ICT as an Enabler for Smart Water Management

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Smart water management has become a key policy issue for the 21st century, as a growing number of factors are impacting the delivery of already scarce fresh water to millions of people. Economic growth, seasonal climatic conditions and rising population are all affecting availability of water resources. Moreover, a number of effects linked to climate change, such as lengthy droughts and extreme weather events, are worsening the situation. This ITU-T Technology Watch Report provides an overview of how ICT can be a strategic enabler for smart water management policies and surveys upcoming ICT standards that will enable smart water initiatives.

The rapid change of the telecommunication/information and communication technologies (ICT) environment requires related technology foresight and immediate action in order to propose possible ITU-T standardization activities as early as possible.

ITU-T Technology Watch surveys the ICT landscape to capture new topics for standardization activities. Technology Watch Reports assess new technologies with regard to existing standards inside and outside ITU-T and their likely impact on future standardization.

Call for Proposals

Experts from industry, research and academia are invited to submit topic proposals and abstracts for future reports in the Technology Watch series. Please contact us at tsbtechwatch@itu.int for details and guidelines.

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Table of contents

ICT as an Enabler
for Smart Water Management

I.   Introduction

One of the major challenges for sustainable development faced by both the developed and developing countries is to ensure that all people continue to have reliable access to water supply and sanitation services. According to the UN World Water Development Report, by 2050, at least one in four people is likely to live in a country affected by chronic or recurring shortages of freshwater[1]. At the international level, the United Nations (UN) General Assembly has proclaimed the years 2005-2015 as the International Decade for Action 'Water for Life'[1]. Its main objective will be to work towards achieving international commitments on water and water–related issues in the United Nations Millennium Development Goals (MDGs) by 2015. Countries agreed through the MDGs and commitments at the World Summit on Sustainable Development in 2002 to halve by 2015 the number of people worldwide without access to safe water and sanitation services. Furthermore, on 28 July 2010, the UN General Assembly declared that safe and clean drinking water and sanitation is a human right essential to the full enjoyment of life and all other human rights[2].

Indeed, sustainable water management policies have been high on the agenda of many governments around the world and the looming global impact of climate change in terms of sea level rise, longer drought periods and flooding is adding more pressure on the availability of fresh water resources to sustain the growing demands of increasing populations and economic growth.

Technologies such as satellite remote sensing in combination with semantic sensor web and geographical information systems can be used innovatively by water authorities to obtain information in real time about water use, to track and forecast the level of rivers and to identify new sources of fresh water. With the impact of climate change, sole reliance on historical hydrologic weather patterns is no longer a viable forecast for water authorities. The availability of information about current conditions in a particular situation on a timely basis is crucial for decision making in water resource management. For instance, flood water management is a dynamic process, changing daily, weekly or monthly, depending on weather conditions and how ecosystems respond to climate variability. ICT provides a unique opportunity for water stakeholders to obtain information in near real time about a number of physical and environmental variables such as temperature, soil moisture levels, rainfall, and others through web enabled sensors and communication networks, and can thus have accurate information about the situation at hand (without physically being there) for their forecasts and decisions. Smart metering technologies can provide individuals, businesses and water companies with information in near real-time about their own water use, thus raising awareness about usage, locating leakages and having better control over water demand.

This ITU-T Technology Watch Report provides an overview of how information and communication technologies (ICTs) can be a strategic enabler for smart water management policies and surveys upcoming standards that will act as a catalyst for successful implementation of smart water management initiatives.

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[1]   See http://www.un.org/waterforlifedecade/background.html

[2]   See http://www.un.org/apps/news/story.asp?NewsID=35456&Cr=SANITATION

II. Relationship Between Water, Energy and Climate Change

Both water and energy are essential in our life. The global demand for energy and water is increasing and at the same time water and energy issues are closely interlinked. Water is used to produce energy; energy is needed to provide water. Both water and energy are needed to grow food crops; crops can in turn be used to provide energy through biofuels.

Similarly, desalination and treating waste water requires tremendous amount of energy which in turn implies using a lot of water in the process for the power that is needed. Both water and energy use can have adverse impact on the ecosystems. Climate change will affect the availability and use of both energy and water. Supplies of water and energy are thus interdependent.

Although most of the planet is covered by water, only 2.5% of it is freshwater, while the rest is salt-water [1]. Of the freshwater, two-thirds is locked up in glaciers and permanent snow cover (although this is changing with the decrease in snow and ice extent) [1]. As climate change progresses it is predicted that it will have dramatic implications on the supply of water. Whereas, in some areas the water supply may increase, for example at higher latitudes, in the water-scarce areas in the mid-latitudes a reduction in available water is forecasted.

Water stress is already high in most of the developing world (See Figure 1). According to the Intergovernmental Panel on Climate Change (IPCC) Technical Paper VI [2], rainfall is likely to decrease in developing countries (esp. those in low lying areas, glacial fed river basins and in semi-arid regions) that are already experiencing water stress as the climate changes. Moreover, according to a report from the Food and Agriculture Organisation (FAO), by 2025, the demand for water is expected to rise by 56% more than is currently available[3]. The management and preservation of current freshwater sources are therefore very critical.

Figure 1:   Water Scarce and Stress Areas

Freshwater availability, cubic metres per person and per year, 2007.

Scarcity — Stress — Vulnerability

Source: FAO, Nations unies, World Resources Institute (WRI).

PHILIPPE REKACEWICZ FEBRUARY 2006

0   1 000   1 700   2 500   6 000   15 000   70 000   684 000   Data non available

Source: UN-Water, http://www.un.org/waterforlifedecade/scarcity.html

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[3]   See ftp://ftp.fao.org/docrep/fao/008/af981e/af981e00.pdf
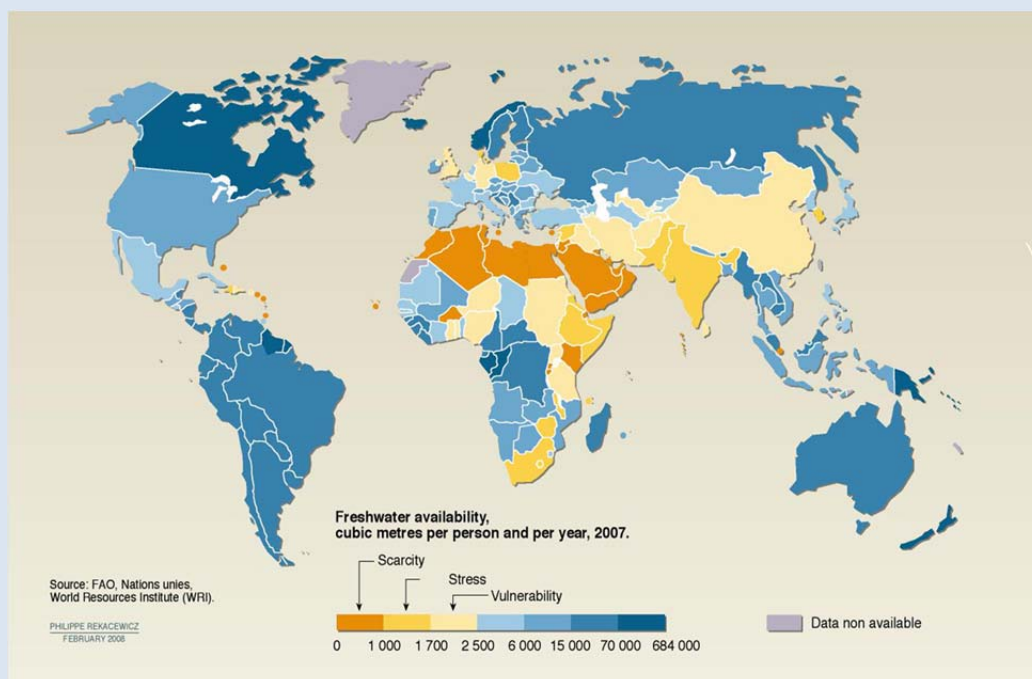
> **Box 1:** **UN-Water**
>
> UN-Water is an inter-agency mechanism formally established in 2003 by the UN High Level Committee on Pro-grammes. UN-Water strengthens coordination and coherence among UN entities and non-UN partners dealing with issues related to all aspects of freshwater and sanitation. This includes surface and groundwater resources, the inter-face between freshwater and seawater and water-related disasters. There are three reporting mechanisms within UN-Water:
>
> - World Water Assessment Programme presenting the triennial World Water Development Report which monitors the targets for the MDGs and the World Summit on Sustainable Development,
> - WHO/UNICEF Joint Monitoring Programme (JMP) on Water Supply and Sanitation monitor global progress towards MDG Target 7.C: Halve, by 2015, the proportion of people without sustainable ac-cess to safe drinking water and basic sanitation and
> - Global Annual Assessment on Sanitation and Drinking-Water reporting on the capacity of countries to progress towards the MDG water and sanitation target and on the effectiveness of external support agencies to facilitate this process.
>
> Some 25 UN agencies are involved in UN-Water. More details about the members of UN-Water can be obtained from http://www.unwater.org.

In areas facing high seasonal variations in rainfall due to changing weather patterns, over-extraction of groundwater can also lead to scarcity of freshwater in the long term. In India, over-extraction of groundwa-ter in the region of Chennai has resulted in sea water entering the groundwater supply nearly 10 km inland from the sea and similar problems can be found in populated coastal areas around the world [3]. Further-more, due to pollution from industries and poor sanitation and sewage systems in some countries, the qual-ity of freshwater sources is threatened.

According to the UN-Water Climate Change Policy Brief [14] understanding the link between climate change and water management is very important in order to be able to monitor and forecast the long term implica-tions of the water cycle for a particular country and also at the global level. However, water management and energy policies cannot be treated in an isolated manner.

In 2008, the IPCC Technical Paper VI [2] indicated that based on records and climate projections there is enough evidence that freshwater resources are vulnerable and can be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems. Over the next century climate change will lead to an amplification of the global hydrological cycle and have a significant impact on regional water resources via changes in precipitation, evaporation and temperature [2].

In addition to climate change, the forecasted increase in world population growth (especially in urban areas and cities) over the next 20 year or so will also lead to significant challenges to problem of increasing water demand especially in areas of food security and fresh water supply availability. The global consumption of water is doubling every 20 years, more than twice the rate of human population growth [1]. According to FAO estimates, 70-80% of the increase in food demand between 2000 and 2030 will have to be met by irri-gation [1]. This means that the demand for water will outstrip supply with growing population and in-creased needs for food, drinking water supply, industrial goods, recreational facilities.

The UN-Water Task Force was set up in 2003 to co-ordinate UN activities in water related issues. Box 1 pro-vides more information about UN-Water activities.

Other water-related impacts of climate change include [1]:-
- An increase in the magnitude and frequency of natural related disasters due to heavy rainfall, such as floods, mudslides, typhoons and cyclones.
- Flows in rivers are likely to decrease during periods of low rainfall, due to higher evaporation rates, and runoff increase with high rainfall events and waste overflows, both of which will degrade water quality.

• Rising temperatures and variations in rainfall are expected in the future to accelerate the retreat and loss of glaciers, impacting on the flow of rivers and thereby affecting agriculture.
• Rising sea-levels will impact coastal zones and islands as well as estuaries, and river deltas.

III.   The Water Footprint Concept

How much water is consumed by people and various sectors of the economy? The water footprint concept is becoming a popular way to understand the total water consumed by nations or for production of consumer products. Similar to the carbon footprint concept which has helped in understanding the level of greenhouse gas emissions (GHG), the water footprint can be a very useful indicator to assess consumption of water for production of consumer based products and can be a more accurate forecast of water demand than national statistics on water use [4]. The Water Footprint Network (WFN), a non-profit body founded by different stakeholders including World Wide Fund for Nature (WWF), UNESCO-IHE Institute for Water Education, United Nations Environment Programme (UNEP) and International Finance Corporation (IFC), has been established to set standards concerning water use and develop methodologies for the assessment of the water footprint. The WFN is also working on common management practice linking water and energy footprints.

The 2009 Global Innovation Outlook Report on Water[4] gives an insight into the volume of water required to produce various goods, for instance:
• 40 litres of water to make one slice of bread
• 70 litres of water to make one apple
• 1,300 litres of water to make one kilogram of wheat
• 10,855 litres of water to make one pair of jeans

These calculations take into account every drop of water used in the production lifecycle, from irrigation to industrial processes, to discharge. According to Hoekstra and Chapagain [4], the four main factors that impact directly the water footprint of a country are:
• Volume of consumption (related to the gross national income);
• Consumption pattern (e.g. high versus low meat consumption);
• Climate (growth conditions); and
• Agriculture (water use efficiency).

Based on the Hoekstra and Chapagain study [4], countries with a relatively high rate of evapotranspiration[5] and a high gross national income per capita (which often results in large consumption of meat and industrial goods) have large water footprints, such as: Portugal (2260 m3/yr/capita), Italy (2330 m3/yr/capita) and Greece (2390 m3/yr/capita). Some countries with a high gross national income per capita can have a relatively low water footprint due to favorable climatic conditions for crop production, such as the United Kingdom (1245 m3/yr/capita), the Netherlands (1220 m3/yr/capita), Denmark (1440 m3/yr/capita) and Australia (1390 m3/yr/capita). Some countries can exhibit a high water footprint because of high meat proportions in the diet of the people and high consumption of industrial products, such as the USA (2480 m3/yr/capita) and Canada (2050 m3/yr/capita) [4].

Water footprints can also be quite useful for businesses, when deciding where to locate their production units, as it can assist in identifying the intensity of water use in water scarce areas and thus understand the potential risks facing their operations. As illustrated in the SABMiller study [5], the water footprint for producing one litre of beer in South Africa compared to Czech Republic is different as the countries have differ-

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[4]   See http://www.ibm.com/ibm/gio/media/pdf/ibm_gio_water_report.pdf

[5]   Evapotranspiration typically refers to the discharge of water into the atmosphere from ground surfaces (e.g soil) and vegetation.

ent evapotranspiration rates and more irrigation is used in South Africa for the crops. More details about the water footprint for a business can be found at Annex 1. A reduced water footprint may, in one case; result in a reduced energy footprint, but in another case may result in an increased energy footprint. Similarly, in a water abundant region it might be appropriate to reduce the energy footprint at the expense of increasing the water footprint, if this cannot be avoided.
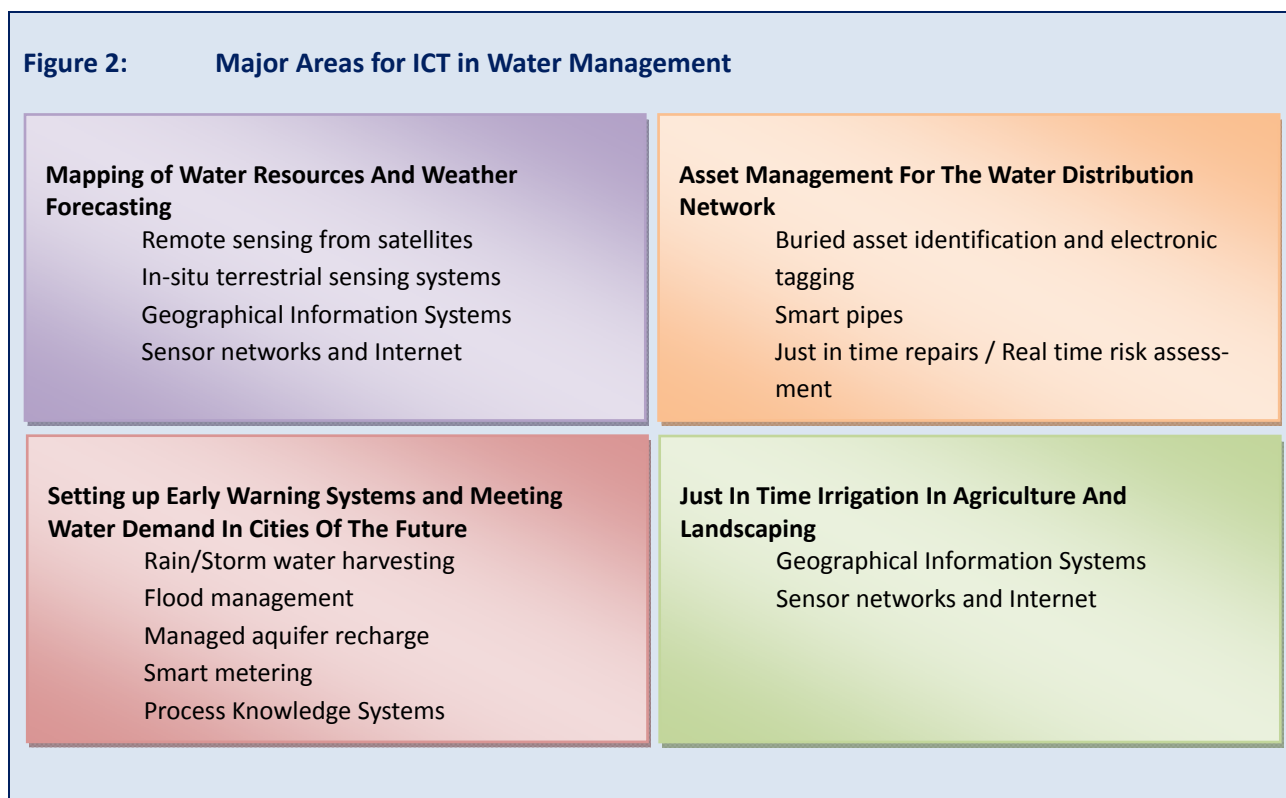
At the level of ISO, work has started on the development of a new standard to provide internationally harmonised metrics for water footprints[6]. ISO 14046, Water footprint – Requirements and guidelines, will complement existing standards on life cycle assessment (LCA) and ongoing work on carbon footprint metrics by ISO technical committee ISO/TC 207, Environmental management.

IV.   Smart Water Management

ICT is recognised as a strategic enabler in the process of developing innovative solutions to address the problems of water scarcities as well as facilitating the analysis of environmental data to enable researchers and climatologists to build more accurate models for weather forecasting as reliance on past data is no longer sufficient in the looming era of climate change. The main areas where ICT could play a pivotal role in water management are shown in Figure 2.

4.1   Mapping of water resources and weather forecasting

Mapping of water resources is becoming increasingly important for water utility companies. Since water resources are finite, water authorities must be able to assess what is the current water supply and its characteristics in order to determine how to meet the future water demands for sustainable economic growth in view of the increased stress climatic variations will place on water resources.

Figure 2:   Major Areas for ICT in Water Management

Mapping of Water Resources And Weather Forecasting
  Remote sensing from satellites
  In-situ terrestrial sensing systems
  Geographical Information Systems
  Sensor networks and Internet

Asset Management For The Water Distribution Network
  Buried asset identification and electronic tagging
  Smart pipes
  Just in time repairs / Real time risk assessment

Setting up Early Warning Systems and Meeting Water Demand In Cities Of The Future
  Rain/Storm water harvesting
  Flood management
  Managed aquifer recharge
  Smart metering
  Process Knowledge Systems

Just In Time Irrigation In Agriculture And Landscaping
  Geographical Information Systems
  Sensor networks and Internet

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[6]   See http://www.iso.org/iso/isofocusplus_bonus_water-footprint

Radio-based ICT systems such as remote sensors are a major source of observation and information about the Earth's atmosphere and environmental conditions. Remote sensing satellite systems and geographical information systems (GIS) permit more efficient monitoring and management of water resources as well as carrying out risk assessment on the hydrological cycle of water. Remote sensing technologies coupled with satellite radiocommunications systems, global positioning systems (GPS) and GIS have been instrumental to the identification new freshwater sources, building models of watershed basin area and analysing environmental problems (See Box 2 for more examples about use of remote sensing and GIS).

The science of weather forecasting and climate monitoring has benefited greatly from development in ICTs. Between 1980 and 2005, over 7,000 natural disasters occurred worldwide in which millions of lives were lost.

Box 2:   Examples of GIS and remote sensing applications in water management programmes

• GIS and remote sensing are used to monitor deforestation in areas such as the Amazon Basin, analyze the effects of climate change on glaciers and Arctic and Antarctic regions.

• The Group on Earth Observations (GEO) is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS) by 2015. GEO comprises 68 countries, the European Union and 46 participating organisations. GEOSS is an international public infrastructure using land, sea, air and space-based Earth observation systems to provide comprehensive environmental data, information and analysis for decision making. It is a 'system of systems' that will proactively link together existing and planned observing systems around the world and facilitate the development of new water information systems where gaps currently exist. It will promote common technical standards so that data from the thousands of different instruments can be combined into coherent data sets. The GEOPortal (http://www.earthobservations.org/gci_gp.shtml) is operated by the European Space Agency and the FAO and provides a web-based interface for searching and accessing data, remote sensing information, satellite imagery, services and applications.
(Source: http://www.earthobservations.org/about_geo.shtml)

• In Europe, the INSPIRE geoportal (http://www.inspire-geoportal.eu/)provides the means to search for spatial data sets and spatial data services, and subject to access restrictions, view and download spatial data sets from the EU Member States within the framework of the Infrastructure for Spatial Information in the European Community (INSPIRE) Directive. INSPIRE aims at making available relevant, harmonised and quality geographic information to support formulation, implementation, monitoring and evaluation of policies and activities which have a direct or indirect impact on the environment. The INSPIRE Directive addresses 34 spatial data themes, including meteorological and hydrology characteristics, needed for environmental applications. It will enable European spatial infrastructure data participants to exchange spatial information as widely as possible [6]. Potential users include policy makers, planners, and managers as well as private organizations, EU residents, and others.

• In China, devastating floods on the Yellow River has claimed hundreds of thousands of lives and has remained a source of concern for centuries. Deforestation, overcultivation and soil erosion have accelerated the flooding. The Digital Yellow River Project implementation was initiated in 2001 with the objective of monitoring the river flow to be able to manage the floods. The Yellow River Basin Geographical Information Center in China, is using GIS, remote sensing, GPS and the Internet to study and predict the Yellow River flow, monitor level of water in the river based on rainfall forecasted and the quality of the water to detect pollution. *(Source: http://www.esri.com/news/arcnews/spring10articles/the-digital-yellow.html)*

– Together with the Beacon Institute for Rivers and Estuaries and Clarkson University, IBM is creating a data platform to monitor in real time the river flow and water quality of the entire length of the 315-mile Hudson River. *(Source: http://www.ibm.com/smarterplanet/uk/en/water_management/visions/)*

– In India, the National Remote Sensing Centre is using remote sensing tools on board satellites to identify new groundwater supplies for exploitation and monitor groundwater quality under the Rajiv Gandhi National Drinking Water Mission to provide drinking water to villages. In West Bengal, GIS and Remote Sensing for environmental mapping, are used to identify arsenic presence, the outline of its concentration and depth of its presence in the district. Based on analysis of this data, the system can map and model the zones at risk.
(Sources: http://www.nrsc.gov.in/Remote.html and http://www.gisdevelopment.net/application/environment/water/mi03204.htm)

Ninety percent of these disasters were caused by weather and water related events such as floods, cyclones and droughts[7]. ITU work in the area of radiocommunication and telecommunication technical standards focuses on the use of ICTs for weather forecasting, climate monitoring, detecting and mitigating the effects of natural disasters. The role of ICTs in weather and climate monitoring is depicted in the World Meteorological Organization's (WMO) World Weather Watch (WWW) system[8].

The World Weather Watch (WWW) is composed of three integrated core system components:
• The **Global Observing System (GOS)** provides high-quality, standardized observations of the atmosphere and ocean surface from all parts of the globe and from outer space.
• The **Global Telecommunication System (GTS)** provides for the real-time exchange of meteorological observational data, processed products, and related information between national meteorological and hydrological services.
• The **Global Data Processing and Forecasting System** provides processed meteorological products (analysis, warnings, and forecasts) that are generated by a network of World Meteorological Centres and specialized Regional Meteorological Centres.

The GOS, GTS and Global Data Processing and Forecasting System are components of the GEOSS. Study Groups of the ITU Radiocommunication Sector (ITU-R) provide necessary support for the development and utilisation of different ICT systems such as:
• Weather satellites that track the progress of hurricanes and typhoons;
• Weather radars that track the progress of tornadoes, thunderstorms, and the effluent from volcanoes and major forest fires;
• Radio-based meteorological aid systems that collect and process weather data, without which the current and planned accuracy of weather predictions would be seriously compromised;
• Broadcast sound and television systems and different mobile radio communication systems that warn the public of dangerous weather events, and aircraft pilots of storms and turbulence; and
• Satellite systems that are also used for dissemination of information concerning different natural and man-made disasters.

All these systems are part of the GOS, employed by the majority of countries. The WWW system is used by a large of number of countries worldwide and helps in saving thousands of lives every year. All ITU Sectors contribute to the development and implementation of the core system components.

Usually, telecommunications networks (except mobile-satellite networks) are one of the first casualties of water related disasters (e.g flooding and cyclones) and this impacts the disaster relief efforts which makes it difficult to assess the scale of the response needed. Telecommunications (wired and wireless) are used for disaster prediction, detection, early warning, damage assessment and planning relief operations including the vital relief assistance such as food aid convoys, aircraft and medical teams to reach those who need them the most. ITU efforts focus on the planning, development and standardisation of ICT solutions used in these situations. After providing assistance for disaster relief and response, ITU undertakes assessment missions to affected countries aimed at determining the magnitude of damages to the network through the use of geographical information systems. More details about the ITU international voluntary and mandatory standards (ITU Recommendations and Radio Regulations) used for environmental monitoring, weather forecasting, prediction and detection of natural disasters, emergency communications and disaster relief are discussed at Sections 5.1 and 5.2 of the report.

4.2 Just in time irrigation in agriculture and landscaping

In recent years, sensors have been increasingly adopted by a diverse array of disciplines, such as meteorology for weather forecasting and wildfire detection, traffic management, satellite imaging for earth and space

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7   See http://www.wmo.int/pages/mediacentre/press_releases/pr_864_en.html

8   See http://www.wmo.int/pages/prog/www/index_en.html

observation, medical sciences for patient care using biometric sensors, and homeland security for radiation and biochemical detection at ports [6]. The sensor semantic web refers to the use of sensor networks for the collection of information about sensors and sensor observations using web technologies. The information collected can be stored and used for further analysis and interpretation which can be used to provide knowledge about a particular context at a specific location in time. This characteristic of sensor semantic web can also be applied in the context of agriculture to save water.

According to the FAO[9], agriculture is by far the biggest water user, accounting worldwide for about 70 percent of all withdrawals, with industry using some 21 percent and domestic (municipal) about 10 percent. The water usage in agriculture varies between developed and developing countries, and for instance, in Asian countries agriculture accounts for nearly 84% of water withdrawals. Irrigation water withdrawal in developing countries is expected to grow by about 14% from the current 2,130 km^3 per year to 2,420 km^3 in 2030 and harvested irrigated area (the cumulated area of all crops during a year) is expected to increase by 33% from 257 million hectares in 1998 to 341 million hectares in 2030[10]. Expansion of the irrigated land area is a vital means to guarantee food supply to the growing world population. The expansion of the irrigated area is restricted by the scarcity of available fresh water resources.

In agriculture, the key is to know when the right time to irrigate is and the right volume of water that should be applied. Wireless sensors can be placed on crops and in the soil to monitor humidity levels, soil moisture and can automatically activate the valves of the irrigation system on a needs basis to provide the required volume of water that is required for the normal health of the plant. One solution developed by yield management system supplier Dacom from the Netherlands, combines wireless sensor technology, Internet, mobile communications and GPS for monitoring plant growth, fertilizer usage, and scheduling of irrigation. The sensors are powered by solar panels. The data measured by the sensors are transferred via mobile communications to a central database. The farmer can analyse what the daily water consumption of the crop has been throughout the different soil layers. This data can be used to determine the optimum time for irrigation. This prevents both damage due to drought stress and excessive watering. For optimal growth of crops, it is important to administer fertilizers correctly and also to be within the legal usage norms for nitrogen and phosphate. The system can advise how much fertilizer and at which point in time it should be applied. The advantage of this system is that the fertilizers can be optimally absorbed by the plant, with improved crop yields as a result.

The sensors, when connected to the Internet, allow for remote management of the system and can enable a farmer to calculate his budget for water based on factors such as soil moisture, crop water retention, weather information and plant characteristics. This type of sensor network is also applied in landscaping and sports ground maintenance such as football grounds and golf courses. Such systems have been used in various parts of the world (for example: the Netherlands, Australia, Canada and the US amongst others).

These and other ways in which ICTs can be used locally and globally to address the problems of food security and hunger have been discussed in an earlier ITU-T Technology Watch Report titled '*ICTs and Food Security*'[11].

4.3   Asset management for the water distribution network

Sensors placed throughout the water distribution network and smart meters at consumer place will become commonplace in order to save water. The outcome will be a system that helps manage end-to-end distribution, from reservoirs to pumping stations to smart pipes to intelligent metering at the user site. For water companies, the capability to be able to identify leaks or carry out repairs on the water distribution network in near real time basis will be crucial.

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[9]   See http://www.wateryear2003.org/en/ev.php-URL_ID=1431&URL_DO=DO_TOPIC&URL_SECTION=201.html

[10]   See UNESCO World Water Assessment Programme at http://www.unesco.org/water/wwap/facts_figures

[11]   See http://www.itu.int/oth/T230100000B/en

Developments in the area of sensors and nanotechnologies could lead to the incorporation of these technologies in the water pipes network. These sensors could be remotely monitored to provide information about the state of the pipe and allow water companies to take proactive action on problems detected on the distribution network and better control over assets. If resulting actions could be taken remotely (e.g., pressure regulation within a system, bypassing a section of pipe until maintenance carried out), or even self healing triggered within a 'smart pipeline system' by the sensors themselves, no undue loss of service would occur.

In order to manage assets, water companies need to have information about the water distribution networks on maps. Having the maps in electronic format rather than on paper enables water companies to carry out more sophisticated analysis and respond faster. In addition, the use of geographical information systems permits water companies to have their entire water distribution network at their fingertips with information about the characteristics of the network (for example, pipe length, diameter, date installed, valve size, pump curve, etc.) and individual customers linked to the system as well. With standardisation of geography markup language and the geospatial web already underway, the information about the water distribution network system could also be provided over the Internet via mobile devices which will also enable field workers to access the information required for repairs and operations more effectively.

4.4   Setting up early warning systems and meeting water demand in cities of the future

Preservation and diversification of freshwater resources, through rain/storm water harvesting [10], desalination, flood management and water recycling or treatment of waste water for use would be at the heart of water management programmes for cities of the future in order to keep up with the increase in population as water demand starts to exceed water supply.

Cities that are located in low lying regions close to the coast or along river deltas (for example, New Orleans, Amsterdam, the wetlands in the UK, parts of Bangladesh) will have to deal with the issue of rising water levels due to climate change which will lead to more extreme weather conditions such as flooding. These areas are often secured with water retaining infrastructures or levees. More than two thirds of European cities have to deal with flood risk management issues on a regular basis; these are issues which will worsen as climate change effects result in more extreme conditions[12]. The UrbanFlood project, which is an EU funded project, is aimed at establishing an early warning system framework that can be used to link sensors built in flood embankments, via the Internet to develop predictive models and emergency warning systems.

Early warning systems will thus have an increasingly important role in mitigating such risks through early detection of conditions and predicting the imminent occurrence of a disaster in advance, and by providing real time information during the event. The sensors can also help in the inspection of the structural integrity of the levees and dams. In addition, the ability to predict whether water retaining infrastructure can withhold the mounting pressure of the rising waters is essential in order to be able to give enough time for a large-scale evacuation if the need arises in the worst case scenario. In the Netherlands, the IJkdijk Foundation, as part of the UrbanFlood project, have been working on building smart levees, which are levees with a network of wireless sensors built-in. The sensor used to monitor soil deformation, is the TenCate GeoDetect[13], which, is the world's first intelligent geotextile[14] fabric and is equipped with optical fibres as well as instrumentation equipment and software. Smart levees can provide information about the level of water, the pressure being exerted on the infrastructure, early warning of soil deformation, changes in temperature, strain and can predict 42 hours in advance whether the levee will break [8].

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[12]   See http://urbanflood.eu/aboutus.aspx

[13]   See http://www.ijkdijk.eu/articles/37746/

[14]   Geotextile is a type of geosynthetic fabric that incorporates optical glass fibers, special instrumentation, and software. It is embedded in dyke bodies during construction of roads, railways, seawalls, retaining walls, tunnels, underground structures, and pipelines to detect the slightest structural deformations and changes in temperature and strain.

Box 3:   Hydrological Sensor Web for South Esk Catchment in Tasmania

The development of the hydrological sensor web for the South Esk Catchment in Tasmania is a research project funded by the Australian Government through the Intelligent Island Program and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Water for a Healthy Country Flagship. The objectives are to establish a sensor web test bed to measure rainfall, wind speed, soil moisture and temperature to build models which will forecast river flow in the 3,350 km2 South Esk River Catchment and develop next generation hydrological and water resource management tools based on emerging OGC standards. The system can enable water authorities to investigate whether water restrictions warnings should be issued for the coming week. The key challenge here is the interaction of a number of heterogeneous services; all located at different geographical locations and operated by different organisations. The project aims at integrating over 40 hydro-meteorological sensors, precipitation forecasts from weather prediction models, rainfall run-off models, and river routing models.

Sources: http://www.csiro.au/science/SensorsAndWaterUse.html and http://www.csiro.au/au.csiro.OgcThinClient/

Semantic sensor web is also being used to forecast river flow based on observation of a number of environmental parameters. One example is the hydrological sensor web for South Esk catchment area in Tasmania (See Box 3).

In cities, which rely on ground water for daily consumption, managed aquifer recharge is a vital requirement to ensure sustainability of freshwater resources in arid and semi-arid areas. Aquifers, permeable geological strata that contain water, are replenished naturally through rain soaking through soil and rock to the aquifer below or by infiltration from streams [9].

Remote sensing and geographical information systems play an important role in the identification of suitable regions for the aquifer. By digitising information about the geography and hydrology of the land obtained from remote sensing and satellite, information such as lithology, rock structure, landcover/landuse, aerial aspects of drainage basins, paleochannels coupled with water table conditions and rainfall data can be analysed in a geographical information system environment to produce composite maps showing suitable sites for construction of artificial recharge structures. In Adelaide, South Australia, research carried out by University of South Australia [9], showed the potential of GIS to investigate areas which could be suitable for storm water harvesting by analyzing land cover, land use and topography. In South Australia storm water is considered as an untapped sustainable water resource. In 2008, managed aquifer recharge contributed 45 gigalitres (GL) to irrigation supplies and 7GL to urban water supplies in Australia [9].

Furthermore, water utility companies worldwide are being challenged to deliver water efficiently. Non-revenue water is the difference between water pumped, treated, and supplied to the distribution system versus water that actually reaches customers. Smart water metering technology can enable water utility companies to track usage more accurately at the consumer end and implement intelligent water pricing plans which would encourage water conservation.

Rather than receiving their water bill at the end of the quarter or the month, consumers will be able to track their water usage in real time and thus able to take action much earlier in case of leakages. According to Pike Research[15], for developed countries, non-revenue water often runs around 20% of the total. Developing countries lose as much as 50% of treated water to distribution system leaks, theft, and poor measurement techniques.

There are two types of smart meters:-
• Automated Meter Reading (AMR) : One way communication of usage data to the utility.

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[15]   See http://www.pikeresearch.com/research/smart-water-meters

- Advanced Metering Infrastructure (AMI) : "two-way" communication that creates a network between the meters/devices and the utilities' information systems. Data flows both directions providing not only remote meter reading but ability to remotely activate meters/devices and the use of variable pricing.

AMR is a predecessor technology to AMI and is currently considered a subset of AMI[16]. AMM sits on top of AMI to manage meters and their data, and therefore is in support of and a client to AMI.

One of the driving forces for the implementation of smart metering in Europe has been the EU Directive on energy end use and energy services[17]. Smart water metering technology incorporates consumption data collection and communications to water meters so that utilities and consumers can monitor usage and minimize waste. A smart water meter displays the water consumed in near real time and can also send alarms for excessive use. It can help to identify leaks so that action can be taken quickly to save water, which, otherwise would not be identified for several months. In Malta (See Annex 2), the government has partnered with IBM to roll out smart meters for electricity and water with objective of being able to better control the demand for water resources.

Research shows that installing a meter in a house so people can see how much water they're using can reduce consumption by 10 percent [15]. According to the Oracle study *Smart Metering for Water Utilities* carried out in the US and Canada in January 2010, approximately 5-10% of American homes have water leaks that drip away 90 gallons a day or more, and if the 5% of American homes that leak the most corrected those leaks this could save more than 177 billion gallons of water annually[18]. The Edison Electric Institute estimates that in the next five to six years, close to 60 million smart meters will be installed in the United States[19]. In New York City, the goal is to install smart water meters for all the city inhabitants by end 2012 and already AMR units have been installed for some 417,000 customers[20]. The total cost of the project is around USD $ 252 million and is expected to bring savings from early identification in leakages, better water usage from consumers and reduction in costs for meter reading. In the state of California, it is expected that the implementation of smart water meters would reduce between 5 – 15% the amount of water consumed[21].

Water usage in manufacturing plants can also be managed more efficiently using ICT. Every manufacturing plant, whether steel, paper, oil, or even microchips must use water in some capacity during operation. Even though industrial water use may be small compared to total public use, it is essential for the many businesses that use it. Industrial water is not only supplied by public entities but is self-supplied, meaning the industry has its own well or other water source. If an industry is self-supplied, the water may be from fresh or saline sources. The manufacturing plant of Intel in Phoenix in the US, uses 2 million gallons of water daily and draws the power equivalent of 54,000 homes every year. Intel obtains most of that power from the Palo Verde Nuclear plant, which uses some 20 billion gallons of water annually to cool its turbines [15].

Cooling water systems are essential in many industrial plants. Proper operation of the cooling system is needed to minimise the impact of total operational costs related to water and energy consumption, chemicals and wastewater discharge. Using too much chemicals can result in corrosion or microbiological growth which can cause system inefficiencies leading to losses in production and/or excessive water consumption. Process knowledge system software can be used in managing automation and control systems and includes turbine control system that helps improve plant performance through integration between boilers and tur-

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[16]   See ITU-T Technical Paper on G.9960 and G.9961 application of smart grid transceivers at http://www.itu.int/pub/T-TUT-HOME-2010/en

[17]   See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006L0032:EN:NOT

[18]   See http://www.oracle.com/dm/offers/fy10/oracle_utilities_testing_water_rport_final_011_11_10v2.pdf

[19]   See http://www.e-grid.net/docs/0911-spectrum.pdf

[20]   See http://www.govtech.com/gt/articles/767739

[21]   See htttp://green.blogs.nytimes.com/2010/03/23/smart-water-meters-take-hold-in-california/

bines thus optimising water consumption. Such systems also provide information in real time about consumption and water analytic tools which enable collection of data about parameters for critical cooling water operations system performance from diverse sources, display visually the current conditions, send reports/alarms in real time about events which can have severe consequences and monitor key performance indicators.

V. Standards for smart water initiatives

5.1 Weather Forecasting and Climate Monitoring

The WMO Global Observing System (GOS) is based on the use of satellite and ground-based remote sensors (active and passive) employed by the meteorological satellite, Earth-exploration satellite and meteorological aids radiocommunication services, which play a major role in climate monitoring and weather forecasting. It is essential that these services have sufficient spectrum and that the frequencies allocated to them remain free of interference. ITU-R, as international steward of the spectrum, allocates the necessary radio frequencies to allow the interference-free operation of radio-based applications and radiocommunication systems (terrestrial and space) used for environment (including water) and climate monitoring and prediction, weather forecasting and disaster early warning and detection. The frequency bands allocated to radiocommunication services and used by environmental monitoring systems are described in the international treaty status Radio Regulations[22]. ITU–R Study Group 7 ("Science services") carries out studies and develops the "Remote Sensing", or "RS" Series of ITU–R Recommendations and Reports. These are used for the design and operation of radiocommunication systems monitoring climate change. Study Group 7, in cooperation with WMO, developed the ITU/WMO Handbook, "Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction"[23]. The handbook describes modern radio technologies, tools and methods employed by the World Weather Watch system.

The standardisation work carried out by ITU–R study groups, have played a key role in the development and utilisation of different systems such as:
- Weather satellites that can track the progress of natural phenomena such as hurricanes and typhoons;
- Radar systems for tracking weather systems such as tornadoes, thunderstorms, and other disasters such as volcanoes and forest fires;
- Radio-based meteorological aid systems that collect and process weather data; and
- Various radio communication systems (satellite and terrestrial) that can be used in emergency situations to communicate information concerning different natural and man-made disasters.

Following the World Radiocommunication Conference 2007 (WRC-07) it was established that the radio-frequency spectrum is a critical resource for remote sensing used by the GOS, additional spectrum was allocated to radiocommunication services involved in environmental observation and ITU–R was requested to carry out new studies for the future development of remote sensing applications and systems under Resolution 673 (WRC-07) on "Radio communications use for Earth observation applications". The results of the studies will be considered by the next WRC in 2011.

The Global Telecommunication System is built on standards developed by ITU–T and ITU–R. Next-generation networks (NGN) and supporting ITU–T Recommendations facilitates data exchange between environment control centres. In order to improve environmental monitoring, ITU has established and strengthened strategic partnerships with WMO and other United Nations agencies, international and national organisations, as well as NGOs and the private sector involved in climate change monitoring.

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[22]   See ITU-R publications for Regulations, Recommendations and Reports at http://www.itu.int/publ/R-REC/en

[23]   See http://www.itu.int/pub/R-HDB-45/en

5.2   Emergency Communications

Emergency communication is crucial for government and humanitarian aid agencies involved in rescue operations, medical assistance and rehabilitation. ITU approves international standards for development and operation of emergency telecommunication systems, provides guidelines (e.g. Handbook on Emergency Telecommunications[24]) for developing countries and deploys temporary telecommunications/ICT solutions to assist countries affected by natural disasters such as cyclones and flooding[25]. This includes the provision of basic telecommunications and telemedicine applications via satellites. Usually, in such situations radio communications are more effective for disaster relief efforts. Recommendation ITU-R S.1001-2 approved by ITU-R Stuy Group 4 ("Space services") provides information on the range of radio-frequencies that can be used by fixed-satellite service (FSS) systems for emergency and disaster relief operations[26]. Recommendation ITU-R M.1854[27] provides information on some satellite systems and the range of radio-frequencies for mobile-satellite service in order to enable a variety of functions such as voice and data communication; field reporting; data collection; position information; and image transmission. Terrestrial and satellite broadcasting radiocommunication systems (audio and television) are very effective emergency communication tools and ITU-R Study Group 6 ("Broadcasting service") approved Recommendation ITU BT/BO.1774-1 "Use of satellite and terrestrial broadcast infrastructures for public warning, disaster mitigation and relief"[28.] This Recommendation provides characteristics and detailed description of satellite and terrestrial broadcasting systems used for disaster mitigation and relief operations.

ITU-T's work in this field includes standardisation of call priority in emergency situations (ITU-T Recommendation E.106[29]). ITU-T also leads the Partnership Coordination Panel on Telecommunications for Disaster Relief (PCP-TDR[30]), which falls under the responsibility of ITU-T Study Group 2. ITU-T Recommendation E.123 provides a standardised language independent means for emergency rescue workers to obtain the contact information for the next-of-kin to an injured person from the mobile handset's directory. Another outcome of ITU-T Study Group 2's work is the assignment of a special country code (888) to the UN Office for the Coordination of Humanitarian Affairs (OCHA) for the purpose of facilitating the provision of an international system of naming and addressing for terminals involved in disaster relief activities (ITU-T Recommendation E.164[31]). This might be used in an area of a country that has been cut off from the national telecommunications, or for natural disasters covering many countries, such as a tsunami.

5.3   Consumer Interface for Smart Grids

At the level of ITU's Telecommunication Standardisation Sector (ITU-T), Study Group 15 has developed home networking specifications under the ITU-T G.hnem banner for smart grid products. G.hnem is the new project "Home Networking Aspects of Energy Management" initiated by ITU-T and the JCA-HN in January 2010. The main goal of the project is to define low complexity home networking devices for home automation, home control, electrical vehicles, and Smart Grid applications. G.hnem uses the AES encryption algorithm (with a 128-bit key length) using the CCMP protocol to provide confidentiality and message integrity. Authentication and key exchange is done following Recommendation ITU-T X.1035.

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[24]   See http://www.itu.int/publ/D-HDB-HET-2004/en

[25]   See http://www.itu.int/emergencytelecoms/index.html

[26]   See http://www.itnewsafrica.com/?p=5929&cpage=1

[27]   See http://www.itu.int/rec/R-REC-M.1854-0-201001-I/en

[28]   See http://www.itu.int/rec/R-REC-BT.1774/en

[29]   See http://www.itu.int/rec/T-REC-E.106/en

[30]   See http://www.itu.int/ITU-T/special-projects/pcptdr/

[31]   See http://www.itu.int/rec/T-REC-E.164/en

Smart grid applications that will benefit from G.hnem include:
- Utility-based demand response programs via broadband Internet communications or AMI systems
- Remote troubleshooting to minimise cost
- Support for real-time demand response systems that compensate users depending on their usage
- Flexible control of appliances to reduce power consumption during peak periods

Earlier in February 2010, ITU-T set up the Focus Group on Smart Grid to identify potential impacts on standards development in the field (for example, ICT and climate change) and investigate future related ITU-T study items to support smart grid development.

5.4   Smart Metering

The Open Metering System Specification (OMS) is the first definition designed to acquire data on electrical energy, gas and water consumption in households and businesses and has been developed jointly by industry associations FIGAWA (German Gas and Water Industry Association), KNX Association and ZVEI (the German Electrical and Electronic Manufacturer's Association) [11][32]. The objective is to develop a complete solution for AMR/AMI as well as standardise smart meter reading devices. The proposal has already been submitted to the European Committee for Standardisation (CEN) with the goal to establish it as pan-European standard. It includes the EN 13757 standard for the data transmission between smart meter and data concentrator [11].

The specification specifies how the data from the meters is to be transmitted from the meter to the authority's back office system in a secure manner. A multi utility communication device (MUC) which can be either integrated in the meter or implemented as a separate device (in case of buildings and apartments) acts as an intelligent data concentrator between the automated meter management (AMM) back office system and the metering device. The specification splits communication between meters and back office into primary, secondary and tertiary communication. Primary communication is between the meter and the MUC and is based on the M-Bus standard (EN-13757). The secondary communication is an extension of the primary communication using repeaters or a multi-hop routing protocol. Proprietary solutions are allowed as for the secondary communication, as no unified network protocol is yet specified.

Communications between the MUC device and the AMM back office (i.e the water/electricity authorities) is based on TCP/IP. The communication backbone is based on technologies such as DSL (ITU-T G.990 series), power line communications or GPRS wireless networks [12]. The specification takes into account the issue of data protection and data security. The AES 128 bit encryption standard is used to secure the privacy of the consumer to prevent unauthorised reading of the meter data, as well as preserving the integrity of the data for the utility company and from fraud by replay of old messages [12].

The power consumption of the communications subsystem is usually the biggest consumer of the battery current. The specification defines a radio protocol for the communications system that allows for battery lifetime for more than 14 years [12].

5.5   GIS Standards

GIS technology requires interoperability. At the heart of the GIS lies its ability to analyse and integrate geographic information from many different sources and organizations. Development of standards in the area of GIS could set new trends and applications for managing water resources and the water distribution network system.

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[32]   See http://www.figawa.de/, http://www.knx.org, http://www.zvei.org/en/homepage/

The Open Geospatial Consortium (OGC) is an international voluntary consensus standards organisation which is involved in the development of standards for geospatial contents and location based services[33]. OGC standards and specifications are technical documents that detail interfaces or encodings to address interoperability challenges. One of the specifications defined by the OGC, the Geography Markup Language (GML), is an XML based language to express geographical features, is also an ISO standard (ISO 19136:2007).

The Geospatial Portal Reference Architecture developed by the OGC provides the basis for an open, vendor-neutral portal that is intended to be a first point of discovery for geospatial content in the context of designing and implementing the Spatial Data Infrastructures being developed by over 50 nations throughout the world [13]. The Geospatial Portal Reference Architecture is based on a Service Oriented Architecture (SOA). The Geospatial Portal Reference Architecture is a major step forward in building information models that help in simulating and visualizing real life situations for better understanding of the problem and help towards building a greener society. It has been used in many diverse areas such as E-Government, National Spatial Data Infrastructures (e.g INSPIRE), intelligent buildings and business geographics. It enables geoprocessing interoperability that makes it possible to exchange heterogeneous geographic information content and share a wide variety of geospatial services over the World Wide Web [13].

At the level of the International Organisation for Standardisation (ISO), Technical Committee 211 is involved in standardisation work for digital geographical information. ISO/TS 19139:2007 defines Geographic MetaData XML (gmd) encoding, an XML Schema implementation derived from ISO 19115. ISO 19115:2003 defines metadata elements, provides a schema (UML) and establishes a common set of metadata terminology, definitions (data dictionary), and extension procedures which :
- Facilitates the organisation and management of metadata for geographic data;
- Allows users to apply geographic data in the most efficient way by knowing its basic characteristics;
- Facilitates data discovery, retrieval and reuse. Users are better able to locate, access, evaluate and utilise geographic data; and
- Enables users to determine whether geographic data in a holding will be of use to them.

Other ISO standards which are used in the implementation of GIS are ISO 19111 Spatial Referencing by Coordinates, ISO 19112 Spatial Referencing by Geographic Identifiers, ISO 19107 Spatial Schema and OGC Observation and Measurement. OGC, ISO TC 211 and CEN TC/287 Working Group are partnering in the development of geo-spatial standards development.

The JPEG 2000 standard was developed by the Joint Photographic Expert Group (JPEG) and issued by ISO/IEC and ITU. JPEG 2000 (ITU-T Recommendation T.800 or ISO/IEC 15444-1) was developed as a high-end alternative to the popular JPEG image format and is emerging as a standard for geo-imaging professionals. JPEG 2000 is highly scalable and can support file sizes into the gigabyte range and beyond, multispectral and hyperspectral datasets with increased bit-depths, and selective decompression of scenes within the image at user-controllable qualities. The OGC is currently working on a standardised mechanism, GML in JPEG 2000 for geographic imagery (GMLJP2) encoding specification, for inclusion of geo-referencing information as XML-encoded metadata within the ISO 15444 JPEG 2000 image format[34] .

GIS Standards support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. These standards enable developers to make geospatial information and services-The concept for collection, information extraction, storage, dissemination, and exploitation of geodetic, geomagnetic, imagery (both commercial and national source), gravimetric, aeronautical, topographic, hydrographic, littoral, cultural, and toponymic data accurately referenced to a accessible and useful with any application that needs to be geospatially enabled. The GIS standards from OGC have played a major role in ensuring interoperability of the GEOSS to address the needs of the ocean science community.

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[33]   See http://www.opengeospatial.org/

[34]   See http://www.opengeospatial.org/standards/gmljp2

5.6   Semantic Sensor Web

The OGC and W3C are the main bodies involved in standardisation in this field. The lack of standardised communications and application program interfaces (API) among the sensor networks is an issue which standardisation activities at the Open Geospatial Consortium (OGC) and Semantic Web Activity of the World Wide Web Consortium (W3C) are trying to address. The OGC recently established Sensor Web Enablement (SWE) by developing a number of specifications related to sensors, sensor data models, and sensor Web services that will enable sensors to be accessible and controllable via the Web [7]. OGC is also working with the Institute of Electrical and Electronics Engineers (IEEE) and the National Institute of Building Sciences to address interoperability between the architecture/engineering/construction (AEC) and geospatial environments. The work is being done under IEEE 1451[35].

In the W3C standardisation work, the semantic web is an extension of the world wide web in which the semantics of information on the web are formally defined. Formal definitions are captured in ontologies, making it possible for machines to interpret and relate data content more effectively. The main technologies of the Semantic Web include the Resource Description Framework (RDF) data representation model and the ontology representation languages RDF Schema and Web Ontology Language (OWL) [7]. Sensor data is encoded based on spatial, temporal and thematic metadata.

By using OGC and W3C standardisation work into the sensor networks and using the web for communications, a framework for enhanced deductive reasoning and querying can be exploited in the sensor networks which could have a lot of potential applications in various domains. The OGC is also working closely with the Internet Engineering Task Force (IETF) Geographic Location/Privacy (GEOPRIV) Working Group on the development on Internet standards for Uniform Resource Identifiers (URI) for Geographic Locations. The GEOPRIV working group is focused on developing and refining representations of location in Internet protocols, and to analyze the authorisation, integrity, and privacy requirements that must be met when these representations of location are created, stored, and used.

5.7   Water Mark Up Language (ML) 2.0 Standard and Water Data Transfer Format Standard

Water observations data are a key element of water resources information systems. The need to accurately monitor, assess and forecast the availability, condition and use of water resources is now more vital than ever. There is a need to define standards for information about climate and environmental data so that data can be easily exchanged among water authorities, meteorological bureaus and other environmental stakeholders

Since 2005, Consortium of Universities for the Advancement of Hydrologic Science Inc (CUAHSI), under the umbrella of the Hydrologic Information System (HIS) project, has developed a variety of web services providing access to large repositories of hydrologic observation data, including the USGS National Water Information System (NWIS), and the US Environmental Protection Agency's STORET (Storage and Retrieval) database of water quality information in the US. CUAHSI web services facilitate the retrieval of hydrologic observations information from online data sources using the SOAP protocol. However, these services had to access different data sources and linking together services developed separately in an ad hoc manner did not scale well. As the number and heterogeneity of data streams to be integrated in CUAHSI's hydrologic data access system increased, it became more and more difficult to maintain the system. As a result, Water ML was developed to provide a systematic way to access water information from point observation sites.

In January 2010, WMO signed a memorandum of understanding with OGC, to enhance the development and use of geospatial standards[36]. Following this, the OGC hydrology domain working group was set up

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[35]   See http://gisdevelopment.net/magazine/global/2009/march/36.htm

[36]   See http://www.wmo.int/pages/mediacentre/infonotes/infonote60_en.html

jointly with WMO to work on the standardisation of hydrological data sets. This also included aligning the initial Water ML specification from CUAHSI with GML. The OGC hydrology domain working group is currently looking into developing a new specification referred to as Water ML 2.0 as an international standard that can be used worldwide for data transfer concerning information and observations related to water. Water ML 2.0 will be an XML schema for time series observations, at specific locations, about climate, river flow and water quality amongst others to streamline data collection and reporting worldwide. Water ML 2.0 will incorporate the semantic web enablement and GML standards of OGC. Water ML 2.0 will provide a standard encoding for data transfer to support the input and update of data into databases, standard data delivery interfaces from databases and applications and the development of applications with a standard data import/export mechanism.

The Water Data Transfer Format (WDTF) Standard project is a key component of the Water Information Research and Development Alliance (WIRADA) in Australia[37]. This project aims to develop and define data transfer standards and procedures for the Australian Bureau of Meteorology to input from existing water data providers, and subsequently for the Bureau to publish for water data users, including decision makers. WDTF is an interim data encoding standard based on the OGC Observation and Measurements (O&M) standard data encoding and is closely linked to Australian statutory requirements and regulations for exchanging water information. The Australian Bureau of Meteorology is also co-sponsoring the development of Water ML 2.0 through its research agreement with CSIRO. The Australian Bureau of Meteorology and CSIRO are contributing to the work being done at the level of the OGC hydrology domain working group on Water ML 2.0.

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[37]   See http://www.bom.gov.au/water/about/waterResearch/wirada.shtml

VI.   Conclusion

Water has a direct impact on food, energy and economic growth security challenges, which the world economy will face in the future. Furthermore, to achieve the MDG goals for water, proper management and use of water resources are essential. Understanding the complex relationships between climate change, water and energy is critical in order for governments to put in place effective and efficient water and energy management policies. ICT has an enabling role in the implementation of smart water management policies.

The report has shown how ICT can bring enormous benefits to water authorities in mapping and monitoring of natural water resources, aquifer recharge as well as in forecasting river flows and advance warning in water related emergency situations such as flooding. The use of sensor networks and Internet communications combined with GIS tools will be having an important role in the future and can be very beneficial to government authorities in not only efficiently managing the water distribution network but also in water quality management, agriculture and landscaping sectors where it can reduce water consumption and wastage. Smart metering technologies will play an important role in measuring water consumption in real time, identifying leaks at the consumer level and at the same time getting consumers more conscious about their water usage. The scope of ITU-T Focus Group on Smart Grid could be extended to include water metering technologies in the future. With developments in plug and play sensors, semantic sensor web, the geoweb, geographical 3D modeling and mobile communications, this field has a lot of potential to offer to water authorities for the future and could be new areas of standardisation work for ITU-T Study Group 16 in the future in collaboration with other standards bodies such as the OGC, W3C and IEEE.

It is important for countries to understand the water footprint and how their water management programmes could impact their energy usage as well. At the level of ITU, the Study Group 5 on Environment and Climate Change could work closely with the WFN and ISO to look into developing models standards for water and energy footprint for nations which would enable countries to understand how the policies they implement will impact on both their water and energy footprints as the two are closely related.

Developing countries could make use of GIS tools for better decision making in water management policies in order to meet the MDG targets for water. Currently developing countries lack resources and know how in order to fully exploit GIS tools strategically. It is another form of digital divide. The ITU jointly with the UN Water Task Force could play an important role in enhancing developing countries' capability to exploit GIS through the development of a standardised GeoWeb toolkit for developing countries which would provide the basic elements needed by water stakeholders. A capacity building programme on GIS and spatial data analysis for water stakeholders in developing countries could also be considered.

Glossary of acronyms

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AES	Advanced Encryption Standard
CCMP	Cipher Block Chaining Message Authentication Code Protocol
CEN	European Committee for Standardisation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CUAHSI	Consortium of Universities for the Advancement of Hydrologic Science Inc.
DSL	Digital Subscriber Line
FAO	Food and Agriculture Organisation
GEO	Group on Earth Observation
GEOPRIV	Geographic Location/Privacy
GEOSS	Global Earth Observation System of Systems
GHG	Greenhouse Gas Emissions
GIS	Geographical Information Systems
Gmd	Geographical Meta Data
GML	Geography Markup Language
IEC	International Electrotechnical Commission
IETF	Internet Engineering Task Force
INSPIRE	Infrastructure for Spatial Information in the European Community
ISO	International Organisation for Standardisation
ITU	International Telecommunication Union
ITU-D	ITU Telecommunication Development Sector
ITU-R	ITU Radiocommunication Sector
ITU-T	ITU Telecommunication Standardisation Sector
JPEG	Joint Photographic Experts Group
MDG	Millennium Development Goals
OGC	Open Geospatial Consortium
OWL	Web Ontology Language
RDF	Resource Description Framework
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SWE	Sensor Web Enablement
UNESCO	United Nations Educational, Scientific and Cultural Organisation
URI	Uniform Resource Identifiers
W3C	World Wide Web Consortium
WFN	Water Footprint Network
WIRADA	Water Information Research and Development Alliance
WMO	World Meteorological Organization
WNS	Web Notification Services
XML	Extensible Mark-up Language

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ANNEX 1: Water footprint of a business

The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business. The water footprint of a business, the 'corporate water footprint', is defined as the total volume of freshwater that is used directly or indirectly to run and support a business. It is the total volume of water use to be associated with the use of the business outputs. The water footprint of a business consists of two components: the direct water use by the producer (for producing/manufacturing or for supporting activities) and the indirect water use (in the producer's supply chain).

Figure 3
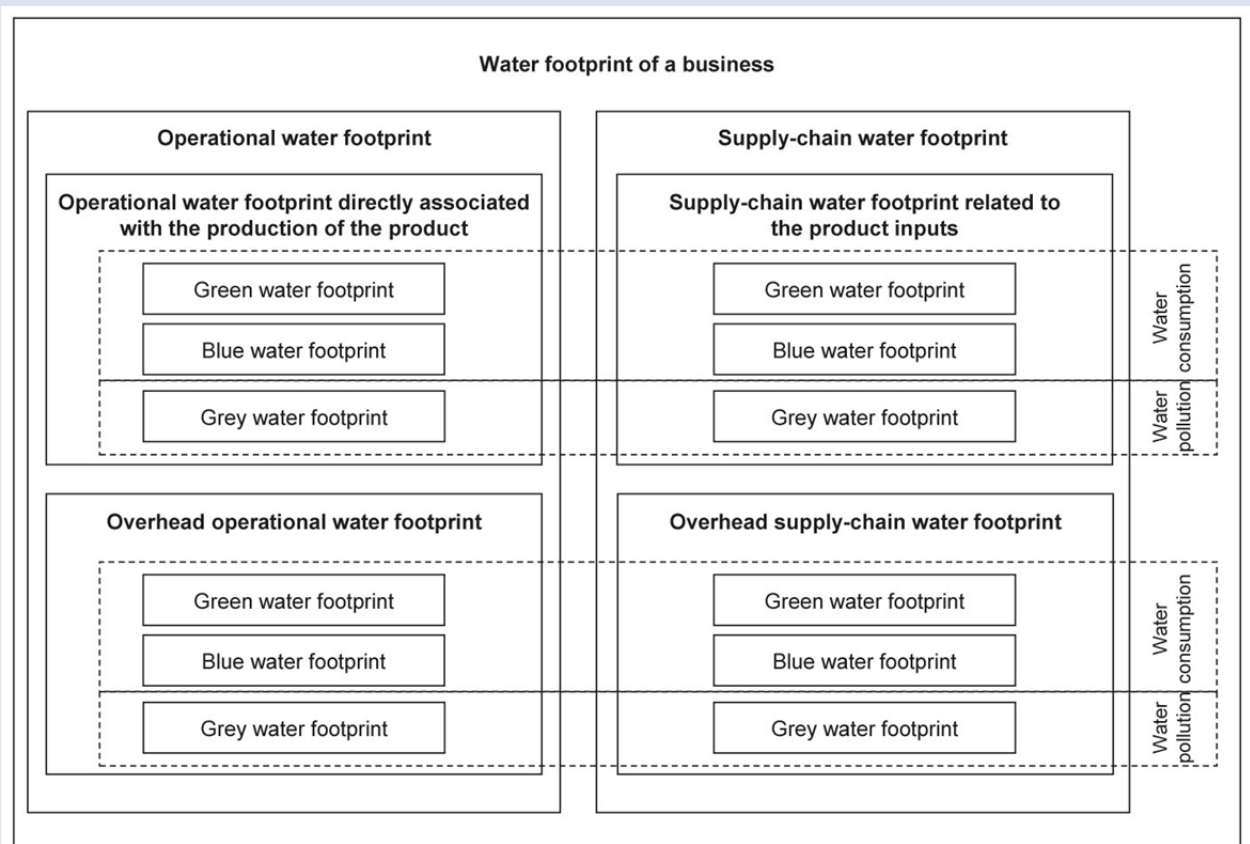
Legend: *Green water: Rainwater,*
          Blue water: Surface/ground water,
          Grey water: Polluted water

Source: http://www.waterfootprint.org/downloads/TheWaterFootprintAssessmentManual.pdf

ANNEX 2: Smart Grid For Malta

Malta's national electricity and water utilities, Enemalta Corporation (EMC) and Water Services Corporation (WSC), have entered in February 2009 into a €70 million, five-year agreement for the design and delivery of a nationwide AMI and smart grid implementation.

The project is the first step in establishing an end-to-end electricity and water smart utility system. When complete, the multi-phased engagement is expected to completely transform the relationship between Maltese consumers and utilities suppliers, while enabling more efficient consumption of energy and water.

The solution, which is provided by IBM, is designed to improve operational efficiency and customer service levels by introducing smart meters that allow clients to better manage consumption. The project will involve replacing a quarter-million conventional electric meters with smart meters and upgrading the water system where it can be monitored and managed remotely. In addition water meters will be integrated with advanced IT applications, enabling remote monitoring, management, meter readings and meter suspensions. The project will also involve the implementation of SAP's ERP-based system and its billing application. Customers will be able to use the Internet to track their utility usage in real-time. They will also be able to choose the best plan and can pre-pay for their services.

This project is expected to optimize operation costs for Enemalta Corp. and also enable WSC to better improve its water management programme. The system is expected to be completed by the end of 2012.

Source : Extracted from IBM and http://metering.com

ANNEX 3: Use of GIS in Water Distribution Network Management in Saudi Arabia

The General Directorate of Water in the Eastern Region (GDWER), in Saudi Arabia receives thousands of calls each year in its service center from people concerning issues such as burst pipes and irregular water supply. The directorate is expected to respond quickly to these incidents. However, it was not always easy to identify precisely where the problem had occurred. Data was also not shared and was often duplicated. GDWER is located in the city of Dammam which is the largest city in the eastern region of Saudi Arabia. The city of Dammam has a population of around 600,000 people.

GDWER implemented an enterprise asset management system which is integrated with a GIS solution, to manage its underground assets. GDWER has implemented a unified, spatially enabled water and wastewater data model to represent all water and wastewater elements, such as wells, pipes, treatment plants, fittings, and house connections.

The GIS was integrated with the Supervisory Control and Data Acquisition (SCADA) system for the well network. The integration allows the GDWER SCADA system to be a part of the central IT network and information infrastructure for quicker response to any malfunctions or anomalies occurring within the well network systems.

When the call center receives a customer call, the system initiates operational response, then uses a predefined workflow to manage event tracking and logging. The workflows developed within the call center software allow GDWER to define and manage its standard operating procedure. The workflows will analyze the system's automated response to an event and escalate the response to a higher level if required.

The user can automatically record an exact location for each event in the network and analyze it to determine the impact on the surrounding area. Using the map location as a reference, the system can then identify assets GDWER has at any particular location and dispatch work crews to respond to the event.

Source : Extracted from ESRI at http://www.esri.com/news/arcnews/spring10articles/gis-improves.html

ANNEX 4: Geographical Information System (GIS) Portals

A GIS portal is a one-stop web application that enables all stakeholders (government and businesses) to create an online search catalog based on GIS industry standards and to develop spatial data infrastructure portals. It allows users to quickly and easily discover and directly use the data and services available on a particular topic for a specific geographic area. GIS portals organize content and services such as directories, search tools, community information, support resources, data, and applications. They provide capabilities to query, search, and manage metadata records for relevant data and services, and then link to the online sites that host content services.

Figure 4 :   **GIS Portal Information Flow**
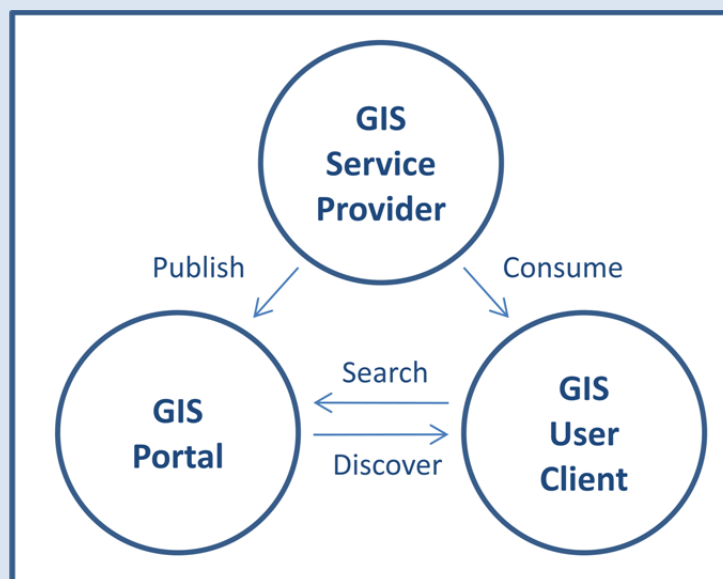
The user views the front-end content of the GIS portal as a website with a collection of pages that describe content, search, and navigation instructions as well as information of general interest to the community of users. The GIS portal front-end sits atop an Internet Map Server that provides metadata management, mapping, geocoding, and data download services. The geoservices data is housed in a database management system (DBMS) that is accessed via a database gateway. Queries to the portal can come from both thick and thin (desktop) clients over HTTP. In this way, users can make use of the portal and fully distributed services over open Internet connections.

Source : ESRI Canada at http://www.esricanada.com/documents/ann-vol7-2-gis-portals.pdf

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