities and challenges of water and wastewater services. Throughout the world, about 85% of drinking water supply provision lies under the public governance. Municipal authority or City Corporation is generally responsible for water supply and wastewater schemes. Another form of public management involves cooperatives and user associations.

Conventional form of governance	Emerging form of governance
Emphasizes the government and bureaucracy	Emphasizes to civil society and markets. The government and bureaucracy are still important entities but with reduced authority
Political power monopoly	Co-steering
Steering	Steering diversity of actors and power diffusion
Hierarchical control	Horizontally shared control
Enforcement of rules and regulations	Inter-organizational relations and coordination
Control	Formal and informal institutions
Top-down management	Co-governing (distributed governance); Decentralization/bottom-up management
Formal institutions	Network governance
Inter-governmental relations	Process orientation; expansion of voluntary exchange; self-governance and market mechanisms; dialogue and partnership; participation and negotiation
Disciplinary knowledge based	Multidisciplinary knowledge based

Table 1. Differences between conventional and emerging forms of water Governance (based on Tropp, 2007)

In this system, customers have decision-making power through participation in elections for different water authorities. The system is externally audited annually.

A public-private governance mechanism in water sector involves transferring asset management or operations of a public water system into private sectors. Several public-private arrangements are service contracts, management contracts, leases, concessions and build-own-transfer programs. In this governance system, ownership of water systems can be distributed between public and private shareholders in a corporate utility. Majority ownership is usually kept within the public sector. In service contract, a private company is responsible for a specific task, such as meter installation, distribution pipe maintenance or collection of bills. Under management contracts, government transfers certain operation and maintenance activities to a private company. Under the concession and Build Operate Transfer (BOT) models, capital investment, commercial risk, operations and management of the project are undertaken by the private sector. Concessions are usually long-term to allow the private company to recover its investments. At the end of the contract, assets are either transferred back to the public sector or another concession is granted. In the BOT model, the role of government is predominately regulatory. BOT models are usually used for water and wastewater treatment plants.

In the private governance system, government transfers the water business to the private sector through sale of shares or water rights of the public entity. In this system, infrastructure, capital investment, commercial risk, and operations and management become the responsibility of the private provider. This model is not generally adopted.

4. Water energy nexus

The close connection between energy and water is generally known as water energy nexus. Significant amount of water is required to create energy. For example, water is used for fuel extraction, refining and production; hydropower generation; and in cooling steam electric power plants fueled by coal, oil, natural gas and nuclear power. In the United States of America, besides agricultural consumption, energy production and power generation systems are major users of freshwater resources (Younos et al., 2009). On the other hand, huge amount of power (energy) is required for water supply schemes – from untreated water collection to treated water distribution. Power is used to operate pumps in water supply scheme and in operating water treatment plants. Irrigation of water requires power. Collection, treatment and disposal of wastewater require power. Uses of alternative water resources need power to operate dual reticulation system. For domestic water heating and cooling purposes, power is required. Shortage of any one or both of water and energy will reduce them. Because of climate change, it is anticipated that available water resources will be reduced in some parts of the world– which will then affect energy production. The impact of climate change on water energy nexus is sometimes called "climate, water and energy nexus". Interrelationships between water and energy are shown in Figure 2.

Table 3 shows average water consumption for different energy production and power generation techniques. The data presented in Table 3 are predominantly for the United States of America and were compiled by Younos et al. (2009). Natural gas production is found to be the most water efficient. Corn-based and soy-based biofuel production

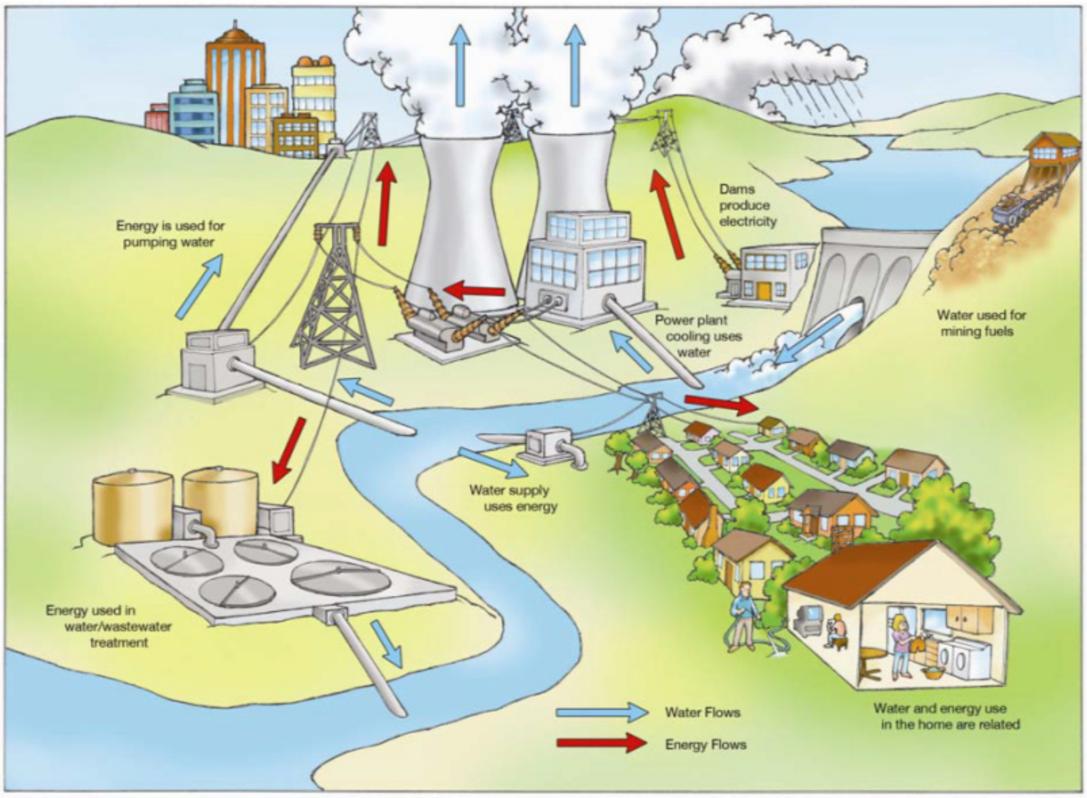

Figure 2. Interrelationships between water and energy (U.S. Department of Energy, 2006)

Fuel source	Water efficiency (Gallons/MBTU*)	Water consumptions
Coal	41 - 164	Coal mining operation, transport and storage, refining process; lubricate drilling equipment, post-mining activities such as land reclamation and revegetation
Natural gas	3	Drilling operation and gas purification, water exerted during drilling operation are reinjected to aquifer
Petroleum/Oil	1200 - 2420	Drilling operation, refining process, water exerted during drilling operation are reinjected to aquifer
Corn-Ethanol	2510 - 29100	Irrigation water demand for corn production
Soy-Biodiesel	14000 - 75000	Irrigation for Soya bean
Hydroelectric power generation	20	Evaporation water loss
Fossil fuel thermoelectric power generation	1100 - 2200	Steam turbine operation, cooling of turbine exhaust, condenser and reactor cooling
Nuclear power	2400 - 5800	Uranium mining and processing, nuclear reactor
Geothermal power	130	Steam turbine, evaporation loss
Solar thermoelectric power	230 - 270	Steam generation, coolant and cleaning purposes

(*MBTU is million British thermal unit)

Table 2. Water consumptions for energy production and power generation (based on Younos et al., 2009)

technologies are the most water intensive. Biofuels are also water intensive because significant amounts of water are required during crop growth. In terms of technology, hydroelectric power generation technique is the most water efficient technology. This is because used water is returned to the source.

Water supply and wastewater treatment systems are energy intensive. About 35% of total energy used by municipalities is used for operation of water and wastewater treatment plants. In the United States of America, about 1.4% of their total energy is consumed for water and wastewater treatment processes (Elliot, 2005). Water demand reduction can decrease energy uses in pumping and treating water. Reduction of volume of wastewater to wastewater treatment plant can also reduce the energy requirements. Adoption of energy efficient technologies can reduce water consumption, and ultimately energy use. Use of alternative sources of energy in water supply and wastewater schemes will reduce greenhouse gas emissions. For example, uses of solar and wind energy to pump water and to heat household hot water tanks can reduce energy consumption (Thrilwell et al., 2007).

5. Intelligent systems

Water treatment processes are governed by a set of complex non-linear relationships between physical, chemical, biological and operational parameters. Traditionally these process relationships are fitted with mathematical models using bench-scale data. These models often perform poorly when two or more key process parameters change simultaneously and in the application of real world treatment plants (Baxter et al., 2001). Plant operators require appropriate tools so that appropriate plant operation conditions are maintained in order to achieve desired effluent quality based on instantaneous monitoring of influent water quality. Coagulation, flocculation and sedimentation processes in water treatment are a prime example. The Jar test is conventionally applied for determination of optimal single coagulant dose. Optimization of multiple treatment chemicals for removal of both particulate matters and organics is a challenging task, particularly if influent water quality changes significantly. Plant operators are generally depending on deterioration of effluent water quality instead of pro-active optimization of treatment chemicals subject to influent water quality.

Artificial Intelligence (AI) is the technique that can control plant operations in a pro-active way. Recent significant development in computing methods opens the door for application of artificial intelligence techniques in water treatment process controls and optimization.

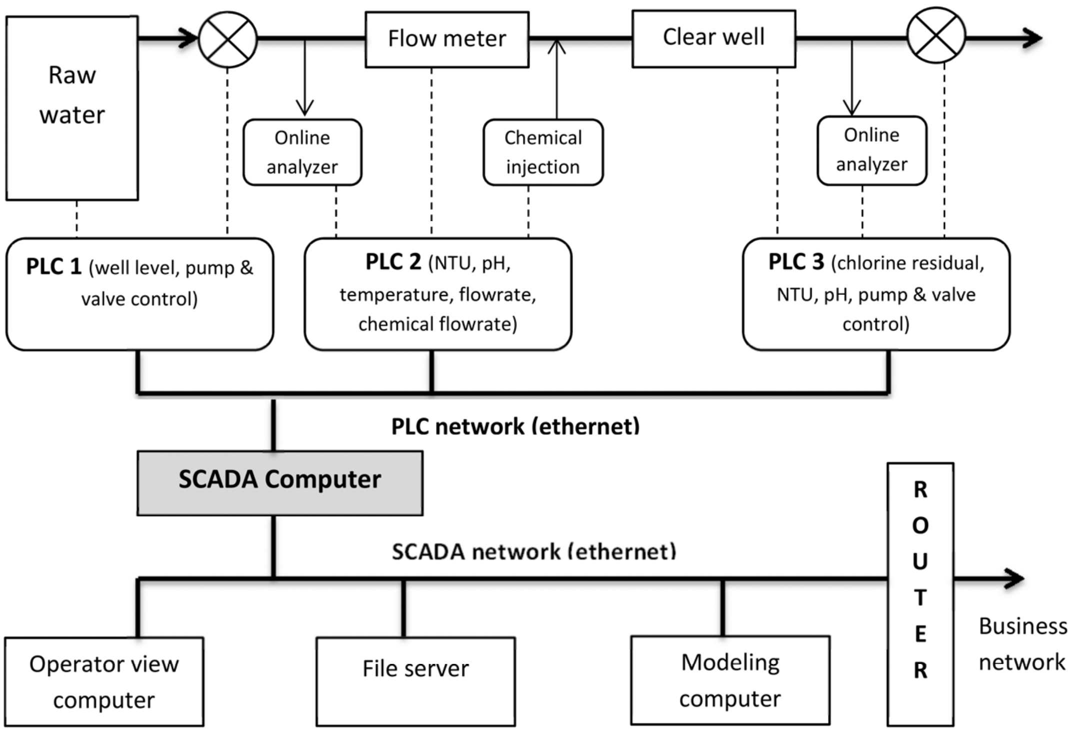

Figure 3. A schematic diagram of SCADA system in water treatment process (based on Baxter et al., 2001)

Application of Artificial Neural Network (ANN) in water treatment problems is an example of artificial intelligence.

The Supervisory Control and Data Acquisition (SCADA) system is the basic infrastructure for process control of water treatment plants (Grady et al., 1999). The SCADA system is capable of monitoring treatment process, real time collection of process data and works as a communication network between treatment plant and other utilities (Baxter et al., 2001). Typical components of a SCADA water treatment system are (1) communication networks (2) computers (3) Programmable Logic Controllers – PLCs and (4) online instruments. Conceptually the SCADA system has three layers namely hardware layer, network layers and application layer. Figure 3 shows a typical water treatment SCADA structure.

As an example, the EPCOR's E.L. Smith water treatment plant in Alberta, Canada (http://www. corp.epcor.com/watersolutions/operations/edmonton/Pages/el-smith-water-treatment-plant.aspx) applied neural network raw water quality classifier to monitor real time raw water quality. The online quality analyzer sends raw water quality data to the central process control computer through the SCADA system where the data are analyzed by raw water quality classifiers before entering to central database system. If any new data or error is detected, an alarm system is activated which requires a plant operator's investigation of sensors. Because of wireless SCADA system, plant operators can monitor the water treatment process operation from a remote computer.

6. Conclusion

Four management aspects were discussed in this chapter; these are (1) data management for water treatment and water supply scheme, (2) governance in water treatment and water supply scheme, (3) water energy nexus, and (4) intelligent systems in water treatment process.

For data management, the chapter discussed guidelines required in water treatment processes as a component of IUWM. The guidelines include [1] local guidelines originated from municipalities, water authorities, and environmental agencies, [2] monitoring database with different hydraulic, quality, and ecological records, [3] guidelines for water cycle component with relevant standards and operational and environmental data, and [4] data representation techniques. Monitoring programs and uncertainties involved in these programs were also discussed.

For water governance, it is found that lack of good governance in water management results in infrastructures not operated in an effective manner and hence benefits from appropriate technologies can't be fully utilized. The public governance, even though may not be the best choice in managing and operating some water sectors, it is found to be the most common system applied worldwide (about 85% applied in drinking water systems). Pure private governance system is not generally adopted.

Discussion of water energy nexus and data related to USA indicates that natural gas production is the most water efficient while corn-based and soy-based biofuel production technologies are the most water intensive. Hydroelectric power generation is also found the most water efficient technology from technology point of view where the used water is returned to the source.

As of Artificial Intelligence and its applications in managing water systems, an example of the EPCOR's E.L. Smith water treatment plant in Alberta, Canada, applied neural network and SCADA system to monitor and control real time raw water quality. Recent advancements in computing methods reflects the growing and significant contribution of applying artificial intelligence techniques in better management and control of water treatment process.

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7. References

Baxter, C. W., Tupas, R. T., Zhang, Q., Shariff, R., Stanley, S., Coffey, B and Graff, K. (2001) Artificial Intelligence Systems for Water Treatment Plant Optimization, American Water Works Association.

Elliot, R. N. (2005) Roadmap to Energy in the Water and Wastewater Industry, Report Number IE054, American Council for an Energy-Efficient Economy, United States of America.

Fletcher, T. D., Mitchell, V. G., Deletic, A. and Maksimovic, C. (2008) Chapter 1 - Introduction. In T. D. Fletcher & A. Deletic (Eds.), Data requirements for integrated urban water management. Paris: UNESCO Publishing and Taylor & Francis.

Global Water Partnership (2003) Effective Water Governance: Learning from the Dialogues, Global Water Partnership Secretariat, Stockholm, Sweden.

Grady, B., Farely, W. and Younos, T. (1999) Telemetry Options for Small Water Systems, Virginia Water Resources Research Center, Virginia.

Miranda, L, Hardijik, M, Malina, R. K. T (2011). Water Governance Key Approaches: An Analytical Framework, Literature Review.

Rogers, P. and Hall, A. (2003) Effective Water Governance. TEC Report No. 7, Global Water Partnership Secretariat, Stockholm, Sweden.

Thirlwell, G. M., Madramootoo, C. A. and Heathcote, I. W. (2007) Energy-water Nexus: Energy Use in the Municipal, Industrial, and Agricultural Water Sectors, Canada – US Water Conference, October 02, 2007, Washington D. C., United States of America.

Tropp, H. (2007) Water governance: trends and needs for new capacity development, Water Policy 9 Supplement 2: 19–30.

U.S. Department of Energy (2006) Energy Demands on Water Resources, A Report to Congress on the Interdependency of Energy and Water, U.S. Department of Energy, United Sates of America.

Younos, T., Hill, R. and Poole, H. (2009) Water Dependency of Energy Production and Power Generation Systems, VWRRC Special Report No. SR46-2009, Virginia Water Resources Research Center, Virginia.