7th World Water Forum

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Science & Technology Process

WHITE PAPER

Preface

The White Paper, the main outcome of the Science and Technology Process of the 7th World Water Forum, is a praiseworthy result of the World Water Forum processes. The paper has been prepared by prominent water experts working together to deliver coherent and insightful responses on scientific and technological tools promoting solutions for pressing global water challenges.

The White Paper accentuates innovative and applicable science and technology on water. The clarity and timeliness of this document enables us to once again recognize the linkages between emerging technologies and information and how they can contribute to solving our water problems. We all know that water affects every aspect of our daily lives. However, the intertwined nature of our relations to the environment calls for more innovative ideas and the upscaling of research for development. This can only be achieved by deeper cooperation among all actors who stand in the front line of tackling water challenges while implementing solutions through practical and applicable technologies. We need collective action from government, industry, academia, and civil society.

The White Paper identifies the current status of water-related science and technology and provides future directions by identifying 'innovation and application of science and technologies' in the sectors of each of the Main Focus areas of the Forum's Science and Technology Process: 1. Water Efficiency, 2. Resource Recovery from Water and Wastewater Systems, 3. Water and Natural Disasters, 4. Smart Technology for Water, 5. Understanding and Managing Ecosystem Services for Water.

We highly commend all contributors who took an active part in the development of this White Paper. We would also like to express our profound appreciation to the partners of the 7th World Water Forum for highlighting the essential role of science and technology in resolving today's and tomorrow's water challenges. We would also thank the coordinating organization of this White Paper, K-water and their cooperative partners. Finally, we wish to thank the organizers of the 7th World Water Forum and especially to the Science and Technology Process Commission for their commitment and support to the Science and Technology Process.

We sincerely believe that the findings and messages presented in this White Paper will contribute to the discussions around the Post-2015 development agenda and help the international community commit to collective action in the future towards practical and tangible science and technology solutions, tools, and methodologies utilizing for water.

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TABLE OF CONTENTS

Executive Summary

This White Paper, as a major outcome of the Science and Technology Process, aims at publishing an 'Innovative report for science and technology in water management'. The White Paper will reflect the past, the present, and the future of five key focuses, mentioning related technologies simultaneously. The 5 Main Focuses of the White Paper are as follows : (a) Water efficiency, (b) Resource recovery from water and wastewater systems, (c) Water and natural disasters, (d) Smart technology for water, and (e) Understanding and managing ecosystem services for water.

Main Focus 1 : Water Efficiency

Water stress and water scarcity are global challenges with far-reaching economic and social implications. Driven by increasing population, growing urbanization, changing lifestyles and economic development, the total demand for water is rising: from urban centres, from agriculture and from industry. But efficiency gains lie within our grasp, and can put us on track to achieve water security for all.

Security won't arrive by itself. The status quo of single digit incremental efficiency falls well short of the mark. And the imperatives of climate change add urgency to current water crises. Yet right now we possess the tools and experience to design and implement a new paradigm of efficient water use, and scale it up quickly to sustain urban, agricultural, industrial and energy systems everywhere.

This *Policy Brief* shows why, how, where, and for whom water and energy efficiency goals became real:

1. **City Solutions.** *Urban water managers who control water losses and combine firm incentives with flexible innovations can quickly close the projected 40% gap between supply and demand.*

2. **Agricultural Advances.** *Farmers who slash waste throughout irrigation systems can grow more food, and earn more per drop, even with 43% less water.*

3. **Industrial Innovations.** *Corporations that push for internal and external efficiency both increase outputs and reduce exposure to risks, even within zero increases in water supplies.*

4. **Power Shifts.** *Judicious early investment can achieve carbon and energy neutrality, or generate net gains, through efficient water and wastewater processes.*

5. **Smart Systems.** *Advanced water technologies – when nested within rigorous legal, administrative, and economic institutions – enable and accelerate 'smart systems.'*

6. **Standard Metrics.** *More inclusive, exacting, and uniform ways of measuring water will yield efficient outcomes both quickly and affordably.*

7. **Stress Relief.** *The fastest, fairest, cleanest and cheapest path to efficiency involves carefully optimizing water pressure to maintain priorities while eliminating excessive strains.*

These *Seven Keys* ensure vital systems do more with less. Each reveals effective tactics and techniques to reduce leaks and losses, boost food security, increase productivity, conserve (or generate) power, and build resilience to escalating shocks. They highlight what has already been achieved and what can be replicated at scale quickly. Efficiency aligns ecological and economic outcomes so that further waste is not only unacceptable, but also unnecessary.

1. City Solutions

Challenge : For decades, cities grew perverse incentives to waste their water. Water prices that do not reflect the economic value of water. Natural monopolies prevent competitors from driving efficiency. Hard surfaces accelerate runoff to erode, pollute, and overwhelm plants.. As demand rises, water stress will only intensify. How can professionals relieve compound pressures of rapid urbanization, thirsty growth, competing demands, nonpoint source pollution, rising labour costs, escalating emissions, and extreme droughts punctuated by flash floods?

Solution : *Urban water managers who control water losses and combine firm incentives with flexible innovations can quickly close the projected 40% gap between supply and demand.*

Action : Whenever governments set binding targets to reduce water use, water losses or greenhouse gas emissions, they generate a lively market for innovative technology. Consumer demand drove widespread adoption of efficient new household appliances that save water and energy. To accelerate demand, and the innovation it stimulates, leaders must incentivize efficient outcomes through tariffs that reflect water's true value and policies that reward efficiency gains.

Result : With institutional incentives fixed in place, flexible innovations emerge:

- Efficiency in the home comes through rebates to phase out older toilets or appliances in favor of high performance models, but the most successful programs measure outcomes, not inputs.
- Efficiency in distribution networks that harmonize water loss reduction with water pressure control, gives opportunity for programs that help flatten a system's peak demand, create water reserves, and reduce long term capital investment needs.
- Rainwater harvesting links ancient technology with a new urgency to collect and store runoff from rooftops or landscapes using surfaces containers or underground check dams.
- Harmless, nutrient-rich greywater from sinks, showers, and washers can safely irrigate and fertilize turf, flowers, or fruit trees, easing strain on energy-intensive treatment plants.
- Low-impact development designs with nature, rather than against it, to slow, spread, and sink runoff, disperse pollutants, and ease strain on urban infrastructure.
- Advancements in Ground-penetrating radar (GPR) and thermal infrared radiation can 'x-ray' networks to reveal vulnerable areas where a leak is cooler or warmer than the surface it.

2. Agricultural Advances

Challenge : As populations swell in number and income, so does their consumption. Soon we will annually require one billion additional tons of cereals and 200 million additional tons of livestock. For decades we grew more by expanding cultivated lands 12%, and doubling irrigation. But arable land is scarce and irrigation water is capped; its 70% share is shrinking under competing demands. At the same time, hungry soils need replenishing with vital nutrients, some of which are finite resources. So how can we feed ourselves?

Solution : *Farmers who slash waste throughout irrigation systems can grow more food, and earn more per drop, even with 43% less water and use vital nutrients such as nitrogen and phosphorus reclaimed from wastewater.*

Action : Effective agricultural water efficiency (AWE) techniques help farmers match every drop to each crop's needs through precision technologies. These increase yields and quality while reducing costs of fertilizer, water, energy, and greenhouse gas releases. The result is higher profits, reliability, and resilience to drought, deluge, reallocations, or price flux.

Result : AWE may involve many forms, tools, tactics and technologies:

- By combining crop selection, irrigation scheduling, and alternative sources of irrigation water, some regions have been able to reduce irrigation losses 43%.
- Other tools measure soil moisture, assess leaf moisture, deploy conservation tillage, maintain soil fertility, and boost water retention capacity.
- Farmers can now fine-tune the crop development stage; the timing and amount of water applied to the root zone; or water

consumed by the crop since the previous irrigation.

- Accurate monitoring– of fertility, crop variety, pest management, sowing date, soil water content, planting density – help systems reach optimal performance, saving water while enhancing yields.
- In-field sensors, geographic information systems, remote sensing, crop and water simulation models, climate predictions are deployed in versatile ways.
- In Korea, AWE cut across spatial, temporal, and political scales, engaging competing stakeholders, to achieve different outcomes:
  - AWE targeted 1,570 reservoirs to monitor real-time flow and storage against drought.
  - AWE rehabilitated 11 reservoirs to secure 0.28 billion tons of water.
  - AWE enhanced performance of 37 irrigation districts in the Yeong-San River basin.

3. Industrial Innovations

Challenge : Public officials worry that failure to quench industrial thirst will stifle economic growth, cause mass unemployment, and corporate flight. So how much water does it actually need? For decades, no one knew. So they projected arbitrary and unreliable future demands, and then set about building dams, aqueducts and pipelines to meet fictional targets. The negative consequences of that supply-side approach have grown intolerable. So how can businesses secure water yet insulate brands from hidden pressure?

Solution : *Corporations that push for internal and external efficiency both increase outputs and reduce exposure to risks, even within zero increases in water supplies.*

Action : 'Future industrial water demand' assumptions were higher than reality. But risks remain. Assessments of 700 large water users show internal and external rewards from industrial efficiency. The first lies within its domain, reducing pressures and/or flows entering a zone, factory, or subsections of industrial processes. The second, outside it, motivates public-private partnerships.

Result : Industries cannot exist without water to clean, cool, churn turbines as steam, or become part of the final product. Markets motivate them to allocate capital and labor for efficiency within and without.

- Just as doctors routinely check blood pressure and heart rate to assess patient health, industrial water professionals use data logging to anticipate operational risk at all times.
- Internationally branded industries aggressively monitor and benchmark use both carefully and transparently, to limit exposure to reputational risk.
- Remote web-based platforms analyse, display, and identify wastage and poor management, and then take corrective measures to avoid damaging the internal water supply network or authority.
- Timing is crucial: highlighting a relatively small (1.5 m^3/hr) leak on the 5th July helped industry fix it within days, not months or years, saving money, water, and risk.
- Data logging has revealed 80% leakage and 10% stolen by water tankers for some industrial zones, leading to corrective action that saved 90% and opened new opportunities.

4. Power Shifts

Challenge : Urban, agricultural and industrial water systems are energy-intensive. Nonstop pumps use 95% of the power for distribution; heating and treatment use even more. Water systems often represent the single biggest users of energy. Some drain 20% of the grid. Energy production and distribution, in turn, requires excessive carbon and water, with some plants consuming 5% of water withdrawals from a basin.

Solution : *Judicious early investment can achieve carbon and energy neutrality, or generate net gains, through efficient water and wastewater processes.*

Action : In the water-energy nexus, emerging efficiency for one resource yields comparable gains for the other. Operational reforms may require intensive retraining, energy audits, investments and longer term plans. But delay escalates economic and ecological risks, while action now turns crises into opportunities.

Result : The vicious spiral of rising water/energy demand can be slowed, and even reversed in a positive direction through conservation, loss prevention, stormwater reduction, or repairs to infiltration. The most effective strategies may convert water systems into net energy producers.

- Treatment plants may capture and burn biogas from anaerobic digesters to generate some or all of their own electricity, turning plant into net zero consumers of energy.
- Other technologies may enable industries and agencies to develop closed-loop systems that optimize water use.
- Significant energy gains come by combining demand response, leak detection, storage tanks, automated meters, and upgrading system pumps, motors, lights, HVAC.
- Micro-hydro may convert pressure and flow in large pipes into electricity, much as a hybrid vehicle harnesses braking power for energy: an alternative to valves that helps regulate pressure.
- Water supply systems can be integrated with a renewable source of energy such as solar cells, wind turbines, and small or run-of-river hydropower.

5. Smart Systems

Challenge : For decades – in order to boost health, growth, and prosperity – public policies set out to provide water at any cost. The heavy asset base these policies delivered were inherently inefficient, contributing to unaccountable waste, and scarcity. The high costs of operating, maintaining, rehabilitating and replacing these systems contributes to a vicious cycle of low cost recovery ratio. Those same decades brought gleaming information communication technology. ICT tools can improve demand response, energy-water nexus, and engagements with family, farm, or factory. But they don't exist in a vacuum, and without non-structural reforms, gains from 'smart' hardware and software may bleed away.

Solution : *Advanced water efficient technologies – when nested within rigorous legal, administrative, and economic institutions – enable and accelerate 'smart systems.'*

Action : Every tool, however innovative, is only as 'smart' as those who wield it. Water professionals achieve efficiency to the extent they anchor and integrate each tool within the non-structural framework.

Result : To reap the full potential gains from smart technology, professionals should nest them within water rights, allocations, tariffs, licensing, regulation, storage, abstraction, energy choices, and markets:

- Advanced Metering Infrastructure (AMI), with 'smart' sensors and signals, lets consumers choose tariffs, while utilities can prioritize usage for special purposes and pricing.
- Smart meters allow time of day billing, reduction of peak demand, leak detection, increased distributional efficiency, non-revenue water reduction, and deferral of capital spending.
- Smart pipes measure water flow and quality to detect strain, temperature or pressure anomalies, so potential leaking can be checked in real time.
- Smart sensors optimize irrigation water by measuring humidity, rainfall, wind speed/direction, soil temperature/moisture, atmospheric pressure, and solar radiation.
- Smart rehabilitation sends image-diagnosing robots to inspect pipes, blasts scaling and rust with an ultra-high pressure water jet, and sprays lining/coating materials evenly inside the pipes.
- Smart green infrastructure – soil, trees, vegetation, wetlands, and open space – can mitigate stormwater runoff and treat it through local storage, reuse or infiltration.
- Smart asset management optimizes capital, operations and maintenance expenditures by providing the desired level of service at the lowest infrastructure life-cycle cost.

6. Standard Metrics

Challenge : A water authority that seeks efficiency from metered clients – housing developments, golf courses, cane fields, manufacturers or power plants –often overlook the single biggest source of waste: itself. 'Non-revenue water' (NRW) reveals the yawning gap between water treated and water invoiced. Loss leaders include: inaccurate billing, deteriorating infrastructure, high pressure, inexact metering, reservoir overflows, excessive flushing, and illegal connections. These are symptoms of much larger mistakes: while estimated losses may be a third to half the input volume, the truth is no one really knows for sure.

Solution : *More inclusive, exacting, and uniform ways of measuring water will yield efficient outcomes both quickly and affordably.*

Action : Too often efficiency is erroneously measured by random or inappropriate metrics. NRW estimates often use simple percentages, which vary wildly by day or season, depending on weather. Paradoxically, when it rains, and demand falls, NRW percentage will appear to have increased; conversely, water loss percentages will appear to decrease in a dry year when demand rises. Both mask the actual physical leaks.

Result : Physical measurement drives efficiency closest to the source with robust and precise indicators.

- The most advanced compares NRW to the length of water mains, or the number of properties or connections, against an optimal level for those metrics, in an Infrastructure Leakage Index (ILI).
- Avoid confirmation or selection bias, 'cherry picking' favorable metrics, categories, inputs, or sources of use.
- High performance dictates that agencies must account not just for some of the water being used in a few random places, but rather all sources throughout the network.
- Rigorous standardized accounting, through the IWA Water Balance, encompasses the measurement and thus management of the system as a whole.
- Meters installed throughout the networks, backed by inspectors with listening devices, help identify the real extent of leaks.
- Modern equipment helps track speed, velocity, and source of noise transmission.

7. Stress Relief

Challenge : Water pressure presents an old, deep challenge of individual vs. collective needs. Centralized, energy-intensive pumps amplify water velocity that only a few may desire, but most don't require. The escalating risk is that excessive pressure compounds stress, leading massive systemic hemorrhaging of water, energy, carbon and money for all. Perversely, the agency itself may elevate pressure for this very reason: more water forced out means more revenues coming in. But such quick gains prove illusory, and erode under the mounting expense as stress opens cracks and widens splits until burst pipes bleed efficiency throughout the system.

Solution : *The fastest, fairest, cleanest and cheapest path to efficiency involves carefully optimizing water pressure to maintain priorities while eliminating excessive strains.*

Action : Care may require investing in time, training, trials, and tests. Yet the effort to optimize pressure yields lasting benefits across every system, urban or rural, ecological or economic, industrial or agricultural. Dramatic efficiency gains may seem silent and invisible, but are substantial, and immediate.

Result : For most water supply networks, and even in some developing countries with intermittent supply, optimal pressure management can be among the most cost effective measures to reduce widespread leakage, deterioration, and waste.

- High pressure increases the size of 'variable leaks', which illustrate a paradox: systems lose more water at night, when communities sleep, than during the day, as demand steadily rises.
- Most networks running at 60-90 m can shift down to the average, yet still quite ample, 20-50 m.
- New electronic, flow modulation, and time controllers can each judiciously reduce pressure by up to two thirds, without compromising the level of service for heavy consumers or fire-fighting.
- Low pressure does not by itself repair or eliminate leaks, but it keeps new ones from forming, and ensures cracks, holes or joints lose water at a far lower rate, by up to 90%.
- Pressure reduction also further scales back systemic and local demands on energy, as well as associated carbon embedded within.

· Major benefits for communities by having a more reliable, constant supply of safe drinking water, and moving away from low pressure intermittent supply problems, and all the impacts that has on livelihoods. This is achieved by firstly removing all pressure surges that intrinsically occur with interrupted supplies, which in turn commonly cause mass water losses of 50% to 90% in many networks around the world, and impairs any rehabilitation and repair work on pipelines.

Main Focus 2 : Resource Recovery from Water and Wastewater Systems

Civilizations developed water and wastewater systems with a focus on treatment technology. The goal was simple: pull clean water in, push dirty water out, and make odours disappear as fast as possible.

But our larger and more affluent populations demand far more resources from far fewer supplies. Budgets have shrunk and climate change is forcing cities and industries to reassess every aspect of our resource life cycles.

As a result, leaders have begun to develop a more sophisticated philosophy and methodology of resource recovery and reuse – towards a low-carbon 're-appearing act'. These concepts are neither new nor radical. But they highlight the troubling gap between theory and practice, which prevents us from capturing valuable benefits at a large scale.

A fundamental shift in our approach and mentality can lead us beyond conservation, efficiency, or treatment toward the optimal recovery and reuse of resources. This Executive Summary illustrates why, how, where, and for whom 'waste' is becoming progressively obsolete.

It provides trends, tools, tactics, perspectives, case studies, and solutions. In sum, this paper reframes our water, energy, and nutrients crisis as an opportunity to create enormous value. The keys to success lie in:

1. **Bottom-Line Benefits.** *Resource recovery and reuse dramatically saves electrical currents and financial currency, effectively earning money that can be reinvested elsewhere in water utilities.*

2. **De-carbonization.** *As governments seek to meet greenhouse gas emissions targets, resource recovery and reuse can slash per capita carbon emissions by 4% annually.*

3. **Effluent Mining.** *Apart from water, energy and nutrients, such as phosphorous, resource recovery and reuse extract new wealth from an old pool of other compounds and substances.*

4. **Cyclic Economies.** *Judicious early investments in reuse and recovery help close the loop in water and wastewater systems, eliminate externalities and build resilience to escalating risks.*

5. **Imaginative (Re)Branding.** *Much as 'used cars' are now highly valued as 'previously owned vehicles', water and nutrients can be judged not by their history but by their quality.*

6. **Linked Outcomes.** *Water reuse may top the agenda, but the hottest topic relating to resource recovery is connected to energy efficiency and recovery in water and wastewater systems.*

7. **Centralized Control.** *While efficiency and conservation gains may come from devolving authority, recovery and reuse take advantage of concentrated water, energy, and nutrients*

The *Keys to Resource Recovery* not only ensure lateral transfer of existing best practices, but raise the bar by enabling new innovations to emerge. Each key reveals the most effective tactics, tools and techniques to generate more energy, enhance food security, increase productivity, secure more water, bring more nitrogen and phosphorous to market, and build resilience to escalating shocks.

In sum, this paper reveals 'waste' as merely a source of food, energy or water. It reminds us that by shifting our fundamental approach to resource recovery and reuse in our systems, 'freedom' really is just another word for nothing left to lose.

1. Bottom-Line Benefits

Challenges : Professionals seeking to recover and reuse the valuable resources from water systems may question its affordability. Financing an overhaul or building a new plant from scratch is daunting. Municipal budgets face fiscal constraints. Even a progressive leader can't justify up-front expenses today, without a clear sense of the return on investment. How can leaders quantify returns – avoided costs, increased savings, new sources of revenue – to ensure gains are easy, clear, dramatic and perpetual?

Solutions : *Resource recovery and reuse generates an electrical current, financial currency, and river currents – natural capital that can be reinvested into the system.*

Actions : Those who make scarce resources 'reappear' can collect and market them. There is high value in energy, nutrients (nitrogen, phosphorous and minerals, including rare earths) and in life's matrix: water.

Results : Water reuse and reclamation have been developed and practised far more than any other recovered resource, to drive end users and utilities alike toward real benefits:

- High quality reclaimed water gains value as drinking water, through monitoring and chemical-toxicology technology, as well as through involvement of different public sectors.
- Recovery of sewage, could earn each European €1.6 per cubic meter; at 50 cubic meters, that equals €80, earning 65% of the value is in water, 12% is in energy, and 23% in nutrients.
- Utilities can earn €1 by eliminating the capital-intensive costs to treat 1 m3 of water, or make it 'ready to be discharged back into nature', earning another €50 per capita per year.

2. Nexus Outcomes

Challenge : Recovered energy from wastewater sounds good in theory. But in practice it must compete with fossil fuels that are cheap, familiar and integrated. Professionals have to adjust infrastructure and institutions to handle biogas or heat. It takes public resources and political will to kick-start markets. Families and firms often require economic incentives to sort and separate waste (including bio-solids) for potential fuel sources, much as they already sort organic material for recycling.

Solution : *Water reuse has traction, but the hottest topic in water and wastewater systems is energy efficiency, production and recovery.*

Action : Systemic changes increase both energy generation and recovery. Most feed into the treatment system, which in turn boosts efficiency, and may even lead to net energy-positive systems.

Results : To recover energy from used water: 1) turn sludge into biogas through anaerobic digestion to create electricity and heat; or 2) concentrate, transport and incinerate the digested product for heat. Both involve trade-offs.

- Water with fermentable organic matter, landfills rich in organics, livestock wastes, food wastes and sludge can be anaerobically digested into biogas (65% methane; 35% carbon dioxide).
- Biogas can be upgraded to compressed natural gas or liquid natural gas for vehicles.
- Within treatment processes, 80% of the chemical energy can be transformed into methane; 35% of the energy in methane can then be converted into electricity, for 28% efficiency.
- More than 500 used water heat pumps, with thermal energy capacity from 10kW to 20MW, in operation.
- China, Finland, Switzerland, and Canada use thermal energy recovery for on- and off-site district heating, sludge drying, and sludge digestion.

3.De-Carbonization

Challenges : Conventional treatment systems don't just pollute water; they choke air. Organic matter in used water is removed, by biological oxidation, to CO2. The residual organic carbon, harvested as sludge, is often incinerated into CO2. And external or internal carbon sources for de-nitrification can result in more greenhouse gas emissions. Energy-intensive 'dissipation' (removal of unwanted characteristics) typically burns fossil fuels, which emit greenhouse gas, which elevates temperatures, which bring drought, floods, and stress in a vicious cycle of rising costs, shocks, fragility and potential collapse.

Solutions : *To meet global carbon reduction targets, resource recovery and reuse offers governments affordable ways to slash annual per capita emissions by up to 4%.*

Actions : Water professionals should also explore harnessing their systems to recover and reuse two increasingly valuable natural assets: clean air and a stable atmosphere.

Results : Recovery of energy and nutrients can help reduce extreme impacts from climate change:

- Replacing natural gas with biogas requires enrichment of methane and removal of carbon dioxide.
- The current 'dissipative' technology demands more energy – up to 1 percent of the total electricity use in industrialized countries – from fossil fuel than is necessary.
- Beyond water and money, resource recovery can annually save each person 140 kWh in electricity, 530 kWh in heat, and 88 kg (1-4% of all sources) in needless carbon emissions.
- Higher returns on cheaper innovations emerge from research, development, and technology.

4. Effluent Enhancement

Challenges : Most technologies don't recover nutrients; they just remove them. And nutrients are rarely of either uniform quality or large quantity. There can be positive or negative consequences of using sludge as fertilizer, as variable levels of mercury and other heavy metals accumulate over time, and risk excess nutrient loads trickling into streams. High start-up and running costs of new recovery plants mean the end products can't compete well at market: it's still cheaper to mine nutrients than recover them.

Solution : *Apart from water, energy and clean air, resource recovery and reuse can extract new wealth from an old pool of nutrients, compounds and substances.*

Action : Treatment plants hold a wealth of nutrients – especially potassium, phosphorus and nitrogen – whose recovery rises with demand for artificial fertilizer, increased yields, food security and irrigation.

Results : Reusing nitrogen at the recovery site can be upgraded to a valuable feed or food.

- 85 percent of all nutrients are linked to agriculture, but other sectors use recovered products too.
- Resource recovery can be as basic and simple as a $20 waterless composting toilet, which can divert urine and faeces into harmless, odour-free ammonia and organic dry 'humanure'.
- Other processes use bacteria to break down sludge, converting human waste into biogas for heating, cooking and generating electricity.
- As agriculture reaches 'peak phosphorous' (90% of which is locked up in five countries) and petroleum-based fertilisers grow scarce, progressive farmers contract for valuable local sludge.

5. Cyclic Economies

Challenge : 100 years is enough. Despite our fast-changing climate, old treatment plants still burn too much carbon, food, water, heat and money. Sanitation destroys nitrogen. We dissipate potential proteins into sewage. We consume 2% of the world's available energy. So while a 20-30% target for waste reduction sounds nice, it is far from full recovery and remains open-ended.

Solution : *Early targeted investments in reuse and recovery can 'close the loop' in our systems, eliminate externalities, and build resilience to escalating risks.*

Action : Components like sulphur, cellulose, metals, and bioplastics will grow valuable with societal acceptance of the cyclic economy.

Result : A truly closed loop demands that we know exactly what resources can be recovered where, how, and for which markets:

- Research can address and delineate the limits to, and potential of, the cyclic economy.
- That economy exists in the context of both primary materials it will consume and of those potentially supplied by the reuse loops that will be developed
- Water professionals must work harder with legislators to construct legal frameworks that clearly define and encourage resource recovery across and within borders.
- Innovative R&D platforms can spur the cyclic economy within the sector of water use and reuse.

6. Imaginative (Re)Branding

Challenge : Culture can make or break resource recovery. People typically react to excreta with disgust. They fear contact with faecal matter as a source of stinking, bacterial, disease-infested filth. They avoid 'waste' at all cost. Technology alone can't transform public perception, or transform sludge, heavy metals or bioplastics from liabilities into assets. That demands marketing a brand with strong appeal.

Solution : *Just as 'used cars' gain high value as 'previously owned vehicles,' let us judge water, energy and nutrients not by their history but by their quality.*

Action : By dealing honestly with materials, we can surmount 'pushing' new supplies to the 'pull' side of demand. No one complains about aquaculture quality, despite fish whose diet is 50% faecal matter.

Results : The resource paradigm must be cleared from "waste"-related connotations, so that:

- Rather than past processes, focus on future products – clean energy, water security, organic products, phosphates, nitrogen, biogas, fertilizer, paper, cellulose, rare earths, and other resources
- Existing 'wastewater treatment plants,' transform into 'resource recovery facilities'
- End users – industry, farm, school, family, airport – may be more willing to use a recovered resource if shown how it shrinks, stops and reverses damage to their self interest.
- Integrate concepts of life cycle assessment, strict quality control and hazard assessment.
- Singapore prioritized Four National Taps: catchment water; imported water; desalinated water; and reclaimed or NEWwater.
- Nano-technology holds promise if it stops scaring people about unknown aquatic consequences.

7. Appropriate Scales

Challenge Size matters. Some recovered water, energy, carbon or nutrient sources are unsuitable to store or transport over long distances. The plant where energy is produced may be too far from where it will be consumed. Uncritical intervention can lead to unnecessary costs or the loss of energy in transmission. Demographic, physical, economic, labor skills and ecological differences mean resource recovery technology cannot be easily or uniformly transferred. What works here may not succeed there.

Solution : *Context-specific gains come from devolving authority, so recovery and reuse optimise water, energy, clean air and nutrients at the source.*

Action : By assessing goals, as well as local supply and demand, professionals develop tools, tactics and techniques that recover the right resources, in the right way, at the right scale.

Result : The hard, visible, physical plant depends on soft, invisible institutional infrastructure put in place:

- Appropriate technology ensures decentralised and urbanised societies gain efficient supplies.
- Resource recovery is no panacea, target, or goal; it is a means to an end that arises from within.
- Durable outcomes depend on an institution's clearly defined agenda, concrete policies, financial incentives, legal frameworks, strict timeframes and cross-sector partnerships.

· Decentralized and locally situated facilities avoid transport issues (a Swedish system produces biogas next to the bus depot) between resource recovery and usage.

Main Focus 3 : Water and Natural Disasters

In recent years, water related disasters – floods, droughts and storms – have grown frequent, affected 4.2 billion people, caused USD 1.8 trillion economic losses, and accounted for 90% of all natural hazards.

Climate change is not coming. It is here. It's underway. And it will only intensify. Our mitigation depends on green energy sources that reduce greenhouse gas emissions. But our adaptation depends on water.

Water is the medium through which climate change becomes real. No city or nation is immune from extremes of protracted droughts punctuated by sudden urban floods. Negative impacts of natural disasters include loss of life, displaced families and livelihoods, and destruction of billions of dollars in property.

We can't predict the degree, extent or timing of impacts. But water professionals today far better understand our escalating vulnerability, and take steps to reduce risk exposure through building resilience.

This Executive Summary illustrates why, how, where, and for whom natural disasters loom large, and offers tested approaches and techniques to anticipate crises and address them in advance. It reframes unnatural shocks less as crises to manage than as opportunities to thrive. Success comes if we:

1. **Play Offense, Not Defense.** *Don't wait and react to future impacts; adopt a proactive approach to water system reforms that reduce waste, build integrity, and lower exposure to rising risks.*

2. **Make Drought the Norm.** *Consider severe and protracted aridity the new rule, with rainfall the rare exception, in order to reach a new equilibrium heading into perpetually drier future.*

3. **Embrace Floods, Naturally.** *Rather than push runoff elsewhere, ease its intensity by slowing it up, spreading its risks out, and sinking its waters down through low-impact development.*

4. **Help Living Cities Breathe.** *Take the lead in turning urban areas into dynamic living organisms, by linking natural water infrastructure in ways that enhance the built environment.*

5. **Buy Low (Tech), Sell High (Yields).** *Invest early in a menu of affordable and interactive options that generate stable, adaptive outcomes over the many volatile years ahead.*

6. **Reform Institutions.** *Explore drought insurance, dam re-optimization, water rights, internal markets, trade in virtual water, pricing, policy, devolution of authority.*

7. **Link Silos.** *Integrate the water-energy-food-health nexus to achieve higher adaptation, mitigation, and valuation of water across sectors.*

The *Solutions to Resilience* illustrate the value of taking early, deliberate and judicious measures to calmly confront an uncertain and troubling future – a future that has already arrived, is growing ever more volatile, but to which we can adapt.

1. Play Offense, Not Defense

Challenge : Climate flux may take the form of record-breaking snows, enduring ice, and frozen ground that disrupts cities and farms. Conversely, it may bring urban heatwaves, protracted droughts, and cracked and barren soils. Or it may bring increasingly frequent and intense typhoons and hurricanes. The one constant will be changes in hydrologic systems, water resources, coastal zones, and oceans. On the whole, wet tropical regions will get wetter, and the dry regions will likely suffer increases in extent, severity and duration of droughts.

Solution : *Don't wait and react to future impacts; adopt a proactive approach to water system reforms that reduce waste, build integrity, and lower exposure to rising risks.*

Action : Accelerate reforms that have begun to improve the efficiency and integrity of operations, with an emphasis on adaptive, decentralized, natural infrastructure measures that increase the adaptive capacity to absorb shocks.

Results : Climate resiliency emerges through integrating silos of the system into a whole.

- Water efficiency and pressure management efforts ensure both the availability of more and better water, but also builds a tighter linkage between supply and demand.
- Low impact development like swales, permeable paving, wetlands and rain gardens can attenuate urban flooding and recharge groundwater recharge by slowing, spreading, and sinking runoff.
- Aligning built and natural infrastructure – conjunctive use of groundwater or dam reoperation, for examples, -- can minimize the peaks and valleys of drought impacts downstream.

2. Assume Drought as the Norm

Challenge : Drought is no longer what we thought it was. Once considered the exception, it is increasingly becoming the norm. Few can universally agree on what it means or how to define it. Even scientist and policy makers can't decide whether a drought has begun, let alone when, or if, they can declare it has ended. Quantifying the impacts and providing disaster relief are more difficult for drought than for other natural hazards due to slow, severe, and long-lasting impacts that may run for decades. Also a global temperature increase of 3-4°C may alter run-off patterns and force another 1.8 billion people to live in a water scarce environment by 2080. Droughts may be increasing in frequency, severity, and duration, which make the traditional reactive approach inadequate.

Solution : *Assume severe and protracted aridity is now the rule, with rainfall the exception, in order to plan for and reach a new equilibrium and thrive in a perpetually dry future.*

Action : Mobilize around the causes and effects of drought, promote information exchange, and introduce innovative techniques, trade, and practices that improve food security.

Results : Proactive drought policy options include:

- Securing a risk and early warning system that conducts a vulnerability analysis, impact assessment, and communication plans;
- Include mitigation and preparedness measures that include the application of effective and affordable practices;
- Build universal awareness by investing in aggressive education, since a well-informed public can share responsibility through an inclusive, participatory decision-making processes; and
- Enhance policy governance through stronger political commitment and accountability.

3. Embrace Floods, Naturally

Challenge : By 2050, rising populations in flood-prone cities, climate change, deforestation, loss of wetlands and rising sea levels are expected to increase the number of people vulnerable to flood disaster to 2 billion. Urban flooding affects developed and developing countries alike. The devastating impact of recent deluge, like that which occurred in Thailand in 2011, means more than half of humankind face volatile weather events in cities. Some degree of exposure to flood risks have long been part of our life, but climate change elevates flood events to new extremes. Worse, these dangers are compounded by unregulated urbanization with impermeable land use and development. Hard surface roads, walkways, parking lots and rooftops accelerates the velocity and amplifies the peak intensity of urban runoff, with devastating consequences in cities around the world.

Solution : *Rather than push runoff elsewhere, ease its intensity by slowing it up, spreading its risks out, and sinking its waters down through low-impact development.*

Action : Forewarned is forearmed: proactive investments in institutional, technical, and communications capacity to empower developers, officials and residents to anticipate build resilience.

Result : Reduce direct and subsidiary damages by planning urban areas to absorb and adapt to sudden natural hazards, using hardware and software tools.

- Enact codes to build or retrofit urban land development that integrates natural infrastructure with the build environment.
- Mitigate impacts of urban flooding by integrating traditional knowledge and developing and early warning systems.
- Develop flood defence systems such as flood gates, doors, and barriers as well as flood forecasting and observation technologies.
- Improve forecasting, warning systems, and visualization of status that the public can rely on.

4. Help Living Cities Breathe

Challenge : Much of the past century of urban development has involved the construction of hard, and rigid infrastructure – concrete sidewalks, asphalt roadways, steel sewerage, straight gutters – to keep a city on a firm base and push water elsewhere. That made sense in an age of reliable weather patterns and a stable climate. But cities no longer live in that age. The solid framework and foundation have become a liability that elevate temperatures to lethal levels in the urban heat island effect, while runoff backs up into streets, and streets back up into homes, buildings, and water or energy installations. This highlights a vexing water and sanitation challenge: a resource can flow clean, with efficient delivery of healthy and equitable water, yet still be fragile. What was seen as support has now become a corset that inhibits a city's ability to adapt to escalating stress, choke points and natural disasters.

Solution : *Take the lead in turning urban areas into dynamic living organisms, by linking natural water infrastructure in ways that enhance the built environment.*

Action : Enact new codes that reward the rapid development and deployment of green spaces that bring new flexibility, distribute local risks and broad responsibility, and build capacity against the worst.

Result : One constant is our need to adapt, when the only sure thing is a sense of uncertainty.

- To avoid rupture, water systems must go beyond 'robust' and be able to bounce back against stress.
- As a rule of thumb, the economic, societal, or ecological life of a city grows resilient to the extent to it anticipates, minimizes, and de-risks water systems.
- Looking ahead, the success of our 'grey' systems depends on integration with green, 'natural infrastructure.'
- But benefits must be shown to be cost-effective, or superior to traditional built approaches, and the most rigorous outcomes require flexibility.

5. Buy Low (Tech), Sell High (Yields)

Challenge : Cities may desire resiliency through adaptive mechanisms, but complex plans take time. They can prove slow and contentious. Special interests may push for pet projects by geography or sector. And infrastructure – natural or built – may still require expensive tools, blueprints, labor and capital expenditures. How can cash-strapped urban governments come up with the money to bring about the necessary changes?

Solution : *Invest early in a menu of affordable and interactive options that generate stable, adaptive outcomes over the many volatile years ahead.*

Action : Deploy affordable, participatory and user-friendly tools that maximize durable outcomes, distribute risks and responsibilities, engage multiple stakeholders, and shift cities to resiliency.

Result : Where uncertainty breeds fear, transparency builds trust: web- and mobile-based information communications technology (ICT) yields knowledge that can be shared.

- From meters to billing systems to temperature gauges, resilient water managers tap into reliable big data that is cheap, anonymous and available. Sharing it interactively can fast track resilience.
- Repurpose existing tools like cell phones, archival data, and closed circuit TV into hydro-informatics – the symbiosis of ICT and water science – to forewarn and forearm stakeholders.
- University researchers harness GIS and 3-D expressions of 'the Internet of things' to analyse signals for flood or drought anomalies that allow intervention in real-time, before it is too late.
- Other recipes combine basic rainfall data with meter readings, add runoff patterns, control for slope, adjust by surface, flood records, and satellite images. The result: a useful, actionable tool.
- Markets help make interactive technology transfer easier, cheaper, and in some cases free: open platforms integrate water data, link sensors throughout utility networks, or offer water R&D.
- These tools yield results across space and time, helping anticipate floods, hurricanes, or droughts, and focus on where damage potential may be highest, allowing managers to rank threat risks.

6. Reform Institutions

Challenge : Technology advances globally and economically. Wind power desalinates the sea. Deep aquifer pumps 'deposit' seasonal flows into groundwater 'banks'. Conversion of waste streams into water, or energy, can generate a potentially drought proof supply. But engineering alone can't work unless nested within a strong institution. Decision-makers need authority to weigh residential equity against industrial demands. Pricing strategies require stakeholder engagement. Pooling risks and cross subsidies demand a deep and stable reservoir of trust, incentives, outreach and coordination.

Solution : *Explore drought insurance, dam re-optimization, water rights, tiered rates, internal markets, trade in virtual water, drought pricing, and devolution of authority.*

Action : Engage constituents in honest discussions of future risks as a way to justify simple, small-scale, isolated pilot demonstration projects that test and build potential institutional reforms and allow the most effective results to emerge on top.

Results : Public, private and philanthropic institutions have allocated funds for sustainable investment strategies, research, and pilots programs to grow institutional capacity.

- The U.S. coordinates efforts of 13 federal agencies to understand why climate is changing, improve predictions about how it will change in the future, and to use that information to assess impacts on human systems and ecosystems and to better support decision making.
- The Netherlands has begun to address, absorb, and build resilience to water impacts from a rising sea level, while the Rotterdam Approach combines knowledge, action and positioning/marketing.
- Japan's environment ministry explores both the impact of and adaptation to climate change, and seeks to spread knowledge of water through "Wise adaptation"
- Korea launched a 'National Climate Change Adaptation Policy' with other 13 ministries to reform policy in 7 areas through basic alternatives for resilience; including tools that help local governments estimate and address vulnerabilities through Local Climate Change GIS.

7. Link Silos

Challenge: The United Nations' proposed 17 Sustainable Development Goals includes #6: "Ensure availability and sustainable management of water and sanitation for all". At the same time, water underpins all 16 other priorities, and is thus both a target and means to an end. Yet as water professionals see temperatures and sea levels rising, monitor groundwater salinity, watch floods escalating and snowpack melting, they lack political capital to build resilience. Water is still rarely seen as the matrix on which all other sectors depend, and its reveal competition between energy, agriculture, industry, and nature.

Solution : *Integrate the water-energy-food-health nexus to achieve higher adaptation, mitigation, and valuation of water across sectors.*

Action : Build collaborative resilience through reforming water policies, and leveraging financing mechanisms, that align with the goals and interests of key stakeholders.

Results : Water is this century's common currency of life, health, trade, energy, nutrition and climate change security.

- Efficient water use in agriculture lowers the global commodity food price index, and through virtual water trade this builds climate resilience for billions of the world's poorest.
- Secure, reliable, nearby taps allow water-fetching women and children to reinvest spare hours into education or remunerative labor
- Universal access to clean, safe, water and sanitation slashes disease and death from dehydration.
- Low-impact development approaches filter runoff in ways that heal hypoxic dead zones offshore, boosting the wild fishery resources on which 4.3 billion depend for vial animal protein.
- Slashing demand for urban water in half eases strain on power grids and lowers carbon emissions.
- Appropriate resource valuation could reduce energy's hunger for 8-44% of all water withdrawals, and water's thirst for up to 33% of all energy.
- Cutting food waste from field to fork by 40% would enhance global nutrition for billions without demanding more water; conversely drip irrigation could produce more food with fewer drops.

Main Focus 4 : Smart Technology for Water

For millennia Egypt gathered water data from step-like infrastructures. Strategically sited along the river, these durable instruments measured the seasonal pulse of currents; recorded water quantity and quality; calibrated how much flood irrigation would benefit all subjects; determined taxation rates based on flow pattern; and detected early potential for risky extremes of drought or deluge.

The Nilometer may be the oldest information and communications technology (ICT) applied to water.

Pharaoh and farmer alike depended utterly on this 'smart' tool. Each recognized it as a means to their own water security. With time it fortified the social contract through layered scientific understanding.

Since then, our end goals have changed little. We still seek to collect, analyse and share water quality and quantity data in a quest for security. Our urbanizing, water-stressed world demands faster, smarter, more precise knowledge. Vital data supports equitable, efficient and ecologically sustainable governance.

But the means at our disposal – the fast-evolving spectrum of clever, complex, costly, and sophisticated tools – may complicate decisions. This Executive Summary helps professionals leverage ICT to achieve their desired outcomes. We outline the trends, tactics and case studies that can convert more data into more food, energy, security, life. 'Smart' water solutions lie in:

1. **Nexus management.** *Intelligent decision-making at systemic levels can incentivise efficient and sustainable use of water and energy, and reduction of greenhouse gases emissions.*

2. **Transparent Trust.** *The most valuable information needs to be free, so any smart water system must be willing to share information globally and across sectors and segments.*

3. **Open Doors.** *The success of any smart water management lies not only in improving the technology, but also in involving, persuading and preparing multiple stakeholders to adopt it.*

4. **Empowered Options.** *Real time monitoring and diagnosis, as well as automatic controls, can improve the supervision and optimization of water demand-supply management.*

5. **Appropriate Scales.** *To enable robust management of big data, support smart monitoring and metering at scales ranging from basins to households.*

6. **Broad(band) Foundations.** *Rapid, reliable decisions require web and mobile-based networks to monitor, acquire and process real-time data on water level, rainfall, runoff and water quality.*

7. **Driving Efficiencies.** *Smart systems, linked to wise legal and economic institutions, can help professionals achieve water and resource efficiency goals.*

The Solutions to ICT seeks to build on best practices and enable new innovations. Information may be power, but only if anchored by those with the wisdom of to use it. Each solution outlines the most effective ways to generate better results, for more people, in a shorter time, with fewer resources.

1. Nexus Management

Challenge : The world has awakened to the risks of the water-energy nexus. Electricity grids grow thirsty while water grids demand more and more power to convey, heat and treat what flows through tap or toilet. The nexus escalates greenhouse gas emissions, increasing exposure to climate impacts. But solutions too often seem slow, cumbersome and expensive; they tend to be aimed at the supply side of the equation – upgrading pumps, plants and generators – rather than address the real, largest, and fastest growing source of energy embedded in water: the end user. It is unclear whether, where or how best water professionals can engage customers in transforming this vicious spiral into a virtuous force for water security, energy efficiency and carbon reduction.

Solution : *Intelligent decision-making at systemic levels can incentivise efficient and sustainable use of water and energy, and reduction of greenhouse gases emissions.*
Action : Set goals that are widely desirable – like avoiding the unmanageable (and managing the unavoidable) impacts of climate change – then use ICT to build a 'smart water grid' (SWG).

Results : A SWG can take many forms, in response to unique contextual and demographic drivers:

- K-water's SWG is developing new & renewable energy technologies for increasing the efficiency of consumed energy in the water supply system to at least 30%.
- The 'Pecan Street Project' in Austin, Texas is implementing a demonstration complex that combines a smart electricity grid and smart water grid for 4,900 households across 2.8 Km^2, applying AMI, sewage recycling technology and Smart Irrigation for gardening.
- Following crippling drought in 2004-2007, Queensland, Australia, developed a SWG to secure water by balancing flows and stabilising supplies at minimum cost.
- Despite high rainfall, Singapore lacks land to capture and store rain. To address shortages, its SWG aims to secure a stable water supply, predict and respond to rapid changes in the global water situation, establish an R&D center for water processing technology, and foster international and domestic water companies to become the world's leading water hub.

2. Transparent Trust

Challenge : Water is highly transactional. People allocate, ration, charge and pay each other for it. Rural tariffs and urban rates put a premium on privacy. Commercial clients, irrigators, and residential customers feel sensitive about usage patterns; urban water providers and governments fear disclosing non-revenue water and waste. Yet 'smart data' remains largely worthless if locked up alone. It serves no purpose removed from context or currency. Real value and knowledge emerge only when information can be accessed, analysed and used to understand, benchmark, integrate and improve the system as an organic entity throughout watersheds and across the borders of nations sharing river currents.

Solution : *The most valuable information wants needs to be free, so any smart water system must be willing to share information globally and across sectors and segments.*

Action : Set up the network of smart water systems based on who can benefit from data, whether residential customers, downstream stakeholders, industrial corporations or the government itself.

Result : Many innovative, effective assessment technologies have been developed and can motivate users.

- Detect leaks by fixed or portable hydrophones, magnetic flux or linear polarization resistance.

· Smart meters indicate anomalies against baselines; signals can alert company and client alike.

3. Opening Doors

Challenge : Despite many attempts to integrate ICT into urban water supply systems, smart technologies continue to face barriers of sociological, ecological and economic limitations. These include public health fears; cost concerns; database quality; workforce skills; assessment capacity; and the requirements, technologies and costs of inspection.

Solution : *The success of any smart water management depends not only upon improving the technology itself, but also upon involving, persuading and preparing multiple stakeholders to adopt it.*

Action : Rather than present smart meters as a hasty 'done deal,' engage clients and other constituents up front, out in the open, to discuss shared social, economic and ecological benefits: safer working conditions, more accurate readings, billing efficiency, leak detection and reduced emissions.

Results : However contentious or costly public outreach may seem on the front end, it pays long term dividends in trust, savings, compliance and accountability.

· K-water shares the data with the KMA (Korea Meteorological Administration), the MOLIT (Ministry of Land, Infrastructure and Transport of Korea) and other relevant entities, and supports its own employees to check hydrological information through smart phone applications anytime and anywhere.

· The website of K-water provides real-time data about hydrological conditions and closed-circuit television footage from dams and weirs to satisfy the public desire for better services.

· Western Australia launched an ongoing campaign with its customers to explain the need to take more responsibility for water.

4. Empowering Options

Challenge : Climate change impacts will be felt most severely on water availability and quality, affecting human wellbeing, industry, agriculture, ecosystems, economies and regional stability. Negative water impacts are falling hardest on the disenfranchised urban and rural poor.

Solution : *Real time monitoring and diagnosis, as well as automatic controls, can improve the supervision and optimization of water demand-supply management.*

Action : Provide widespread access to data – or even to the tools that generate that data – in ways that shorten the distance between provider and recipient, supply and demand.

Result : Smart systems are emerging in affluent cities and developing rural landscapes alike.

· In Africa, Water for People is harnessing ICT by encouraging end users to alert the government when and where a groundwater pump is broken or contaminated.

· Two-way signals combined with interactive web-mobile alerts allow urban users to see whether they have a leak, where it may be, what to do about it and how fixing it can save money.

· Connectivity increases accountability, encourages end users to take responsibility and improves the performance and responsiveness of governments.

5. Appropriate Scales

Challenge : ICT often seems like a 'one-size-fits-all' package that gets marketed and sold to affluent megacities or large industries. The world may be urban, but cities vary dramatically by region and context. Many water systems – especially older ones, strained to capacity – are limited by small budgets, outdated technology, unskilled human resources and political constraints. Yet these are the very systems that could benefit most from having tools that could empower and integrate stakeholders to achieve water security.

Solution : *To enable robust management of big data, support smart monitoring and metering at scales ranging from basins to households.*

Action : As technology grows more affordable through economies of scale, it falls within reach of more systems to distribute risks and encourage resilience.

Results : The right to water corresponds to the responsibility of those who demand it.

- A decentralized water system used for water supply can be understood as a system where intensively concentrated urban water load is mitigated; a water grid connecting different water supply systems is provided; and a sufficient amount of storage capacity to provide against any emergency situation is secured.
- Smart asset management optimises capital, operations and maintenance expenditures by providing the desired level of service at the lowest infrastructure life-cycle cost.

6. Building Broad(band) Foundations

Challenge : Smart water management never emerges in a vacuum. Any ICT system for water – providing broad access for all stakeholders to high quality hydrological data – must walk before it can run. Egypt's Nilometer grew refined over decades, but even it required institutional capacity to track, record, store and share data through a common language base, with shared access, and constant real-time communication.

Solution : Rapid and reliable decisions require web and mobile-based networks to monitor, acquire and process real-time data on water level, rainfall, runoff and water quality.

Action : Take advantage of public, shared and relational databases or web-based systems. A smart data processing system includes: real-time data processing; a client/server communication network configured with satellite, VHF, CDMA, etc; 24/7 monitoring; closed-circuit television footage from major risk areas; and text message services for risk alerts.

Results :

- Smart sensors optimize irrigation water by measuring humidity, rainfall, wind speed/direction, soil temperature/ moisture, atmospheric pressure, and solar radiation.
- K-water operates a real-time information system to provide data about hydrological conditions; Smart rehabilitation technology sends image-diagnosing robots to inspect pipes, blasts scaling and rust with an ultra-high pressure water jet, and sprays lining/coating materials evenly inside the pipes.
- The system functions to combine real-time data (covering water level, rainfall, water quality, etc.) and video footage of closed-circuit televisions from major dams, weirs or rivers, streams in the country for 24/7 monitoring services.
- Relevant data are collected from sensors installed in monitoring facilities, and transmitted to a communication room, or control room, through either wired or wireless communications technologies.

7. Driving Efficiencies

Challenge : A century of cheap or free water has accelerated the depreciation of water infrastructure, led to systemic unaccountable waste, created a culture of entitlement and caused urban and rural water scarcity. ICT tools hold out the potential to improve demand response, reverse the energy-water nexus into a positive direction, and engage clients to work with the provider rather than against it. But smart technology alone needs institutional reforms to prevent water from bleeding away, silent and invisible.

Solution : *Smart systems, nested within wise legal and economic institutions, can help professional achieve water and resource efficiency goals.*

Action : To reap the full potential gains from ICT, nest them within water rights, allocations, tariffs, licensing, regulation, storage, abstraction, energy choices and markets.

Results : Integrating smart tools help build a more efficient and accountable non-structural administrative framework.

- Advanced Metering Infrastructure (AMI), with 'smart' sensors and signals, lets consumers choose tariffs, while utilities can prioritize usage for special purposes and pricing.
- 'Smart' meters allow time of day billing, reduction of peak demand, leak detection, increased distributional efficiency, non-revenue water reduction, and deferral of capital spending.

· 'Smart' pipes measure water flow and quality to detect strain, temperature or pressure anomalies, so potential leaking can be checked in real time.

Main Focus 5 : Understanding and Managing Ecosystem Services for Water

Rivers have been, and remain, our most vital water infrastructure.

Headwaters collect it. Forests retain it. Meadows control its extremes. Currents deliver it. Eddies produce food from it. Aquifers store its surplus. Wetlands filter it. Wind and sun desalinate it all over again.

What should nature invoice us for this endless hard and productive work on our behalf? Until recently the answer was: 'No charge'. But water professionals have begun to approach this question in radical new ways, developing new valuation tools, and seeking answers with an increased sense of urgency.

Humans tend not to value what comes for free. We claim water is 'priceless' but treat it as worthless. Our cities take reliable upstream flows for granted, and convert downstream flows into open sewers.

That's changing, fast. This Executive Summary illustrates why, how, where, and for whom watersheds yield dramatic benefits – most recently defined as "the direct and indirect contributions of aquatic ecosystems to human well-being" – that enhance what we've built. Successful outcomes emerge if we:

1. **Move Nature from 'Red' to 'Black'.** *Shift aquatic ecosystems across the policy framework from the column of 'fixed liabilities' that we avoid into 'liquid assets' that generate yields.*

2. **Monetise what's Priceless.** *Deploy clear analytical tools that give explicit value to the hidden ways natural infrastructure adds value to society.*

3. **Slow, Spread & Sink It.** *Decompress and decentralize urban runoff techniques to bring back a watershed's former health, rhythm, velocity, and reliability.*
4. **Seek Symbiosis.** *Convert the reactive 'environmental impact assessment' into a proactive evaluation of how much development can benefit from naturally functioning water flows.*

5. **Scale Economies.** *Encourage and reward investments in natural water infrastructure at every level, from backyards to river basins, and rooftops to reefs.*

6. **De-Risk Development.** *Leverage nature as a fast, secure, and cost-effective insurance policy against escalating shocks to our manmade systems.*

7. **Redefine Relations.** *Transform nature, neither our subordinate nor superior, into an equal partner with which to build a mutually dependent, resilient and productive future.*

Solutions through Ecosystem Services illustrate that when we secure, value, and invest in natural capital, it repays healthy long term dividends. Each introduces the most effective ways that 'natural infrastructure' of aquatic ecosystems can support water, energy, and food security, for all, forever.

1. Move 'Nature' from Red to Black

Challenge : The concept of an "aquatic ecosystem" is easy to grasp but hard to classify or define. All too often it gets ranked as a complex problem for scientists to explore and for governments to manage. As a result, otherwise healthy rivers – and the fish, plants and wildlife species within them – loom as a barrier to progress, an obstacle that development must somehow address or overcome or mitigate (or ignore) so that societies may advance. This misperception has turned out to be harmful not only to natural infrastructure, but also dangerous to the cities that utterly depend on it. Can cities really reflect the true value of water for society? Yes.

Solution : *Shift aquatic ecosystems across the policy framework from the column of 'fixed liabilities' that we avoid into 'liquid assets' that generate yields.*

Action : Compare the many gains from the integrity of robust watersheds against the rising costs of replacing them in perpetuity through building new manmade infrastructure.

Results : The most durable and affordable approach to urban development is often the greenest:

- Wetland integrity need not be lost and mitigated but rather reinvested in as an adaptive strategy to reduce impacts from floodwaters, and costs of stormwater treatment.
- Swales along roadsides filter heavy metals and biochemical that generate savings both from avoided costs and more stable and productive aquatic life and food security.
- Breaking down curbs into green spaces slow not only runoff, but also traffic, reducing traffic congestion, urban stress and social risks.
- Centralised stormwater treatment plants finds valuable and complementary support from strategically designed green spaces, especially at crossroads.

2. Monetise what's Priceless

Challenge : Rivers that belong to everyone are too often valued by no one in particular. Constituents in every government, at every level, naturally enjoy goods and services watersheds provide for free; conversely, they resent being asked to pay for them. And while economists can explain on paper the benefits from 'putting a price tag on nature,' they can't win office on promises to raise the cost of water, the cost of food, and the cost of energy for everyone. If restoration of watersheds is desirable for society, can its benefits be monetized, without generating a political backlash? Yes.

Solution : *Deploy clear analytical tools that give explicit value to the hidden ways natural infrastructure adds value to society.*
Action : Present watershed health on a menu of options, demonstrating if, how, where, and why green and low-impact development is less expensive than built up alternatives.

Results : Measuring ecosystem services in monetary terms is crucial for policy implementation:

- New York City happily invested in the integrity of upstream rural headwaters when shown that doing so cost a fraction of a downstream urban treatment plant.
- Businesses and officials in seven Northern Andean cities like Quito, Ecuador and Bogota, Columbia invest matching 'water funds' into upstream watersheds for downstream security.
- South Africa's taxpayers invest in labor intensive projects to remove invasive alien weeds, because doing so generates more water at less cost than built infrastructure.
- The Netherlands is testing a program to compensate farmers who manage their land for the ecological benefits of watershed services.

3. Slow, Spread & Sink It

Challenge : Every country on earth is undergoing rapid industrialization, an unprecedented experiment with unforeseen outcomes. As more than half of humanity lives and works in cities, land use patterns generate undesirable impacts both on and from declining watershed health and stability. Governments easily identified and addressed industrial pipes spewing toxic discharge, but now face a new threat from rain hitting impermeable surfaces. Runoff from tar rooftops, driveways, roads, parking lots, and industrial complexes combine new, unwieldy and potentially lethal non-point source (NPS)_ pollution. This NPS cocktail runs through gutters, and drains into water bodies, as untreated discharge. It steadily poisons rivers with heavy metals, and suffocates life by biochemical oxygen demand, two thirds of which now come from polluted stormwater runoff. Can cities escape pollution that rushes in from everywhere all at once? Yes.

Solution : *Decompress and decentralize urban runoff techniques to bring back a watershed's former health, rhythm, velocity, and reliability.*

Action : Adopt low impact development (LID) and green vegetation cover to intercept, absorb, and store rainfall and runoff in an affordable and aesthetic policy response.

Results : LID harnesses society's goals with natural processes in impervious areas as it:

· Eases both the timing and peak of runoff from extreme storms to reduce the sudden surprise, biochemical loads, heavy metals, and extreme impacts of urban flooding.

· Maintains drinking water supply by decreasing exposure to risks of contaminated stormwater overflows.

· Increases individual property values of sites by improving the exterior aesthetic nature for the community, while lowering the rising plumbing, insurance, maintenance, and treatment costs for all.

4. Seek Symbiosis

Challenge : Decades ago local, city, regional, and federal governments began to adopt various assessment tools that promised to reduce the negative impacts on aquatic ecosystems. These have faltered, due largely to inherent flaws and disincentives. First, they demanded too few and too little in countermeasures, applied too infrequently, coming too late in the planning process. Also, they pitted environmentalists against private interests in an escalating arms race, with officials caught in the crossfire. Finally, in trying to avoid the downside of negative damage to watersheds, they ignored the potential upside of positive benefits from precautionary measures from watersheds. Is there a better way forward? Yes.

Solution : *Convert the reactive 'environmental impact assessment' into a proactive evaluation of how much development can benefit from naturally functioning water flows.*

Action : Low Impact Development (LID) and natural infrastructure approaches include and integrate the development plan to overcome hydrological, social and ecological problems caused by urbanization so that humans can coexist with the ecosystem.

Results : Natural infrastructure doesn't replace built infrastructure; each supports the other:

· Dams benefit from forests and meadows that stabilize soils, maintain snowpack, attenuate floods, store runoff, and hold back erosion upstream.

· Lakes, aquifers, floodplains and wetlands provide water storage and therefore reduce the reservoir size along with the labor, equipment, and mitigation costs to build it.

· Terraced landscapes, green roofs, planted medians, and permeable pavements recharge groundwater, reduce floods, cut sediment loads, capture pollutants, and filter runoff.

· Well-functioning natural watersheds extend the life of hydropower and irrigation technology, and justify their integration through a longer, higher return on investment.

5. Scaled Economies

Challenge : Our manmade infrastructure for irrigation, hydropower, or municipal water was built on a foundation of relatively stable equilibrium, or 'stationarity,' but that no longer exists. Water's quality, quantity, productivity and health is being degraded at every level. Responses are fragmented. Governments mandates are broken into silos. Urban and rural institutions work in isolation. Competing users talk past each other. The lack of coordination breeds delays, distrust, and conflict. And the scope is often narrowed to single issue crises rather than the spectrum of freshwater flows and processes across scales. Can we widen and expand the set of interests to align stakeholders? Yes.

Solution : *Encourage and reward investments in natural water infrastructure at every level, from backyards to river basins, and rooftops to reefs.*

Action : Prioritise a focus on watershed-based outcomes to build policy support, engage water and wastewater operators, and leverage investments in natural infrastructure.

Results : Urban LID policies to integrate retention, infiltration, and circulation can aggregate across groups of actors and collaborative efforts to yield massive regional benefits:

· Frieberg, Germany applies small scale decentralized types of vegetated swale, infiltration basins, bioretention and constructed wetlands in urban land use.

· As part of a national project, Chungcheongnam-do, Korea designs small scale bioretention, infiltration trenches, horizontal subsurface wetlands, and free water surface flows.

· Cities in the UK install green drainage systems to manage runoff and NPS pollutants, leveraging ecological mechanisms that connect water, green spaces, and scenic values.

· Social networks with a wide scope of actors can connect institutions across scales to build trust, share information, identify knowledge gaps, and create nodes of expertise.

6. De-Risk Development

Challenge : Humanity depends on stable watersheds for food, energy, transportation, health and culture. Unfortunately, these life-supporting freshwater systems are extremely complex and now increasingly unstable. After millennia of co-evolution at a literally glacial pace, both nature and societies are being forced to undergo sudden, accelerated and extreme shifts into undesirable states that may be impossible to reverse. Global change is forcing local economies to confront unprecedented risks. If we can't stop or predict disruptive risks, can we absorb and adapt to their inevitable impacts? Yes.

Solution : *Leverage nature as a fast, secure, and cost-effective insurance policy against escalating shocks to our manmade systems.*

Action : Just as auto insurance companies structure rates based on safe driving, so too can underwriters base premiums and risk ratings on policies that encourage 'natural infrastructure ' and 'low impact development.'

Results : Public, private, commercial and industrial complexes take locally and demographically appropriate measures to build resilience to a more volatile and unstable water future:

· Makanya, Tanzania is investing in rainwater harvesting, conservation tillage, and other productive and affordable small-scale water innovations to break dryland poverty traps.

· China is investing 100 billion USD over a decade to secure the natural capital of river system services against urban flooding, loss of topsoil, desertification, and ecotourism.

· Korea's 'Four major River Restoration Project' is investing in natural capital to secure supplies, control floods, enhance water quality, boost culture, and develop the region.

7. Redefine Relations

Challenge : Our ancestors carved out and grew civilizations alongside rivers. They saw nature as chaos, and sought to bring order to its hostile and malignant forces of drought, turbulence, and deluge. Their engineers began to subdue, harness, tame and domesticate aquatic ecosystems, halting, diverting and draining currents before they could 'empty' and thus be 'wasted' into the sea. Now younger and more affluent generations seek to reverse these policies. Rejecting the 'anthropocentric' mindset for 'eco-centric' outlook, they demand rivers be liberated, unleashed, left alone to return to a feral, unruly, and wild existence. Both enslavement and neglect are impractical and unaffordable in our increasingly thirsty world.

Solution : *Transform nature from subordinate or superior into a full and equal partner with which to build a mutually dependent, resilient and productive future.*

Action : Learn to use the services of aquatic ecosystems with the same care a craftsman devotes to his tools, in order to build or restore useful works with integrity, diversity, durability, and beauty.

Results : Secure development comes from recognizing people and nature as inextricably linked:

· U.S. coastal cities are embracing policies to improve stormwater runoff, water quality, and resilience through natural infrastructure, especially in schools and public spaces.

· Aquatic ecosystems are disrupted by demands to take water away from rivers, but also by changes in land use that affect the amount and quality of water flowing into them.

· Preservation and regeneration of native open vegetation, or rain gardens, can extend runoff detention time in the sources, connect impervious areas, and improve drainage.

· Minimizing impervious areas through common values can improve infiltration rates, link flows, absorb extreme risks, and enhance runoff quality.

· Managing stormwater runoff through natural sources helps reduce impacts, and dependence on conventional drainage pipes, sewer lines, and treatment ponds.

Efficiency

Main Focus 1

Water Efficiency

We describe the characteristics, the challenges, the smart approaches, and the innovative technologies of urban, industrial and agricultural water efficiencies pursuing some scientific or technological solutions for implementation.

Water Efficiency

1.1 INTRODUCTION

Water scarcity is an international problem with economic and social effects. Driven by increasing populations, growing urbanization, changing lifestyles, and economic development, the total demand for water in urban areas is rising. The cities and towns of low-income countries and emerging economies are affected more severely because of increased consumption and the difficulties involved in managing complex leaking pipe networks. According to a World Bank study (2007), the renewable fresh water availability per capita is expected to halve by 2050 (relative to 2007), a trend that will probably be exacerbated as climate change makes many regions hotter and drier or climate more uncertain. Despite the increased stress on water resources, many water users, decision-makers and managers are still unaware of practical, cost-effective water efficiency improvements they can make. Strategies or plans for water efficiency are largely lacking, both in public and private sectors.

The world population rises by approximately 200,000 a week, and perhaps this alone emphasizes the need for governments and water utilities not only to increase the absolute volume of water supply itself but also to focus on improving the efficiency of water use and conveyance. However, it is common for lower-income countries to be losing as much as half the water that it treats and pumps into a distribution network owing to underground leakage. It is worthy asking "Why has the expertise of water loss reduction gained in some countries not been successfully transferred and why do such enormous losses continue despite the efforts of aid donors and multi-million dollar projects?" One of those donors, the World Bank, recognized that the issue has as many non-physical, non-engineering and non–scientific factors related to management, government, corruption and pricing, among others. These are often causes beyond the control of the utilities.

The greatest water volume saving and financial benefit from any water utility that can gain in the low-income countries is through paying attention to underground water losses leaking from pipe networks. There are many higher income countries that also struggle with the same issues or fail to recognize the importance of reducing such losses. This saving has been proved many times to be far greater than any other potential gains in efficiency, whether these are from reductions in industry or household use. The exception is in some developed countries, where interventions have successfully maintained losses from underground leaks at a much lower level, and they now justifiably focus on efficiencies in consumer usage.

The reduction of these efficiencies has beneficial environmental and economic impacts on every aspect of running a water business. The skills for water loss reduction are known, and have been applied successfully in many places. Therefore it is also worth asking "Why do we still have most of Asia, Africa, South America and the Middle East, possibly over a third of the world still losing such high volumes?"

Developed countries have varying degrees of success, but many still have to reduce losses to a reasonable level that would be deemed acceptable by their communities. "Who needs to be the global leaders on this issue?" is also a reasonable question to ask, as there appears to be a void in this arena. The issue is obviously complex. It needs government leadership, cooperation with aid agencies and a drive to successfully assist many communities in the world, through a reinvigorated international effort. The world needs a major review of water efficiency aspects and water management, which identifies what can influence successful change.

Recently, water shortage crises have increased the efficiency of water management in Korean industrial, urban and agricultural fields, and energy use in water and wastewater systems. Many useful approaches have been applied for efficient water management and some innovative technologies have been proposed and tested to lead to much more efficient water use. Korean experiences are introduced and illustrated as some of the reference for possible applications.

Governments, aid agencies and water utilities committed to best practice require the application of a total water cycle approach to the management of their resource base, to capture holistic efficiency. Delivering on the notion of "catchment to tap" requires not only operational, engineering and corporate professionals, but also catchment and environmental experts who have first-hand knowledge, experience and passion to deliver a holistic management outcome.

The improvement of water use efficiency by industrial, institutional and individual consumers in buildings, agriculture and in industrial processes is also very important. Water efficiency is an indicator of the relationship between the amount of water required for a particular purpose and the amount of water used or delivered (Vickers, 2002). A related concept is water conservation, where the emphasis is on the accomplishment of a function, task, process or result with the minimal amount of water. Water efficiency concerns reducing waste rather than restricting use. It also emphasizes the influence users can have on water consumption by making small behavioural changes to reduce water wastage and by choosing more water-efficient process steps and products. Another important dimension to water efficiency is the emphasis on closing the water cycle through recycling and reuse (AFED, 2010).

In this section, we will describe the characteristics, the challenges, the smart approaches and the innovative technologies of the four water efficiencies; urban water efficiency (UWE), industrial water efficiency (IWE), agricultural water efficiency (AWE) and energy efficiency in water and wastewater systems (EE) pursuing some scientific or technological solutions to implementation.

1.2 URBAN WATER EFFICIENCY

1.2.1 Characteristics of Urban Water Efficiency

Urban water systems can be categorized by their water supply and stormwater systems. Issues of the water supply system deal with having enough capacity based on water demands and reducing water losses. Issues of the stormwater system mainly include prevention and mitigation of urban flooding as well as reduction of non-point source pollutants.

A major issue that water utilities must address is the considerable difference between the volume of water they treat and distribute, and the volume that is invoiced to their customers. This gap is known as urban water loss, or non-revenue water, and can be an enormous proportion of the total amount of water treated and distributed. Experts who investigate this issue commonly find between a third and a half of the input volume is lost. Factors contributing to this gap are related to management methods of water accounting practices, inaccurate billing systems, deficient customer registration, leakage caused by deteriorating infrastructure, unfavourable water pressure management, inaccurate metering, reservoir overflows, unnecessary flushing, and insufficient and illegal connections to the water distribution network.

A common mistake is to use a percentage figure to express water losses, as this can often be very misleading when used for showing improvements or inefficiencies. Although percentages appear can be easily understood, the fact that leakage is compared with the input volume of water which is often extremely variable from day to day and is strongly influenced by weather. If it rains, the total input volume will reduce significantly, as no garden irrigation will take place. However, the water losses from leakage runs continuously (at various flow rates) unless action is taken to detect and repair leaks. Therefore, if the water losses are expressed as a percentage of the input volume that has reduced significantly because of rain, the percentage losses will increase when in fact they have not changed. Conversely, the percentage water losses will appear to reduce during dry periods when the demand increases. Water managers who have a very dry year to deal with will have to supply a much larger input volume, making the water loss look much less as a percentage, without finding or repairing any leaks. Percentage water losses must therefore be used with caution and provide only a very rough guide to the situation at any one time; they should not be used for comparing progress.
The use of percentages can therefore mask whether a system is being well managed. Other, useful performance indicators of physical leakage include the use of water volume losses compared with length of water mains, or the number of properties or connections, and the use of an index developed by the International Water Association, called the infrastructure leakage index (ILI). This index provides a simple performance indicator of physical leakage in a water supply system by comparing the actual leakage to the theoretical minimum level of leakage that could be achieved for the particular system. An ILI ratio of 4 for example, indicates that the water losses experienced by a particular system are four times what they could be. It is often impractical to set a target of 1.0 for the ILI. Furthermore, the target levels vary from country to country and are dependent on many factors, including the cost of supplying the water and the costs associated with reducing the losses. Many utilities around the world are now adopting the ILI as one of their key performance indicators although the International Water Association always recommends the use of more than one performance indicator if possible.

All utilities are therefore encouraged to use a range of indicators that suit their needs, allowing for their rural/urban mix of property density, but are advised to include the ILI, and exclude percentages. In cases where there is high per capita usage, the losses as a percentage will appear to be low and will hide the fact that significant savings can still be achieved.

The other important aspect of urban water loss efficiency, is to account for all water that is used. This accountancy system attempts to identify for water managers and board directors where investments are best made to reduce losses, and is well known as an International Water Association Water Balance. Most utilities have difficulty analysing the various components of their water balance. By adopting a standard approach to the water balance it assists the organization in accounting for all water used in its system An important element in this new methodology and terminology is the elimination of the term "unaccounted-for water", which has been replaced by the term "non-revenue water", since it is possible to account for all water. The International Water Association Water Balance is shown below. (Figure 1.1)

The best method for detecting the location of underground leaks requires large water meters to be installed on the networks to measure flow rates into smaller zones, as high night time flows can indicate leakage within the zone. This can be followed up by inspection. As all leaks make a noise, various listening devices can be used to identify the position of the leak which is usually where the noise is loudest. Sophisticated equipment such as leak noise correlators can also be used to find leaks by measuring the speed of transmission of leak noises. Knowing the pipe material, the velocity of the noise transmission is within a known range, and by measuring the time delay of the leak noise reaching two points along the water main, the approximate location of the leak can be determined. Other acoustic methods of leak detection are available, with varying degrees of cost and success.
One of the most important key performance indicators for a water utility is reflected in how well it can control and reduce such leaks. Good performance in reducing losses has a direct

correlation in achieving the following :

(a) demonstrated understanding of how the complex network operates
(b) a reduction of contamination issues
(c) the deferment success for the need for new dams and reservoirs
(d) reductions in the operational cost of pumping and treating water
(e) a reduction in the need for new trunk mains to meet peak demands
(f) a reduction of interruptions of continual supply tocustomers
(g) successful reduction of environmental impacts

If pressure controls are also introduced, then they will also reduce the rate at which leaks occur, and extend the life of the pipes through reducing material fatigue. All these factors have a significant impact on the community, and affect the long- and short-term costs of running a water business.

1.2.2 Challenges of Urban Water Efficiency

The urban water supply system is challenged by the vulnerability of water supply capacity due to population growth and water availability based on climate change. The urban stormwater system is challenged by the risk of urban flooding due to climate change and growth of nonpoint source pollutant loads by increasing impervious areas.

1.2.2.1 Challenges in Urban Water Supply

Municipalities often implement better management practices of urban water supply and demand through strategies such as water efficiency programs. The objectives behind the implementation of programs by water utilities are diverse. Two common reasons are to expedite population and economic growth without greatly increasing the requirement for new or magnified water supplies, and to avoid water infrastructure expansion projects like the construction of new treatment and storage facilities for water supply or wastewater. In addition, water-efficient programs can be driving forces that avoid environmental anxiety and state regulatory requirements.

There are several types of urban water efficiency programs that can be implemented to reduce potable water use. Many objectives to reduce indoor residential water demand by replacing inefficient water using instrument, such as toilets and clothes washers, with more efficient high performance models. This is often achieved through a rebate program that encourages the purchase of efficient fixtures, but sometimes utilities give away fixtures or offer direct installation of them. The key measure appears to be the regulation of fixtures and appliances that use water. This, in addition to the regulation of the water efficiency of new premises (housing, factories, offices and shops) and new developments, is very important as a focus for governments, utilities and councils to focus on. Residential outdoor water use is also regularly targeted with efficiency programs. Some other programs are designed to reduce other water uses, commercial and industrial, a time of with peak water demand, or the water delivery system itself.

<table>
<tr><td rowspan="2">Own Sources</td><td rowspan="10">System Input (allow for known errors)</td><td>Water Exported</td><td rowspan="5">Authorised Consumption</td><td rowspan="3">Billed Authorised Consumption</td><td rowspan="3">Revenue Water</td><td>Billed Water Exported</td></tr>
<tr><td rowspan="9">Water Supplied</td><td>Billed Metered Consumption</td></tr>
<tr><td rowspan="8">Water Imported</td><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td rowspan="7">Non-Revenue Water</td><td>Unbilled Metered Consumption</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Mains</td></tr>
<tr><td>Leakage and Overflows at Storages</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer Metering</td></tr>
</table>

Figure 1.1 International water association water balance developed by the water loss specialist group (Waldron T, 2002)

Municipalities also employ education programs and local ordinances to improve water efficiency.

The followings are some emphasis of the most popular urban water efficiency programs. These examples show what is possible, and certainly practical, among municipalities. They can be used as a reference to recognize and understand the wide range and multiplicity of best practices in urban water efficiency, their associated costs and savings, and the categories of communities that have approached water efficiency efforts. It is worth noting that just as objectives for approaching water efficiency efforts differ, so do the results, in terms of decreasing surface or groundwater withdrawals and the balance of sources for a particular water utility.

1.2.2.2 Challenges in the Urban Stormwater System

Urban stormwater drainage systems have been improved and can efficiently drain water from the urban area to provide convenience to the public. Changes in the hydraulic efficiency of storm water collection systems with artificial channels and storm sewers increase the velocity of flow. In an efficient approach, stormwater from roofs is transported to storm drains through gutters and downpipes; and curbs and gutters are designed to transport storm water away from the road surface to storm drains. Thus drainage systems quickly send the runoff directly into receiving waters compared with pre-urbanized conditions. The surface topography is reformed in open areas and the retention period of the water is reduced.

Urban runoff is understood as a cause of pollution in its own right from the pollutants carried in stormwater runoff. Modern drainage systems that collect runoff from impervious surfaces (e.g., roofs and roads) ensure that water is effectively transported to waterways through pipe networks, indicating that even small storm events result in increased waterway flows. Increased stormwater flow can lead to stream erosion, encourage weed invasion, and alter natural flow regimes from delivering higher pollutants in the urban catchment.

1.2.3 Smart Urban Water Efficiency

This section introduces new and innovative technologies to reduce the challenges in urban water systems. The new and innovative technologies for urban water supply system will discuss reducing water loss technology such as rainwater harvesting system and greywater reuse (Figure 1.2). The new and innovative technologies for urban stormwater systems will introduce stormwater best management practice and/or low impact development facilities.

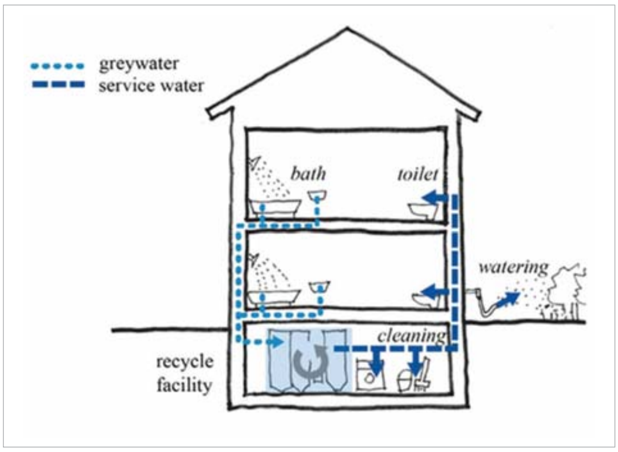


Figure 1.2 Schematic of greywater reuse on building level (Schuetze and Santiago-Fandino, 2013)

1.2.3.1 Reducing Pipe Losses from Networks : the Fundamental Importance of Pressure Management

In some countries, it has been understood for over one half century that efficiency management of pressures is the essential foundation of effective leakage management. However, recognition of this fact is not universal. This is because water distribution systems are installed to deliver water to customers at a selected minimum pressure, and this minimum is not often exceeded with the realization of the impact on leakage. In some conditions, it has not been traditional to take pressure into account when compiling leakage data, comparing performance or setting targets. The International Water Associations Water Loss Specialist Group have advanced various techniques over the past few years to estimate the benefits of pressure reduction and control, and utilities have taken up the benefits of these practices. In some systems where pressure management has been introduced, selection of appropriate control valves and/or adequate maintenance has not resulted in problems.

The significance of pressure on the leakage from water supply systems can be traced back to a theory suggested by Ledochowski in 1956, which has since been adopted by most water loss practitioners throughout the world and is used to explain why leakage from some water supply systems is more sensitive to pressure than from others. Perhaps the amazing aspect is that many water utilities still prefer to provide the maximum pressure, as more pressure equals more water billed and hence more income. The basis for the theory by Ledochowski relates pressure not just to bursting pipes, but also to opening and closing cracks and splits in buried pipes as the demand for water by customers changes throughout the day. Different pipe materials tend either to leak through small holes whereas other leaks occur through joints and cracks in the supply pipes and the area of the leak tends to increase as the pressure increases, usually during the night while customers draw only a very small amount of water.

Metal pipes are prone to corrosion and as such most leaks from them tend to occur through holes that which are generally regarded as fixed area leaks. Leakage from plastic pipes and asbestos cement pipes often occurs through the joints and splits along the pipe which can almost close up completely at low pressures but can open up significantly at high pressures. Such leaks are termed variable area leaks because of the size of the pipe split varies according to the pressure; therefore these types of leak change according to hourly demands that change the pressure. As demand reduces when communities sleep, then pressure in the network rises and opens the splits which lose more water than during the daytime consumption periods.

John May and Allan Lambert advanced this knowledge through the International Water Association, and developed prediction methods for water managers and engineers to estimate the likely savings that can be achieved through the introduction of better pressure management. Most pressure-reduction systems appear to have a payback period of between 3 months and 2 years, making pressure management one of the most rewarding interventions that can be made by a water utility; they also have major environmental benefits that are rarely evaluated.

Pressure management is clearly one of the most important interventions to be considered when attempting to drive down water losses from any water supply system. Leakage is driven by pressure, and while it must be acknowledged that pressure management is not the answer in every case, it is often one of the most cost-effective measures to reduce leakage and wastage that can be considered.

No "one-size fits all solution" exists in pressure management applications. It is the responsibility of the water supply manager or water demand specialist to design and specify a solution for each system that is both sustainable and financially viable.

Electronic pressure controllers were first introduced in the early 1980's. They provided greater control in allowing the outlet pressure from the pressure reducing valve to be adjusted in accordance with either time of day or the flow requirement through the valve. Since then, various additional enhancements have been developed either through more sophisticated electronic devices or through numerous new hydraulic controllers. Each device has its benefits and limitations, and the problem facing the water manager is often to select the most appropriate form of control to suit a specific application.

Water supply systems worldwide are generally designed to provide water to consumers at some agreed level of service. This is often defined as a minimum level of pressure at the critical point which is the point of lowest pressure in the system. The typical average system pressure is usually considered to be of the order of 50 meters with a minimum pressure of around 20 meters. Many uncontrolled water networks commonly have pressures of 60-90 meters. It is not unusual to find extremes of 150 meters in undulating hilly area, far above the desired pressure that customers would want. A two-story property has ample pressure at 20 meters to provide excellent flow to showers and other domestic needs; therefore systems designed to deliver more than this will eventually create large volumes of water losses.

However, many parts of the world have systems that have so many leaks that they have to operate on some form of intermittent supply where water pressure is only provided for an hour or two every day or in extreme cases every 2-3 days. When dealing with such systems which are common in many parts of the world, it is meaningless to discuss the different forms of advanced pressure control and the main priority in such cases must be to provide some level of continuous supply even if at very low pressure. However, the lack of pressure control in these systems will have been part of the reason that the system leaks so badly.

Managing water pressures in a supply area is therefore not a simple issue and there are a great many items to consider. The common factor in every system is the fact that leakage is driven by pressure: if the pressure is increased, the leakage will also increase: if the pressure can be reduced, the leakage will be reduced. To reduce leakage through pressure management, it is necessary to reduce the water pressure without compromising the level of service for the consumers and fire-fighting. If the water pressure in a system can be reduced, even for a short period during times of low demand, the water leakage from the system will be reduced.

It must always be remembered that pressure management does not eliminate leaks or repair any existing leaks. All leaks in the network before the introduction of pressure management remain as leaks after the pressure management installation has been commissioned. The benefits of pressure management are mainly through the fact that the leaks will run at a lower rate at any time where pressure has been lowered as can be seen in Figures 1.3 and 1.4

Figure 1.3 Underground leak running at low pressure (Brothers K , 2002)

Figure 1.4 Underground leak running at high pressure (Brothers K , 2002)

In addition, the lower pressure regime reduces the rate at which new leaks develop, -sometimes by 90% or even more. The financial benefits of the reduction in new bursts and prolonging the life of the reticulation system are rarely included in the financial analyses, despite the fact that they dominate the financial viability of most pressure management projects. Pressure management will usually provide a very attractive payback on the initial investment. A consideration for pressure reduction is that energy has been used to obtain this pressure. Therefore an additional benefit for returning reduced pressure via energy transmitted to the grid rather than via mechanical restriction, is worthy for research.

Flow-modulated pressure control provides even greater control and flexibility than time control. It will normally provide greater savings than either of the two previously mentioned options; however, this greater flexibility (and savings) comes at a price. The electronic controller is more expensive and it requires a properly sized meter in addition to the pressure reducing valve. It may not always be cost effective to use the flow modulated option, and careful consideration should be given to the specific application before selecting flow-modulated control. One key advantage is that the flow modulated option will not hamper the water supply in the case of a fire; however, the additional savings achieved may be offset against the extra cost of the controller and need for a meter together with the likely additional down-time associated with a more complicated device. There are more components in a flow modulated installation which, at some time, are likely to fail. The additional savings generated from such a controller must therefore be weighed up against the likelihood of such component failures and the availability of the necessary technical support to operate and maintain the equipment.

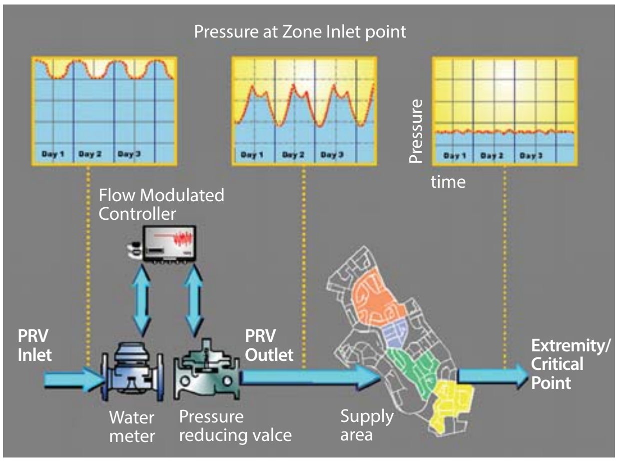


Figure 1.5 Flow modulated pressure control (McKenzie R, 2001)

This form of pressure control has various advantages over the simpler time-control or fixed-outlet control in that it provides greater flexibility and will generally achieve greater savings. It also helps to address any concerns about the fire-fighting flow requirements; in the respect that in the case of a fire, the controller will open up if required to maintain the necessary system pressure to support the increased flow.

Pressure management can be very effective but is not the answer in all cases; however, it has become such an important factor to managers who have experienced such advances. In Tokyo a control room has been now set up where engineers constantly have information available about the pressure in each section of the city, and their only role is to reduce where possible any slight minimum amount of pressure to each sector of the city, knowing the savings are potentially enormous. Two other examples from South Africa are described below.

Case Study 1 from South Africa : Cape Town

The City of Cape Town was the first city in South Africa and one of the first major cities in the world to successfully commission a large-scale pressure management project specifically to reduce leakage during off-peak periods. The Khayelitsha installation was the first such installations to be commissioned in South Africa and was completed in 2000 amid great publicity and press coverage. Previously such forms of pressure management had been limited to small areas with a few thousand connections. The Khayelitsha installation demonstrated that advanced pressure control could be implemented over much larger areas, -in this case approximately 80,000 connections. The installation was designed to control the water pressure to over 450,000 residents living in an area of approximately 24 km^2, using fixed-outlet pressure control with additional pressure reduction at off-peak periods using electronic time and flow control. The savings exceeded all expectations and the project demonstrated that pressure management could be applied to large areas and was not restricted to small zones. This project remains one of the largest of its type in the world and continues to operate successfully more than 14 years after it was commissioned. Some details of the project are provided below.

The level of leakage was estimated from the night -time water use to be almost three-quarters of the water supplied to the area. The minimum night flow (MNF) was measured to be in excess of 1,600 m^3/hour which is sufficient to fill an Olympic-sized swimming pool every hour.

The average daily flow was reduced from 2,500 m^3/hour to 1,500 m^3/hour, representing an annual saving of 9 million cubic meters or approximately 40% of the original water use. A summary of the actual savings achieved from the first 2 years of operation is provided in Table 1.1. It should be noted that more recent estimates achieved from the installation made by the City of Cape Town suggest savings of approximately US$0.5 million per year. The installation cost approximately US$0.5 million to design and construct and it was estimated that the payback on the installation was less than 2 months.

Table 1.1 Summary of Khayelitsha savings for initial 2 year period

Description	Basis of calculation	Volume saved	Value of saving (US$ million)
Direct water savings in 2002	Based on ± US$0.4/ m^3	9 million m^3	± 3
Direct water saving in 2003	Based on ± US$0.4/ m^3	9 million m^3	± 3
Delay to infrastructure – 2 years	7% of R35 million/year	Saving in financial charges	± 0.5
Maintenance and replacement	ZAR250 000 per year		-0.05
Total saving over 2 year period			±$6 mil

Case Study2 from South Africa : Sebokeng

The Sebokeng/Evaton pressure management project was the second large pressure management project to be constructed in South Africa. It was designed and commissioned by the same team that completed the famous Khayelitsha installation. It is in fact larger than the Khayelitsha installation and uses a similar design although it was modified to allow greater flexibility as required to supply different pressures to two separate areas. The project is located to the south of Johannesburg in the industrial heartland of South Africa and supplies water to approximately 480,000 residents located in the Sebokeng and Evaton areas. It was estimated that the wastage in the area before the project was commissioned was 80% of the water supplied to the area which in turn represented an annual water bill of US$12 million. The project cost approximately US$1 million to commission and a further US$1 million to operate and maintain over the 5-year project period. The project had a pay-back period of less than 6 months.

Figure 1.6 Flow modulated pressure control (McKenzie R, 2001)

The actual savings achieved are summarized in Table 1.2 and depicted graphically in Figure1.7. As can be seen from Figure1.7, the water supplied to the area at the start of 2008 is almost the same as it was at the start of 2001 which clearly highlights the true level of savings that have been achieved.

1.2.3.2 Reducing Pipe Losses from Networks : Ground-Penetrating Radar

This method could, in principle, be used to detect leaks in water pipes to detect anomalies in the pipe depths or to identify their specific location. However, it has been in development for over 20 years, and has continually failed to meet the optimistic, and hopeful, outcomes. To be able to Xray the pipes underground and their leaks has always excited the industry; however the poor results so far have not met expectations.

Nevertheless, the theory has produced on-site equipment that attempts to provide a picture of the underground pipework. Soil that is saturated by leaking water slows down radar waves and makes the pipe appear deeper than it should be. Ground-penetrating radar is similar in principle to seismic and ultrasonic techniques. A transmitting antenna sends a short-duration pulse of high-frequency electromagnetic energy into the ground. The pulse is partly reflected back to the ground surface by buried objects or voids in the ground or by boundaries between soil layers that have different dielectric properties. Reflected radar signals are captured by a receiving antenna. The grounds interior is scanned with radar waves in a manner similar to that of ultrasound to obtain a

Table 1.2 Summary of Sebokeng savings for the first 60 months of operation

Period	Water Consumption (m2)		Savings		
	Expectesd (m2)	Actual (m2)	Savings (m2)	Rands	SUS
Months 1-5	18,721,000	14,614,000	4,107,000	11,499,600	1,691,118
Months 7-12	18,751,000	12,785,930	5,965,070	16,702,196	2,456,205
Months 13-18	19,403,000	13,886,451	5,516,549	16,218,654	2,316,951
Months 19-24	19,423,000	13,877,370	5,545,630	16,304,152	2,329,165
Months 25-30	20,086,000	15,269,040	4,819,960	14,788,067	2,112,581
Months 30-36	20,206,000	15,633,153	4,572,847	14,038,640	2,005,520
Months 37-42	20,827,000	15,870,850	4,956,150	15,918,988	1,768,776
Months 43-48	20,766,000	15,692,825	5,073,175	16,487,819	1,831,980
Months 49-54	21,452,000	16,479,970	4,972,030	16,159,098	1,901,070
Months 55-60	21,438,000	16,874,423	4,563,577	14,831,621	1,744,897
Total Mothes 1 to 60	201,015,000	150,984,012	50,030,988	152,948,838	20,158,263

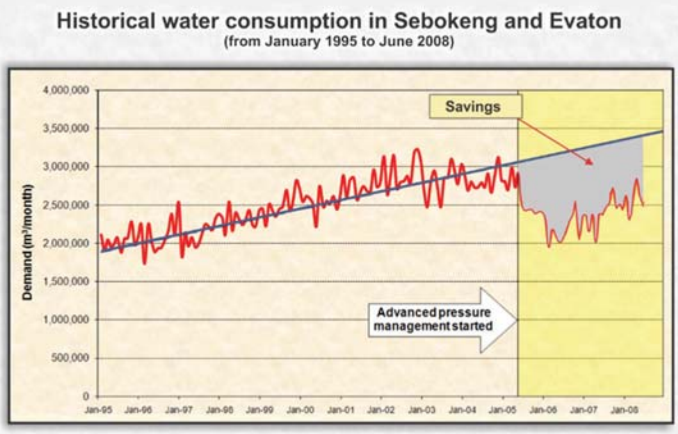


Figure 1.7 Water consumption in Sebokeng and Evaton areas for a 1 year period

cross-sectional image. If major advances can be made with this type of technology, then it would be extremely useful to all water utilities, and be could be used to identify other buried services such as electrical and telecommunications cables

1.2.3.3 Reducing Pipe Losses from Networks : Thermography

This technique uses thermal infrared radiation and represents it as visible images. The ground surface above a leak may seem cooler or warmer than the surface farther away from it in an infrared radiation image. The differences in the temperature of leaking water and the overlying soil may be influenced by this temperature difference; considerable heat may be transferred between leaking water and surface soil. Also, soil close to the leak becomes saturated by leaking water, which may adjust its thermal features and make it a more active heat sink relative to dry soil away from the leak. A thermographic examination of an area uses a high-resolution infrared camera system. The camera should be focused on the ground surface and should capture images over a period of time. Several variables such as ambient temperatures of air and soil, relative humidity, seasonal effects, and others affect this technique, and it requires sophisticated equipment and user skill. It is not yet commercially available as an inexpensive, user-friendly package. However, many experiments have been performed for many years using infrared photography from the air. The benefits have been of value only in rural areas which indicate the ground is not covered by roads and paths, as the temperature changes do not tend to be shown in concreate or other construction coverings.

1.2.3.4 Rainwater Harvesting

Rainwater harvesting is defined as a technology that is used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques (for example jars and pots) as well as more complex techniques (such as underground check dams). Ancient civilizations within Asia and Africa applied of the techniques and they can still be used as a major source of drinking water supply in rural areas. Applied systems are typically composed of three principal functions: the catchment area, the collection device, and the conveyance system.

The viability of rainwater harvesting is highly dependent on the amount and intensity of rainfall in a specific locality. Generally, the catchment area and type of catchment land use can change depending on household demands. As rainfall distribution is not usually even over the year, rainwater collection can only provide supplementary sources for household demands. The feasibility of rainwater harvesting systems is also a component of: the quantity and quality of water available from other sources, household size and per capita water requirements, and budget availability. The decision-maker has to stabilize the total cost of the project against the available budget, including the economic benefit of conserving water provided from other sources. In the same manner, the cost of physical and environmental reduction associated with the development of available alternative sources should be estimated and added to the economic analysis.

1.2.3.5 Greywater Reuse

Greywater is water from bathroom sinks, showers, tubs and washing machines. It may include certain household cleaning products. While greywater may sound "dirty", it is a harmless and useful source of irrigation water in a yard. If it is discharged into lakes or estuaries, the nutrients in greywater become pollutants. However, they are useful fertilizer for plants. Besides the apparent benefits of saving water, reusing greywater prevents it from entering the sewer or septic system, thereby the reducing the chance that it will pollute local water bodies. Greywater is reused for irrigation by urban residents and in our backyard gardens in the natural hydrological water cycle. The simplest way to use greywater is to connect it to the outside and uses it on garden plants or fruit trees. Also, greywater can be used on vegetables as long as it does not touch edible parts of the plants. It is necessary not to put anything toxic down the drain in any greywater system.

While greywater clearly offers an opportunity to reuse water that would otherwise be discarded, great care must be taken, particularly in hot climates, to ensure that its storage does not become a potential source of bacteria that can result in disease. If a greywater system is not operated and maintained properly, it will fail to provide a safe supply of water for washing and/or irrigation. Anyone proposing to use of greywater must ensure that those who will use it are properly educated on the benefits and pitfalls of such systems to prevent possible contamination of the potable water supply or the spread of disease.

1.2.3.6 Stormwater Best Management Practice and Low-Impact Development

Because of the increasing importance of the environmental impacts of land development and concerns about non-point source pollution, it has become necessary to develop efficient substitutions for the integrated drainage and treatment approach that has been the basis for stormwater management programs and systems. To reduce and even prevent negative stormwater runoff impacts and to develop adaptive treatment closer to the original impacts, new strategies must be developed. Such strategies, known collectively as low impact development (LID), seek to reduce and/or prevent negative runoff impacts in site planning and both nonstructural and structural practices that preserve pre-developed hydrologic response to precipitation. LID techniques interact with the process, controlling stormwater runoff and pollutants closer to the source rather than responding to the rainfall-runoff process like centralized and providing site design methods that can considerably reduce the overall impact of land development based on stormwater runoff (NJ DEP, 2003). In general, LID endorses the concept of designing with nature (Figure 1.8).

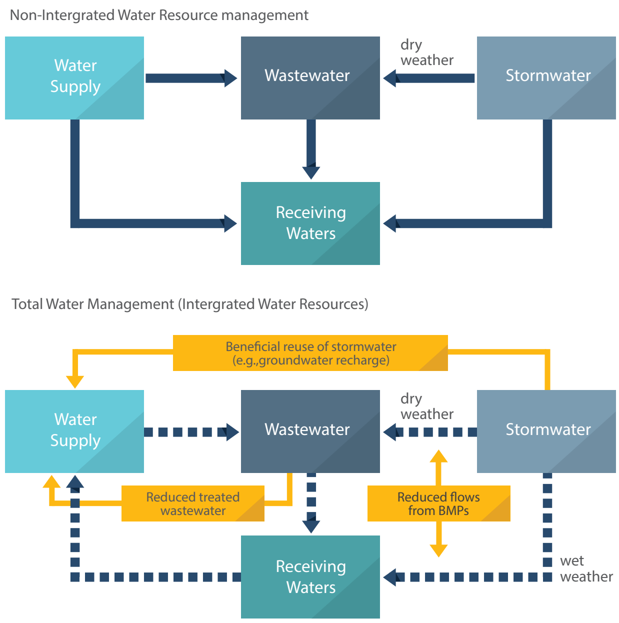


Figure 1.8. Traditional versus integrated water management including best management/LIDs (US EPA, 2012)

1.2.4 Innovative Technologies for Urban Water Efficiency

This section will introduce the application of information and communications technology to urban water systems to improve the efficiency dealing with economic growth, climate change, population growth, and so on.

1.2.4.1 Smart Pipes

Smart pipes combine multi-functional sensors that not only sense strain, temperature and pressure anomalies, but also measure water flow and quality during service. They can provide information to water managers based on continuous monitoring and inspection features guaranteeing safer water supply distribution. Smart pipes connected with a wireless processor and antenna enable data to be directly transferred to a command center and detection and location of potential leaking can be checked in real time.

Originally, smart pipes were developed to convey oil, gas and hazardous liquids. However, their applicability to water networks has been realized, slowly. Public water supply systems are necessary for such research and development in water distribution. The technology for cities to monitor their water supply systems more accurately with different parameters is provided by wireless sensor networks.

Sensors can also be applied to optimize the water used in irrigation, or for measuring hydro-climate parameters such as air temperature, air humidity, soil temperature, soil moisture, leaf wetness, atmospheric pressure, solar radiation wind speed/direction and rainfall etc. The variety of applications within cities can be from park irrigation or commercial irrigation to considering better management and more accurate allocation of water resources between divisions (ITU, 2014).

1.2.4.2 Smart Meters

Smart meters are electronic devices that have advanced metering infrastructure which provides the real time measurement of parameters such as electricity, heat, gas, and water consumption. These tools are rapidly adapting in response to market services and governmental protocols. In the case of water consumption, these smart meters not only consist of an embedded controller that interfaces with a metering sensor and a wireless transmitter, but also display and communications extensions. A data logger which enables continuous monitoring of water consumption of a building, a business or a home connects the meter. The development of smart meters, occasionally allows two-way communication between the meter and a commend center by transferring data through various channels such as power lines, the Internet, or by telephone. The organization of smart meters within an urban infrastructure enables remote accessibility of consumption data which improves correlated issues such as meter reading and billing, detection of leaks, illegal connections and tamper alerts, as well as enhancing the determination of peak demand (Figure 1.9) (ITU, 2014).

The potential exists for time-of-day billing, to encourage people to use a lower cost water at non-peak times, and to increase the efficiency of existing distribution systems. The important gain to utilities would be to defer capital spending on trunk mains required in growing communities to meet future peak demands. Such an introduction also gives consumers options in choosing tariffs to suit their needs. It gives utilities options for identifying usage for specific purposes, such as irrigation of gardens, and could therefore also introduce increased type charges for such usage.

1.2.4.3 Smart Management of Efficient Stormwater System

Stormwater management is rapidly evolving beyond engineered measures applied at the site level to an approach that controls stormwater at the regional, community, and site scales through natural measures., These strategies, referred to as green infrastructure(GI), manage stormwater in a cost-effective, sustainable, and environmentally friendly way. Green infrastructure (For further discussion, refer to 5.3 Science and Technology of Natural and Green Infrastructure management) consists of soil, trees, vegetation, wetlands, and open space to mitigate total runoff and treat what is produced through storage, reuse or infiltrated of rainwater. Regular practice assumes that lower-density development offers enough open space to minimize impacts of several development-related problem and contains smart growth strategies which encourage compact development, with natural areas protected for their aesthetic, recreational, or ecological value (NJ DEP, 2003).

1.3 INDUSTRIAL WATER EFFICIENCY

1.3.1 Characteristics of Industrial Water Efficiency

Growing population and economic pressures, combined with traditional approaches to water supply and management, have led to the unsustainable use of the world's freshwater resources. National institutions need to change their ways to avoid water shortages, ecological collapse and economic disaster. Improved efficiency and increased conservation are the cheapest, easiest and least destructive ways to meet future water needs. Most developed countries have developed numerous smart technologies for water efficiency and conservation.

The concept of conservation and improved management of water use goes back several decades. Baumann et al. (1980) defined water conservation using a benefit-cost approach: "the socially beneficial reduction of water use or water loss". This definition specifies that water conservation

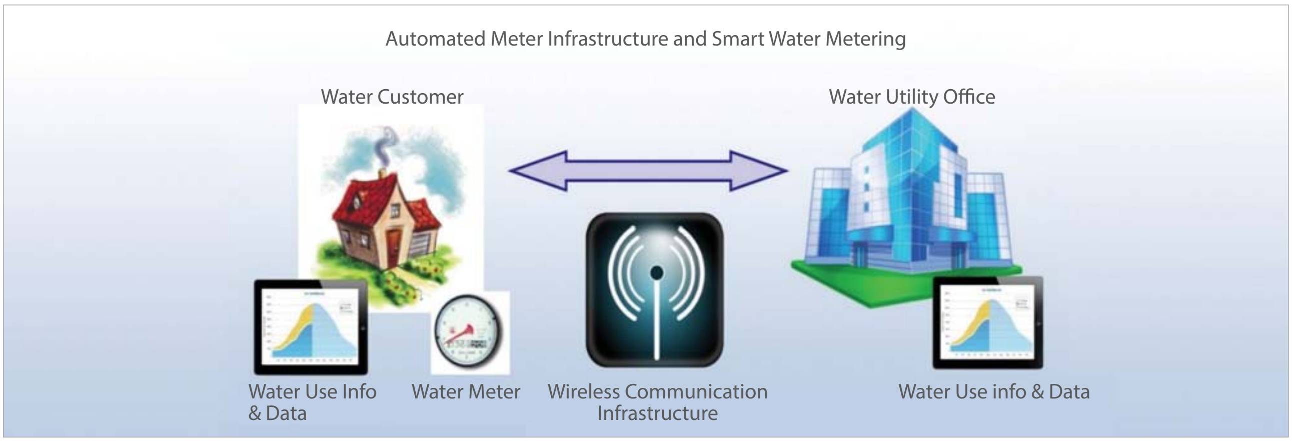


Figure 1.9 Schematic of smart meter technologies (http://www.allianceforwaterefficiency.org/smart-meter-introduction.aspx)

involves trade-offs between the benefits and costs of water management options. In recent years, academics and water professionals have made a major effort to ensure that water conservation signifies the reduction of water use through the improved efficiency of various uses of water without the reduction of services.

The concept of efficiency is also useful when put into the context of investment decisions. “Efficiency” offers insight into the level of conservation reached when the incremental cost of reducing demand is the same as the incremental cost of augmenting supply. Using this criterion, water utilities or individuals would invest in water conservation programs until the conserved water is as expensive as new supplies. This takes into account all the costs and benefits of water conservation and supply augmentation, including environmental and other external factors.

Therefore, water efficiency can be defined as the use of improved technologies and practices that deliver equal or better service with less water. Water conservation has also been associated with the reduction of water use and doing less with less water, typically during a water shortage. In general, water conservation is used synonymously with water efficiency.

Recently, many crises have decreased the efficiency of water management in industrial, urban, and agricultural settings, and of energy in water and wastewater systems. Many useful approaches have been applied to efficient water management, and some innovative technologies have been proposed and tested to improve efficient water use further.

1.3.2 Challenges of Industrial Water Efficiency

What is the potential for water conservation measures and efficiency improvements throughout the world? Remarkably, no international institute or organization has ever made a comprehensive effort to find out. Without information on the potential for water conservation, questions about industrial production, ecosystem restoration, migration policy, land use, and urban growth are much harder to answer, or worse, the provided answers may be wrong.

1.3.2.1 Inexact Industrial Water Demand

The conventional water problem for industrial sectors is how to increase water supplies to meet some projected future demand. The conventional solution is to build infrastructures such as dams, aqueducts and pipelines, to capture water in wet periods for use in dry periods and move water to dry regions from wet regions. However, the environmental and social consequences of this approach have become increasingly intolerable, even as the demand for water supposedly grows. Failing to meet this projected industrial water demand will lead to economic catastrophe, massive unemployment and industrial flight.

Moreover, projections of industrial water use are increasingly recognized as arbitrary and unreliable. Future use of water has usually been assumed to be a direct function of production, population size, economic wealth, and per

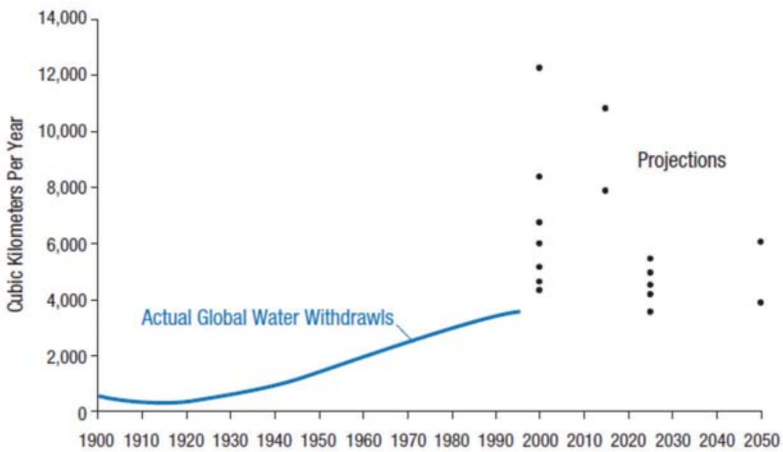


Figure 1.10 Global water projections and actual withdrawals (Black dots represent various projections made from 1967 to 1998) (Gleick et al., 2003)

capita water use per unit of wealth. As these factors increase, traditional estimates of future industrial water use increase with them. Recently, however, it has become increasingly apparent that these traditional projections are usually wrong. Figure 1.10 shows actual water withdrawals globally together with projections of future water use made over the past 40 years. That is, projections of future withdrawals have regularly been substantially higher than actual withdrawals because of inappropriate assumptions about future demand.

Water use efficiency and saving of water in the industrial sector is often raised as a problem area and the industries involved tend to be criticised for not being pro-active in saving water. Following water use assessments in over 700 large industrial consumers, it has become apparent that there are two key problem areas that must be considered when dealing with industrial water use efficiency and both require completely different approaches.

The first and most obvious issue involves the efficiency of water use within industrial processes, where water can be used for cleaning, steam production and cooling, as well as being an ingredient in the final product from the industry concerned. Many large industries, particularly those with an international footprint, are pro-active in trying to reduce their water consumption. They monitor water use very carefully and compare it with that used in similar plants around the world. As greater efficiencies are developed in different parts of the world, processes in certain factories may be modified to reduce water use. Unfortunately, in many cases, it is extremely difficult and sometimes impractical to alter the processes within an existing industrial process owing to the huge costs involved. The specific industry must either continue to operate with a less efficient process or close the factory, and develop a new factory somewhere else that uses a more efficient process.

In the past few years, developments in remote monitoring and internet-based data display systems have created a platform where large industrial water users can monitor and analyse their water use on a "live" system. Such systems provide real-time information on water use which is extremely valuable in identifying both wastage and poor management practices. When presented with such information, industrial users will usually take corrective measures to reduce their water wastage and modify their management practices to avoid damaging their internal water supply network as well as that of their water supply authority.

Managing the water supply in a large industry is in many cases similar to managing the water supply into a small town or zone. Leakage can occur at any time, and can often run undetected for days if not years unless the water use is being properly monitored and analysed by a competent manager. Identifying the source of the problem is often a problem in itself; one of the most useful tools in addressing such problems is the analysis of logging data related to the water process.

Logging involves recording pressures and/or flows entering a zone, a factory or sub-sections of an industrial process. This can be compared to a doctor recording the blood pressure and heart rate to determine the health of a patient. The logging results often highlight problems within the industry system, which can then be addressed. Without regular logging results and associated analyses, such problems can exist unnoticed for months if not years, and result in higher leakage and wastage or poor service delivery.

In recent years, with the advent of global system for mobile communications (GSM) and general packet radio service (GPRS) based loggers, it is now possible to capture and transmit logging information with relative ease. There is no substitute for reliable "real-time" flow and pressure information; where available, it will facilitate the analysis of efficient use of water by companies. To demonstrate the value of the logging results, a few real examples are discussed below.

1.3.2.2 First Example of Logging

In this example, shown in Figure1.11, the flow logging result highlights a leak developing in an industrial facility where a relatively small leak of approximately 1.5 m^3/hour is clearly evident on 5 July. Under normal circumstances, such a leak would most probably have remained undetected for a month or two until some account manager picked up the abnormally high water account. It would then have taken another week to identify and repair the problem. Using some form of live logging, the leak was identified and repaired within a week. The identification and repair time will obviously vary, depending on how difficult it is to find and repair the leak. Usually such leaks develop under some concrete slab where they are very hard to find and even harder to repair but at least the logging information can alert the consumer to the problem.

1.3.2.3 Second Example of Logging Showing 90% Water Loss

The true value of continuous live monitoring of water use at an industrial level is demonstrated by the example shown in Figures 1.12 and 1.13. These show the water use of a large industrial user. Figure 1.12 provides the daily water use figures that were being provided to the industrial user from their own smart metering system. The water use figures were compared with their monthly water accounts from their bulk water supplier to confirm that the accounts were correct. The industrial user concerned, was relatively confident that their water use was under control because it had not changed significantly over a 3 year period when the monitoring of the daily water use was first introduced.

Figure 1.13 shows the detailed logging analysis derived from a live logging system that monitors the water use every 15 minutes and provides the results via the internet. On examination of the detailed flow logging results it was established that more than 80% of the water being supplied to the industry was leakage and a further 10% was theft by water tankers. This information proved very valuable to the industry concerned which was then able to address its high water use. This example clearly highlights that such information is often a more significant problem than process efficiency.

Flow and pressure logging is already an essential element of any comprehensive water efficiency demand management strategy developed both for industry and water utilities. Such logging is now also being recognized as a cost-effective measure in managing leakage and water use in large industries. With the recent advances in cell-phone communication technology, the costs associated with real-time logging and the associated internet access have greatly reduced to the extent that it is now within reach of many new potential users. When considering the use of real time logging, a new user must carefully consider the available options and select a system that best suits their needs and budget. Each data transmission system has its advantages and disadvantages. Some of the key considerations include the following:

(a) cost of the logger
(b) costs associated with the data transmission (sim card costs, monthly rental etc.)
(c) reliability of the equipment
(d) power source required for the equipment and battery life in case of battery powered units

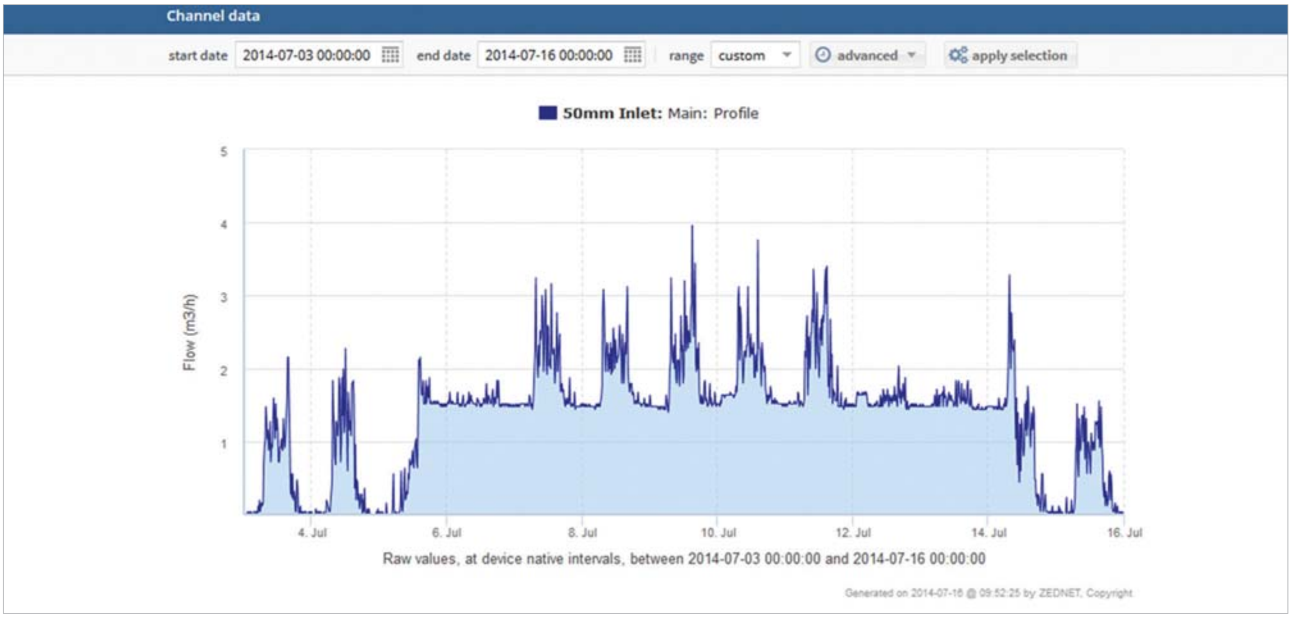


Figure 1.11 Flow logging into an industrial consumer (McKenzie, 2014)

(e) software requirements for the equipment
(f) ease of use and ease of programmability of the loggers
(g) water resistance of the loggers (i.e. IEC standards 60509:1989 IP 68etc.)
(h) useful life of the loggers

While it is acknowledged that industrial water users can reduce their water consumption through the introduction of more efficient processes, there is often a more significant water loss problem associated with the water supply system to industry. From experience, the following key issues are often neglected which can have a very significant impact on the water consumption of an industry:

(a) buried or illegal connections into an industrial site
(b) illegal use of unmetered fire connections
(c) unmetered fire supplies which have significant leakage
(d) leakage on the industrial water supply network which is not detected due to the absence of proper flow and pressure monitoring
(e) broken and/or inaccurate metering

1.3.2.4 Underestimated Water Price

Because of water's special characteristics, such as its combined public good and economics of scale aspects, and for other good reasons, governments have always played an active role in its ownership and management. Despite good reasons for this involvement, government management, however, leads to serious misallocation and waste of water resources. Several problems relate to government involvement, including fragmented public-sector management and neglect of water quality (with serious health and environmental consequences and inadequate pricing of water resources) (Asad et al., 1999).

Pricing water well below its economic value is prevalent throughout the world, even in developed countries. Much has to do with public perception. In fact, many countries have historically considered water as free. In practice, this has focused water resource management on an expanding supply, since that is politically expedient. Pricing and demand management approaches have therefore received much less attention.

The result of this low pricing is a major misallocation of water (at least in economic terms), wasted water resources, serious debt burdens or fiscal deficits for the government agencies charged with water management responsibilities, and poor service delivery to users (especially the poor). As populations increase and the cost of expanding infrastructure continues to incresas, governments are increasingly looking towards implementing improved water pricing methods so as to more effectively and efficiently manage the resource. The importance of pricing as a tool to achieve efficient water allocation and conservation will depend on the relative value of water. When good quality water is plentiful and cheap, it does not pay attention to invest in costly monitoring devices and pricing systems. However, as water becomes scarce, it

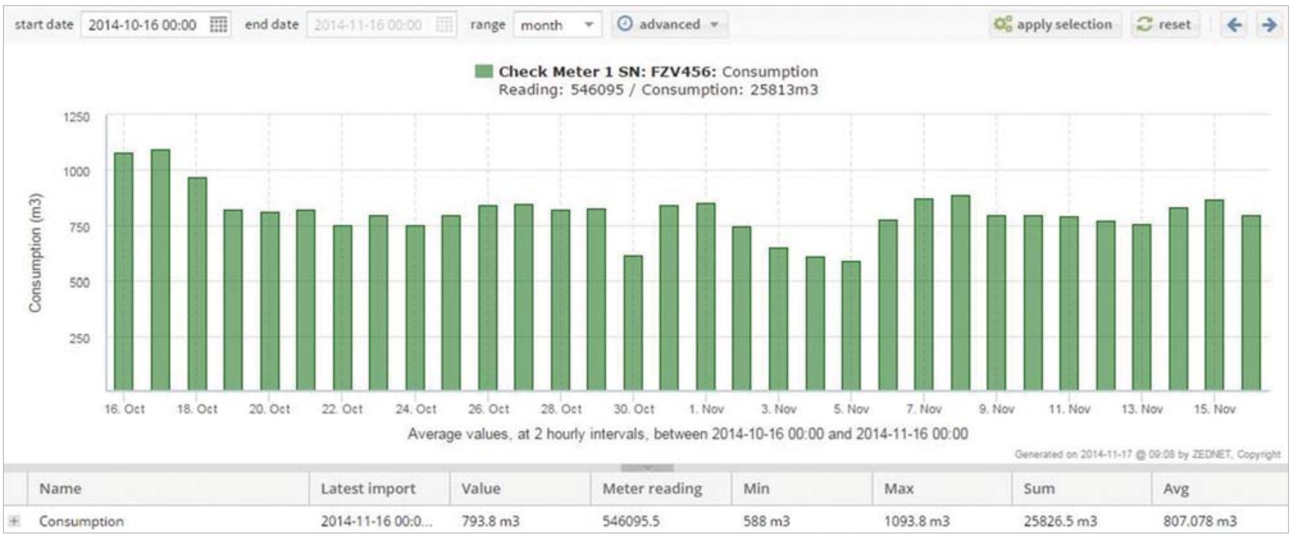


Figure 1.12 Typical daily flow consumption for an industry (McKenzie R, 2014)

becomes increasingly worthwhile to measure, monitor and price water appropriately.

1.3.2.5 Insufficient Information

Generally, a lack of information prevents effective action. Although we can accurately measure water use and the potential for conservation thanks to the available information, increases in the accuracy of future, estimates are needed. Data on self-supplied and reused water are particularly poor. When water use is not metered, it is considered wasted. With very few exceptions, water uses should be monitored and measured so that actual use can be evaluated and compared with the benefits that water provides. Unfortunately, many industrial water uses are not metered.

In addition, industries sometimes choose less-efficient technologies because they are operating with incomplete information. Thus, educating decision-makers about conservation opportunities is necessary. Because water efficiency programs are already successfully reducing water use, this is another important mechanism to give agencies and industries an opportunity to share success stories. Sharing information on these success stories in industry forums, user groups or conferences can help promote more widespread efforts.

1.3.2.6 Aged Water Mains and Infrastructures in Industry

Most developed countries have experienced the ageing of industrial water distribution networks (pipes), in the same way that distribution systems experience it as shown in Figure 1.14 (Malm et al., 2012). Infrastructure improvements and rehabilitation need to reduce the leaks and pipe failures and enhance water quality. Rehabilitation work on water pipes involves tremendous costs, and thus decision-making for network rehabilitation, must be able to handle multiple difficulties (Torterotot et al., 2005).

Figure 1.14 Damaged pipes (Malm et al., 2012)

1.3.3 Smart Industrial Water Efficiency

In general, three steps are required to move towards a smart, water-efficient world. The first step is to identify the potential for improvements in water-use efficiency and allocation. The second is to identify the institutional, economic, and technical barriers that impede these improvements. The third is to implement appropriate economic, educational, and regulatory policies needed to remove the barriers and

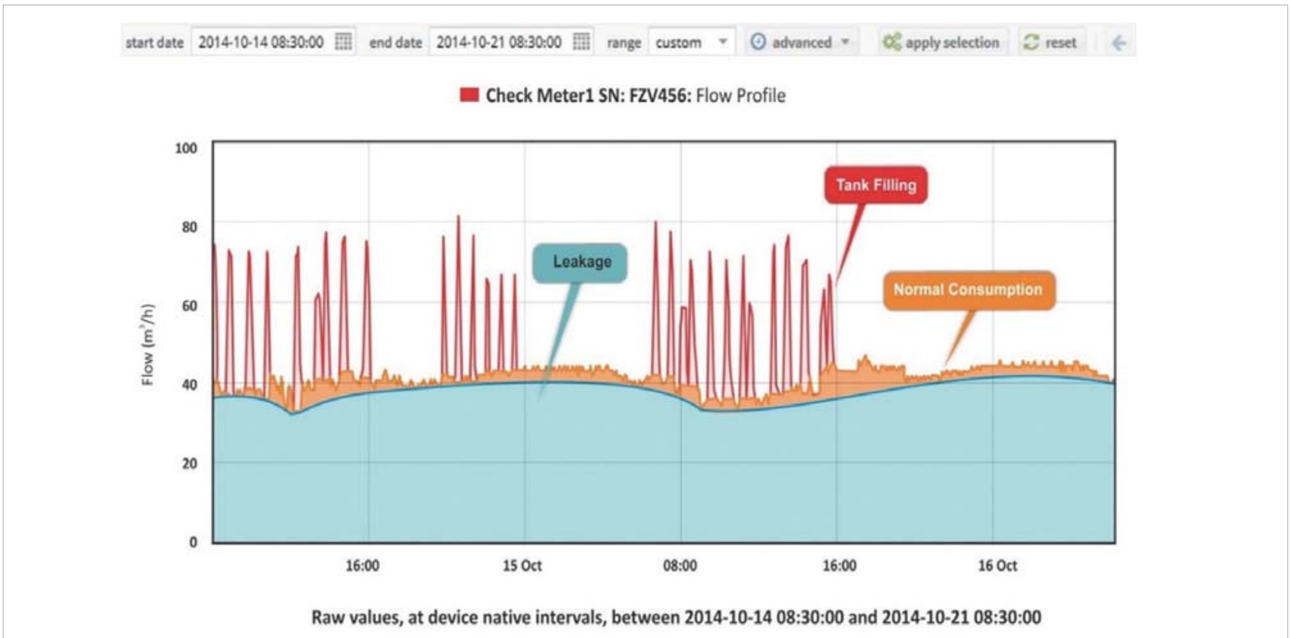


Figure 1.13 Breakdown of live logging for the same industry (McKenzie R, 2014)

capture the available water savings. Therefore, there are some requirements for smart, industrial water efficiency, which consist of economic, technical, regulatory, institutional and educational, and information efficiencies.

1.3.3.1 Economic Efficiency

Economic efficiency mainly focuses on monetary incentives such as rebates and tax credits, as well as disincentives such as higher prices, fines and penalty rate structures. These incentives and disincentives aim to increase the awareness of industrial water users to the true, accurate water value and the total costs of acquiring and using water.

1.3.3.2 Technical Efficiency

Technical efficiency can be achieved by reducing industrial water demand and can be controlled through technology and structural measures (e.g., retrofitting of equipment, reducing leaks, metering, and recycling). It can be improved through advances in water-use technology and changing the physical nature of a system such as by replacing water saving cleaners or recycling water used to clean semiconductors during chip manufacturing.

1.3.3.3 Regulatory Efficiency

Regulatory efficiency can be improved by governments or water supply agencies that encourage water conservation. Some of their mechanisms include funding public education programs, adopting appliance standards, and proper design and application of factories or office buildings.

1.3.3.4 Institutional Efficiency

Institutional and educational efficiency can be achieved by encouraging improvements in water use efficiency, including economic, technical and regulatory efficiencies. There are various tools that can inform industrial water users about the potential for these improvements, the options available for users, and the costs and benefits of different techniques and institutions.

1.3.3.5 Information Efficiency

Information efficiency can be partly achieved by labelling and metering, which assist in understanding water use, setting proper prices, and managing water demand. This is actually also a pricing effect, as consumers can directly see the economic impacts of their water use.

1.3.4 Innovative Technologies for industrial Water Efficiency

Industrial water crises have been approached in various smart ways such as reducing losses, reducing overall water use, employing water reuse practices and stabilizing water supply systems. The general method for reducing water losses is by fixing leaking pipes after identifying them with various monitoring and measurement technologies. The ways to reduce overall water use are an automatic shutting-off system when water is not in use and a remote control system for smart monitoring and operation. There are many applications of water reuse practices such as wastewater reuse and reclamation for industrial use. Methods for stabilizing the water supply system include the construction of dual water supply networks and rehabilitation of old water networks.

1.3.4.1 Nonstructural Policies

Existing structural technologies are available to greatly reduce industrial water use without reducing quality of life, goods, services and productivity. However, current techniques cannot avoid future water shortages due to unexpected events such as climate change, disasters, population growth and increased water demand. Therefore, smart nonstructural measures should be tried to enhance industrial water efficiency.

Industrial examples of smart nonstructural policies that will help capture the conservation and efficiency potential include proper pricing of water to encourage waste reduction, financial incentives for low-flow appliances, proper design of subsidy and rebate programs, new national efficiency standards for appliances, education and information outreach, water metering programs, and more aggressive local efforts to promote conservations. However, efficiency and conservation cannot be completed with ease even if these policies are used.

1.3.4.2 Reclaimed Water Use

The representative improved technology is reclaimed and recycled water as a secure source of industrial water use. For limited industrial water use, reclaimed water use has increased sharply because new water-secure infrastructures such as large dams cannot be constructed easily in most countries. Therefore, various innovative membranes have been created for performance improvement. In addition, many developed countries have made provisions for promoting reclaimed and recycled water use.

1.3.4.3. Image Diagnosing Robot and Automatic Equipment of Rehabilitation for Pipes

Recently, image-diagnosing robots using vision technology, as shown in Figure 1.15 have been developed to check condition inside pipes, using a high-performance zoom/tilting mounted camera image system. It can provide 360° panoramic views inside the pipes that are more than D150 mm and curved up to 45°.

In addition, two systems for rehabilitating small and large pipes have been developed. Automatic equipment for small pipe rehabilitation can remove scale and rust using an ultra-high pressure water jet (2,500 bars) and spraying a variety of lining/coating materials evenly inside the pipes. The small diameter rehabilitation system consists of cleaning and lining systems. The cleaning system can adjust the water jet pressure according to the extent of deterioration of the pipes, and prevent pipe damages. The lining system controls nozzle velocity and thickness according to the characteristics of the paint and applies a disk or spray nozzle method selectively (Figure 1.16).

A line care system for rehabilitating large pipes has also been developed Figure 1.17. It consists of (a) inspecting the pipe drainage and condition, (b) washing inside the pipes, (c) removing inside paint, (d) surface treatment, (e) painting, and (f) inspecting the paint and recovering the valve chamber. There are four innovative machines to do this; a water jet cleaning machine for step 2; an induction scraper machine for step 3; an impeller blasting machine for steps 4 and 5; and an inside lining machine for step 6.

1.3.4.4 Making water from Air

A Dutch company has found a way to produce water from air. The rainmaker concept is a system whereby a stand-alone wind turbine is placed in rain-lacking regions. The system's wind turbine does not drive a generator to produce electricity, as is commonly the case. Instead it drives a heat pump which is directly powered by the wind turbine's blades. With the heat pump the water vapour in the air is condensed and collected for domestic or irrigation purposes. This system is especially suited for environments without proper infrastructure and access to water sources. Because the turbine forces air through a heat exchanger, where the air is cooled, condensation takes place. When the temperature falls below its dew-point, water droplets form and are collected in a water storage compartment. Warm ambient air, in particular, may contain large amounts of water. Lowering the temperature of air requires relatively little energy. By doing so large volumes of water become available by condensation and can be utilized as drinking water or irrigation water. These devices are being operated in the Netherlands and Kuwait (http://dutchrainmaker.nl) (Figure 1.18).

Figure.1.15 Description of image diagnosing robot


Figure 1.16 Small diameter rehabilitation system

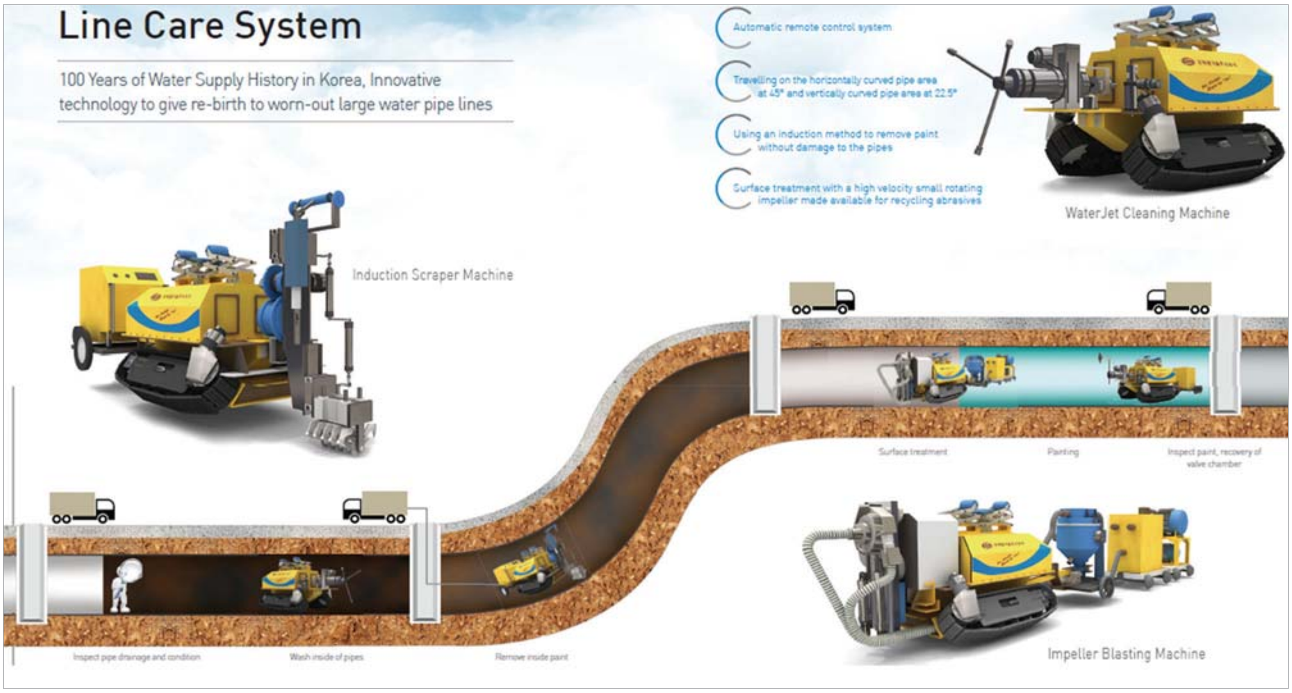


Figure 1.17 Line care system for large pipe rehabilitation

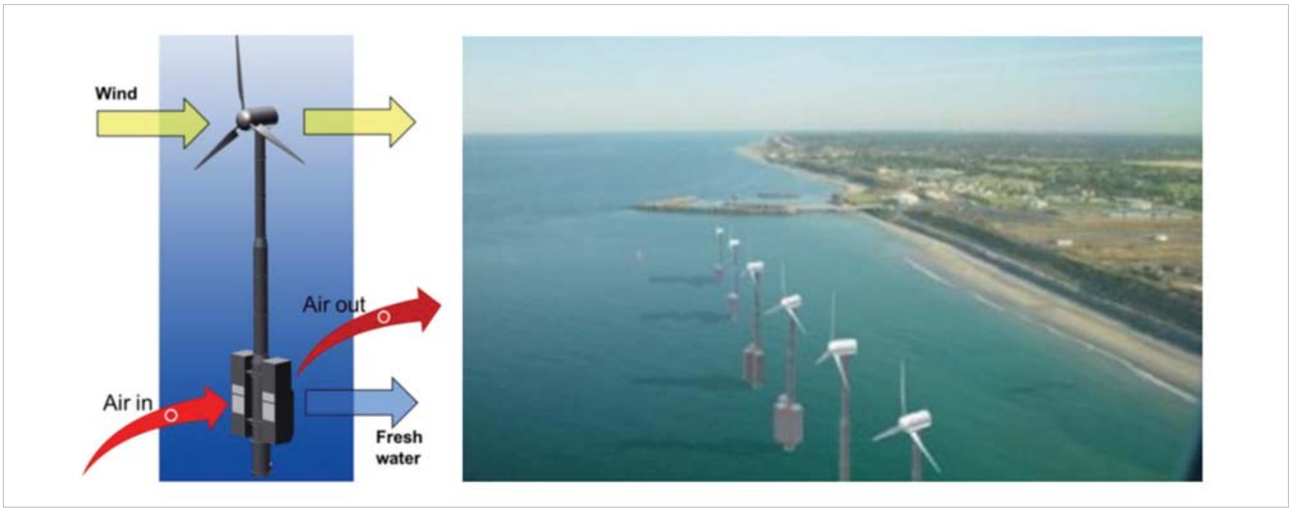


Figure 1.18 Concept of rainmaker device and its application in Netherlands (http://dutchrainmaker.nl)

1.3.4.5 Infrastructure Asset Management

In water and wastewater systems, an "asset" is a component of a facility with an independent physical and functional identity and age (e.g. pump, motor, sedimentation tank, main). The renewal and replacement of assets that make up a nation's water infrastructure is a constant and ongoing task. To manage this important part of a utility's business efficiency, many have turned to asset management. This approach has gained recognition across the world and across all infrastructure heavy sectors for its effectiveness in maximizing the value of capital as well as reducing operations and maintenance expenditures.
(USEPA; http://water.epa.gov/infrastructure/sustain/am_resources.cfm).

Various types of rehabilitation framework based infrastructure asset management has appeared in recent years. Infrastructure asset management is the integrated, multidisciplinary set of strategies in sustaining public infrastructure assets such as water treatment facilities, sewer lines, roads, utility grids, bridges and railways. Generally, the process focuses on the later stages of a facility's life cycle specifically maintenance, rehabilitation, and replacement. Therefore, effective infrastructure asset management should be necessary for aged water-related infrastructures when considering various hazards and risks.

Asset management is maintaining a desired level of service for assets to provide what is wanted at the lowest life-cycle cost. Lowest life-cycle cost refers to the best appropriate cost for rehabilitating, repairing or replacing an asset. Asset management is a framework that is being widely adopted as a means of pursuing and achieving sustainable infrastructure. It is the practice of managing infrastructure capital assets to minimize the total cost of owning and operating them while delivering the desired service levels. A high-performing asset management program incorporates detailed asset inventories, operation and maintenance tasks, and long-range financial planning to build system capacity, and it puts systems on the road to sustainability (Figure 1.19).

1.4 AGRICULTURAL WATER EFFICIENCY

1.4.1 Characteristics of Agricultural Water Efficiency

The world population reached 7 billion in 2012 and is expected to increase to about 9 billion by 2050. To meet the demands of the growing population, the Food and Agriculture Organization of the United Nations (FAO 2011) said that another 1 billion tons of cereals and 200 million extra tons of livestock products would need to be produced every year. To make food security a reality, the world's cultivated area has grown by 12% over the past 50 years, and the global irrigated area has doubled from 139 million hectares in 1961 to 301 million hectares in 2009 (Figure 1.20). Accordingly, agricultural water use is estimated to account for 70% of all water withdrawn from aquifers, streams and lakes, and more than 90% of the agricultural water intake is for irrigation (FAO, 2007, 2011).

In an increasing number of countries, existing water resources are already fully exploited. Agriculture therefore faces a great challenge in coping with growing water scarcity and increasing demands for food production. Part of the solution lies in improving agricultural productivity and water use efficiency (FAO, 2007; Bergez et al., 2012). Improving AWE is one of the significant challenges to ensure food security, and different structural and non-structural alternatives have been applied for better use of water in water-limited conditions (Boutraa, 2010).

AWE has been generally defined as the ratio of crop yield to water used to produce the yield; it can also be translated into the amount of water used to produce a crop (Ali and Talukder, 2008; Boutraa, 2010; Fan et al., 2012). The term can be used for a wide range of scales from the basin to the farm

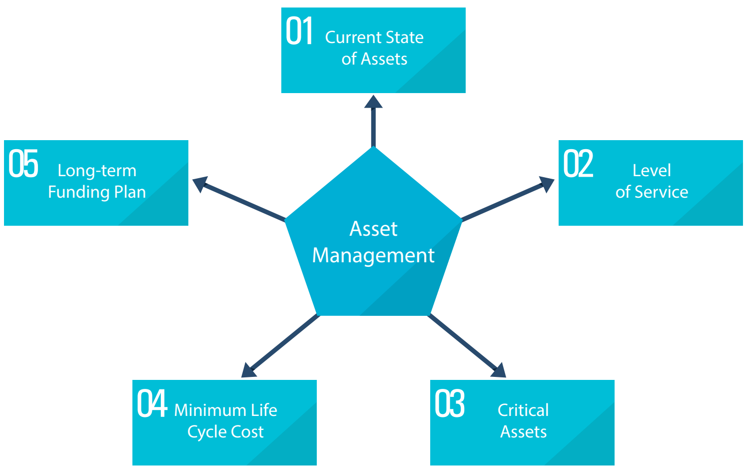


Figure 1.19 Five core questions of asset management framework (US EPA,http://water.epa.gov/infrastructure/sustain/am_resources.cfm)

or to the level of plant part. Different similar terms are in use, as follows:

(a) Water productivity. This represents the ratio of above-ground biomass per unit of water transpired by the crop (Steduto, 2007). Water productivity is often used with AWE interchangeably but has different meanings. AWE interests mainly the water districts or management agencies, while water productivity interests more farmers and research community (Levidow et al., 2014).

(b) Irrigation efficiency. Irrigation engineers have another term for AWE: irrigation efficiency. This is expressed as the ratio of water beneficially used to total water applied. Sinclair et al. (1984) specifically defined it as the ratio of biomass per unit of irrigation water used, i.e. the sum of transpiration by the crop and evaporation from the soil. There are more than 30 different definitions of irrigation efficiency currently used (Edkins, 2006). Irrigation efficiency focuses on the amount of water released from a water source to ensure beneficial uses (Jensen, 2007). It provides a measure of how well the system handles or uses this water, is able to convey it without 'waste' (efficiency component) and convert it to productive use (efficacy component) (Halsema and Vincent, 2012).

(c) Water conservation. California DWR (2012) used the term "water conservation", defined as the efficient management of water resources for beneficial uses, preventing waste or accomplishing additional benefits with the same amount of water. Water conservation measures are means of reducing water diverted or delivered to meet crop water requirements or other beneficial uses.

AWE is still very low in most developing countries owing to poor irrigation management and lack of investment in infrastructure (Fan et al., 2012). Even in developed countries, most irrigation systems perform below their original capacity and are not adapted to the needs of today's agriculture, which faces unfavorable changes in circumstances. So, more supportive investment in innovative water-efficient devices and management technologies is required, which is expected to contribute water security in the agricultural sector as a core component of balancing water supply and demand in the future (Benito et al., 2009).

1.4.2 Challenges of Agricultural Water Efficiency

1.4.2.1 Adaptation to Climate Change

Climate change is expected to alter the patterns of temperature, precipitation, and river flows upon which agricultural systems depend. In the future, weather patterns will become more uncertain and the frequency of extreme climate events, such as typhoons and droughts, will increase. This could make existing water problems even worse in many regions (Benito et al., 2009). For example, the percentage of global

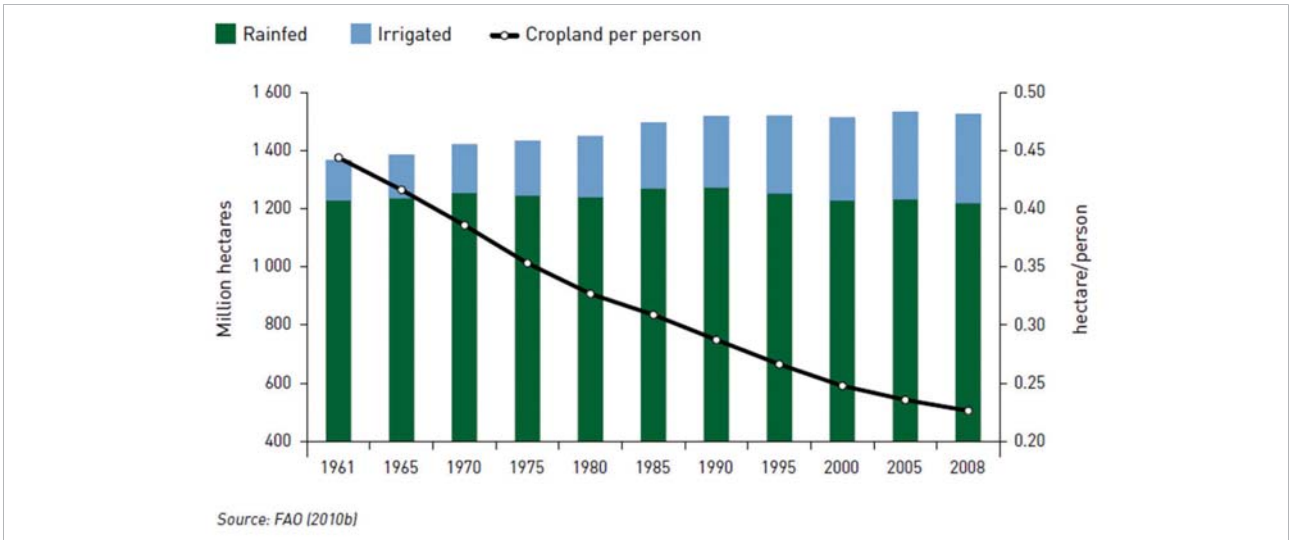
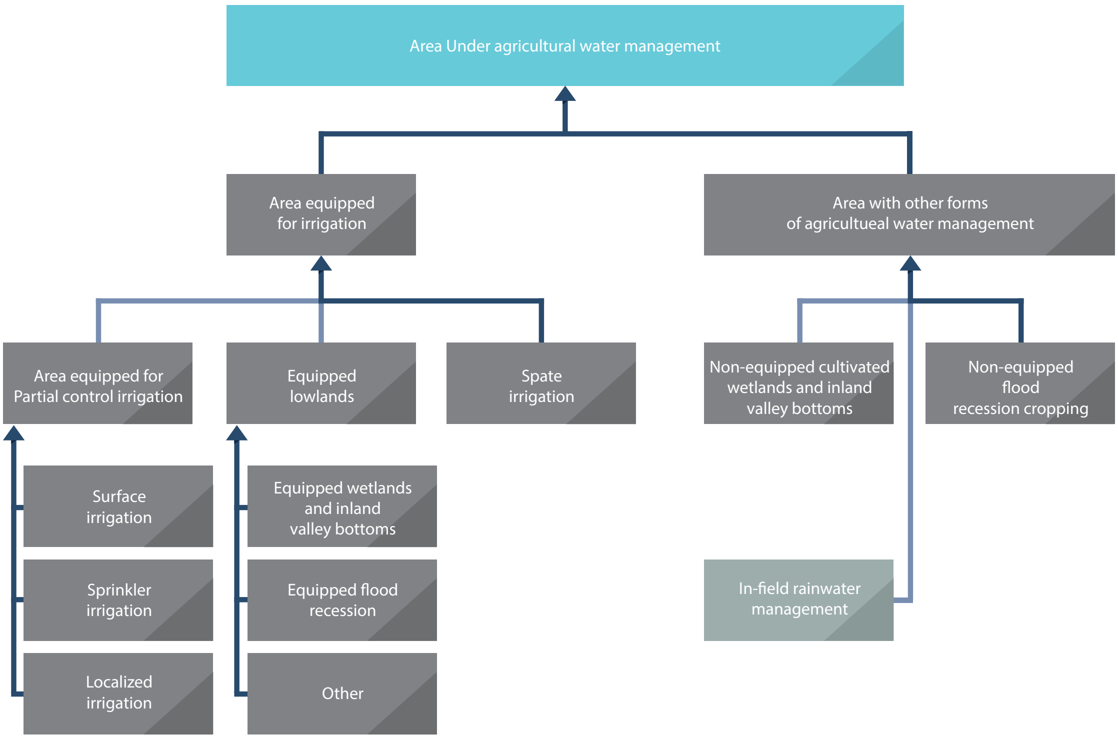


Figure 1.20 Evolution of land under irrigated and rainfed cropping (1961-2008) (FAO, 2010b)

land classified as 'very dry' has doubled since the 1970s, and natural water storage capacity and long-term annual river flows are declining (Morrison et al., 2009). Meanwhile, some agricultural systems may gain net benefits from temperature increases as more land becomes suitable for crop cultivation. However, overall, climate change could make it more difficult to grow crops and to manage water resources in the same ways and the same places in the past (AEA Energy & Environment, 2007; FAO, 2011). Therefore, agricultural water management practices need to be re-arranged to meet the changes in circumstances, which may be possible with innovative water-saving technology through all processes from farm to basin level. Certainly, adaptation and mitigation strategies should focus on increasing resilience of farming systems to reduce current and likely risks such as droughts, excessive rainfall and other extreme events (FAO, 2011)).

1.4.2.2 Improvement of Water Management Practices

Both potable and agricultural water management have become challenging issues because of the growing demand for water saving and productivity improvement. As shown in Figure 1.21, there is a wide variety of water management practices both for catchment management and for agriculture. The choice of applicable practice needs to consider different factors about the ecosystem as well as crop production. Various management techniques have been developed and evolved over time to increase and intensify production, reduce crop failure risk, diversify production, increase efficiency and sustain natural resources. Improvement in water management practices could help farmers to achieve more reliable, profitable and sustainable production, to be better prepared to deal with increasingly erratic climate patterns, and to respond effectively to different water demands (IFAD, 2012). Applying the right depth of water in the right place and at the right time by selection of the system type, ensuring adequate water delivery, maintaining equipment, and irrigation management may further improve the efficiency by 5-20% (Benito et al., 2009).



Note : Areas in grey correspond to the FAO typology. In-field rainwater management was added by Peacock in his 2007 report for IFAD.

Figure 1.21 Modified FAO agricultural water management (AWM) typology (IFAD, 2012)

Environmental professionals and catchment managers bring diversity both to the strategic planning and operations of a water business that:

(a) contribute expert knowledge and leadership associated with managing a water business environmental footprint
(b) deliver the diversity of thought required to avoid "group think", through the ability to undertake robust debate about the planning and management of water resources (it is more than sustainable yield)
(c) provide an ability to suggest alternative options and ideas for addressing a common problem
(d) bring internal ownership and accountability for the application of a multi-barrier approach that manages source risks through the protection and maintenance of environmental values that support healthy raw water quality
(e) expand intellectual property to add value to both the water business, and in some cases a regional community (knowledge is not exported to consultants operating from a remote urban centre)
(f) develop cooperative working relationships that transcend jurisdictional barriers and manage a water source over its entire catchment or agricultural zone
(g) improve community standing and brand recognition as a leader in the industry, and foster constructive relationships and trust among regulatory agencies through the proactive management and response to environmental issues

1.4.2.3 Modernization of Water Infrastructures

Ageing water infrastructure exacerbates negative impacts of drought and flooding, and many countries are burdened with repair and maintenance responsibilities. Poor maintenance of the water infrastructure leads to inefficiencies in water use and water losses through leakages inducing an increase in water withdrawal and application rates per unit area irrigated (OECD, 2010). Such infrastructure could not achieve sufficient water use efficiency, even if state-of-the-art technologies are adopted for water-conservation irrigation. Moreover, climate change affects the functioning and operation of existing water infrastructure. Current infrastructure may not be robust enough to cope with the impacts of climate change on water supply reliability and flood risk because of the change in circumstances compared with past design standards. Concerns for the renewal or upgrade of water infrastructure must be investigated and resolved to improve water efficiency as well as to ensure safety from natural hazards.

1.4.3 Smart Agricultural Water Efficiency

1.4.3.1 Expansion and Enhancement of Water Monitoring System

Accurate monitoring of water used is an essential part of reasonable water management, and helps reach optimal performance in saving water while enhancing yields (Levidow et al., 2014). Knowledge on water usage and flow in a region is a first step for raising water efficiency in agriculture. It becomes increasingly significant as competition for water increase between uses and regions. Furthermore, to implement comprehensive water management for high-level water efficiency, different factors affecting crop yield should be observed as well, such as fertility, crop variety, pest management, sowing date, soil water content, planting density, and so on (Bouttraa, 2010; Levidow et al., 2014). The measurements can be obtained through different direct and indirect methods including on-ground and over-ground sensor systems, and can be interpreted with the support of ICT technologies.

(a) The Korean Rural Community Corporation (KRC) has invested in a reservoir water level monitoring project since 2001, which targets 1,570 agricultural reservoirs having effective storage above 0.1 million m3 to watch reservoir flow and alert flood and control storage water for drought in real time (https://rawris.ekr.or.kr).

1.4.3.2 Development and Rehabilitation of Water Resources

Various initiatives are being made to increase the water storage capacity of soil under agricultural land use or to utilize ineffective waste flow in terms of crop consumption. To some extent, the modernization of irrigation systems has steadily progressed and water productivity has improved considerably (COPA-COGECA, 2007; Levidow et al., 2014). However, several irrigation schemes must still be rehabilitated in cases where they have deteriorated over the years in terms of both operation and structural stability.

(a) In South Korea, the agricultural reservoir embankment rehabilitation project (2009-2015, total 11 agricultural reservoirs, US$2.7 billion) has been carried out a part of the four major river restoration project. The project is still in progress to secure flood and drought prevention including stream management flow. The KRC is expected to secure total 0.28 billion tons of additional water.

1.4.3.3 Enhancement of Water management Technology

A combination of improved irrigation scheme management, investment in modern technology, knowledge development and training can substantially increase water use efficiency and improve supply to the often poorly-benefited users (FAO, 2011). AWE gains are possible through suitable crop selection, proper irrigation scheduling, effective irrigation techniques, and using alternative sources of water for irrigation. Highly-efficient irrigation involves fine-turning the time and amount of water applied to crops based on the water content in the crop root zone, the amount of water consumed by the crop since it was last irrigated, and the stage of crop development. It is essential to plan for irrigation properly and match the amount of water provided to a crop's water needs,- both for yield optimization and for water efficiency (Levidow et al., 2014). To achieve this, it is necessary to enhance the water management technology and carefully consider investments in more efficient irrigation systems. The use of new technologies (e.g., soil moisture and canopy sensors) can be considered to match the water supplied with the crop water requirements. Careful consideration must be given to the use of appropriate agricultural practices, such as conservation tillage, management of soil fertility and water retention capacity, and irrigation management to reduce losses (Levidow et al., 2014). The European Commission also emphasized technological innovation in the field of water, given that water efficiency will be an increasingly important factor for competitiveness (CEC, 2008). Within just the member states of the European Union, the water saving potential from irrigation is expected to be up to 43% of the current volume abstracted by new technology and water management systems (Benito et al., 2009).

Water conservation and water use efficiency may result in water savings and/or co-benefits including improved water quality, energy savings and emission reduction of greenhouse gases. The water saved can be used to meet agricultural, urban and environmental water demands. Applied irrigation water that becomes surface tail water or deep percolation

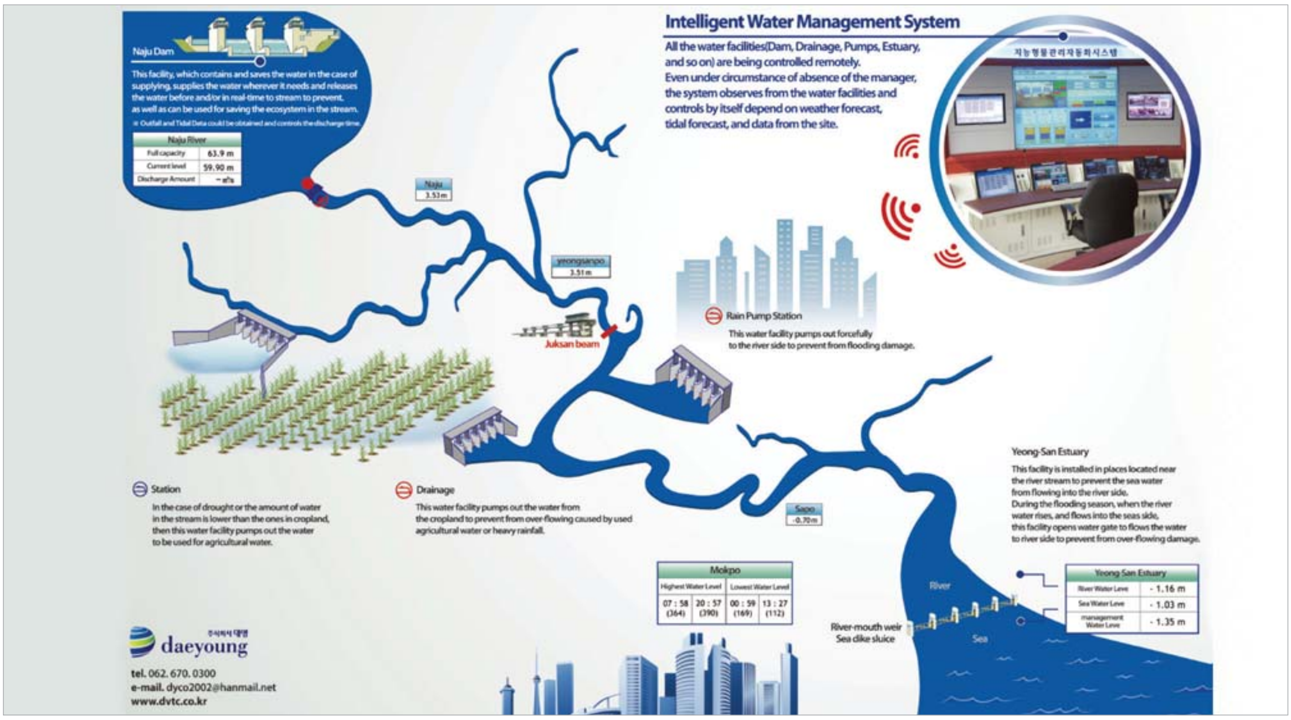


Figure 1.22 Intelligent water management system (TM/TC) applied to Yeong-San River, South Korea

that is recoverable may be used by other farmers, cities or the environment. However, being more efficient in some circumstances may mean more costs and more energy use. So, third-party impacts should not be disregarded before mandating any significant water conservation or efficiency measures (California DWR, 2012).

(a) The Korean government has already made progress in updating and modernizing irrigation practices and technology, and more advancement is expected through ICT development. For example, a TM/TC (tele-metering and tele-control) project has been realized since 2001 to watch floods and manage drought in irrigation districts by using information and communications technology (ICT)-based monitoring and control technology. The project will be continue until 2021 with a total spend of US$0.5 billion. So far, it has been completed in 37 irrigation districts (Figure 1.22).

1.4.3.4 Development of ICT Applications

Water management is complex because it concerns different spatial and temporal scales and multiple stakeholders with varying goals. Information on the temporal and spatial variability of environmental parameters, their impact on soil, crop, water and other components of farming all play a major role in formulating farmers' strategies. Today, farmers and water-related stakeholders can utilize the convergence of several technologies including in-field sensors, geographic information systems (GIS), remote sensing, crop and water simulation models, prediction of climate and advanced information processing and wire/wireless communications (Panchard et al., 2006). Information systems can contribute to inform decisions about water management allocation. At the strategic planning level, they enable optimized planning of irrigation infrastructures assist planning decisions in the face of increasing climatic variability. At tactical level, they can be applied for identifying the optimal allocation of water for a given period (season or year). At the operational decision-making level, they can contribute to optimizing water distribution at the farm level by providing technical information and advice, and offering farmers educational programs on best practices to adopt (OECD, 2010).

People have been trying to identify reliable methods and provide recommendations on appropriate equipment for accounting and measuring used water resources as well as produced, distributed, consumptive use and return flow water volumes. Technological developments in respect of irrigation will encompass sensors and communication, intelligent watering systems and high-efficiency delivery mechanisms for water and nutrients, as well as the means of incorporating all of these elements into irrigation packages (EIO, 2011; Levidow et al., 2014). In practice, innovative irrigation practices to enhance water efficiency, gaining an economic advantage while also reducing environmental burdens can be hardly implemented without an ICT basis. Farmers generally lack adequate means and incentives to know the water use of crops, actual irrigation applications, the yield response of crops to different water management practices, and thus current on-farm water efficiency levels (Levidow et al., 2014). However pumping costs, being the highest component of total water costs can be the key driver for change and on-site alterations.

1.5 ENERGY EFFICIENCY IN WATER AND WASTEWATER SYSTEMS

1.5.1 Characteristics of Energy Efficiency in Water and Wastewater Systems

Water and energy resources are essential to economic growth and public welfare. Water and wastewater treatment systems are among the most energy-intensive facilities owned and operated by local government or public services in most countries. Energy is needed to extract, treat and convey water and wastewater. For decades, the energy consumption by the water and wastewater sector has considerably increased as a result of implementation of new technologies and approaches to safeguard water quality and to meet new regulations.

This section describes water energy efficiency in the water and wastewater sectors. The practice of water and wastewater systems requires new energy management strategies and solutions which need to improve energy efficiency and to be innovative, cost-effective and environmentally friendly.

A membrane as applied to water and wastewater treatment is simply a material that allows some physical, chemical or biological components to pass more readily through it than others. The degree of selectivity depends on the membrane pore size. The coarsest membrane, associated with microfiltration (MF), can reject particulate matter and retain bacteria. A tighter ultrafiltration membrane can also reject viruses. An even tighter nanofiltration membrane is more selective than reverse osmosis, rejecting a high amount of bulk organic matter and many micro-pollutant, while the tightest/least selective reverse osmosis can also reject singly-charged (i.e. monovalent) ions, such as sodium and chloride. Given that the hydraulic diameter of these ions is less than one nanometer, it stands to reason that the pores in a reverse osmosis membrane are very small - a few nanometers - whereas those of microfiltration may be greater than a micron in size.

1.5.2 Challenges of Energy Efficiency in Water Treatment and Supply

Water supply treatment is the process of removing contaminants from water, making it clean enough for its desired use, most often to drinking water standards. Several new energy-intensive advance treatment processes and technologies are being deployed in the water utility sector and there are needs to investigate possibilities to reduce their energy footprint. There is also a need to identify and optimize existing policies, practices and perceptions to lower energy consumption associated with water treatment and distribution. Water distribution systems can be energy generators rather than energy consumers. This section explores evaluates the efficiency of energy used to treat and distribute potable water.

1.5.2.1 Energy of Water Management

The main goal of sustainable management of water supply systems is to develop new strategies and solutions that can guarantee the uninterrupted delivery of good quality water to populations, with no adverse environmental consequences, and with as low operational costs as possible. There are numerous examples of such solutions associated with water management.

Energy efficiency in water and wastewater sector can be accomplished through measures such as water conservation, water loss prevention, stormwater reduction and repairs to sewer system to prevent groundwater infiltration. Measures to reduce water consumption, water loss, and wastewater lead to reductions in energy use, and result in savings associated with recovering and treating lower quantities of wastewater and treating and delivering lower quantities of water.

1.5.2.2 Energy Efficiency for Water Supply and Distribution

A significant amount of municipal energy use occurs at water and wastewater treatment facilities. With pumps, motors and other equipment operating 24 hours a day, 7 days a week, water and wastewater facilities can be among the largest consumers of energy in a community and thus among the largest contributors to the community's total greenhouse gas emissions (US EPA, 2013). There are several clear energy efficiency and demand management opportunities in the water supply sector. Pumps account for up to 95% of the energy used to distribute drinking water, so any management technique that can enhance pump efficiency could have significant impacts on distribution's energy consumption.

Energy opportunities have focused on use of efficient pumping systems (pumps, motors, variable frequency drives), reduction of distribution leaks and implementation of automatic meter reading. Unlike water treatment plants, water distribution systems often do not have the luxury of moving the bulk of their load off-peak. Not only must pumps maintain constant pressure within the network, but it is the end user who ultimately determines when the system bears the most loads, much like with electrical power grids. Better knowledge of demand and the use of storage tanks and water towers can help remedy these difficulties.

Perhaps the largest unanswered question in this area stems from the possibility that water distribution systems can be energy generators rather than energy consumers. Installing micro-hydro technologies in larger pipes can convert energy from the pressure and flow into electricity (Vilanova and Balestieri, 2014). These systems could be an energy producing way to regulate pressure rather than using pressure valves.

1.5.2.3 Energy Efficiency for Water Treatment

Economic and environmental costs in water sector can be reduced by improving the energy efficiency of the equipment and operations of water treatment facilities, by promoting the efficient use of water, and by producing energy in the water treatment system (Water in the West, 2013). Improvements in energy efficiency allow the same work to be done with less energy; improvements in water use efficiency reduce demand for water, which in turn reduces the amount of energy required to treat and distribute water.

Water treatment utilities can improve energy efficiency by installing control software, use of efficient pumping systems (pumps, motors, variable frequency drives), efficient disinfection equipment, and implementation of lighting and heating, ventilation, and air conditioning (HVAC) improvements (US EPA, 2013). Improving energy efficiency at a water or wastewater treatment facility reduces electricity demand, thus avoiding the risk of brownouts or blackouts during high-energy demand periods and helping to avoid the need to build new power plants. Water efficiency strategies reduce the risk of water shortages, thus helping to ensure a reliable and continuous water supply.

1.5.2.4 Improvement of Energy Utilization in Water Applications

Opportunities for improving energy efficiency in these facilities fall into three basic categories: (a) equipment upgrades, (b) operational modifications and (c) modifications to facility buildings. Equipment upgrades focus on replacing items such as pumps and blowers with more efficient models (US EPA, 2013).

Operational modifications involve reducing the amount of energy required to perform specific functions, such as wastewater treatment. Operational modifications typically result in greater savings than equipment upgrades, and may not require capital investments. Modifications to buildings, such as installing energy-efficient lighting, windows, and heating and cooling equipment, reduce the amount of energy consumed by facility buildings themselves.

1.5.2.5 Renewable Energy from Water System

Water supply systems can be integrated with a renewable source of energy such as solar cells, wind turbines, and small micro hydropower (Vilanova and Balestieri, 2014). The advantages of such solutions are numerous. It is possible to produce electricity, which can be fed to the national electricity transmission grid or be used locally. From the point of view of water supply systems, such solutions can also be used to power water pumps supplying water to villages and urban areas, or for supplying water for industrial and irrigation needs. Such solutions can provide the backbone for sustainable development in both urban and in rural areas. When compared with conventional water supply systems, these solutions have a lower carbon footprint and contribute towards climate change mitigation.

1.5.3 Smart Wastewater Reuse and System Efficiency

The efficient use of water needs to take into account its safe reuse and the efficiency of the transporting pipe networks, the process treatment costs and the impacts on society. The opportunity for water reuse depends on the industrial wastes entering the sewer networks and the varying standards and capability of the local sewage treatment plants. The designs of sewage treatment plants have historically been specified according to latest scientific knowledge, affordability and to meet the essential requirements for safety in terms of both human and environmental impacts. This then results in the effluent water from sewage treatment plants being discharged at many different standards. However, this volume of effluent water can be more than 50% of the water consumed and used by societies;, therefore any potential reuse can impact directly on society's fresh water needs.

1.5.3.1 Energy for Wastewater Collection

Energy savings in the wastewater utility sector are linked to best management practices and system optimization. There is also a need to identify and optimize existing policies, practices and perceptions to lower energy consumption associated with wastewater treatment use and reclamation of water and wastewater (US EPA, 2013; WERF, 2010). Substantial amounts of energy could be extracted from wastewater. Biogas and biosolids have an enormous potential to offset the energy needs of wastewater treatment plants, and in many places varying degrees of such practices have been started. The potential for renewable energy facilities in water and wastewater to generate energy savings or costs is little understood by many from a holistic impact point of view, and any such analyses will only be advanced once an economic benefit is available or the industry is motivated towards achieving such goals.

The first stage of wastewater treatment consists of a network of sewers collecting wastewater and transporting sewage from the customer to the wastewater treatment facility. Wastewater pumps are intrinsically less efficient (than water pumps) because they pump both liquids and solids. They therefore have greater clearances between the pump impeller and the casing, allowing much of the pumped water to return to the intake. Ideally, agencies should place potable water treatment facilities upstream and at a higher elevation from their customers, with the wastewater treatment facilities downstream and at a lower elevation, to harness gravity where possible to cut back on pumping and treatment costs. Moreover, water intakes are often placed above wastewater outfalls on rivers (WERF, 2010).

Ageing wastewater collection systems result in additional inflow and infiltration, leading to higher pumping and treatment costs. Moreover, infiltration, particularly along coastlines, leads to deterioration of water quality from increased total dissolved solids and poses problems for wastewater reuse.

1.5.3.2 Energy Reduction for Wastewater Treatment

Energy-efficient equipment often has a longer service life and requires less maintenance than older, less efficient technologies. Efforts to improve water efficiency or promote water conservation can also extend the life of existing infrastructure owing to lower demand, and can avoid the need for costly future expansions. Wastewater utilities can improve energy efficiency by modifying of aeration equipment, anaerobic digestion, lighting and heating, ventilating and air conditioning (HVAC) improvements, protection from leaks, installing control software, and using efficient pumping systems (US EPA, 2013; WERF, 2010).

Upgrading to more efficient equipment and right-sizing equipment for the capacity of the facility (plants and pipes often are oversized, to accommodate future peak load). Pumps and other equipment used beyond their expected life operate well below optimal efficiency. In addition, energy is embedded through pipe systems, since leaking drinking water pipes require more energy to deliver water to the end user. Leaky sewer lines allow groundwater to infiltrate and increase the flow of water into the wastewater treatment plant. All water systems have losses, which are cumulative along segments of the water-use cycle. Projects to address water loss and improve end-use efficiency can be promoted as both water- and energy-savings investments.

It is widely recognized that water utilities need improved energy management to develop a better understanding of their current energy use. Optimizing system processes, such as modifying pumping and aeration operations and implementing monitoring and control systems through supervisory control and data acquisition systems, can be used to increase the energy efficiency of equipment.

1.5.3.3 Wastewater Reclamation and Reuse

Most of this effluent or treated wastewater is returned to streams, rivers or lakes. However, recycled water presents many benefits to utilities and customers, such as reduced energy consumption associated with production, treatment and distribution of water; a drought-resistant and stable source of local water; and significant environmental benefits, like reduced nutrient loads to receiving water bodies because of reuse of the treated wastewater and thus avoided discharge (Water in the West, 2013). Water recycling is often one of the cheapest sources of water, after efficiencies in agricultural and urban water use, although high capital investments, public acceptance, strong incentives and legislation are needed.

Human ingenuity has continued to deliver technology that can theoretically treat even the most degraded source of water to a drinking water standard. However, reuse of sewage effluent holds psychological fears for communities related to the possibility that the water may still be contaminated and dangerous, or that human error in treatment may occur. Therefore they are rarely willing to have such water supplied for drinking water purposes, regardless of the scientific advances that enable such standards to be achieved. However, where the water can be reused safely, usually for agricultural use, then communities and environmentalists give enthusiastic support. Unfortunately, the cost of transporting the effluent from the treatment plants to point of reuse, whether by pipes of tankers, is prohibitive. This changes if the environmental impact of discharging locally may result in an environmental or human safety impact, at which point alternative options are essential.

Development of sewer systems evolved from buckets to piping raw sewage into the closest river to treat the waste through a sewage treatment plant. Contamination of potable water from sewage in some instances around the world, has resulted in many countries developing regulatory regimes that have often forced utilities to adopt the most technologically advanced treatment process with its high energy and maintenance costs, to produce a very high-grade effluent, including removing most of the nutrients, which is then discharged into the environment.

Alternative appropriately sized pond treatment technologies that use the environment to treat the water can be more suitable in some cases, where the water is treated to a level that is "fit for purpose" and recycled to agriculture. This would also recycle the nutrients from whence they came. The dissolved nitrogen and phosphorus contained in this water is ideal in promoting crop growth. This provides a large water reuse capability for towns and semi-rural areas.

Domestic Wastewater Treatment in Developing Countries, Earth Scan (Mara D., 2004) which promotes the use of lagoons that are appropriately sized. Treatment quality is a function of the length of time the wastewater is detained in the lagoon. The diurnal pH fluctuations due to algal blooms destroy the pathogens, in conjunction with other natural processes, and deliver a safe water for reuse. The scale can be from a small village through to mega-cities of the future including Nairobi, Kenya. Further work undertaken in Queensland, Australia for small remote inland rural communities in central Queensland has proven that it is possible to improve effluent quality with minor amendments to existing lagoon treatment plants. Lagoons also have the added advantage of not requiring high skill levels to operate and maintain.

Fit-for-purpose recycled water has been successfully demonstrated in Queensland for the past 20 years. Sewerage is treated to deliver a class B effluent which is predominantly used to irrigate sugar cane and plantation eucalypts. In this period over 39 gigalitres of recycled water was beneficial reused, preventing over 840 tonnes of nitrogen and 114 tonnes of phosphorus from being discharged into the environment, and at the same time improving crop yields. Table 1.3 demonstrates achievable crop yields.

Figure 1.23 Rock filter upgrade to third lagoon – Biggenden STP, Central Queensland, Australia (Robbins and Heron, 2014)

Table 1.3 Wastewater irrigation - production improvement in Sugar Cane, Queensland Australia (Heron D, 2013)

Farm type	Tonnes cane/ per hectare	Tonnes of sugar/ per hectare	AUD$/ per hectare
Dry land (No Irrigation)	54.6	6.29	970
Wastewater Irrigation	79.2	10.22	1753
Improvement with recycled wastewater	45%	63%	80%

At the other end of the spectrum is recent work using titanium oxide photocatalysis to produce hydroxyl radicals, which has proved to be effective in decomposing virtually all organic contaminants and oxidising various anions. Photocatalytic water treatment is fast emerging as a treatment for the future owing to the potential low energy input required once further advances are made (using ambient UV as opposed to on-site generated UV to excite the catalyst). With improvements that are envisaged, this technology has the potential to be more competitive in both cost and reliability than existing technology (e.g. ozone, activated carbon).

1.5.3.4 Energy Production from Wastewater Reatment

In addition to energy savings linked to best management practices and system optimization, substantial amounts of energy could be extracted from wastewater treatment. Some water utilities are generating energy on-site to offset purchased electricity (WERF, 2010). Beyond efficiency measures, they illustrate ways in which water utilities are reducing their energy costs by recovering energy from municipal waste and by using the resulting biogas to generate electricity, heat the plant, and in some cases sell electricity back to the grid.

Biogas from sludge has a great potential to compensate for the demand for energy to operating wastewater treatment plants. Capturing the energy in wastewater sector by burning biogas produced from anaerobic digesters in a combined heat and electric power generating system allows wastewater facilities to produce some or all of their own electricity, making net zero extra energy needs.

Sludge to fuel technology involves converting sludge to an alternative fuel and in so doing achieves long-term, stable recycling in wastewater sludge treatment. The resultant biosolid recovered fuel can be sold as a valuable product and is a more cost-effective way of recycling dewatered sludge than disposal. It is also helpful in reducing greenhouse gas emissions, using carbon-neutral sewage sludge as solid fuel. Carbinization technology can make efficient use of the heating value of sewage sludge by drying to low moisture content, and making further beneficial use of sewage sludge by producing a pelletized, easy-to-handle biosolid recovered fuel as a substitute for coal.

1.5.3.5 Renewable Energy from Wastewater System

Some power supply technologies can also be used by wastewater utilities to supplement their commercial power sources (WERF, 2010). To be effective, these auxiliary and supplemental sources can provide the power necessary to run the wastewater treatment plant efficiently and effectively, and have a short start-up time if they are to be used in an emergency.

Wastewater utilities can implement cogeneration and other on-site renewable power options to provide reliable power to wastewater treatment plants on either a continuous or emergency basis. Although diesel or natural gas power generators have been used to reduce peak energy demands on a short-term basis, novel technologies such as solar panels, wind turbines, low-head hydropower, fuel cells, wastewater heat recovery and co-digestion driven generators can provide on-site renewable power on a continuous basis Water in the West (2013).

1.6 SUMMARY AND RECOMMENDATIONS

1.6.1 Recommendations for Urban Water Efficiency

For urban water efficiency, it is recommended that the governments and international aid agencies are asked to review with urgency their collaborations to reduce the unacceptably high levels of water losses in many parts of the world, and to set targets for gaining success in each country. They are encouraged to radically alter their own programs to achieve worldwide improvements, and to form project collaborations with regional and international water associations. All water utilities provide an annual water loss audit and a 12 month plan for further reductions. Utilities report losses using the International Water Association's infrastructure leakage index, and also losses related to the number of connections/and/or length of water mains in litres per connection or kilometer of mains, specifically avoiding percentages. The research on ground-penetrating radar is encouraged and advanced, or alternatives are investigated.

The research is encouraged on water pressure controls (pressure reducing valve) that return energy to communities. The research is encouraged to investigate low-cost methods of leakage identifiers on all new underground pipework. The all utilities employ a water demand management officer with responsibilities for reducing underground losses. All water utility boards, and corporations are briefed on the importance of water loss reduction and the benefits of having water losses as a key performance indicator of the organization. The meter manufacturers are encouraged to research, with smart meters on the inclusion of time of day billing and the identification of irrigation timings separately to domestic usage. That methods are identified to resolve comprehensive and standardized urban water pricing issues. Appliance/water use technology replacement is accelerated; and water-efficiency standards are updated. A loading order for water that can serve as a guidepost for policies and decisions at local, regional, and country levels is adopted. Water utilities increase investments on water-efficiency projects. It is necessary to collect more and better water-use data.

1.6.2 Recommendations for Industrial Water Efficiency

There are some requirements for smart industrial water efficiency, which consist of economic, technical, regulatory, institutional and educational, and informative efficiencies. The industrial water efficiency recommends to encourage water audits of industry which log all pressures and flows and to avoid undervaluing water prices. Also, it is necessary to utilize incentives and disincentives for water saving and conservation. Encouraging the development and improvement of water efficient technology and employing regulations and provisions to encourage industrial water-efficiency. It support various educational programs to educate industrial water users on the real value of water and develop a smart informative water management system to collect all water-related monitoring data. Finally, rehabilitate aged water networks and water-related infrastructures based on infrastructure asset management assessment and inspections are suggested.

1.6.3 Recommendations for Agricultural Water Efficiency

All agricultural regulators should be encouraged to identify the world's best practice to introduce major water efficiency standards and requirements.

The world faces the enormous challenge of producing almost 50% more food by 2030 and doubling production by 2050. This will probably need to be achieved with less water, mainly because of growing pressures from urbanization, industrialization and climate change (OECD, 2010). It will be important in future for farmers to receive the right guidance to increase water use efficiency and improve agricultural water management. Water efficiency improvements can provide several important benefits to farmers. In particular, they can increase yields and improve crop quality while reducing fertilizer, water, and in some cases, energy costs, resulting in higher profits. Additionally, the efficiency can improve the reliability of existing supplies and reduce vulnerability to drought and other water-supply constraints (Pacific Institute, 2014). Different structural and non-structural alternatives have been tried to make more efficient water management in agriculture, and there should be further discussion on modelling and monitoring approaches for water management, wireless technology for smart water management, adopting advanced spatial information technology (geographic information systems and remote sensing), encouraging financial investment and sustainable research and development for increasing agricultural water efficiency and financing water management infrastructure for agriculture.

1.6.4 Recommendations for Energy Efficiency

That water utilities perform an annual energy usage audit, and develop a 12-month plan for energy reduction. Energy is required to extract, convey, and deliver water of appropriate quality for diverse human uses, and then again to treat wastewaters before their return to the environment. Energy efficiency in the water and wastewater sector targeted to reduce energy consumption, to recover energy and resources, and to minimize the environmental footprint of water and wastewater systems.

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Recovery

Main Focus 2

Resource Recovery from Water and Wastewater Systems

Global trends, current technology and practices, and existing examples of resource recovery are expounded on as a means to illustrate the practical need and opportunity for a concerted effort towards greater resource sustainability through holistic application of resource recovery methods.

Resource Recovery from Water and Wastewater Systems

2.1 INTRODUCTION

The current global environment has shown trends of increasing urbanization, growing and more unevenly distributed world population, and extreme events of floods and droughts due to climate change. Such factors are leading to greater pressure on the usage efficiency and allocation of water, nutrients, and land around the world. Furthermore, with the rise in global population, there will be higher resource utilization and an increased need for resources such as clean water. By necessity, this leads to greater treatment demands and consequently more costs as well as energy usage. However, with current practices, although recovering resources from facilities such as wastewater treatment plants has drawn increasing attention worldwide, large amounts of used water are still being dumped or drained directly back into nature, especially in low-income countries. It is time that used water (henceforth called "used water" in some parts of this paper) is re-examined and considered as a form of used solid, gaseous, and aqueous resources.

Driven by environmental, economic, and ecological benefits, the importance of water conservation, source separation, energy efficiency, and resource recovery from water and wastewater systems are becoming more globally recognized. The development of re-use and recycling within the water and wastewater sectors provides major opportunities for improving environmental performance, creating climate benefits, reducing costs, and further supporting the resilience of human and natural systems under water stress.

Resources recovered from water and wastewater systems can range from water itself to energy, nutrients, and other materials. Currently, there are already some real applications for reused water (indirect or direct potable reuse) and recovered materials in agricultural, industrial, aquifer management, and urban applications.

2.1.1 Objectives and Structure of This Chapter

Resource recovery from water and wastewater systems is now a rapidly developing field where science, technology, and practice come together. A range of new initiatives is underway to promote and accelerate the development and uptake of resource recovery science and technologies. Innovation on resource recovery in the water cycle has been evolving quickly, but examples of large-scale and marketable applications from current scientific innovations are still lacking. The key issue is how to move from new research and innovations to pilots and further to full-scale applications, while taking into account the following: (a) investment opportunities for scaling up research and innovation; (b) the market potential for the resources recovered; (c) appropriate public policy, stricter regulations, and institutional arrangements to support and accelerate resource recovery; (d) coping with potential emerging pollutants persisting in the recovered resources; and (e) the needs of multiple stakeholders integrated into technologies, markets, policies, new initiatives, current research, and innovative applications. In practice, resource recovery is also directly linked to the scale of the water and wastewater systems (centralized versus decentralized, for example), and to the locally specific conditions.

This chapter has the following aims: (a) to update water professionals, other interested professionals, and policy makers on the current status of resource recovery from water and used water; (b) to raise awareness among policy-makers in order to raise goodwill and to influence its acceptability by the public of recovered resources; (c) to stimulate change through clever economic incentives for innovation; and (d) to contribute to the build-up of legislative bases and guarantee the quality of recovered resources.

Following the introduction, the key drivers for recovery of each respective resource will be described, and the current practices on the scientific and technological aspects of resource recovery from water and wastewater systems will be addressed, supported by examples of its applications and by research needs. There are many new ideas and emerging research and innovations developing. Therefore one of the sections will be devoted to addressing some examples still at the lower part of the innovation curve. Further development of resource recovery faces many obstacles, and thus the most important challenges that currently exist will be described thereafter, together with some proposed potential solutions and best practices. In this context, consideration is also given to the consequence of building new "resource recovery plants". At the end of this chapter, a research agenda on how to move this forward and how to scale up innovations relating to resource recovery from water will be suggested.

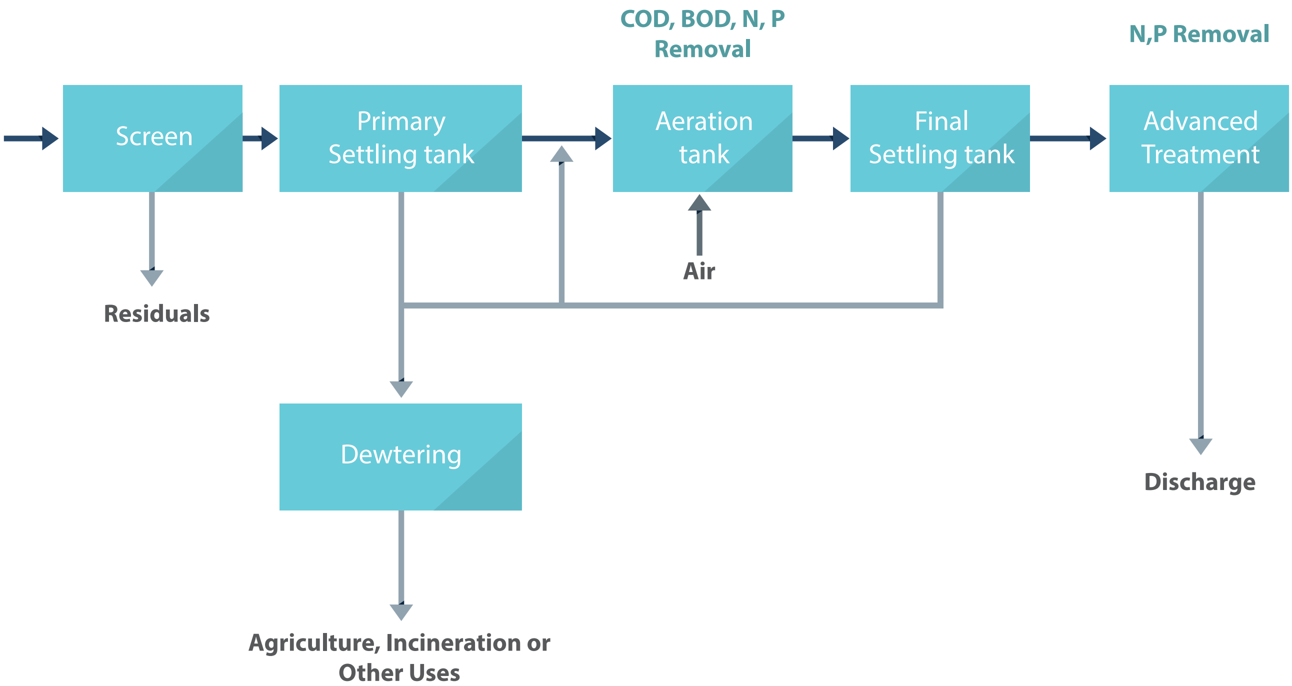


Figure 2.1 Conventional wastewater treatment (Namkung, 2014)

2.2 RESOURCE RECOVERY, ITS DRIVERS AND CHALLENGES

As the term implies, resource recovery is the practice of recovering resources. The phenomenon can most easily be described as making use of a resource that otherwise go to waste. There is currently a fundamental shift in the way we use resources and value used water. Conventionally, used water is treated by removing nutrients, discharging treated water, and utilizing residuals for agriculture and other uses (Figure 2.1). In this process, valuable nutrients and resources are wasted and the environmental impacts from landfills accumulate over time.

A wastewater treatment plant in which a focus on resource recovery is applied, provides an example of a structure that tries to maximize the outputs of such a process. An example is illustrated in Figure 2.2. This figure gives an overview and contrasting example of how a wastewater treatment process can be constructed and which types of product might be recovered from the treatment system (e.g., fertilizers, heat, metals and fuel, etc.). The substances and methods used in this visualizing example will be elaborated upon in the following text.

The recovery of resources can be divided into several sections. In the text below, the practice is divided into the components of water, energy, nutrients, and other high-value-added components. Some examples of what recovered resources entail are provided in each section, as well as an investigation of typical drivers for each respective resource.

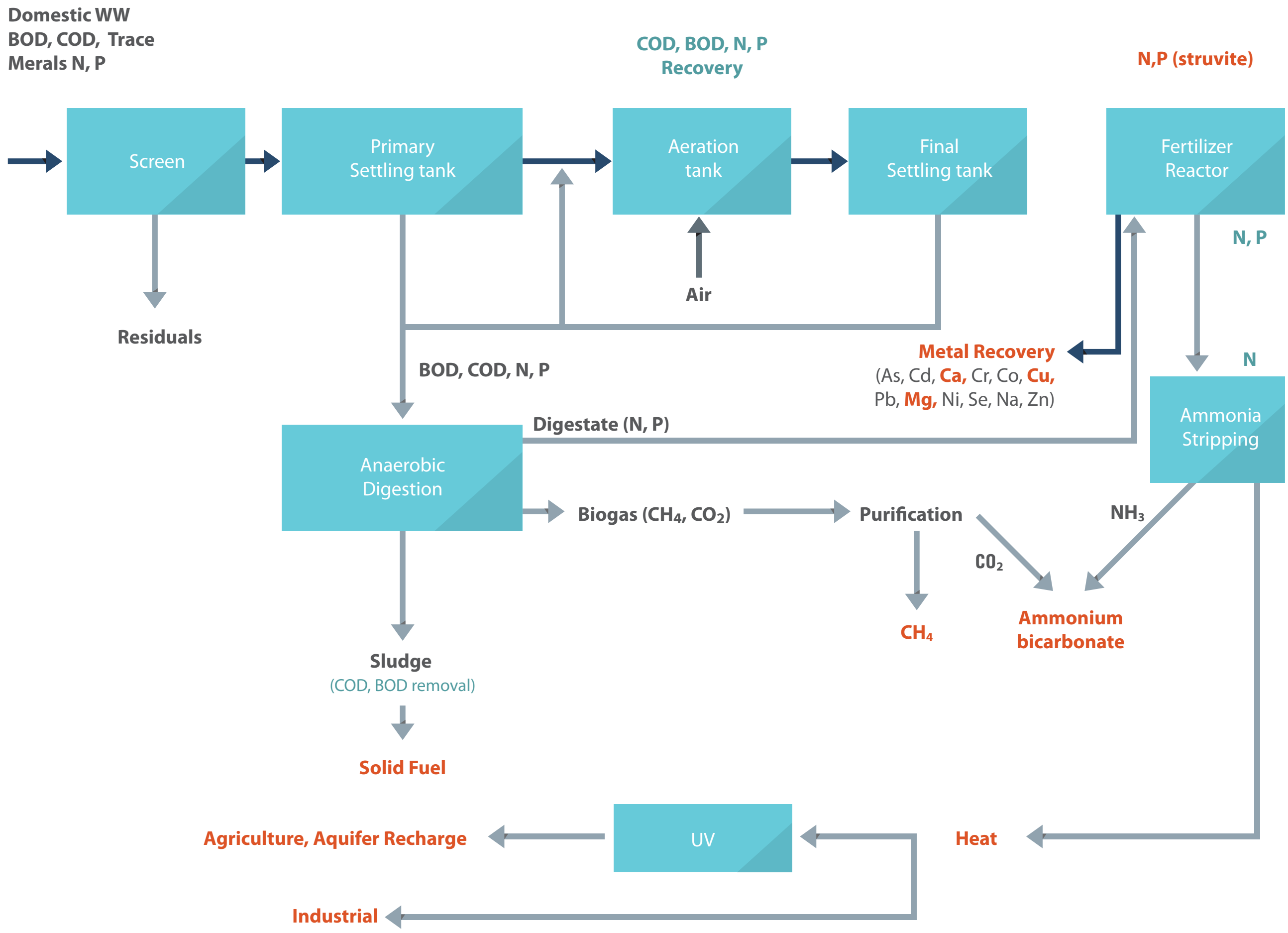


Figure 2.2 An example of a new paradigm wastewater treatment (Namkung, 2014)

2.2.1 Water

2.2.1.1 Water Reuse

Water is one of main substances that can be seen and used as a recovered resource. It is the first matter elaborated upon as it is viewed as the most important. Water can be recycled from various sources and to varying degrees. The number of uses for the end-product is in direct correlation to its level of treatment. Two different ways water can be recycled are through wastewater treatment plants and through water desalination units. In the former, polluted water is cleaned to a specific standard depending on the usage of the end-product whereas the latter entails removing salts and other minerals from saline water. Examples of desalination are often seen in coastal areas. As for used water, it can contain up to 99.5% of water (Meda et al., 2012), and therefore beholds an enormous pool of resources. Used water can be collected, for example, from households and industries.

There are three distinct phases in which water can be treated: primary, secondary, and tertiary. No use is recommended after primary treatment whereas the number of instances water can be used increases with augmenting treatment (US EPA, 2012). A portion of suspended solids is removed in primary treatment while secondary treatment entails removing a fraction of these substances, typically followed by disinfection. Tertiary treatment, or advanced treatment, involves removing nutrients as well as suspended and dissolved solids, among others. Advanced oxidation processes and ultrafiltration followed by reverse osmosis are additional barriers against microbial and chemical contaminants (Drewes and Khan, 2011).

The end-product of recycled water can be divided into different categories. One of these is that water from a treatment plant process can be reused internally within the plant, for example for transportation or for energy production. Examples of such can be seen from a water reclamation plant in Singapore in which industrial water is used for semiconductors, and from a Pohang wastewater treatment plant in South Korea that reclaims used water for reuse in steel mills. A second category of recovered water is for non-potable uses, while the third is for potable usage. Non-potable water can be used, for example, to water lawns, and for showers or cleaning. Another example includes recharging groundwater and saltwater intrusion barriers. Examples of both cases can be seen in Belgium (Dewettinck et al., 2001) and in the Orange County Water District (OCWD) in California in their Groundwater Replenishment System, in which pipelines transport water from an advanced water purification facility and to a seawater intrusion barrier (Lenker et al., 2014). A picture of one of the facilities can be seen in Figure 2.3. Other examples of such practices include management of aquifer recharge and aquifer storage and recovery. Management of aquifer recharge is based on the role of geobarriers within the non-saturated zone of the aquifer whereas aquifer storage and recovery uses various sources of water, which allows inter-seasonal freshwater storage in existing aquifers.

Figure 2.3 Water treatment facility in Orange County, California, USA

Irrigation is another use for non-potable water. Currently 10% of the world's crops are watered with reused water as irrigation water (Jiménez and Asano, 2008). This percentage varies regionally, with an extreme in Vietnam where the equivalent number is 80%. Statistics show that the agricultural sector is the biggest user of water, consuming 70% of the total worldwide withdrawal (World Bank, 2011) and, thanks to its oxidative capacity, has the potential to mitigate several types of pollution. It is therefore of use to match such huge demand with the appropriate supply.

Today's technology has enabled us to treat used water to a degree that it can be used for drinking. Recycled water as potable water can be used both directly and indirectly. Advanced treatment, which is typically a combination of tertiary water and ultraviolet filtration, can produce water that can be used for drinking. An example is the plant in Oostduinkerke in Belgium (Dewettinck et al., 2001). Another is in Singapore with its potable recovered water that goes by the name 'NEWater' (Tortajada, 2006). A third example is Windhoek in Namibia, which has had its direct potable reuse plant running since the late 1960s (Law, 2003). Recovered and recycled water can also be used for drinking purposes after it has first been discharged into an environmental setting, such as a pond, before it is treated to drinking water quality standards.

2.2.1.2 Drivers

As can be seen, there are several steps and phases in which water can be recovered. Reasons for this push can be many, and drivers are seen both at local and at global levels. One important factor is water scarcity. Worldwide demand for water is increasing due to population growth and changing lifestyles including changing dietary patterns. This is evident because global withdrawals have tripled over the past 50 years (WWAP, 2009). It is estimated that withdrawals for water will exceed current accessible and reliable supplies by 40% by the year 2030 (Addams et al., 2009). This huge gap can be minimized by methods of using recovered water.

A report from 2014 further shows that 700 million people across the world do not obtain drinking water from improved sources (WHO/UNICEF, 2014). As consumption of water is necessary for survival, a deficit of the resource can turn into a question of national security and independence. One big motive behind the success of the Public Utilities Board (PUB) in Singapore is because they wanted to decrease levels of water importation from Malaysia (Tortajada, 2006).

Water scarcity can be linked to the number of available water resources. One underlying factor to Windhoek's progressive idea of using recovered water was that they did not have any alternative water sources (Law, 2003). The dry region of Saudi Arabia is another example as it has a goal of meeting 10% of its water demand by water reuse (Redwood and Huibers, 2008). During a severe drought in Australia from 2005 to 2007, water consumption decreased from 300 to 130 litres per day (Olsson, 2012). This is another example that illustrates the driver of water awareness correlated to limited supply.

For treatment plants, using water that is already being transported to the plant and re-using this internally is much more effective and efficient than using external water for such purposes. Therefore, costs can be directly offset. The economic benefits of using recovered water can also be noticed when using reclaimed water for non-potable water uses, such as flushing toilets. Money is saved as this water does not need to be treated to drinking water standards. Another procedure related to costs is the link between water quantity and water quality. Discharging water into water bodies that has not been cleaned can be damaging to the environment and can disrupt the ecosystems into which it is released. From this point of view, cleaning water that is being discharged is cheaper than rehabilitation or reconstruction of a disoriented ecosystem.

Financial assets as a driver can also be seen on a household level. In Swedish households, total water consumption was reduced by 20% upon installing individual water meters (Olsson, 2012). This example highlights publically shared information as a further driver for the wiser use of resources.

2.2.1.3 Challenges for Water

While the drivers are many, there are also several challenges in recovering water. Treating water to a certain level requires a pool of resources, including adequate equipment, financial assets, expertise, and knowledgeable staff. It is also necessary that the quality is assured through testing. Apart from the technical and scientific skills and equipment that are required for control, it is also necessary that a functioning, trustworthy regulatory body is functioning. This body needs to follow guidelines and set structures in place.

Another challenge could be the rules and regulations themselves. One challenge might be that there is a lack of guidelines and set documentation in how to go about testing, or to have acknowledged targets. On a global level, there are very few documents guiding recovered practices. One of the few that exists is the World Health Organization's "Guidelines for the safe use of waste water, excreta and greywater" (WHO, 2006). Even on a regional level, it is rare to see such documentation. The European Union has its Water Framework Directive with the overarching goal of reaching good ecological status in water bodies in all European Union countries, yet it lacks Union-wide standards in terms of water reuse as well as in the interconnection between water and energy (Schröder, 2014).

Rules that do exist, such as on a national and local level, can be viewed as too rigid and strict and can indirectly be an obstacle by making the practice too costly. The regulations set need further to be appropriate and targeted to the local context for them to be credible and enforced. For example, when irrigation with used water was banned in Ghana and Senegal, the policy was mostly ignored (Redwood and Huiters, 2008) because of the imminent need for water.

If water to and from treatment plants is to be used for different purposes, such as for both potable and non-potable uses, an infrastructure is needed. Separation of pipes is then not only needed in the plant but also in the households and industries. It is costly and can be tricky to change this with existing buildings in place, whereas it is easier to include such ideas in the designing and planning phases. Buildings must further be connected to a treatment plant that applies such distribution, or to several different treatment plants to satisfy the needs.

The human mind-set and way of viewing water is another factor that can be both an obstacle and an opportunity. Water is often regarded as an abundant resource, which makes it more difficult to motivate practices of recovering it. The way that treated water is valued is also a question put forth for discussion. Furhtermore, there is a debate on the use of water both for potable and for non-potable resources. Some people would not want to drink water that has been treated from a wastewater treatment plant, even though it does not inflict any damage to the human body. This is commonly known as the "yuck" factor. There are numerous examples in which planned water reuses have failed because of such opposition. One of these is from California, in which the public's unwillingness towards water re-purification halted the project (website : 2, 3). A contrasting example from a multi-use recycling project from the West Coast of the USA highlights efforts in social awareness about water reuse as a factor in its success (Po et al., 2003). One reason why the Singaporean example has been so successful is because of its targeted effort in marketing the brand of potable water as safe and informing the community of the different processes and treatment procedures. Using non-potable water for irrigation or applying human excreta as fertilizers are other examples in which the attitude of the practice has altered its speed of implementation. It is therefore vital to encourage acceptance from the public and decision-makers while planning construction of water recovery facilities.

2.2.2 Energy

2.2.2.1 Energy Efficiency and Recovery

Energy is another important resource that can be recovered. An important reason to focus on energy for resource recovery is that the energy contained in used water is theoretically sufficient to cover the energy that is needed for its treatment (Lazarova et al., 2012). Potential energy, chemically bound energy, and thermal energy are different major forms of energy contained in used water (Meda et al., 2012). To a large extent, energy from used water is stored as thermal energy. The process of treating used water both requires energy and can produce different forms of energy in the procedure.

As with water, energy can be recovered from water in several ways. One of the two major routes of recovering energy from used water is to turn sludge into biogas through anaerobic digestion. The other method is to concentrate the sludge and transport the digested product for central incineration, with or without anaerobic digestion beforehand. The former can recover electricity and heat when a combined heat and power system is installed whereas the latter turns sludge into heat.

In an anaerobic digestion process, microorganisms transform the readily biodegradable portion of volatile solids in sludge (also called biosolids) into biogas. The latter is a mixture of methane (usually about 65%) and carbon dioxide (the remaining 35%). Sources of biogas include used water containing fermentable organic matter, landfills rich in organics, livestock wastes, and food wastes. Biogas can be upgraded and supplemented to compressed natural gas and liquid natural gas, of which the latter can be used as fuel in vehicles. Using biogas instead of natural gas requires that the biogas is enriched in methane and that carbon dioxide is removed. Processes such as pre-treatment in which the bacterial cells present in the biosolids are broken, and co-digestion in which readily biodegradable feedstock is added, are ways to enhance the biodegradable portion of biosolids from which biogas can be produced. Within the treatment process (excluding the energy loss due to heat dissipation) about 80% of the chemical energy contained in the original reduced matters can be transferred into methane; around

35% of the embedded energy in the methane can then be converted into electricity in a combined heat and power unit (Batstone et al., 2015). The overall energy recovery efficiency is about 28%.

Heat recovered from treatment plants can be used for district heating, sludge drying, and thermophilic heating in a sludge digestion process (Hawley and Fenner, 2012). Thermal energy from used water can be concentrated by heat pumps. In 2008, 500 used water heat pumps, with thermal capacities varying between 10 kilowatts and 20 megawatts, were in operation (Schmid, 2008). The heat can be used on-site and off-site for district heating. China, Finland, Switzerland, and Canada are examples of countries in which thermal energy recovery from used water has been tested (Hawley and Fenner, 2012).

Currently, most recovered energy from treatment plants is used on-site. This includes both producing electricity and heat needed for the ongoing processes. An example in which the produced energy is transported elsewhere is a treatment plant in Strass, Austria, which sells their excess electricity back to the grid.

One way to reduce the energy needed for treatment of used water is to substitute energy-demanding processes by less demanding ones, for example by replacing the nitrifying–denitrifying bacteria with anammox bacteria. These latter bacteria are anaerobic ammonia-oxidizing organisms which typically require sequencing batch reactors for the process. The previous focus on energy efficiency is, however, currently shifting to energy neutrality instead, and having production that exceeds consumption, which is illustrated by the Austrian example.

2.2.2.2 Drivers

As with motives to recover water, multiple benefits can be linked to recovering energy. Globally there is a huge demand for energy. Research shows that our energy consumption has seen an annual growth rate of 2.4% during the past decade (1). Further numbers indicate that our energy consumption will increase by more than 8,000 million tons of oil equivalent in less than 30 years (Global Energy Statistical Yearbook, 2013). This alone is a reason to make optimal use of energy sources, both by reducing energy needs as well as recovering energy.
One important factor in recovering energy is the money that is to be made, or rather saved. Energy is typically the single most expensive item in a treatment process. In a wastewater treatment plant, energy can be derived through using internal sources that are at hand to create fuel. In producing energy, money does not have to be in place continuously, nor is infrastructure necessary to import energy from elsewhere. There is, however, an initial start-up cost related to such conversion, and therefore long-term thinking and an appropriate investment plan are needed.

A driver of energy recovery can be the demand. One such example is the Austrian treatment plant, which sells the excess energy back to the grid (Crawford, 2010), thereby making money while meeting a need. Energy produced can also be sold as fuel. An example from Stockholm, Sweden, shows that biogas produced within treatment plants is used for the capital's bus fleet (Jonerholm, 2012). These examples provide a glimpse of how the buyers and users for recovered energy can be multiplied. The latter example can be correlated to rules and goals, which can singlehandedly act as drivers. Stockholm has a goal to be fossil-fuel free by 2050 (City of Stockholm, 2014). This aim functions as an incentive to produce the supply, such as biogas, that can help meet that goal and upcoming need.

As is the case with recovered water, energy can easily become a question and interest of national security. A country that is able to produce its own energy will have less dependence on energy-rich countries, which can tie into political will and diplomacy. This is an example in which incentives that stem from other sectors can affect the coverage and speed of recovery. Emission of greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, can also be reduced through the process of recovering resources in the energy-field, which can also act as an accelerator of the practice. One of the two main drivers for the energy-producing plant in Austria was its aim to reduce greenhouse gas emissions (Wett et al., 2007).

2.2.2.3 Challenges for Energy

One challenge relating to energy efficiency and recovery is that some energy sources produced are not suitable for storing or transporting long distances. This requires that the facility producing the energy is close to where the energy is to be consumed, thereby avoiding unnecessary costs and avoiding energy loss in transportation.

There is further a question of demand versus supply, and how they feed each other. If there is no immediate demand, treatment plants might not be enticed to produce a specific product that is not in demand. In Strass, Austria, the municipality offers to buy any leftover energy. Such institutional infrastructure, therefore, needs to be in place, apart from the physical infrastructure itself. The latter requires resources such as skills and money. It is easier to argue for such an extension if there is a known buyer at the other end.

Another challenge is that recovered energy needs to be able to compete with fossil fuels. Fossil fuels are well known, established, and implemented into the system already. Devices and mechanics for handling non-fossil fuels, such as biogas, need to be adjusted accordingly. A huge limitation noticed with compressed natural gas and liquefied natural gas is lack of a widely extended infrastructure for gas filling stations. This component requires resources and a will. Governments have been seen to initially subsidize biogas cars to kick-start the market.

The importance of using recovered energy is not only limited to institutions and governments but also to households. In many Scandinavian countries, people sort their organic waste, which is converted into biogas. Some treatment plants further collect organic waste from industries, such as restaurants or facilities producing organic waste, that also need to separate their waste correctly and have the infrastructure in place for doing so.

Classification of different substances can become a further obstacle. For example, biosolids in the USA are classified as solid waste as opposed to a renewable fuel (WERF, 2013). This makes it difficult to receive money or other incentivizing means when wanting to turn biosolids into energy. The same difficulties can be seen when materials are regulated as hazardous waste (Allen, 1993).

2.2.3 Nutrients

2.2.3.1 Nutrient Recovery

There are multiple nutrients that can be recovered from wastewater treatment plants. The two that are most commonly discussed are phosphorus (P) and nitrogen (N). Removing these components from the liquid stream is an acknowledged and executed practice (WEF, 2009). Even so, however, the act of recovering these substances is limited. Chemical phosphorus products are the main focus within nutrient recovery (Latimer et al., 2012). Recovering

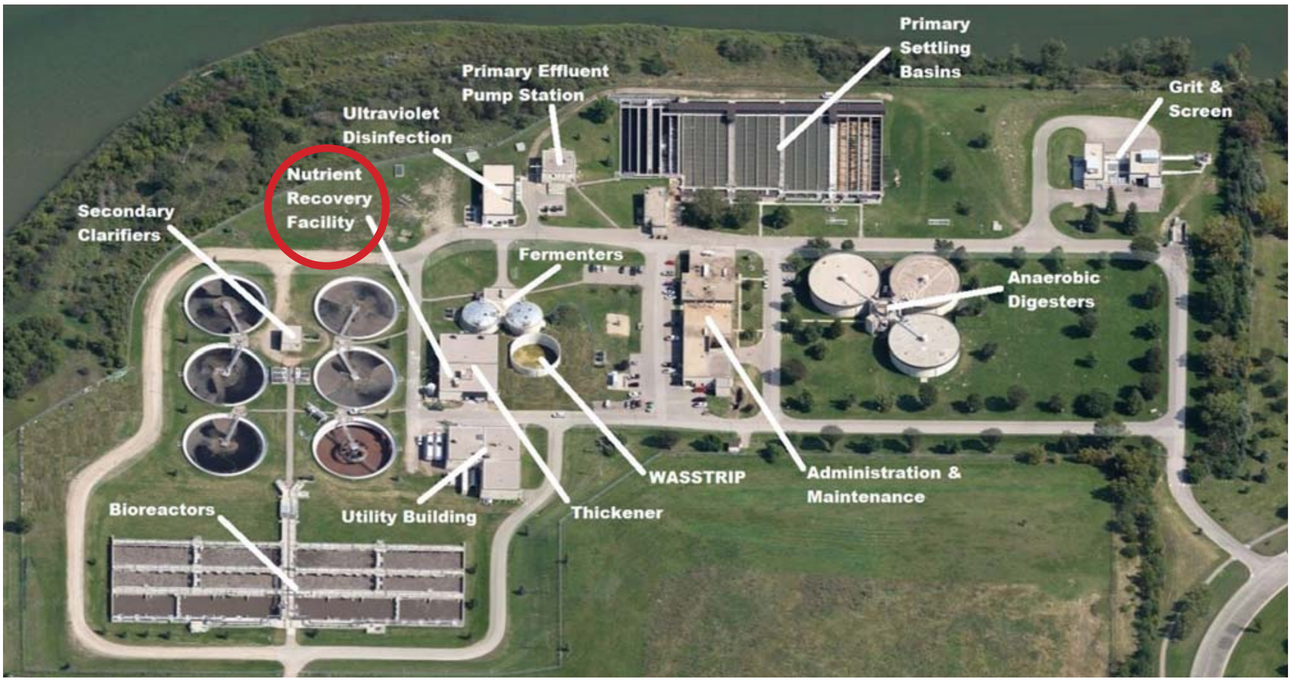


Figure 2.4 Saskatoon wastewater treatment plant, Canada

phosphorus from used water can be in the form of magnesium ammonium phosphate, calcium phosphate, or iron phosphate. Magnesium ammonium phosphate, or struvite as it is more commonly known, can be separated from used water because of its specific gravity (Latimer et al., 2012). In struvite production, nitrogen can also be recovered. Techniques typically require concentrations exceeding 1,000 milligrams of NHL (Morales et al., 2013). Research shows that for both phosphorus and for nitrogen, crystallization is the established technique with the highest recovery rate (WERF, 2012).

Recovered phosphorus and nitrogen, for example can turn into fertilizing pellets. Struvite is an example of such a component, as is ammonium sulphate, which can be produced from the sludge digestion processes by stripping and adsorption. A treatment plant in Olburgen, the Netherlands, is an example where struvite is produced in the form of a fertilizer (Shultz, 2009). One of the facility's treatment plants deals with rejected water for an industrial processing plant producing potato chips. The high amount of phosphate in the potato peel is used to advantage (van Lersel, 2014) and results in the marketable product of a fertilizer that is used on sport fields, among others. Other examples of treatment plants that produce fertilizers include wastewater treatment facilities in Maine, USA, and in Saskatoon, Canada. The latter is illustrated in Figure 2.4, in which the nutrient recovery facility is circled.

Moreover, there are developments underway in which the nitrogen is upgraded to microbial biomass, for instance by means of hydrogenotrophic bacteria, and thus can be recovered as a high-value edible microbial protein (Matassa et al., 2015)

2.2.3.2 Drivers

There is a growing gap between demand and supply for nutrients worldwide. Most evident is that of phosphorus, which is primarily used as fertilizer in agricultural production and for which there is no substitute. Some talk of 'peak P' and estimate that this will occur by the year 2033 (WERF, 2012). If the stock keeps being used at the current rate, the global reserves of the non-renewable element will be exhausted within 80 years (Jasinski, 2012). Recovered nutrients represent a desirable product that at the same time preserve the declining pool of resources.

Furthermore, 90% of the phosphorus stock is found in five countries in the world (WERF, 2011). These countries have a trade advantage over importing countries. Once again, recovered resources can be related to issues of national dependence. If recovering and generating its own phosphorus, a region or country does not have to be reliant on others, which can be a motivational factor in recovering nutrients.

Although phosphorus is non-renewable, reactive nitrogen can be derived from the Haber-Bosch process. This energy-intensive process costs money, which could be further saved if nutrients are recovered instead. The production of reactive nitrogen and ammonia nitrogen also produces considerable amounts of greenhouse gases and is dependent on natural gas, which would then be minimized if production was done differently. It is estimated that our use of nitrogen will triple between 2000 and 2050 (Leflaive, 2012).

Both nitrogen and phosphorus currently accumulate in the environment at unwanted levels. Receiving waters can be disrupted by a high influx of nutrients, and ecosystems can alter in the water body, which can also affect terrestrial surroundings and organisms. An overflow of nutrients in water bodies can, for example, result in a growth of cyanobacteria, and some strains of these blue-green algae can cause illness in people and animals (Backer, 2009). A big driver for removal of these nutrients is, therefore, the pollution and widespread consequences to which it can lead. If a treatment plant put in effort and money in removing these, there could be an economic benefit in recovering these nutrients as well. Penalties in the form of costs of not removing nutrients can, therefore, instead turn into financial gains by selling products containing substances earlier regarded as waste. As there is an immediate need both of phosphorus and of nitrogen, there is already a pronounced demand and market for it.

Regulations can also be a driver for nutrient recovery. In Europe, there is a positive correlation between the countries with the strictest regulations and those that invest in phosphorus recovery at an early stage (Stark, 2004). Examples of such countries are Sweden and the Netherlands. Rules and laws can further be an indirect driver to nutrient recovery as rewards can be distributed to operations practising recovery, or, on the contrary, enforcing fines for the excessive discharge of nutrients.

2.2.3.3 Challenges for Nutrients

As recovery of phosphorus and nitrogen is not yet too common, there are only a few good practices that can be copied and replicated. There is, furthermore, a clear imbalance between the number of technologies that remove nutrients and those that recover them.

Another challenge that occurs when recovering nutrients is that the end-products need to be of the same quality every time. Apart from having technologies that can handle this, this also means that it would be beneficial if the incoming material was always of a similar composition. For a product to be interesting to customers, it is also of relevance that the quantity of the produced material is large and is at a consistent rate. This indirectly means that the incoming material not only needs a specific quality but also a similar quantity.

There is an ongoing debate investigating the positive and negative consequences of using sludge as fertilizer. While taking care of a material that otherwise would have gone to waste, some point out that it is difficult to check levels of mercury and other heavy metals that can appear in the sludge and accumulate over time. Using sludge also presents difficulties with controlling the amount of nutrients that are applied to fields. Plants may have a small window of characteristics, such as pH, that needs to be established for crops to make proper use of the nutrient. The risk is that the excess nutrients will trickle to nearby water streams.

Infrastructure can once again pose challenges. When, for example, wanting to separate urine and faeces at the household level, especially made toilets and a network system of pipes must be in place. This practice can also require acceptance and willingness to use the system properly from the standpoint of the user. When designing such a system, it is therefore of importance to work concurrently with the community in organizing, for example, informational events and campaigns.

Money is another obstacle for recovering nutrients. Apart from the fact that there are start-up and running costs of such facilities, the products must compete on the market. At the moment it is cheaper to mine nutrients rather than to recover them, which is another challenge. Destruction and re-synthesis of active nitrogen is cheaper than recovered nitrogen for example. Furthermore, the market value of nutrients and recovered nutrients is today not fully developed, which can hamper recovery technologies.

Producing a product, such as fertilizer for sport fields, requires a partnership between two different sectors. When talking about recovered nutrients, many are limited to thinking solely about agricultural crops. Eighty-five per cent of all nutrient products are linked to the agricultural sector (Latimer et al., 2012). While the agricultural field is important, a challenge is further to look to recovering products to be used in other sectors.

2.2.4 Other Valuable Components

Apart from water, energy, and nutrients, there is a pool of other compounds and substances that can be recovered. One such example is longer-chain organic compounds that can be broken down into short-chain carboxyl acids by mixed cultures, which in turn can be upgraded to medium-chain carboxylic acids, such as n-caprioc acid (Agler et al., 2012), or long-chain carboxylic acid, such as poly hydroxyl alkanoates (PHAs). PHAs can be converted into biodegradable plastic which, compared with other plastics, are not as harmful to the environment. This has been known for decades, but the reason why it has not become a commercial product is because of competition by plastics made from fossil fuel. It is very difficult to brand a market for plastic at a price that both makes it attractable for customers while yielding a worthwhile profit from it.

One of the industrial chemicals that can be recovered from water and used water is sulphate. This can be done in a two-stage process in which the end-product is elemental sulphur. Apart from producing sulphur, the process can further recover metals, such as copper, nickel, and zinc, as marketable metal sulphides. Another example of a chemical element that can be recovered is copper to be used for wire production, for example. A wastewater treatment plant in China that treats water from an active copper mine in Jiangxi Dexing (see Figure 2.5) recovers this element. The facility has a capacity of treating 24,000 m^3 of water per day. Apart from recovering copper, iron is removed in the procedure. If recovered, iron can be used as a raw material or as a catalyst.

Figure 2.5 Copper-recovering treatment plant, China

When recovering metals, features such as initial concentrations of the metal, origin of used water, and the choice between recovering one metal and a group of metals, are all such that needs to be considered. Ion exchange, leaching, using magnetic nanoparticles, and foam fractionation are examples of technologies that can recover heavy metals (Kurniawan et al., 2006). Noble metals from industrial waste effluent can be recovered through photocatalysis (Kurniawan and Babel, 2003). The by-product ash can be further chemically modified to recover metals from used water (Aklil et al., 2004).

A resource that is new in resource recovery is cellulose. Schiphol Airport in the Netherlands is an example, where wipes used for drying hands are separated and processed into biomass. This idea is also marketed directly to users while informing them of the procedure. Figure 2.6 is a photo of a sticker that is displayed in bathrooms in the airport.

Recovering toilet paper is being further researched. The idea is to extract cellulose at treatment plants and remake the same product again. As with all technologies and ideas, it must function in a suitable context. Recovering cellulose would, therefore, not be applicable in places where the culture is such that toilet paper is not used.

Figure 2.6 Example of a recovered resource. Photograph: Eitrem Holmgren (2014)

2.2.4.1 Challeges for Other Value-added Components

One of the biggest challenges when investigating other value-added components is the overall economics. For example, in metal recovery there are high start-up and operating costs. In the case of PHAs, one of the key hurdles for growth of commercial PHA applications is the price of the biopolymer relative to that of conventional fossil-fuel-based polymers (Anterrieu et al., 2013). Extraction of products from the used water matrix is technologically also a considerable obstacle. As has been discussed, some of the obstacles extend well beyond their sector. This is also important for high-value-added components. In fact, it might even be more important in this field than others, seeing the amount of acknowledgement and research that water and energy is getting, for example.

2.2.5 High- versus Low-income Countries

Challenges and obstacles for resource recovery can differ geographically as well. One distinction that can be made is the number of opportunities that arise in high- versus low-income countries.

In high-income industrialized countries, coverage by sewage facilities is high and practically all used water is treated at an advanced level, which includes removal of carbon, nitrogen, and phosphorus. In low-income countries, on the other hand, sewage coverage and treatment rates are seen to be less than 10% (Van Loosdrecht and Brdjanovic, 2014). This difference in coverage alludes to the amount of attention and focus that resource recovery is getting.

In low-income countries, the amount of recovered resource applications can be linked to limited financial and governmental support with insufficient policy and regulations. One particular example of hindering resource recovery in low-income countries is given by Chandran (2014), which relates to the management of faecal sludge. This example illustrates obstacles arising from the collection and treatment of sludge to the potential sales of biosolids. First, there is a lack of policy and regulations on dumping and collecting the sludge, and there is a high cost of transporting the sludge to a treatment centre. At the treatment stage, there is a lack of political will to invest in treatment of faecal sludge and no funds are budgeted for the operation and maintenance of such treatment processes even if it has been established. Third, even if the sludge is treated and generated into biosolids, there is no market for compost or biosolids, especially if they are for community-based initiatives, which then leads to low sales of biosolids and very limited additional potential revenue coming from biosolids sales. Consequently, this whole cycle is not viable economically.

As such, advanced countries can invest in recovering resources as well as possibly having the institutional framework and infrastructure to put investments into practice. Rules and regulations may further be stricter which can be seen as an accelerator for resource recovery. Regulatory body moreover needs to be in place to quality control and assure the procedures are being executed as decided upon. It has been noted that the rate of development is correlated to legislation (Stark, 2004), which further highlights the critical role of guidelines and laws within the field of resource recovery.

In countries in which the treatment for drinking water is not very advanced, there might not be an incentive for having facilities for treating used water, let alone recovering resources. In fact, in many countries today, water from households and industries is directly discharged into streams, lakes, and oceans without prior treatment. While this is a challenge for starting a resource recovery process, it also provides an opportunity. When building treatment facilities, they can be structured in a way that takes care of the potential resources. For example, water can be internally reused and the facility can heat itself from the products it cleans.

2.2.6 Consequences of New 'Resource Recovery Plants'

Apart from investigating challenges for specific recovered resources separately, it is also worthwhile contemplating obstacles and possible consequences that might arise when building a treatment plant that recovers resources (i.e., a 'resource recovery plant'), or when transforming an ordinary treatment plant to a recovery plant. Infrastructure must, for example, be taken into account. Decentralized and locally situated plants and facilities could be solutions for avoiding large transport distances. For example, a treatment plant in Sweden producing biogas for the buses is located adjacent to the bus depot (Jonerholm, 2012). Units recovering heat from used water is another example in which it is beneficial to have the source close to the point of usage. Another process to consider is separating used water from households and industry, which might be of use and further help stimulate public acceptance and trust.

Finally, it should be kept in mind that once a new resource recovery plant is built, it is heavily dependent on continuity of encouraging overall regulation and legislation. Indeed, experience of subsidy to the biogas sector in Europe has shown that an unexpected decrease in financial support can have dramatic consequences on the overall cost/benefit of installed plants and, moreover, can destroy the willingness of the sector dealing with environmental technology to invest in such recovery approaches. Hence, a major consequence of private, public, or combined investment in recovery plants is that the overall conceptual framework of striving for a cyclic economy and the business model that underpins it must be secured for several decades to come. This might seem evident, but the current fluctuations in the prices of fossil fuel and certain other commodities warrant careful consideration and dedicated commitment upfront for any large-scale industrial action in this domain.

Therefore, a holistic and interdisciplinary approach and will are necessities while discussing and planning increased resource recovery. Collaboration and communication are keywords in a process that requires resources as well as a common vision. This proves another challenge, which can further be seen in other fields of resource recovery practices. It is, consequently, necessary to urge for an open mind, not only when it comes to the development of a specific product but also in the range of possibilities of products to be explored.

2.2.7 Common Traits

As can be seen from the discussion above, there are several recurring challenges that are outlined. Resource recovery can lack financial support and an investment strategy. This relates especially to technologies and ideas that are at an early stage of innovation. In addition, bringing research and innovative technologies into practice also has challenges related to the dimension of scale to establish a business. A rule of thumb is that for the conventional chemical industry, 10,000 tonnes of chemical products are needed per year to be a business. This fact relates to questions such as quantity and quality. Infrastructure is another theme that must be contemplated when discussing resource recovery.

A further general obstacle could be the technologies themselves. For example, some technologies such as those dealing with micro-pollutant removal and effluent disinfection all require energy (Mark et al., in Jenkins and Wanner 2014). This is also the case for desalination plants. As such, there is always a trade-off with the advantages of recovering resources, which needs to be acknowledged.

Another common challenge is the disconnection between different sectors and disciplines. One such is the lack of communication between researchers, industries, and the demand sides. Cultural and social barriers are other aspects leading to obstacles within the field of resource recovery, as well as a proper lead from governments and regulators.

2.3 ACCELERATING INNOVATION

2.3.1 Innovation

Innovation is the process of translating an idea or invention into a good or service that creates value or for which customers will pay. To be called an innovation, an idea must be replicable at an economical cost and must satisfy a specific need. In business, innovation often results when ideas are applied by a company to meet the needs and expectations of its customers.

Increasing pressure on already scarce natural resources drives new developments, the willingness to use resources more efficiently, and finding alternative ways to produce and reuse resources. Since the activated sludge process was presented a 100 years ago (Arden and Lockett, 1914), invention and research in sewage treatment have been developing, and in recent years faster than the past several decades. Up to now, most water technologies have aimed to dissipate the components in used water. But we are moving towards a cyclic economy in which there is the desire to use and reuse

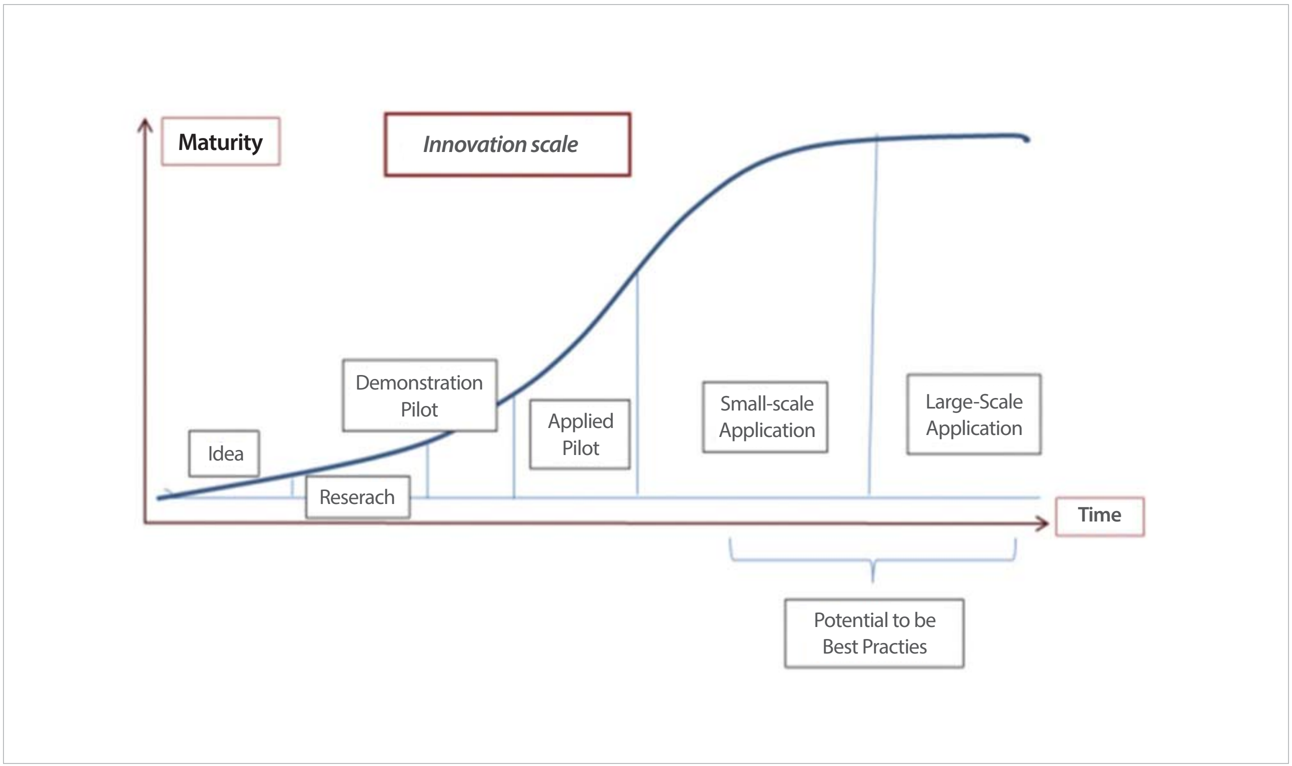


Figure 2.7 Innovation curve (IWA, 2014)

with minimum destruction and further generate profits from recovered resources. For this, new research and new innovations are needed.

There are several phases that a technology or idea must go through to flourish and evolve into a full-scale application. Figure 2.7 illustrates these various stages on a scale of innovation, with the x-axis showing time and the y-axis maturation. The stages can vary in length and resources required. Some technologies, for example, need a lot of prior research and pilot testing before they reach an applied pilot stage, whereas for others it may take longer to move from small- to large-scale applications. The latter have the potential to become both good practices and role models within their field.

However, there can be several simultaneous processes an innovation must go through for new ideas or new research to be obtained. One such can be social acceptance and societal adoption. An innovation is of no use if a technology is fully developed and works well in the laboratory but the users do not accept the procedure or the end-product. Obstacles along the innovation scale are plenty and, as has been elaborated upon in the previous section, can deal with policy aspects, investment, and support in different formats, among others.

Initial ideas and research that provide solutions to existing issues tend to have a higher chance of getting funding for implementation of research and piloting. After reaching the demonstration and applied pilot stages, some real applications might be expected, and even commercialized and used in smaller and larger quantities respectively.

Real applications such as artificial fertilizers have proved that recovered resources can have potential markets.

2.3.1.1 New Research and Innovative Technologies

With sustainability requirements on energy efficiency, water reuse, and resource efficiency, for example, recent changes within water, especially wastewater, systems have been more rapid than in the 20th century. New research and innovative technologies link to biological treatment processes, incorporating discoveries from microbiology into the treatment process and new technologies on recovering chemicals and biofuels, among others. Given below are several examples of innovative technologies that are at different stages along the innovation curve.

New ideas and research at an early stage of the innovation curve can be in the fields of energy, nutrient harvesting, new biomolecules, and food production (De Vrieze et al., 2013; Matassa, Boon and Verstraete, 2015). Some examples are bio-electrochemical systems/processes (BES) (Rabaey et al., 2010; Pikaar et al., 2014); using light or bacteria/algae to capture and upgrade products from used water (Hülsen et al., 2014); implementation of advanced genomic knowledge to make microbiomes function better (McDougald et al., 2012); converting recalcitrant organic materials into building blocks for subsequent biological conversion into liquid fuels and chemicals (Richter et al., 2013); and using recovered resources for biopolymers/hydrocolloids.

Especially in the field of energy recovery and energy efficiency, there are several new technologies that can be seen in practice or read about. Data in McCarty et al. (2011) and Batstone et al. (2015) show that anaerobic used water treatment is the currently most widely applied technology to recover energy from used water, collected as methane production. In the USA, approximately 3% of the total electricity consumption went on used water treatment in the mid-1990s (Burton, 1996). It was predicted in 1996 that electricity requirements would increase by 20% in the upcoming 20 years. As has previously been noted, the overall energy recovery efficiency is approximately 28%. With more effective methane-driven chemical fuel cells, the efficiency capacity can increase from 28% to 40%.

Some innovative technologies within the realm of energy focus on low-energy treatment concepts during the treatment process, such as Verstraete's "major and minor water line system" (Verstraete et al. 2009) and McCarty's low energy mainline process (McCarty et al. 2011). These can contribute to substantial changes from conventional activated sludge to resource-positive platforms (Batstone et al., 2015).

An alternative to the typically used anaerobic digestion for energy recovery is through microbial fuel cells, which generate electricity through oxidation of organic matter by microorganisms (Logan, 2008). Common microbial fuel cell systems consist of an anode and a cathode chamber separated by a membrane. In the system, in which ammonia can be further recovered, used water is treated at the same time as energy is produced through conversion of chemical energy into electrical energy. Several research groups throughout the world are researching the fuel cells. However, because of issues relating to reactor design and electrode configurations, microbial fuel cells have only reached the pilot study stage and none have been demonstrated as feasible beyond the laboratory scale.

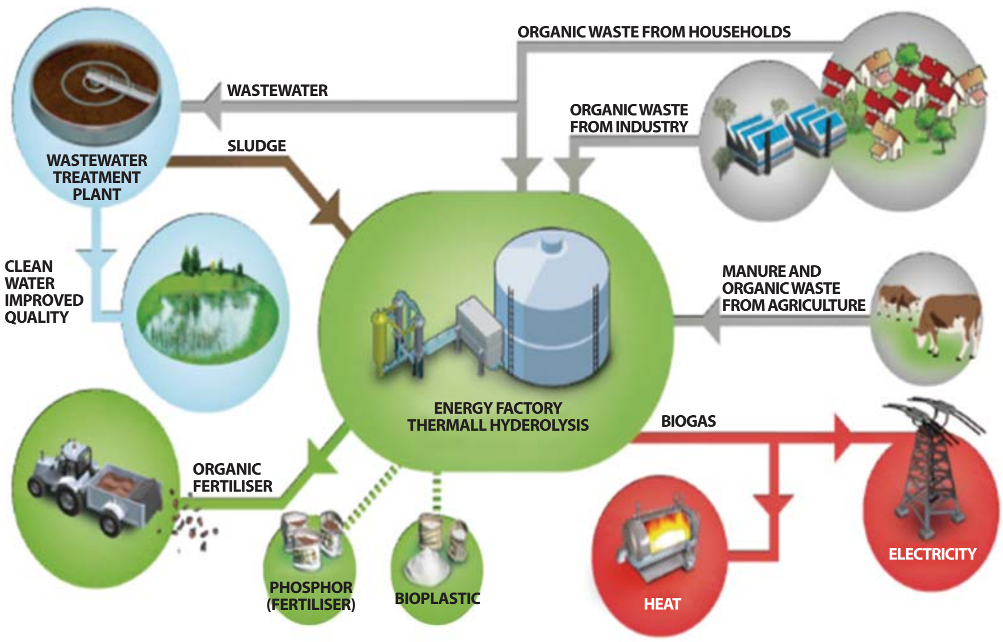
Another example that follows a similar line, but which has been successfully applied in a larger scope and is further advanced on the innovation scale, is Billund BioRefinery in Denmark. Among other things, the plant recovers nutrients, water, and energy (Figure 2.8) (Krüger, 2014). In the plant, the energy factory is considered the heart of the operation. The technology applied in the energy section of the plant is named ExelysTM (Krüger, 2014), and Billund BioRefinery is the first plant to apply it on a large scale. ExelysTM, which is an enhancement to anaerobic digestion, can treat different types of organic, industrial, or municipal sludge, in addition to handling grease.

2.3.2 Adoption

There are many aspects that can encourage innovation. One important factor that is easy yet detrimental to forget is the fact that inventions and innovations need to be adopted to be practised and applied in a full-scale setting. Therefore, it is crucial that the innovations meet a specific target group and are suitable for the local context. These are all factors that need to be defined in the early stages of developing new ideas or concepts.

Based on Everett Rogers' concept of Diffusion of Innovation (Rogers, 1983), an innovation is spread through communication over a certain period of time among members in a social setting. Factors with the biggest influence on the rate of an innovation's adoption are the extent to which people view an innovation as being consistent with their needs, values, and norms, as well as the degree to which an innovation is perceived to be advantageous among potential adopters.

Rogers divides adopters into five different categories: innovators, early adopters, early majority, late majority, and laggards. When plotted over time on a frequency basis, the adoption of an innovation follows a normal, bell-shaped curve (Rogers, 1983) as seen in Figure 2.9. The



Figrue 2.8 Billund biorefinery (website 4, Kruger, 2012)

figure illustrates the adoption of an innovation over time by the members of a social system. The percentages in the curve symbolize approximate fractions of adopters in each category, under the assumption that everyone becomes an adopter.

Adopters can vary in time, space, and context (Eitrem Holmgren, 2013). Early adopters of one recovered resource may be laggards in the adoption of another. Adopters can also vary geographically. On the topic of sludge management, for example, the main actor in the Netherlands is the industry, in Sweden it is politicians and environmentalists, while Italians value technical aspect-providers as more important (Stark, 2004).

2.3.3 Accelerating Innovation and Adoption

Extending these innovation and diffusion curves (Figures 2.7 and 2.9), it can be seen that for resource recovery from water and wastewater systems there are multiple factors that need to be taken into consideration. One important theme is to understand the development process of innovations and to identify future adopters. In line with this, there are certain aspects that can be considered to speed up the process and to accelerate innovation and adoption.

To scale-up and replicate innovations, firstly it is important to contribute to the global needs of resource recovery and to realize their applicable values. This will in turn link to investment aspects and market perspectives of scaling up innovations. Second, creating the societal norms of resource recovery and changing mind-sets of stakeholders is also an essential component. Thus, understanding the pool of adopters at hand is necessary. Third, moving from ideas to full-scale applications will greatly depend on the relevant policy and regulations.

It is also necessary to consider removing barriers to innovation as research needs the following factors (JPI Water SRIA, 2014): exploring regulatory, governance, education, and management conditions that contribute to removing barriers to innovation; considering the effect of the price of water; reducing the time to market with building demonstrators in order to close the gap between research-related demonstration and market-opening demonstration, etc.

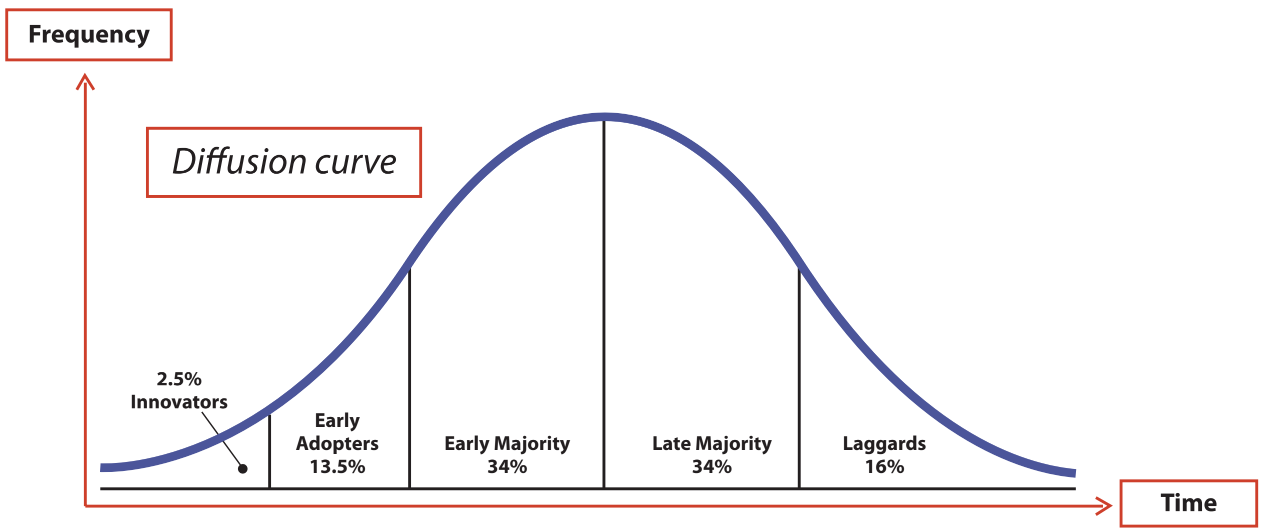


Figure 2.9 Diffusion curve for adopters of innovations (adapted from Rogers, 1983)

2.3.3.1 Economic and Investment Aspects

One factor linking to the process of bringing research and innovative technologies into business requires investments to be recovered within a certain time span. This time span for molecular biology or medical research is some 20 years, whereas resource recovery has a much shorter timeframe.

Figure 2.10 gives an overview of investment and income in the process from ideas to products that generate money. Based on some sources (website, 5), there are generally two product innovation strategies: the first is new product innovation, which is essential to push the boundaries of existing markets and to discover and pursue new opportunities in the global economy; the second involves substantial investment in research and development and product design, to extend the market life of products through product extension strategies that drive long-term profitability and future iterations of product development.

As finance has been identified as one of the major challenges both in developing and in accelerating technologies, an economic platform needs to be provided. A partnership between researchers developing technologies and companies wanting to apply these could be an example of a way to bridge this gap. Resources themselves further need to be accurately valued and end-products need to be prized accordingly. Financial aid in the form of subsidies, tax reliefs, or beneficial loans can also help accelerate innovation and adoption.

2.3.3.2 Understanding the Adopter

When accelerating innovation, it is important to know, accurately understand, and target the audience and end user. This needs to be done at an early stage in the planning phase as well as on multiple levels. It is also important to recognize that different groups of people can be important at different stages of the process. For phosphorus recovery, for example, legislation and technical feasibility have been identified as the main drivers at the beginning of the innovation curve, whereas economic viability, environmental stability, and social acceptance are the essential factors for full-scale implementation (Stark, 2004). Furthermore, such changes and alterations need to be acknowledged at the point of design. As the challenges differ between context and countries, as has been elaborated in the previous section, the local context needs to be taken into consideration as well.

Understanding the end user can be practised in many ways. An example where the end user has been taken into consideration is for NEWater in Singapore (website, 6). The project team realized early on that they needed to emphasize that recovered water could be used as drinking

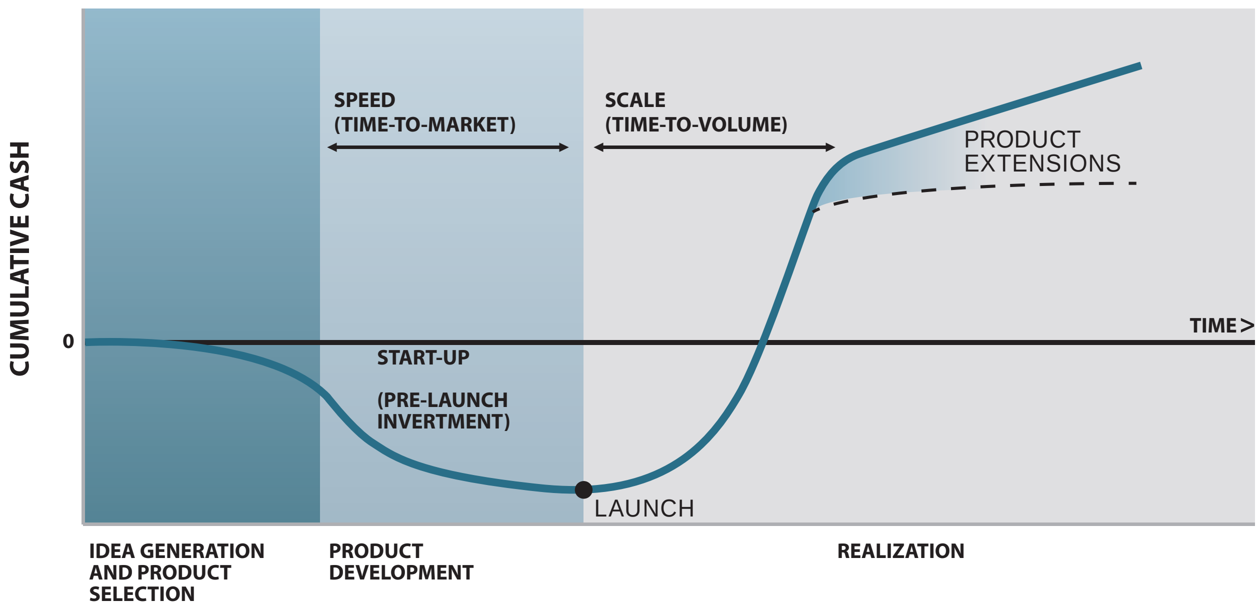


Figure 2.10 Product design, research, and development cash curve (website, 5)

water, thus overcoming the 'yuck factor'. They did this through successfully campaigning and providing people with sufficient information to raise public awareness. The launch of the NEWater project was done simultaneously with a massive outreach through media, briefings at community centres and schools, panel debates, and study visits to the water treatment location site. One of the main goals with this launch was to prove that it was safe to drink the treated water. The term "NEWater" proved to be effective as well because it encouraged, rather than discouraged, people to consume the product. In other projects, the phrase "recycled water" as opposed to "repurified" water has been suggested. Rebranding can also be done through changing the phrase "wastewater reuse" to "water reuse", the latter being considered as more appealing (UN, 2014).

A way of influencing future adopters is to provide successful case studies and demonstration test sites. These can act as role models and show positive results, which can trigger further technologies and ideas. Another way of increasing the pool of potential adopters and users is through having technologies that can perform several steps and result in multiple outputs. Examples can help offset costs while maximizing outcomes, which are appealing components for adopters.

Information and data collection can be further keys in accelerating both innovation and adoption. For example, realizing that some resources, such as phosphorus, are rapidly decreasing throughout the world could be an incentive for generating new ideas to recover them. Spreading information about a new technology and its successes could further attract new adopters.

2.3.3.3 Policy and Regulations

As has been discussed, regulations and policies need to be carefully taken into consideration when up-scaling a technology. The importance of laws and guidelines can be factors determining the development of resource recovery from water and wastewater systems. Regulations need to be in place and they need to be enforced and followed up. It is also desirable that policies help stimulate and encourage both innovation and adoption. Examples of these are tax reliefs, subsidies, and lenient regulations on new technologies.

An example of the influence of policy and regulation on resource recovery can be seen in China. In 2000, China issued an official plan named "Technology and Policy of Municipal Sewage Treatment and Pollution Prevention and Control" (website, 7, 9). This action plan for water pollution prevention and control was submitted to the central government by the Ministry of Environment in November 2014 for approval (website, 9). There are a series of specific regulations and approaches about used water collection, treatment, disposal, and recycling use for many purposes including environmental protection, resource conservation and recycling, industrial sustainable development, as well as biological and ecological security and health. To enhance the implementation of the policies and regulations, China's State Council announced plans at the end of 2011 to spend RMB3.4 trillion (US$536 billion) on environmental protection before the end of 2015, of which RMB380 billion (US$60 billion) would go to urban wastewater systems including reuse. More than half (56%) of this is expected to come from private sources (website, 8). This example highlights the push from government as well as positive interaction between government and the private sector for an accelerated development in used water treatment and resource recovery.

2.4. CONCLUSIONS AND RECOMMENDATIONS

2.4.1 Conclusions

This paper has described different resources in terms of water, energy, nutrients, and others to be recovered. Among others, current practices on resource recovery from water and wastewater systems have been overviewed along with their drivers and challenges.

(a) As the first focus and top of the agenda, water reuse and reclamation have been developed and practised far more than any other resources that have been recovered. Reclaimed water can have a quality as high as any other drinking water, through best practices combined with top-notch technology, particularly monitoring technology and chemical-toxicology technology, as well as through involvement of different public sectors. Through the review and examples shown in this paper, drivers, challenges, and potential solutions to overcome challenges are provided.

(b) Although water reuse is on the top of the agenda, the hottest topic relating to resource recovery is connected to energy efficiency and recovery in water and wastewater systems. Energy-related matters within water and wastewater systems include both energy production and recovery. Most of the energy forms generated or recovered are reused to feed into the treatment system, which in turn increase energy efficiency and occasionally lead to energy-positive systems.

(c) There are multiple nutrients that can be recovered from wastewater treatment plants, with phosphorus and nitrogen being the most commonly recovered nutrients. Nutrient recovery was partly triggered by the success of using artificial fertilizer for food production, which also stimulated discussion on food security and utilizing reused water for irrigation. The time has also come to reuse nitrogen by directly upgrading it at the site of recovery to a valuable feed or food.

(d) Valuable components such as sulphur, cellulose, metals, and biochemically generated organics (bioplastics for instance) have potential to gain more attention as societal acceptance of the cyclic economy gains more importance.

There are some common themes that can be derived from the different resources that can be recovered. One is that there is a great need for the resource while there is not a specific demand for recovered resources per se. This distinction is of great importance. There is a shift in mind-set that is needed as the current, urgent demand may be met by resource production through alternative methods. The status of “recovered resource” must be cleared from its all too often “waste”-related connotation.

Financial assets as well as rules and regulations can act both as obstacles and as opportunities. More technologies are needed while at the same time the end-products must have a fair chance of competing on the market. The user, be it a treatment plant, a farmer, a school, residents in households, or an airport, must accept the practice and be willing to use it. Collaborations between different stakeholders, such as public and private partnerships, are few today; as such, there is great room for improvement. Many of the technologies and resource recovery practices further require that different sectors work together, preferably at an early stage of the process.

The intrinsic and added value of material and substances that is referred to as “waste” needs to be realized and approached accordingly. It is also important to keep in mind that what might be practised in one setting may not be suitable or appropriate in another, thereby highlighting the need to plan context-specific approaches. Fear of unacceptance can be a challenge in the field of resource recovery as it can hinder ideas and projects. In recovering resources, a trade-off will always be seen and it is important to weigh holistically the short- and long-term benefits against the costs.

2.4.2 Recommendations

In the overall context of recovery of resources from water and used water, there are several recommendations that can be made, targeting practitioners, developers, adopters, and innovators as well as decision-makers who indirectly can change the course of resource recovery.

(a) The good practices and role models that are currently being applied should be further investigated and learned from. These existing “showcases” give evidence and possibilities of other up-scaled applications, and at the same time they should be examined in detail in terms of their technical and economic validity, and their appropriateness for extension and general application worldwide. Specifically, these cases should be used to open up discussions with the social and cultural sectors to assess and adjust their overall acceptability in the context of different religions, cultural habits, and economic benefits.

(b) New ideas and innovative technologies relating to resource recovery from water and used water are being increasingly developed. This enables the possibility of exploring the potential of resource recovery from water to its full capacity. Plenty of new areas are only starting to be examined (such as blue energy resulting from mixing cleaned used water and seawater, electro-(bio) synthesis in used water, food from secondary resources, etc.) and have to receive the mandate and the support to cover new grounds. Yet, at the same time, there is a necessity to explore carefully the boundaries of the eco-efficiency of each of these potential developments and potential recovery products, and the way they can accommodate the needs of the ever-growing economy of the entire planet.

(c) Systematic management and integration in planning are vital. This considers the option of dealing with resource recovery from water not only post factum, but upfront in the water chain where pristine resources are used. In other words, it is of value to do as other sectors are doing, which are now orienting themselves towards recovery and therefore interact a priori with the designers of commodities (e.g., electronic apparatus, cars, etc.) so that they can be de-assembled in an elegant way, allowing re-use without entailing excessive costs. To do so, the water industry needs to liaise with its partners such as the food, detergent, and pharmaceutical industries, as well as relevant stakeholders. Collaborations such as these can aid in approaching a design of processes and products that are conceived not to be destined as end of pipe, but rather as part of a cyclic economy. To reach potential environmental and economic benefits from the recovered resources, the water industry will have to bridge with other industrial sectors such as the energy, chemical, food, and manufacturing industries to identify and particularly quantify the potential demands that these sectors hold in terms of commodities recovered from the water cycle. Moreover, the water sector should also align with the industrial sector dealing with the recycling of solid and other wastes. Indeed, it is essential that the recycling processes are fully focused on the "pull" side and moreover acquire sufficient dimension of scale that they can be properly engineered and controlled in terms of mass flow and quality performance. The research agenda should clearly identify and address the overall chain as well as upgrade the concept of "water treatment" to the level of "downstream processing".

(d) It is of crucial importance to communicate to society in general and to the stakeholders such as end users in particular that the drinking and used water sector is willing to contribute to minimizing damaging practices by integrating process steps that no longer only use, but also re-use, the resources that are present in the water cycle. To that extent, the water sector will have to integrate the concepts of life cycle assessment, strict quality control, and hazard assessment in this cyclic way of dealing with water.

(e) It is also of crucial importance that the water sector intensifies its interactions with international and national bodies of legislators to construct workable legal frameworks in which resource recovery is clearly defined for its operational acceptability across borders and within each country. Moreover, the water sector should also interact with policy-makers in terms of economic platforms that will facilitate the cyclic economy within the sector of water use and reuse, as well as innovative research and development within this field.

(f) There is a major need to promote financing for research and development in the science and technology of resource recovery at large, and embedding it in the planning of global needs for the coming decades. It is essential to encourage both innovation and transition towards upscaling the implementations of resource recovery, particularly in the water sector. Research can be of a further critical nature in the sense that it dares to address and delineate the limits that can be attained by the cyclic economy. Indeed, resources to be recovered are limited and the sustainability of the planet must be assessed in the context both of the primary materials it needs and will continue to consume and of those potentially supplied by the reuse loops that will be developed.

Overall, resource recovery from water and wastewater systems should be empowered by the fact that it will bring forward new technical approaches that will become integrated in rural systems as well as in industrial society at large. These technical approaches will, thus, help decentralized and highly urbanized societies to have better and more efficient supply of water in all its applications. Moreover, on a global scale, this new way of integrating the cyclic economy in the world of water supply and use will strongly help to abate climate change as it affects the critical issues of energy saving and emission of greenhouse gases in many ways. It is of prime importance to inform decision-makers and the general public as a matter of urgency about the potential but also the risks and limits of resource recovery from water and wastewater systems. Finally, it is crucial to set well-defined agendas for concrete policies to proceed in terms of financial encouragement for these new approaches and to establish legal frameworks with timeframes of at least several decades, so that the overall perspectives of resource recovery will become internationally recognized and accepted as well as practised.

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Disasters

Main Focus 3

Water and Natural Disasters

The global climate change is a phenomenon already underway and affects exceedingly unusual natural patterns of weather events and water cycle. Therefore we need our efforts to solve water related problems such as droughts and floods due to the climate change through adaptation.

Water and Natural Disasters

3.1 INTRODUCTION

As many devastating impacts of recent natural disasters such as the flood, drought in Asia, Europe, and America indicates, mankind is vulnerable to extreme weather events in both developing and developed countries. Clearly, such extreme events have already been part of our life but may be driven even more by climate change in the future. Global climate change is now well known and its impacts are a stark reality(Zimmerman, 2002). That is, the global climate change is a phenomenon already underway and causes exceedingly unusual natural patterns of weather events and water cycle. Climate change is predicted to have a range of serious consequences, some of which will have impact over the longer term, like droughts, while some have immediate and obvious impacts, such as intense rainfall and flooding. Floods and droughts are major natural disasters involving loss of life and the destruction of property. So, we may need advanced technologies and measures in order to cope with natural disasters. Also, the climate change impact and adaptation for water related disasters are important issues.

As addressed in the section 3.3, quantifying the impacts and providing disaster relief are more difficult for drought than for other natural hazards due to long lasting impacts that can filter through economies and the environment for months, years and even decades. In recent years, concern has grown worldwide that droughts may be increasing in frequency, severity, and duration given changing climatic conditions and documented increases in extreme climate events. The frequent occurrence of drought coupled with increasing severity of its impacts make the traditional reactive approach inadequate. Proactive risk management is therefore necessary, particularly to reduce water shortage in water supply systems. The first phase of a proactive approach is an assessment of water resources availability. The second phase foresees a continuous monitoring of hydro-meteorological variables and water reserves status in order to identify possible water crises and to apply the necessary mitigation measures before a real water emergency occurs. By taking advantage of recent progress in drought monitoring and climate prediction, governments can empower local communities to anticipate and prepare for drought and reduce their impacts. This can be achieved by strengthening the producer organizations, promoting the climate change resilient crops and livestock, and facilitating access to market intelligence, excess water conservation in rainy season and motivating community to save water by reducing unnecessary use. Drought policy options should be provided in each of four principle areas: (a) risk and early warning, including vulnerability analysis, impact assessment, and communication; (b) mitigation and preparedness, including the application of effective and affordable practices; (c) awareness and education, including a well-informed public and a participatory process; and (d) policy governance, including political commitment and responsibilities.

Urban flooding, which is addressed in Section 3.4, is a growing issue for developed and developing countries and for reducing impact on people, buildings, and municipal and industrial infrastructure. Furthermore, urban areas are becoming more vulnerable to flooding than ever before due to climate change and rapid and unregulated urbanisation and land use. Therefore, it is important to mitigate the impacts of urban flooding by integrating latest technologies and traditional knowledge as well as developing appropriate management and early warning systems. The major objective for mitigating urban flood is not only on reducing direct and subsidiary series damages but also better planning a resilient urban area to natural hazards. Climate change and fast land development associated with urbanization and without appropriate planning further intensify the vulnerability of the urban areas from flooding. In order to mitigate and overcome those challenges, technical and management solutions have been developed. As technical solutions, flood defence systems such as flood gates, doors, and barriers as well as flood forecasting and observation technologies are developed. The representative management solutions for flood control are the integrated flood management system and the flood warning system. It is important to note that the balance between applying the technologies to mitigate urban flood effects and reshaping the urban environment into flood defensive is also a critical action in the future.

The section 3.5 reviews the strengths of technologies used for disaster risk management and the challenges in using them and introduces useful examples and application plans of technologies supporting disaster risk management such as Information and Communication Technology (ICT), space technology including remote sensing technology, geographic information system (GIS). These technologies can play a significant role in the analysis of the potential risk and can help identify measures to prevent or reduce damage loss and allow for a resilient recovery from a natural disaster that can be exacerbated by manmade factors such as globalization, population growth, poverty, urbanization and changes in land use and climate change. Although scientific knowledge and technology are advanced, it is needed for effective application of these technologies to develop universal methodologies for disaster risk management and to convince people who are not familiar with disaster risk management especially, developing countries and local communities even in the advanced country. For one solution, an international platform for information sharing and technology transferring is suggested in the last part of the section 3.5. For the successful adaptation, policy-makers and practitioners should be fully aware of the latest scientific knowledge on disasters risk management, and be capable of utilizing those scientific findings. Also national platforms should be empowered to incorporate technology into real practice which can help to adopt a common methodology on data collection and economic analysis of disasters and also to realize evidence-based policy making on disaster risk reduction to be practiced globally.

3.2 CLIMATE CHANGE : IMPACT ASSESSMENT AND ADAPTATION

3.2.1 Background

Floods, droughts and windstorms are the most frequently occurring natural disaster events and account for almost 90% of the 1,000 most disastrous events since 1990(WCDRR, 2014). The occurrence of floods and droughts are expected to increase with a changing climate, with the IPCC predicting these water-related disasters to increase in both frequency and severity, as the whole global water cycle is affected by global warming. Since the original Rio Earth Summit in 1992 floods, droughts and storms have affected 4.2 billion people (95% of all people affected by disasters) and caused USD 1.3 trillion of damage (63% of all damage). USD 2.5 trillion economic losses from disasters so far this century – 70% relate to floods and droughts. Water-related hazards account for 90% of all natural hazards, and their frequency and intensity are generally increasing (WWAP, 2012). By 2050, rising populations in flood-prone lands, climate change, deforestation, loss of wetlands and rising sea levels are expected to increase the number of people vulnerable to flood disaster to 2 billion. Current IPCC projections of rising temperatures and sea levels and increased intensity of droughts and storms suggest that substantial population displacements will take place within the next 30-50 years, particularly in coastal zones (WWAP, 2009). A global temperature increase of 3-4°C could cause changed run-off patterns and glacial melt will force an additional 1.8 billion people to live in a water scarce environment by 2080 (NHDR, 2007). Water is key in managing disaster and addressing climate change impacts, because water is the medium through which most climate impacts and many disasters such as droughts and floods are felt.

Climate change is a crucial issue for our future and already affecting climate, people, and resources in this world. These impacts are projected to grow and there is the urgent need to address water related disasters due to the climate change, especially, in developing countries. Therefore, we need to mitigate negative impacts and take advantage of possible opportunities. Also, the adaptation strategies should be implemented with recognition of both local experiences and innovative technologies to provide decision makers with cutting edge information on the vulnerability to climate change.

3.2.2 Framing the Callenges

3.2.2.1 Impact of Climate Change on Water Related Disasters and Climate Risks

Climate change is strongly affecting many aspects of systems related to snow, ice, and frozen ground; emerging evidence shows changes in hydrologic systems, water resources, coastal zones, and oceans (IPCC 2007). Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent by the end of this century, as global mean surface temperature increases (IPCC, 2013). Climate change has also contributed to a rise in extreme weather events including stronger typhoon intensity, heavier localized rainstorm, and increases in extent, severity and duration of droughts. As hydrologic variation due to the climate change is becoming more severe in time, especially, floods and droughts have frequently occurred throughout the world causing the damage of property and loss of life. Therefore, more intensive natural disasters such as floods and droughts are expected to occur in future (UNISDR 2008).

Components of population growth, urbanization, and industrialization have also an important connection to both the challenges and solutions to the problem of climate change. Rapid increase in these components exacerbates vulnerability to the negative consequences of climate change – including floods, droughts, environmental deterioration, and declining food production. For an example, many of the global megacities (those with populations over 10 million) are located on the coast: Tokyo, Jakarta, Shanghai, New York City, Mumbai, Bangkok and Lagos, to name a few. Their locations are borne out of necessity: 90 percent of global commerce is done by sea. So while urbanizing along the coastline allows countries to more easily tap into global trade, coastal cities may be vulnerable to sea level rise and more frequent and intense typhoons, hurricanes and other extreme weather events that could result from climate change(http://gt2030.com/2012/07/18/urbanization-and-the-global-climate-dilemma).

Flooding and droughts can cause a range of health impacts and risks including: death and injury, contaminated drinking water, hazardous material spills, water shortage, food security, and water related disease. Water quality and ecological problems can be also occurred by temperature change due to the climate change.

Responding to climate-related risks involves decision-making in a changing world, with continuing uncertainty about the severity and timing of climate-change impacts and with limits to the effectiveness of adaptation. Uncertainties about future vulnerability, exposure, and responses of interlinked human and natural systems are large. This motivates exploration of a wide range of socioeconomic futures in assessments of risks. Key risks are potentially severe impacts relevant to Article 2 of the United Nations Framework Convention on Climate Change, which refers to "dangerous anthropogenic interference with the climate system." Risks are considered key due to high hazard or high vulnerability of societies and systems exposed, or both (IPCC 2013):

(a) Risk of death, injury, ill-health, or disrupted livelihoods in low-lying coastal zones and small island developing states and other small islands, due to storm surges, coastal flooding, and sea-level rise.

(b) Risk of severe ill-health and disrupted livelihoods for large urban populations due to inland flooding in some regions.

(c) Systemic risks due to extreme weather events leading to breakdown of infrastructure networks and critical services such as electricity, water supply, and health and emergency services.

(d) Risk of mortality and morbidity during periods of extreme heat, particularly for vulnerable urban populations and those working outdoors in urban or rural areas.

(e) Risk of food insecurity and the breakdown of food systems linked to warming, drought, flooding, and precipitation variability and extremes, particularly for poorer populations in urban and rural settings.

3.2.2.2 Scientific Evidence from Climate Change Analysis

The climate system has a number of preferred patterns of variability having a direct influence on elements of the hydrological cycle. Theoretical and climate model studies suggest that, in a climate that is warming due to increasing greenhouse gases, a greater increase is expected in extreme precipitation, as compared to the mean. The observational and modelling studies lead to an overall conclusion that an increase in the frequency of heavy precipitation events (or in the proportion of total rainfall from heavy falls) is likely to have occurred over most land areas over the late 20th century, and that this trend is more likely than not to include an anthropogenic contribution (Bates et al., 2008). Snow cover has decreased in most regions, especially in spring and summer. Northern Hemisphere snow cover observed by satellites over the 1966–2005 period decreased in every month except November and December, with a stepwise drop of 5% in the annual mean in the late 1980s (Bates et al., 2008). Global mean sea level has been rising and there is high confidence that the rate of rise has increased between the

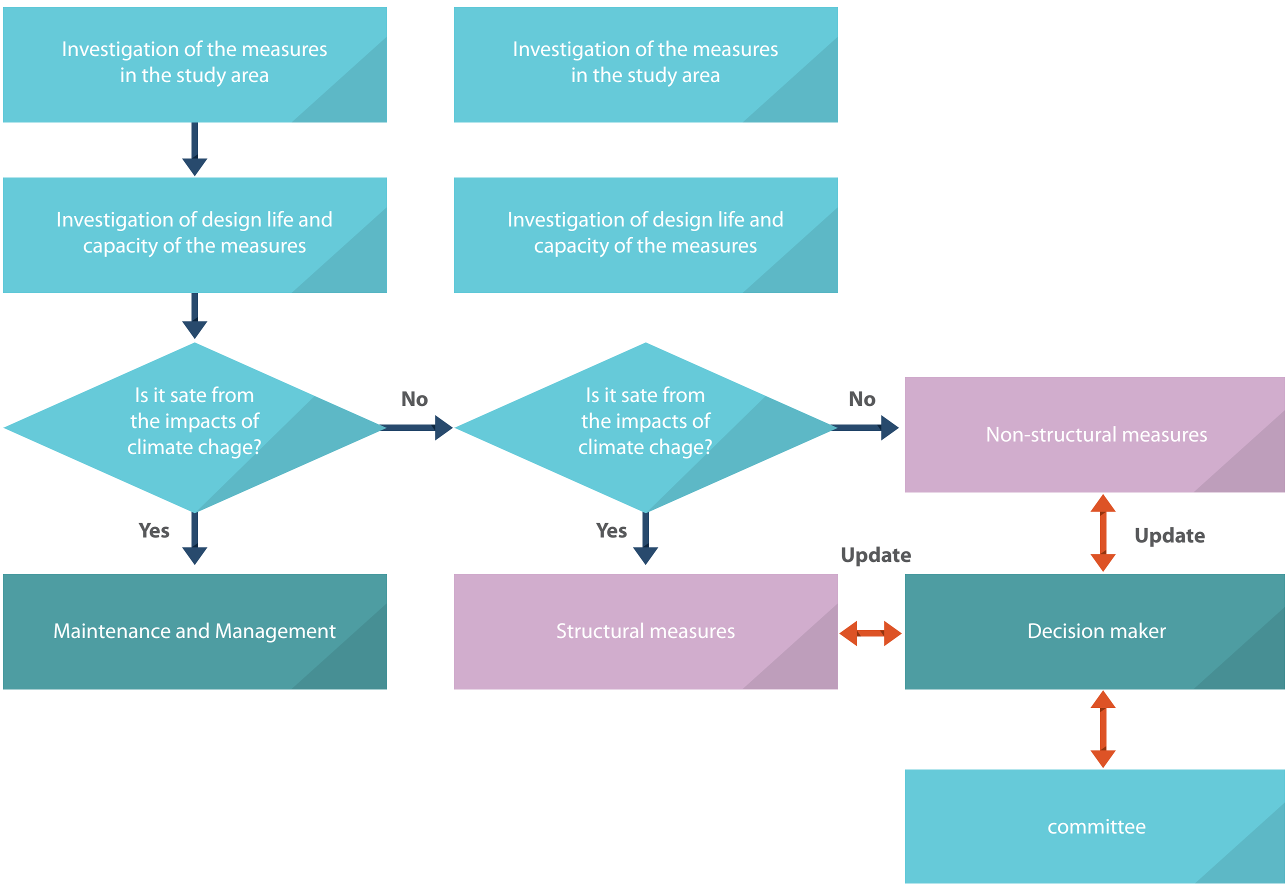

Figure 3.1 Decision making procedure for adaptation of new design criteria considering climate change (NEMA, 2011)

mid-19th and the mid-20th centuries. The average rate was 1.7 ± 0.5 mm/yr for the 20th century, 1.8 ± 0.5 mm/yr for 1961–2003, and 3.1 ± 0.7 mm/yr for 1993–2003. Trends in runoff are not always consistent with changes in precipitation. This may be due to data limitations (in particular the coverage of precipitation data), the effect of human interventions such as reservoir impoundment (as is the case with the major Eurasian rivers), or the competing effects of changes in precipitation and temperature. There is, however, far more robust and widespread evidence that the timing of river flows in many regions where winter precipitation falls as snow has been significantly altered. Higher temperatures mean that a greater proportion of the winter precipitation falls as rain rather than snow, and the snowmelt season begins earlier (Bates et al., 2008).

In recent decade, much more severe natural disasters such as flood and drought have been occurring in South Korea and this may be due to the global warming caused by climate change. Therefore, South Korean government tried to develop new design criteria for structural measures considering climate change effects that will both prevent or reduce the impacts of natural disasters for public security. National Emergency Management Agency (NEMA) in South Korea suggested the design criteria of structural measures based on the frequency analysis for rainfall, snowfall, and wind speed under climate change. To quantify the impact of climate change on rainfall and snowfall, a GCM model of CNCM3 is used that was developed by Centre National de Recherches Meteorologiques, France and A1B, A2, B1 climate scenarios for the simulation of each meteorological data are used. The reason that CNCM3 GCM model is used here is based on the work of Kyoung (2010) who tested 24 GCM models provided by IPCC's Fourth Assessment Report (AR4) for the selection of a proper model which can be used in the Korean peninsula. The increasing rate of future design criteria of each element by the study were recommended as following Table 3.1 (NEMA, 2011) (NEMA was currently changed as Ministry of Public Safety and Security (MPSS)).

When the design rainfall in the future under climate change is larger than the current design rainfall, a decision is needed whether a new design value for the measures should be adapted or not. This decision procedure was suggested in Figure 3.1 (NEMA, 2011)

Table 3.1 Changing rate of design criteria recommended for the future (NEMA, 2011)

Elements	Projection Periods			Remarks
	2011-2040	2041-2070	2071-2100	
Rainfall Depth	+10 %	+10 %	+15 %	Daily Data
	+15 %	+15 %	+20 %	Hourly Data(1hr)
Snowfall Depth	-10 %	-20 %	-30 %	Daily Data
Wind velocity	+5 m/s	+5 m/s	+5 m/s	Northern inland regions of Korea
	+10 m/s	+10 m/s	+10 m/s	Southern inland regions of Korea

3.2.3 Framing the Solutions

3.2.3.1 Better Understanding Climate Change and Improvement of Technologies

We may need better understanding of climate change processes to address problems due to changing climate. Also we may need knowledge improvement of climate models, climate systems, analytical techniques and uncertainty for providing more precise solutions about the problems which can be occurred by climate change.

(a) Evaluation and Improvement of Climate Models The models used in climate research range from simple energy balance models to complex Earth System Models (ESMs) requiring state of the art high-performance computing. The choice of model depends directly on the scientific question being addressed (Held, 2005 ; Collins et al., 2006). Applications include simulating paleo or historical climate, sensitivity and process studies for attribution and physical understanding, predicting near-term climate variability and change on seasonal to decadal time scales, making projections of future climate change over the coming century or more and downscaling such projections to provide more detail at the regional and local scale. Computational cost is a factor in all of these, and so simplified models (with reduced complexity or spatial resolution) can be used when larger ensembles or longer integrations are required. Climate models have continued to be developed and improved since the AR4, and many models have been extended into Earth System Models by including the representation of biogeochemical cycles important to climate change. Model development is a complex and iterative task: improved physical process descriptions are developed, new model components are introduced and the resolution of the models is improved. After assembly of all model components, model parameters are adjusted, or tuned, to provide a stable model climate(IPCC, 2013).

(b) Quantification of Climate System Responses Observational and model studies of temperature change, climate feedbacks and changes in the Earth's energy budget together provide confidence in the magnitude of global warming in response to past and future forcing. The net feedback from the combined effect of changes in water vapour and differences between atmospheric and surface warming is extremely likely positive and therefore amplifies changes in climate. The net radiative feedback due to all cloud types combined is likely positive. The equilibrium climate sensitivity quantifies the response of the climate system to constant radiative forcing on multi-century time scales. It is defined as the change in global mean surface temperature at equilibrium that is caused by a doubling of the atmospheric CO2 concentration. Equilibrium climate sensitivity is likely in the range 1.5°C to 4.5°C, extremely unlikely less than 1°C, and very unlikely greater than 6°C. This assessment reflects improved understanding, the extended temperature record in the atmosphere and ocean, and new estimates of radiative forcing. The rate and magnitude of global climate change is determined by radiative forcing, climate feedbacks and the storage of energy by the climate system. Estimates of these quantities for recent decades are consistent with the assessed likely range of the equilibrium climate sensitivity to within assessed uncertainties, providing strong evidence for our understanding of anthropogenic climate change(IPCC, 2013).

(c) Analytical Techniques and Uncertainty Hydrometeorological elements such as precipitation, humidity, and so on may be obtained from climate change scenarios and models then need to be downscaled in space and time for assessing future impacts of natural disasters, for example, drought and flood analysis in the future. Downscaling techniques for drought and flood analysis should be developed for more accurate representations of the future elements. The reproduction of extreme values for the future is a challenging problem even though the techniques have been developed and therefore the reproduction methods should be developed for analyzing water related disasters of drought and flood, and for reducing uncertainty in the analysis. Even though the researches have shown that the snowfall will decrease in the future, the number of extreme snowfall events can also increase in time. Therefore, the reproduction techniques of extreme values need to be improved.

3.2.3.2 Examples for Adaptation to Climate Change

The U.S. Climate Change Science Program coordinates the efforts of 13 federal agencies to understand why climate is changing, to improve predictions about how it will change in the future, and to use that information to assess impacts on human systems and ecosystems and to better support decision making. UK established the Climate Change Act (2008) that aimed to help reduce the amount of pollution to help prevent the advancement of global warming. This act will be implemented till 2050 that help reduce the gas usage by 80% and increase renewable energy by 15%. In Netherlands, because the effect of climate change has a greater influence, the Delta Committee was established an official committee. Sea level rise is also important issue in Netherlands. Rotterdam, Netherlands has set the objective to reduce CO2 emissions by 50% and be fully climate proof by 2025. General aims are to improve the quality of life, create economic spin-offs and to become an inspiring example to other delta cities. The Rotterdam Approach rests on three pillars: knowledge, actions and positioning/marketing.

The following tools assist the development process: the 'route planner' sets out milestones for selected key themes, the 'climate atlas' outlines region-specific impacts of climate change, scenarios and already implemented measures, and the 'barometer' serves as a communication-oriented monitoring tool. In France, an example of EXPLORE 2070. In Japan, the Committee on Climate Change Impacts and Adaptation Research was established to discuss "Wise adaptation" under the initiative of the Ministry of the Environment (MOE), Japan.

In Korea, 'National Climate Change Adaptation Policy' was pronounced by the Ministry of Environment (ME) with other 13 ministries (ME, 2010). These include adaptation policy in 7 areas and 3 basic alternatives for adaptation (Figure 3.2). The policy for the future considering climate change is being established in local governments based on the estimated vulnerabilities for 7 areas by a tool called LCCGIS (Local Climate Change GIS).

3.2.3.3 Adaptation Strategies

Disaster risk management has historically operated under the premise that future climate will resemble that of the past. Climate change now adds greater uncertainty to the assessment of hazards and vulnerability. This will make it more difficult to anticipate, evaluate, and communicate disaster risk. Uncertainty, however, is not a new problem. Previous experience with disaster risk management under uncertainty, or where long return periods for extreme events prevail, can inform effective risk reduction, response, and preparation, as well as disaster risk management strategies in general. Because climate variability occurs over a wide range of timescales, there is often a historical record of previous efforts to manage and adapt to climate-related risk that is relevant to risk management under climate change. These efforts provide a basis for learning via the assessment of responses, interventions, and recovery from previous impacts. Although efforts to incorporate learning into the management of weather- and climate-related risks have not always succeeded, such adaptive approaches constitute a plausible model for longer-term efforts.

Learning is most effective when it leads to evaluation of disaster risk management strategies, particularly with regard to the allocation of resources and efforts between risk reduction, risk sharing, and disaster response and recovery efforts, and when it engages a wide range of stakeholder groups, particularly affected communities. In the presence of deeply uncertain long-term changes in climate and vulnerability, disaster risk management and adaptation to climate change may be advanced by dealing adequately with the present, anticipating a wide range of potential climate changes, and promoting effective 'no-regrets' approaches to both current vulnerabilities and to predicted changes in disaster risk. A robust plan or strategy that both encompasses and looks beyond the current situation with respect to hazards and vulnerability will perform well over a wide range of plausible climate changes (IPCC, 2012).

Figure 3.2 National climate change adaptation policies of South Korea (ME, 2010)

3.2.3.4 Lessons Learned and Future Direction

Water related disasters are an important issue and we should make and implement the plans for adaptation to climate change. Today, the world faces many challenges: climate change, water related disasters containing flood and drought. Solution such as a section 3.2.3.1 offers the possibility of wise analysis and allows us to see Impacts, Adaption and Vulnerability differences. It also offers us the ability to acquire and verify facts. The section 3.2.3.1 now makes it possible to better understand and communicate the social and physical complexities of disasters. Climate policies – including water related disasters – can be more effective when consistently embedded within broader strategies designed to address national and regional development pathways. The impact of climate variability and change, climate policy responses, and associated socioeconomic development will affect the ability of communities to achieve development goals. Despite difficulties and uncertainties, adaptation is critical to prepare individuals, communities, governments, and international agencies for the changes that are coming. Understanding the lessons learned from water related disasters can facilitate the process of designing and implementing strategies, policies, and measures to reduce vulnerability and increase adaptive capacity. And, we will be able to solve climate change related problems based on scientific understanding, impact and adaptation, mitigation and international negotiation through global networks.

3.2.4 Accelerating Innovation

3.2.4.1 Advanced Climate Change Adaptation

Adaptation is place- and context-specific, with no single approach for reducing risks appropriate across all settings. Effective risk reduction and adaptation strategies consider the dynamics of vulnerability and exposure and their linkages with socio-economic processes, sustainable development, and climate change. Adaptation planning and implementation can be enhanced through complementary actions across levels, from individuals to governments. National governments can coordinate adaptation efforts of local and subnational governments, for example by protecting vulnerable groups, by supporting economic diversification, and by providing information, policy and legal frameworks, and financial support. Local governments and the private sectors are increasingly recognized as critical to progress in adaptation, given their roles in scaling up adaptation of communities, households, and civil society and in managing risk information and financing. A first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability. Strategies include actions with co-benefits for other objectives.

Available strategies and actions can increase resilience across a range of possible future climates while helping to improve human health, livelihoods, social and economic well-being, and environmental quality. Integration of adaptation into planning and decision making can promote synergies with development and disaster risk reduction. Adaptation planning and implementation at all levels of governance are contingent on societal values, objectives, and risk perceptions. Recognition of diverse interests, circumstances, social-cultural contexts, and expectations can benefit decision-making processes. Indigenous, local, and traditional knowledge systems and practices, including indigenous peoples' holistic view of community and environment, are a major resource for adapting to climate change, but these have not been used consistently in existing adaptation efforts. Integrating such forms of knowledge with existing practices increases the effectiveness of adaptation. Decision support is most effective when it is sensitive to context and the diversity of decision types, decision processes, and constituencies.

Organizations bridging science and decision making, including climate services, play an important role in the communication, transfer, and development of climate-related knowledge, including translation, engagement, and knowledge exchange. Existing and emerging economic instruments can foster adaptation by providing incentives for anticipating and reducing impacts. Instruments include public-private finance partnerships, loans, payments for environmental services, improved resource pricing, charges and subsidies, norms and regulations, and risk sharing and transfer mechanisms. Risk financing mechanisms in the public and private sector, such as insurance and risk pools, can contribute to increasing resilience, but without attention to major design challenges, they can also provide disincentives, cause market failure, and decrease equity. Governments often play key roles as regulators, providers, or insurers of last resort. Constraints can interact to impede adaptation planning and implementation. Common constraints on implementation arise from the followings: limited financial and human resources; limited integration or coordination of governance; uncertainties about projected impacts; different perceptions of risks; competing values; absence of key adaptation leaders and advocates; and limited tools to monitor adaptation effectiveness. Another constraint includes insufficient research, monitoring, and observation and the finance to maintain them. Underestimating the complexity of adaptation as a social process can create unrealistic expectations about achieving intended adaptation outcomes (IPCC, 2013). Figure 3.3 shows flow chart for the advanced climate change adaptation strategies.

Poor planning, overemphasizing short-term outcomes, or failing to sufficiently anticipate consequences can result in maladaptation. Maladaptation can increase the vulnerability or exposure of the target group in the future, or the vulnerability of other people, places, or sectors. Some near-term responses to increasing risks related to climate change may also limit future choices. For example, enhanced protection of exposed assets can lock in dependence on further protection measures. Limited evidence indicates a gap between global adaptation needs and the funds available for adaptation. There is a need for a better assessment of global adaptation costs, funding, and investment. Studies estimating the global cost of adaptation are characterized by shortcomings in data, methods, and coverage. Significant co-benefits, synergies, and trade-offs exist between mitigation and adaptation and among different adaptation responses; interactions occur both within and across regions. Increasing efforts to mitigate and adapt to climate change imply an increasing complexity of interactions, particularly at the intersections among water, energy, land use, and biodiversity, but tools to understand and manage these interactions remain limited. Examples of actions with co-benefits include (i) improved energy efficiency and cleaner energy sources, leading to reduced emissions of health-damaging climate-altering air pollutants; (ii) reduced energy and water consumption in urban areas through greening cities and recycling water; (iii) sustainable agriculture and forestry; and (iv) protection of ecosystems for carbon storage and other ecosystem services (IPCC, 2013).

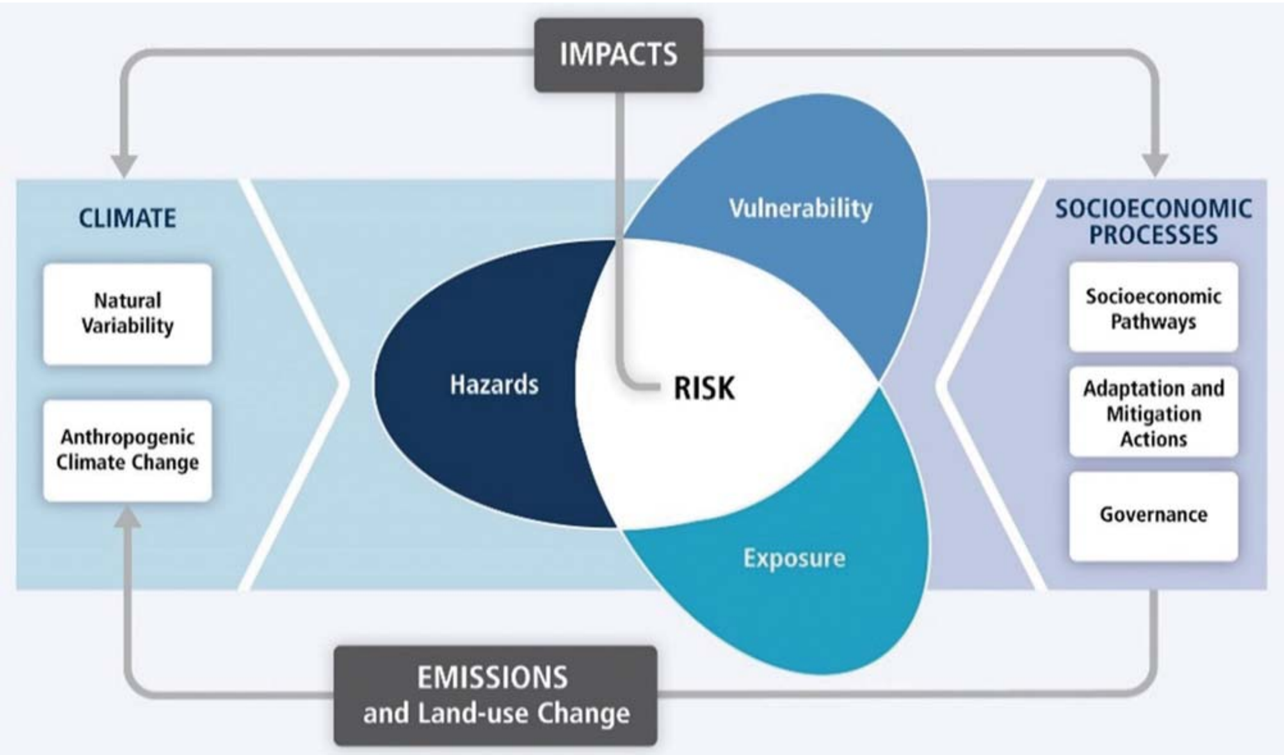

Figure 3.3 Advanced climate change adaptation strategies (IPCC, 2013)

3.2.4.2 International Cooperation

Climate change is a global challenge and requires a global solution. Therefore we need global and international collaborations to solve the climate change problems, especially, water related disasters. The followings are collaboration examples of two organizations and a conference to solve the disaster problems due to the climate change.

(a) UNISDR

The United Nations (UN) International Strategy for Disaster Reduction Secretariat (UNISDR) was established in 1999 as the successor to the Secretariat of the International Decade for Natural Disaster Reduction. UNISDR leads the organisation of the Global Platform for Disaster Risk Reduction, which meets every two years and has become the main global forum for guidance on the implementation of the Hyogo Framework for Action (HFA) and share experience among stakeholders. The formal mandate of UNISDR is given by the UN General Assembly, and is to serve as the focal point in the United Nations system for the coordination of disaster reduction and to ensure synergies among the disaster reduction activities of the United Nations system and regional organisations and activities in socio-economic and humanitarian fields.

(b) ESCAP/WMO Typhoon Committee

The ESCAP/WMO Typhoon Committee is an inter-governmental body organized under the joint auspices of the Economic and Social Commission for Asia and the Pacific (ESCAP) and the World Meteorological Organization (WMO) in 1968 in order to promote and coordinate the planning and implementation of measures required for minimizing the loss of life and material damage caused by typhoons in Asia and the Pacific. The Typhoon Committee develops activities under three substantive components: meteorology, hydrology, and disaster risk reduction (DRR), as well as in training and research. The mission of the Typhoon Committee is to reduce the loss of lives and minimize social, economic and environmental impacts caused by typhoon-related disasters through integrated and enhanced regional collaboration.

(c) ACUDR

The Asian Conference on Urban Disaster Reduction (ACUDR) is a biennial event bringing leading scientists, decision makers and NGO-agents in the field of disaster management from the Asian countries. It was agreed by DMST (Disaster Management Society of Taiwan), ISSS (Institute of Social Safety Science, Japan) and KOSHAM (Journal of Korean Society of Hazard Mitigation) during the annual Symposium of the DMST in 2011.

3.2.4.3 Integration, Improvement, Expansion of Current Knowledge

(a) Updating global and regional vulnerability/resilience to water related disasters

Vulnerability and exposure to disasters is increasing as more people and assets locate in areas of high risk. Since 1970, the world's population has grown by 87 per cent. During the same time, the proportion of people living in flood-prone river basins increased by 114 per cent and on cyclone-exposed coastlines by 192 per cent (UNISDR, 2012).

There are strong trends towards increasing knowledge-sharing and understanding about building resilience in communities at risk from water-related disasters, especially those likely to arise from climate change. A holistic approach that integrates water into socio-economic development planning is being adopted and should be further supported. This approach applies the principles of integrated disaster risk management and is a direct form of strengthening resilience and reducing vulnerabilities to extreme events. Some localities are already implementing monitoring and people centred early warning systems in communities most at risk from water-related disasters. Further support is needed to mainstreaming a preparedness approach to water-related disaster management, which responds to the needs of communities and is implemented efficiently.

Various adaptation measures that respond to climate variability, and build upon existing land and water management practices, have the potential to strengthen the resilience of vulnerable communities to climate change and to ensure water security, and directly contribute to sustainable development (WCDRR, 2014). Governments and water related institutions will need to be strengthened to deliver results across the broad spectrum of floods, droughts and related areas.

(b) Integration of emerging technologies

Technological innovations of water related disasters and vulnerability to climate change reduction measures provide unprecedented opportunities to build resilience and deepen connectivity. Experiences from the region and around the world have proven that disaster prevention and preparedness, enabled by communication and space technologies, can be far more effective and less costly than ever before(http://www.unescap.org/our-work/ict-disaster-risk-reduction).

A number of emerging technologies can be integrated into measures for solving water related disasters and impact of climate change. Among them, Information and Communication Technologies(ICT), Nano Technology(NT), Energy Technology(ET), Bio Technology(BT), Remote Sensing(RS) and Geographic Information System(GIS) can be utilized in sensing, preparing, and responding to water related disasters.

The ability to properly measure progress of technologies, like ICT, GIS, RS and so on, will be a key tool that allows policymakers to make informed decisions. These emerging technologies are important tools for understanding and supporting water related disaster resilient communities.

The section 3.5 reviews some detail information for emerging technologies related to water disasters.

(c) Improvement of analytical tools and techniques

Improvement of analytical tools and techniques are related GCMs, limitation of downscaling techniques, selection of hydrological tools, and uncertainty involved in both water related disasters and climate change.

GCM is generally a global and continental scale climate model and can produce relatively reliable weather forecasts in annual and seasonal values. IPCC 4th Assessment Report published in 2007 suggested the ensemble results can be more reliable. However, most of the GCM models have limitations in its spatial and temporal resolutions. Also the downscaling techniques should be advanced for more accurate reproduction of data in the specific area and time scale concerning surface water and groundwater.

An appropriate approach for the assessment of uncertainty in climate prediction scenario as well as in downscaling procedures and hydrological impact modeling is also significantly important. Uncertainty measures could provide an estimate of confidence limits on model results and would be of value in the application of these results in risk and policy analyses. Development and application of ensembles of hydrologic models can be followed for an improved understanding of the impact of the complexity of process descriptions on simulated hydrological variables and predictive power, evaluation of intrinsic variability, and uncertainties in hydrologic modeling.

It is recommended that improvement is required in the scaling procedures for the utilization of RCM results in regional watershed management and evaluation and improvement of transferability of existing bias correction methods between station measurements and RCM outputs for future climate conditions.

(d) Appropriate technology

Appropriate technology is simple enough that people can manage it directly and on a local level. Appropriate technology makes use of skills and technology that are available in a local community to supply basic human needs.

Commonly discussed as a form of economic development, this type of sustainable technology is an alternative to technology transfer from developed to developing countries. Technology transfer is often patronizing, with one party telling the other what to do and what they need, while appropriate technology places both parties on an equal level. Appropriate technology is attractive because it makes households and industries more self-sufficient, and most things can be managed at a local level. It is believed that technology transfer to developing countries would bridge the development gaps between developed and recipient developing countries (Edoho, 2009).

3.2.5 Research & Developing Agenda

3.2.5.1 Increasing Urban Resilience and Sustainability

Resilience is the ability of something to return to its original shape after it has been pulled, stretched, pressed, bent, etc. Also urban resilience is defined as the "capability to prepare for, respond to, and recover from significant multihazard threats with minimum damage to public safety and health, the economy, and security" of a given urban area. The resilience concept appears to be particularly pertinent for framing urban planning and development policies and programmes. At the international level, this has become evident by a number of influential publications, conferences, and projects focusing on climate change adaptation. For example, the World Bank published a "primer" on "climate resilient cities" (Prasad et al., 2009), which was directed at urban decision-makers in east Asia. International urban capacity-building programmes and conferences have used notions of resilience prominently in their approach and programming, such as "urban climate change resilience" and "resilient cities".

Resilience not only means preparing cities to better respond to natural disasters, perhaps even more importantly, it also means taking steps to prevent disasters. Disasters like the recent Rio landslide are only partially the result of natural forces; they are also the result of failed urban planning and development. This places the imperative for urban disaster risk reduction squarely in the hands of municipal planners, politicians and the urban community at large.
(https://agenda.weforum.org/2013/01/the-importance-of-urban-resilience)

Resilience is also increasingly popular at the national level of policy-making. This is noticeable, for example, in Australian policy. In 2011, the Council of Australian Governments, the peak intergovernmental forum involving representatives of all three levels of government, adopted a National Strategy for Disaster Resilience (COAG, 2009). The strategy, aimed at providing high-level guidance on disaster management, makes ample reference to climate change impacts as an important factor in working towards greater disaster resilience. In 2011, the Australian Government announced a A$4.5 million climate change adaptation funding stream for local government, entitled "Building Resilience of Coastal Communities" (Commonwealth of Australia, 2011). Reference to resilience can also be found in many municipal climate change strategies and plans.

3.2.5.2 IWRM and Smart Water Grid

The Global Water Partnership's definition of Integrated Water Resources Management (IWRM) is widely accepted. It states: 'IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems'. The Integrated Water Resources Management (IWRM) has been recognized as means for the most efficient water supply, use, conservation, and water related disaster reduction under the climate change. Also water is needed to generate energy and at the same time energy is needed to provide water to homes and industries. Water provides crucial ecosystem services and a lack of sanitation and safe drinking water services as well as polluted water is a major public health threat. Water is thus not a sector but a vital resource for societies, cultures, the environment and economies that require strong coordination to be effectively managed. Therefore, IWRM can also contribute to environmental and energy disaster prevention.

Research needs as mentioned in the European Strategic Research and Innovation Agenda highlight the needs of improving water management to mitigate the harmful impacts of extreme events considering diagnosing droughts, floods and impaired water quality as a result of climate change developing people centered monitoring and extreme water system, including both expert and local knowledge; setting up risk management strategies taking into account socio economic needs, environmental dynamics/risks and land use in areas vulnerable to droughts and floods; maximising the reliability of projections of precipitation at various spatial and time scales; developing integrated modelling across surface water and groundwater, coastal and fluvial systems, hydrological and meteorology, water and sediment transport; improving existing hydrodynamic models coupled with the development of a monitoring scheme adapted for aquifers in order to improve the quantitative management of resource.

Urban water systems face sustainability and resiliency challenges including water leaks, over-use, quality issues, and response to drought and natural disasters with the urbanization process. Information and communications technology (ICT) could help address these challenges through the development of smart water grids that network and automate monitoring and control devices. Potential benefits of smart water grids include improved leak management, water quality monitoring, intelligent flood and drought management, and energy savings (Mutchek and Williams, 2014).

3.2.5.3 Advancing Technology for Climate Change Analysis and Adaptation

Adaptation can be reactive while in others, it needs to be anticipated especially for investments with very long timescales (Hallegatte et al. 2007). Anticipation necessitates detailed information on how local climates will change. However, for various reasons detailed in Hallegatte (2009), future local climates are uncertain: there is still a large uncertainty on future greenhouse gas emissions, on the reaction of global temperature to changes in greenhouse gas concentrations and on how a change in global mean temperature would translate into changes at the local scale, the last being particularly important for adaptation in water management. To cope with this situation of increased uncertainty, Hallegatte (2009) proposed to follow Lempert and Collins (2007) and to implement robust anticipated adaptation strategies that aim at reducing vulnerability in the largest possible range of climate changes (Nassopoulos et al. 2012). Now we understand there are multiple sources of uncertainty in assessing climate change, its impacts, and moving forward with adaptation responses. In some cases, uncertainties interact, usually resulting in an increase in overall uncertainty. Understanding interactions can be accomplished qualitatively through the use of conceptual models or expert judgment or quantitatively through models and decision support systems (Glick et al. 2011).

How to move forward in the face of uncertainty? Although it would be easy for a natural resource manager to be paralyzed by uncertainty, there is also a considerable amount of good advice and recommendations for moving forward with adaptation strategies amidst this uncertainty. First many proposed broad adaptation objectives are relatively robust to uncertainties associated with climate change – that is good actions regardless of whether projected changes in climate play out as we think they will (Groves et al. 2012). Second, there are a number of techniques to help reduce uncertainties such as using simulation analyses that account for uncertainties, sensitivity analyses that explore how robust certain models or adaptation strategies are to various assumptions, and scenario analyses that examine a range of possible outcomes of either impact projections or results of implementing adaptation objectives (Glick et al. 2011). Finally, employing an adaptive management approach in which adaptation management objectives are evaluated through monitoring and evaluation (Lawler et al. 2010; Cross et al. 2012) is critical to providing managers the feedback necessary to make continual changes to address new information and uncertainty (http://yale.databasin.org/pages/coping-uncertainty).

The decision-making framework is illustrated on next page in Figure 3.4. It identifies the key stages comprising 'good practice' in decision-making. It covers the whole decision-making process, from problem identification through to implementation and monitoring of the decision. As shown in the Figure 3.4, these are:

Structuring the problem:
(a) Stage 1 : Identify problem and objectives;
(b) Stage 2 : Establish decision-making criteria, receptors, exposure units and risk assessment endpoints;

Analysing the problem: (tiered stages)
(a) Stage 3 Assess risk;
(b) Stage 4 Identify options;
(c) Stage 5 Appraise options;

Decision-making:
(a) Stage 6 Make decision;

Post-decision actions:
(a) Stage 7 Implement decision;
(b) Stage 8 Monitor, evaluate and review.

The focus of this section is upon identifying and treating the risk and uncertainty associated with decisions where climate change may be a significant factor. This emphasis is reflected in the level of detail with which the individual stages in the framework are described. For example, the options appraisal and decision-making stages require the use of a variety of standard techniques, and these stages are therefore described more briefly, although we emphasise the treatment of uncertainty. The aim of using the framework is for the decision maker to identify where climate change is a material consideration. Where climate or climate change are significant, the decision-maker should aim to identify adaptation options for the decision (such as no regret options) that are robust to the key sources of uncertainty. At each stage of the framework, it is important that a balanced approach is taken to both the climate and nonclimate factors that represent sources of risk and uncertainty. The framework aims to deliver a decision-making process that allows decision-makers and other stakeholders to define and refine their attitude to risk. This can include precautionary approaches (Green Alliance, 2002).

The decision process should, in general, involve all stakeholders. Nevertheless not all stakeholders may agree with the objectives and criteria defined by the primary decision-maker. This framework may be useful to those stakeholders excluded from or peripheral to certain decisions, aiding the examination or review of the decision-making process adopted by the primary decision-maker (Willows et al. 2003).

This framework was purposely developed to be flexible, allowing it to be applied to the wide range of decisions that may potentially be affected by climate change. This means it can be applied to many different types of decisions across a wide variety of sectors, and including commercial and public decisions concerning policy, programmes and projects (Willows et al. 2003).

3.2.5.4 Appropriate Technology Considering Locality

Until now, many appropriate technologies have been developed and many plans responding to flood damage are studied and implemented. So far, appropriate technology has mainly supported by technologies of donor countries rather than considering local conditions in developing countries. These supported facilities and technologies are not being properly maintained. Poor maintenance managements and inappropriate technology make it difficult to operate facilities, and eventually caused facilities to state of dormancy. For example, the idea behind PlayPump is simple, and it's not

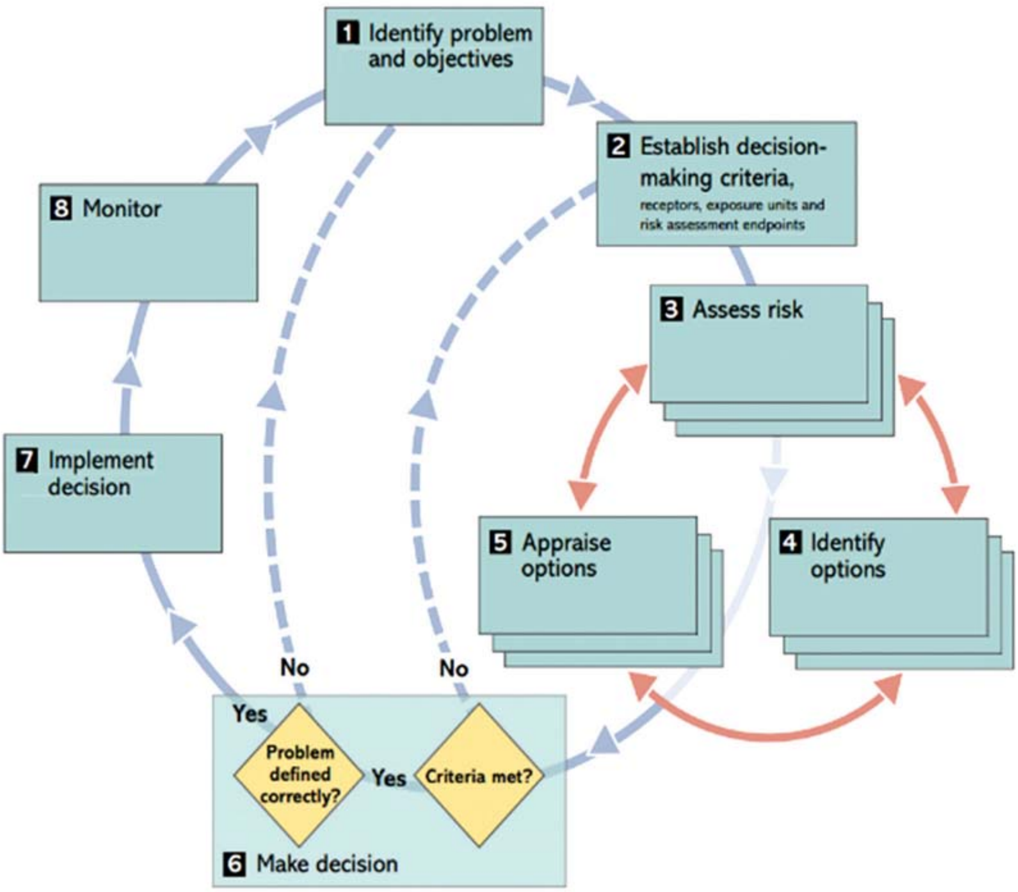

Figure 3.4 A framework to support good decision-making in the face of climate change risk (Willows et al. 2003)

hard to see why so many people got so excited about it. A merry-go-round type device is installed and connected to a water pump. As children play on the merry-go-round, water is pumped into a storage tank, and is then available on demand. Frontline originally reported on the technology in 2005, leading to a tremendous amount of excitement, including support from Laura Bush and AOL Founder Steve Case.

As the new Frontline story reports, however, it seems that PlayPump hasn't lived up to its original promise and even its strongest backers have had to admit that the large-scale roll-out they had originally planned was not realistic. In order to improve this problem, type of supporting technology and management plans should be established through joint research with local research institutions and regional research survey as well through Science Policy dialogue.

3.2.6 Recommendations

Adaptation is place and context specific, with no single approach for reducing risks appropriate across all settings. Adaptation planning and implementation can be enhanced through complementary actions across levels, from individuals to governments. Prospects for climate-resilient pathways for sustainable development are related fundamentally to what the world accomplishes with climate-change mitigation. Greater rates and magnitude of climate change increase the likelihood of exceeding adaptation limits. Significant co-benefits, synergies, and tradeoffs exist between mitigation and adaptation and among different adaptation responses; interactions occur both within and across regions. Strategies and actions can be pursued now that will move towards climate-resilient pathways for sustainable development. The sustainable water resources management considering climate change is able to maintain the harmony of ecological, environmental and hydrological effects. We must do our effort to reduce the water disaster risk gap between developed and developing countries due to the climate change. Appropriate technologies should be shared and exchanged each other for preventing disasters and for living together in this world. Also the world organizations and developed countries should help the low income countries from the disasters, especially, water related disaster problems. The global weather patterns and ecosystem are changing due to the climate change. Therefore, world's water industry is also greatly affected by climate change. Water industry has been considered in the aspects of water supply, wastewater treatment, water reuse, and seawater desalination. However, water related disasters might be included in water industry area because the disasters will be more and more important issues due to the climate change.

3.3 DROUGHT MANAGEMENT IN A CHANGING CLIMATE

3.3.1 Background

Drought is one of the extreme events, which is a recurring multidimensional phenomenon associated with deficit in available water. It can be caused by declines in precipitation, increases in evapotranspiration, or a combination of them. Drought is of particular interest because of its potential long-term impacts on water resources, agricultural production, economic activities, and ecosystems. Its most crucial aspect is the significant decrease of streamflow and the lower water storage in reservoirs, conventionally referred to as hydrological drought. This may be partially attributed to the change of climatic conditions, which is an additional threat that puts increased pressure on hydrological systems and water resources (Allen et al. 2011). Recently, drought vulnerabilities has got more attention due to a series of recent and severe droughts in regions as diverse as the United States Central Great Plains drought (Hoerling et al. 2014), the Horn of Africa and Sahel droughts in 2011 (Lyon and DeWitt 2012) and the Big Dry or Millennium drought of Southeast Australia (McGrath et al. 2012). Since the beginning of 21st century, severe droughts affected vast areas of South Asia, including Western India, Southern and Central Pakistan. These regions have been among the perennially drought-prone regions of the world. India, Pakistan, Sri Lanka and Afghanistan facing droughts at least once in every three-year period in the past five decades, while Bangladesh and Nepal also suffer from drought frequently. In 2012, Pakistan declared emergency in Tharpakrakar and Mirpur Khas districts due to severe drought and many people had to be resettled (Miyan 2014). Recent work further suggest that global aridity has increased in step with observed warming trends, and that this drying will worsen for many regions as global temperatures continue to rise with increasing anthropogenic greenhouse gas emissions (Cook et al. 2014).

Significant uncertainties were found in recent and projected future drought trends, especially regarding the extent to which these trends will be forced by changes in precipitation versus evaporative demand (Sheffield et al., 2012). Globally, both precipitation and evapotranspiration are expected to increase with warming, a consequence of an intensified hydrologic cycle in a warmer world. Regional changes in precipitation and evapotranspiration, and the dynamics that drive such changes, are nevertheless more uncertain, despite the fact that these changes are perhaps of greatest relevance to on-the-ground stakeholders (Cook et al. 2014). Separating the total ensemble uncertainty of future drought projections into contributions from internal variability, the GCM formulation and Green-House Gas (GHG) concentrations scenario uncertainty shows mostly negligible contributions from the GHG concentrations scenarios, but large contributions from internal variability for the next decades, especially for SPI. This depicts that there is only limited potential to focus on the likelihood range of near to mid-term meteorological drought projections.

On the other hand, the total uncertainty for Soil Moisture Anomalies (SMA) is dominated by uncertainty from GCM formulation already in the near future, which means that in principle GCM improvements could substantially reduce the spread of the projections, although the existing large uncertainty regarding land surface processes constitutes a huge challenge. Ongoing efforts to consolidate existing soil moisture data from in-situ measurements and satellites into consistent data products will enable a much better evaluation of GCMs over the coming years. These new data together with more realistic GCMs will allow for more reliable analyses of soil moisture changes in both past and future. Much of this uncertainty comes from the GCM formulation, which can hopefully be improved once that more exhaustive and consistent data of the land surface become available (Orlowsky and Seneviratne 2013).

3.3.2 Framing the Challenges

3.3.2.1 Historical Droughts, Its Spatial and Temporal Distribution

The recent historical record shows that there is a wide spatio-temporal variation in the natural climate system. Due to lack of direct observations, methodologies uncertainties and choice and geographical inconsistencies, there is low confidence in an observed global-scale trend in drought or dryness (lack of rainfall) (IPCC 2013). In speaking of global trends in drought, then, the meaningful questions are; (a) whether the frequency, intensity, and duration of droughts are changing in most or all of the regions historically prone to drought, and (b) whether the total area prone to drought is changing. Figure 3.5 summarizes some of the observed changes in climate extremes. Overall, the most robust global changes in climate extremes are seen in measures of daily temperature, including to some extent, heat waves.

Precipitation extremes also appear to be increasing, but there is large spatial variability, and observed trends in droughts are still uncertain except in a few regions. While robust increases have been seen in tropical cyclones (TCs) frequency and activity in the North Atlantic since the 1970s, the reasons for this are still being debated. The TCs variously affects soil moisture droughts via late drought initiation, weakened drought intensity, and early drought recovery. Assessment of the influence of Atlantic TCs on the eastern U.S. drought regime at regional scales was studied by Kam et al. (2012) for the period of 1980 to 2007. From their findings, the TCs reduced the average duration of moderately severe short-term and long-term droughts by less than 4 (10% of average drought duration per year) and more than 5 (15%) days yr−1, respectively. In addition, they removed at least two short-term and one long-term drought events over 50% of the study region. Despite the damage inflicted directly by TCs, they play a vital role in the alleviation and removal of drought for some years and seasons, with important implications for water resources and agriculture. There is limited evidence of changes in extremes associated with other climate variables since the mid-20th century (IPCC 2013).

Each of the five years since 2001 is one of the six warmest years overall in the 165 years from the available record period, where the two warmest years on record are 1998 and 2005. Using prediction from different climate models with different scenarios, the temperature in 2011-2030 is likely to be 0.64 – 0.7°C higher than the temperature in 1980-1999. If effective measures have not been taken for reducing GHG by 2100, the global surface temperature will rise between 1.8°C and 4°C above the 1990 levels. This will be three to six times the warming the planet has experienced since pre-industrial times (ComEU 2007). From heat waves to cold snaps or droughts to flooding rains, recording and analyzing climate extremes poses unique challenges, not just because these events are rare, but also because they invariably happen in conjunction with disruptive conditions. (IPCC 2013).

Some examples of the worst droughts worldwide over the past recent decades are as follows:

(a) The 1981–1984 African Drought

During 1981 to 1984 Africa suffered from severe drought where an astounding 20 nations of Africa were under severe drought. Entire rivers and lakes completely dried up. Up to 20,000 people starved to death each month. Although the total number of people who perished is not completely known, it is estimated that over 1 million people died as a direct result of the drought (http://www.wxedge.com).

(b) The 1987-1989 US Drought

The three-year drought of the late 1980s (1987-1989) covered 36% of the United States at its peak. Compared to the Dust Bowl drought, which covered 70% during its worst year, this does not seem significant. However, the 1980s drought was not only the costliest in U.S. history, but also the most expensive natural disaster of any kind to affect the U.S. (Riebsame et al. 1991). Combining the losses in energy, water, ecosystems and agriculture, the total cost of the three-year drought was estimated at $39 billion. Drought-related losses in western Canada exceeded $1.8 billion dollars in 1988 alone (www.ncdc.noaa.gov).

(c) The Big Dry or Millennium Drought of Southeast Australia (1997–2011)

The Big Dry one of the most severe and longest droughts on record over southeast Australia began around 1997 and continued until 2011. This drought is regarded as a local phenomenon attributed to the lack of negative phases of the Indian Ocean Dipole

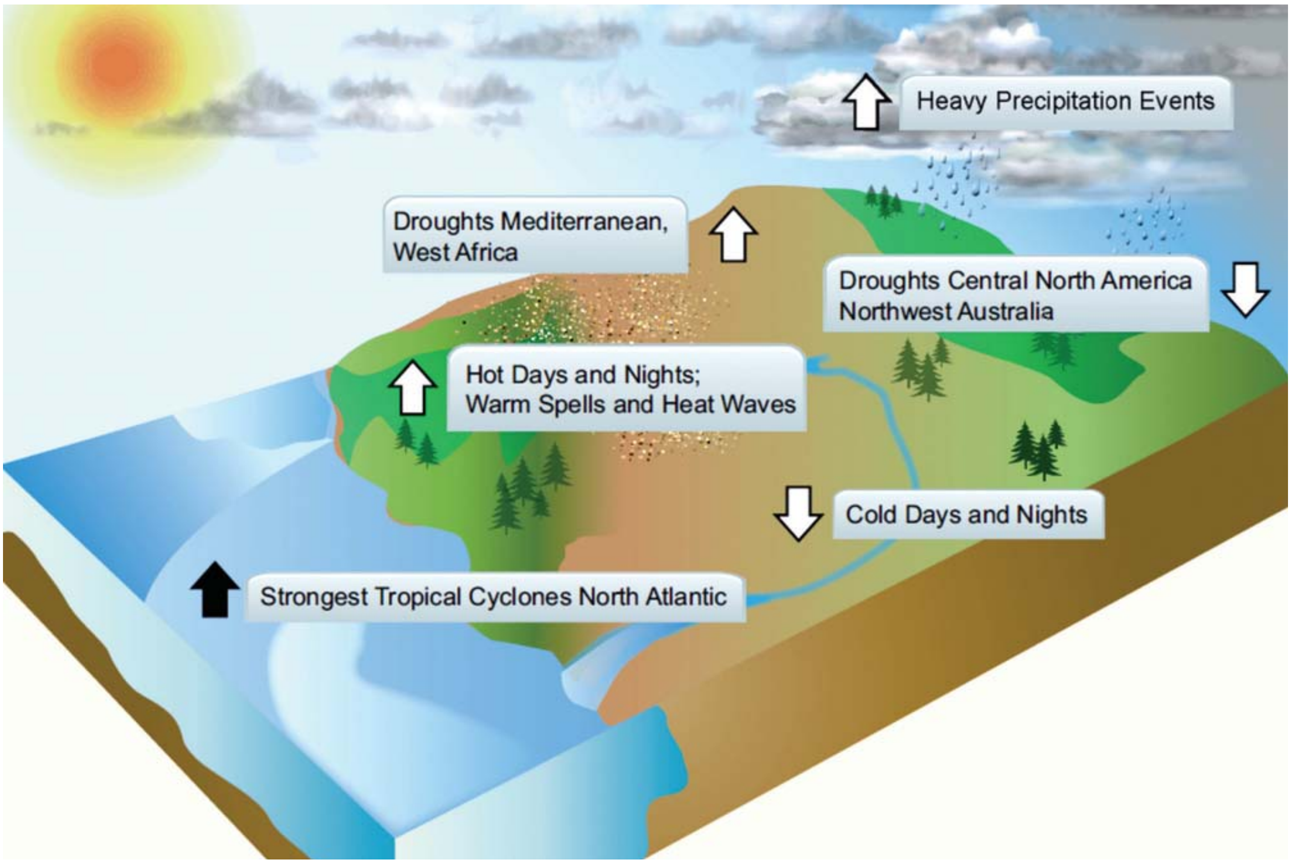

Figure 3.5 Trends in the frequency (or intensity) of various climate extremes (arrow direction denotes the sign of the change) since the middle of the 20th century (except for North Atlantic storms where the period is from the 1970s) (IPCC 2013)

(IOD). The IOD is an irregular oscillation of sea surface temperatures and atmospheric circulation in and around the Indian Ocean, characterized by the Dipole Mode Index (DMI). In the negative phase, with warmer waters off northwest Australia, the atmospheric circulation brings moisture across the continent in a southeasterly direction. In the positive phase, southeast Australia experiences lower rainfall (McGrath et al. 2012). With the official end of the drought declared in 2012, the Federal Government had provided $4.5 billion in drought assistance (www.bbc.com).

(d) The 2011 East Africa drought

Between July 2011 and mid-2012, a severe drought affected the entire East Africa region. It was declared as the worst drought in 60 years which caused a severe food crisis across Somalia, Djibouti, Ethiopia and Kenya that threatened the livelihood of 9.5 million people. The total death toll was reported as 50,000 to 260,000. Many refugees from southern Somalia fled to neighboring Kenya and Ethiopia, where crowded, unsanitary conditions together with severe malnutrition led to a large number of deaths. Other countries in East Africa, including Sudan, South Sudan and parts of Uganda, were also affected by a food crisis (www.wikipedia.com).

(e) The Great Plains, United States 2012 drought

The 2012 drought in the central Great Plain USA was the most extensive drought in half a century. The absence of processes produces rainfall over the central Great Plains caused the drought. These include springtime low-pressure systems and their attending warm and cold fronts that act to lift air masses and produce widespread rains. The deficit in rainfall in 2012 was -34.2 mm, which was about 53% of the region's long-term mean rainfall (73.5 mm). This deficit broke the record of -28.4 mm observed in 1934 and corresponds to a departure of 2.7 standard deviations. The 10 driest years (including 2012), ranked in order of their rainfall deficits, were 2012, 1934, 1936, 1901, 1976, 1913, 1988, 1953, 1911, and 1931. Impacts from the 2012 drought emerged swiftly and Loss was estimated more than $12 billion (U.S. dollars) (Cook et al. 2014).

3.3.2.2 Short and Long Term Drought Impact on Environmental Services

Water is a strategic resource for socio-economic and environmental development. However, water scarcity and droughts pose challenges for this development, which has been highlighted in different water policies, and in national and regional growth initiatives. To combat water scarcity and drought issues, The European Commission (EC) listed possible measures to cope with water crisis and water saving. The EC highlighted on priority basis and recommended shifting from a risk/emergency to a planned drought management approach and which has already proved in other regions as United States (Estrela and Vargas 2012). From European Environment Agency (EEA 2009) report point of view the impacts of drought and water scarcity may be summarized into: (a) economic impacts; (b) social impacts; and (c) environmental impacts.

(a) Economic impacts

- Deficiency in public water supply with implications in related sectors like tourism.
- Prices of food, energy and other products increase as supplies are reduced.
- Hydropower production may also decrease.
- Uncertainty on crops yield and deeper abstractions for use in agriculture.
- Higher level of risk for human and wildlife by range fires due to extended droughts.
- Unemployment, increased credit risk for financial institutions, capital shortfalls, and eventual loss of tax revenue for local, state, and federal governments.

(b) Social impacts

- Public safety, health, conflicts between water users.
- Inequities in the distribution of impacts and disaster relief
- Increase of water prices due to compensating measures.
- Migration of water-intensive industry.
- The migrants increasing pressure on the social infrastructure of the urban areas, leading to increased poverty and social unrest.

(c) Environmental impacts

Drought also affects the environment in many different ways. Like humans, plants and animals nourishment depends on water. When a drought occurs, their food supply can shrink and their habitat can be damaged. Sometimes the damage is only temporary and their habitat and food supply return to normal when the drought is over. But sometimes drought's impact on the environment can last a long time, maybe forever. Examples of environmental impacts include:

- Damages to plant and animal species and wildlife habitat
- Lack of food and drinking water for wild animals
- Increase in disease in wild animals, because of reduced food and water supplies
- Migration of wildlife
- Loss of biodiversity with increased stress on endangered species or even extinction
- Seawater intrusion due to over-pumping of groundwater aquifers
- Lower water levels in reservoirs, lakes, and ponds
- Decrease of air and water quality.
- Loss of wetlands
- More wildfires
- Wind and water erosion of soils and threats of desertification
- Deterioration of landscape quality

Some of these effects are short-term, conditions returning to normal following the end of the drought. Other environmental effects last for some time and may even become permanent. Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes, and vegetation. However, many species eventually recover from this temporary aberration. The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological productivity.

Human interaction with the physical environment has increasingly transformed Earth-system processes. Reciprocally, climate anomalies and other processes of environmental change of natural and anthropogenic origin have been affecting, and often disrupting, societies throughout history. Transient impact events, despite their brevity, can have significant long-term impact on society, particularly if they occur in the context of ongoing, protracted environmental change. Major climate events can affect human activities in critical conjunctures that shape particular trajectories of social development (http://www.pnas.org).

3.3.2.3 To Understand Importance of Shifting the Focus from Hazard Vulnerability/Resilience and Coping Capacity of Drought

The latest assessments show that due to problems with past observing capabilities, it is difficult to make conclusive statements about drought long-term trends (IPCC 2013). However, regardless of droughts lasting a short or long period of time, the droughts may have long lasting consequences for societies. To cope with the short and long term drought impacts, the traditional reactive approach is inadequate and risk management approach becomes necessary particularly to reduce water shortage in water supply systems (Rossi and Cancelliere 2013). A few basic principles should be adopted for effective hydrological risk management. First of all, drought is a natural variable based on meteorological conditions, but its severity impacts depends on the vulnerability of water supply systems and of socio-economic sectors as well as on the effectiveness of the adopted mitigation measures. To reduce our vulnerability to droughts, we need to change from passive crisis management to proactive risk management. We must boost society's capacity to cope before the next drought strikes.

The reactive approach or passive crisis identifies the mitigation measures only after the drought has begun and which is inadequate to reduce water shortage and highly inefficient in terms of financial resources. Conversely, the complexity of drought impacts requires a comprehensive preventive, anticipatory approach to risk, consisting essentially of two different phases: drought management plan development and implementation of the identified measures (both before and after event begins). In first phase of Proactive approach, an assessment of water resources availability is carried out to meet different demands, then different elements of water supply are analyzed to evaluate the water shortage risk. After drought impact analysis on different sectors, the actions are taken into account to reduce drought vulnerability and actions to mitigate drought impacts are defined in the planning documents. The second phase foresees a continuous monitoring of hydro-meteorological variables and water reserves status in order to identify possible water crises and to apply the necessary mitigation measures before a real water emergency occurs (Rossi et al. 2008). To promote a proactive approach, WMO, UNCCD, FAO and other partners are organizing a high-level meeting on national drought Policy from time to time to tackle this hot issue in future (Rossi et al. 2008).

Around 1.3 billion of the world's population lives on arid, semiarid, mountainous, or steep terrain. Such lands are often prone to drought, which can result in environmental, economic and humanitarian disasters. However, being drought prone is not necessarily the same as being vulnerable. Much depends on how dependent the economy is on rain and on whether the country's risk management and infrastructure are adequate and appropriate for dealing with drought. Given the potentially devastating impacts of drought on the lives and livelihoods of the poor, drought preparedness and adaptation to climate variability and change are key priorities in World Bank strategies. That the international community must respond to drought emergencies in the short term are understood. This note, however, concentrates on long-term measures for prediction, management, and mitigation that are aimed at minimizing the life-threatening and economy-weakening consequences of drought. Since drought tends to be a systemic shock, cutting across many sectors, it is critical that interventions seek to deepen relevant country-level dialogue and mechanisms for responding via macro-level frameworks such as development policy lending, Country Environmental Analysis, and the Comprehensive Development Framework (Esikuri 2005).

3.3.3 Framing the Solution

3.3.3.1 Understanding Dominant Drought Risk Parameters

Assessments of available water resources and their temporal and spatial distribution, as well as the analysis of flood and drought risks are of great importance to preserve the health of human societies and environmental systems. When looking at global change scenarios, these types of assessments are severely constrained by limited data availability, uncertain model results, and incomplete scenario assumptions. As long-term average values are generally considered the more reliable outputs of climate and large-scale hydrological models, many climate impact studies have focused on mean renewable water resources and average flow conditions, while assessments of seasonal changes and extreme flows have been rare. Beyond the average trends, however, changes in the frequencies of extreme events, such as floods and droughts, may be one of the most significant consequences of climate change. Moreover, during extreme low and high-flow events the threats to human societies and the environment are likely to be most critical, and the conflicts between competing requirements to be most intense. Thus growing attention has recently been drawn, both from a scientific and political perspective, on understanding the risks of extreme hydrological events with regard to global change (Lehner et al. 2006).

Evidently, extreme flood and drought events can cause tremendous damage to economy and ecology and, in the worst case, bear enormous risks for life. They are phenomena that are not constrained by watershed or international boundaries, and they can grow to afflict large areas and many countries simultaneously. Climate change is expected to alter average temperature and precipitation values and to increase the variability of precipitation events, which may lead to even more intense and frequent floods and droughts. As general future trends, increases in average precipitation and its variability are expected, suggesting higher flood risks, while less rainfall, prolonged dry spells and increased evaporation may increase the frequency of droughts in southern areas. Because of their large-scale character, it has been recommended that droughts should be studied within a regional context. This constrains regional assessments of climate change effects, as the results of the individual case studies may be incomparable due to the application of different climate change scenarios, different hydrological models, or different statistical methods. Even using the same hydrological model in multiple basins may not solve this problem, as small to meso-scale models are normally developed for certain areas and conditions and often need strong tuning or model modifications when transferred, e.g. from cold humid to hot semiarid areas (Lehner et al. 2006).
Some of the drought risk parameters that need assessment and evaluation to cope with future drastic situation are as following.

(a) Climatic Factors
- Precipitation deficit (overall, during specific stages of crop growth, by location)
- Temperature variation (mean, max, min, and amplitude)
- Evapotranspiration
- Frost and other hazards (dry wind, sandstorms etc.)

(b) Water Resources
- Reduction in runoff, streamflow/river flow, spring discharge, temporary rivers, snowmelt
- Water storage (% reservoirs filled)
- Ground water recharge

- Wells (discharge reduction, number of dried wells, draw down)
- Water allocation/use by sector (% reduction)

(c) Economic Sectors: Agriculture
- Cropped area (changes by crop)
- Cultivation date
- Failures/delays in crop germination, plant density, number of tillers
- Crop yield reduction (irrigated and rainfed, per unit area, total)
- Damage to quality of produce

(d) Economic Sector: Livestock, Forests and Rangelands
- Range and pasture lands production and quality
- Reduction in livestock (deaths, sale, slaughter)
- Reduction in birth rate, death of newly born animals
- Reduction in forest products (timber, charcoal, wood)

(e) Social Impacts
- Food insecurity - malnutrition, famine
- Unemployment
- Population migration
- Disease occurrence
- Unemployment
- Incidence of theft, racketeering, social unrest

(f) Environmental Impacts
- Habitat and ecosystem losses (wetlands, riparian habitat)
- Wildlife losses
- Soil and water salinization
- Soil degradation (erosion, organic matter/fertility reduction)
- Soil and water pollution (www.drought.unl.edu)

3.3.3.2 Scientific and Technological Basis of Drought and Coping with it Both Spatially and Temporally

Droughts are complex natural hazards that distress large worldwide areas every year with serious impacts on society, environment, and economy. Over the past 150 years, the average global temperature has increased by 0.5–2 C° (Wang et al. 2014). Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation of the Intergovernmental Panel on Climate Change (IPCC) suggests that there will be virtually certain increases in frequency and magnitude of unusually warm days and nights at the global scale in the whole 21st century. Higher temperatures will increase the potential evapotranspiration and possibly result in an increased occurrence of drought. Drought is one of the costliest natural disasters. Data from the Emergency Event Database (www.em-dat.net) show that the number of drought disasters accounts for only 5% of total disasters, but the losses can amount to 30% of the losses from all natural disasters. The effects of drought have recently evoked interest beyond the scientific community (Wang et al. 2014).

Since the 1970s, characteristics of drought such as intensity, duration and affected area of droughts are increasing. In recent years, large scale intensive droughts have been observed on all continents, affecting large areas in Europe, Africa, Asia, Australia, South America, Central America, and North America and high economic and social costs have led to increasing attention to droughts (Mishra and Singh 2010). The readers are encouraged to study the Mishra and Singh (2010) comprehensive drought review about the impacts of droughts on different continents around the globe. The percentage of the world subjected to extreme drought (assessed based on drought indicators) will expand from 1% to 30% in the 21st century, and the number of severe drought events and drought duration are likely to increase. In particular, severe drought can have devastating effects, such as significant crop yield losses, an increased risk of forest fires, exacerbated and intensified land degradation and desertification, and increased competition for resources and social violence, because of its long-lasting and wide areal extent. In 2002, 26 states in the United States were affected by severe and extreme drought, and total losses exceeded $2.7 billion (Wang et al. 2014).

Some common drought vulnerability factors include; low rainfall, increased temperature, more evapotranspiration, low soil moisture holding capacity, absence of irrigation facilities, livestock without adequate fodder, lack of water storage facilities, poor water management, deforestation, over grazing, water consuming cropping patterns, excessive ground water draft, soil erosion, population growth and urbanization, industrialization, and global warming etc.

Shortage of water poses a great threat to nature, quality of life, and economy. Increasing water demands lead to conflicts among competing water users that are most pronounced during drought periods. The study of the climate variability may contribute to a more correct management of such extreme climatic occurrences. Recently, there has been debate on the apparent increase, regarding the event frequency and the affected area, of droughts and on the possible physical causes of such circumstance (Santos et al. 2010). Therefore, it is of great significance to develop a drought monitoring model to monitor the distribution and intenseness of droughts, which is crucial for drought warning and resisting effectively. As the temporal and spatial changes contribute to the diversity of drought conditions, it is necessary to perform naturalization for these changes during the development of the improved drought monitoring model (Liu and Xiang 2008).

The spatial-temporal analysis of drought is one of the most important aspects of drought disaster mitigation. To identify the world's severely drought-prone areas, given that the corresponding ground area for a 0.5-degree grid in different latitudes is different, Wang et al. (2014) proposed a more precise spherical area-based statistical method. The corresponding ground area per 0.5-degree grid was obtained by integral calculation in latitude and longitude directions. They analysed drought based on the global standardized precipitation Evapotranspiration Index data set from 1902 to 2008, where global, Northern Hemisphere, Southern Hemisphere, and major crop-planting regions from six continents were treated as statistical units. The inter-annual variability characteristics of the severe drought area for each statistical unit were investigated. To study the spatial distribution characteristics of the global frequency of severe drought, the drought frequency was calculated based on drought events identified by continuous drought months on a grid level. Six major crops (wheat, maize, rice, soybean, barley, and sorghum) were chosen to study the impact of drought events on agriculture. From their results they found an overall upward trend in all continents except Oceania as shown in Fig. 3.6. They identified drought-prone areas as those with patchy distribution and frequently drought-prone areas (with 10–20% occurrence probability of drought) were distributed in regions surrounding chronically drought-prone areas (with more than 20% probability). Global chronically drought-prone areas have increased significantly, from 16.19% in 1902–1949 to 41.09% in 1950–2008. Chronically drought-prone areas of agriculture are located in the center of southern Europe, some areas of the South America, and eastern Asia. Their conclusions can provide a scientific basis for the management of drought mitigation strategies on a global or national scale. Identifying the drought-prone areas can help decision-makers to take drought into account in resource planning and help to select drought-tolerant crops in drought-prone agricultural areas.

The European Drought Observatory web pages contain drought-relevant information such as maps of indicators derived from different data sources (e.g.,precipitation measurements, satellite measurements, modelled soil moisture content). Different tools, like Graphs and Compare Indicators, allow for displaying and analysing the information and irregularly published "Drought News" give an overview of the situation in case of imminent droughts. This has been developed in the framework of the EuroGEOSS project considering the INSPIRE specifications and GEOSS interoperability arrangements. The project established a drought metadata catalog to allow access to resources for drought monitoring. It is fully integrated with local and national systems in Europe and international drought early warning systems as a European contribution to a Global Drought Early Warning System (http://www.eurogeoss.eu/).

3.3.3.3 Striving towards Horizontal and Vertical Integration of Existing Drought Early Warning Systems

(a) Operationalize drought monitoring system
- Diagnosing the causes of drought versus water scarcity in regional scale
- Consistent monitoring and reporting
- Responsible agencies (environmental, water basin agencies, …)

(b) Provide forecast and warning information
- Seasonal outlooks
- El Niño/La Niña
- Sea surface temperatures
- Economic and social trends
- Linked to drought plan “triggers”
- Developing management strategies focusing on cost benefit analyses of agricultural evapotranspiration vs. water conservation for alternative hydrological uses
- Forecasting the incidence of drought events under

climate change scenarios

(c) Develop or modify current data and information / communication delivery systems
- Improve system over time with experience
- Enhance delivery of information to users (i) Cellular (ii) Webinars
- Weekly bulletins/extension
- Monthly cabinet meetings/briefings, etc.

3.3.3.4 Improving Drought Mitigation Indicators and Measures to Reduce Damage

Drought is not only caused by insufficient total precipitation, but also directly caused and increasingly aggravated by a number of consecutive no-rain days within the rainy season, usually called dry spells. Dry spell (DS) is defined as consecutive days with the daily precipitation amount less than a certain threshold, i.e. a dry spell is preceded and followed by rainfall days exceeding the threshold. Dry spell analysis helps to better recognize the dryness impact. Research relying on the monthly precipitation can sometimes lead to incorrect results, and consequently many researchers all over the world have studied drought using dry spell analysis (Huang et al. 2014). To prevent and alleviate the potential drought damages, many cities and states in the USA have developed their drought mitigation plans. These plans are usually composed of three to four drought severity levels and their respective mitigation measures. Nonetheless, for a drought mitigation plan, defining drought indicators based on the identification of different drought severities is critical.

Mainly, the drought indicators are established according to streamflow, precipitation, water levels in lakes and reservoirs, soil moisture content, and groundwater level (Chen and Chan 2007). A number of different indices have been developed to quantify a drought, each with its own strengths and weaknesses. They include the Palmer drought severity index (PDSI), rainfall anomaly index (RAI), crop moisture index (CMI), Bhalme and Mooly drought index (BMDI), surface water supply index (SWSI), national rainfall index (NRI), standardized precipitation index (SPI), and reclamation drought index (RDI). The soil moisture drought index (SMDI) and crop-specific drought index (CSDI) appeared after CMI. Furthermore, CSDI is divided into a corn drought index (CDI) and soybean drought index (SDI), and vegetation condition index (VCI). Based on the studies for drought indices, considered: the priority of water allocation among the various uses, the indications provided by drought monitoring systems and the method adopted to assess drought risk. With reference to the latter, the individualization of risk levels (i.e. alert, alarm and emergency), associated with different groups of interventions, could be a valuable tool for decision makers. In nutshell, it should be pointed out that an integrated drought management strategy is a key step toward the reduction of the most adverse drought effects, since it makes possible to shift from a reactive to a proactive approach, which is widely recognized to be the more appropriate way for a successful drought mitigation (Rossi et al. 2007).

Sechi and Sulis (2010) developed a methodology to support the decision making process of water authorities facing droughts in complex water systems. The methodology is based on a full integration of optimization and simulation tools. The exploratory power of the optimization allows the rapid estimation of subsets of flow variables related to forecasted demands supplies and shortages that are used as operative indicators of the drought risk in future hydrological scenarios. The simulation model uses these indicators as triggers of mitigation measures in a proactive approach to drought. In the case of an overly optimistic forecast of the hydrological scenario, the proactive approach does not completely eliminate the risk of shortages. In this case, further measures have to be implemented in the water system simulation in a reactive approach to drought. These can include more expensive and higher impact measures to be taken later, after the severity of the drought event has been highlighted.

3.3.4 Accelerating Innovation

In order to build long-term resilience to drought it is necessary to combine traditional methods with local knowledge, and innovative technological tools with community-based solutions. Innovations in drought response and resilience offer hope and the ability to predict, withstand, and overcome future drought crises (Othowai et al. 2012). Drought as natural disaster continues to threaten the livelihoods of millions of people. Combating drought is utmost necessary to achieve sustainable development goals, including the maintenance of ecosystem services, and improving the livelihoods of millions of people living in drought-prone regions. The effects of climate change heighten the risk of droughts and drought severity and

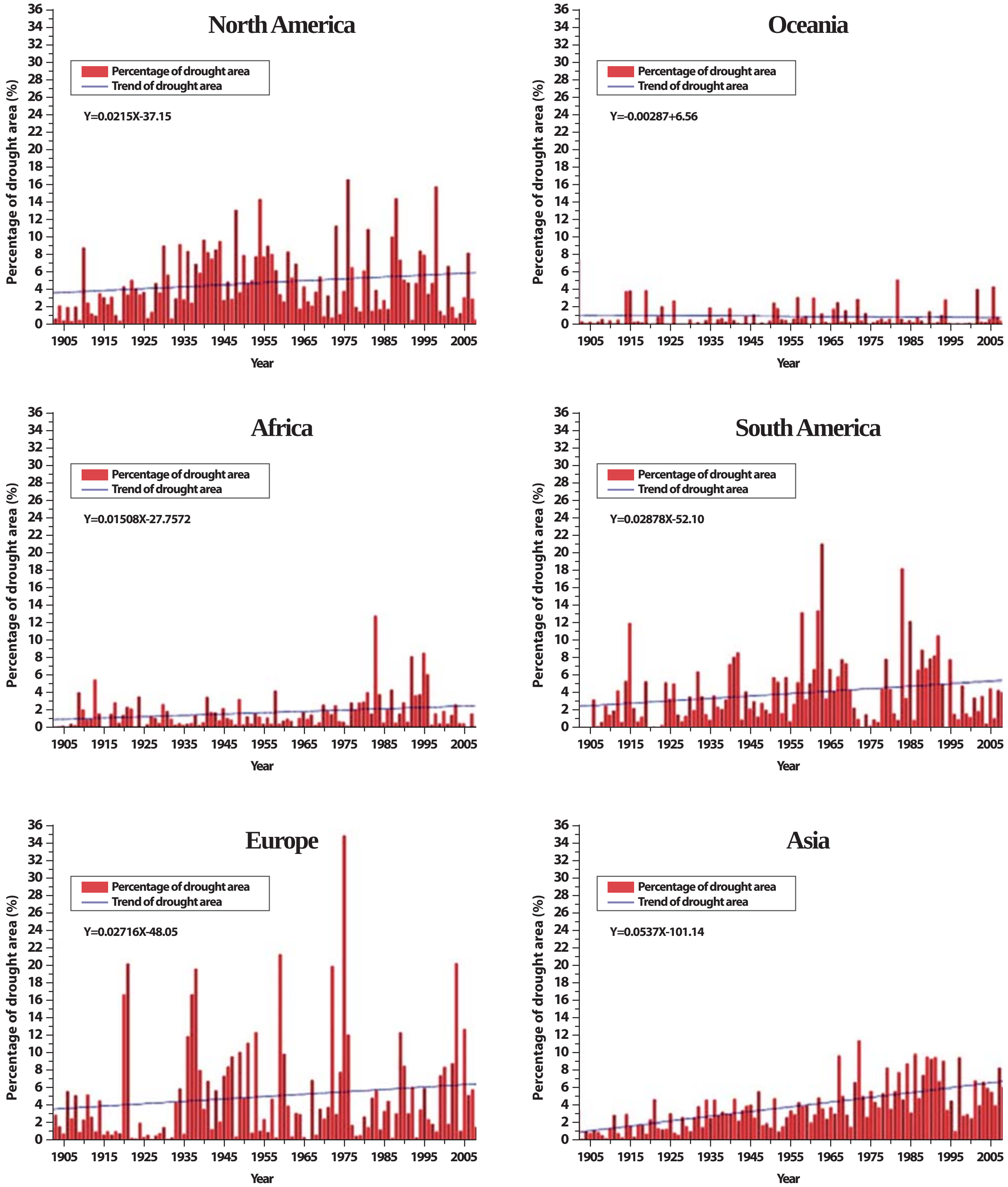

Figure 3.6 The severe drought area in each continent. (The red histogram represents the interannual variability of the severe drought area for each continent during the period from 1902 to 2008; the blue line represents a changing trend of severe drought area) (Wang et al. 2014)

increase the need for effective drought management and disaster risk reduction. Drought must be included as an integrated part of sustainable development cycle, considering social, economic and environmental aspects. Strategies for drought management, including contingency planning should be incorporated into sustainable agricultural practices, soil conservation, crop diversification and integrated water resources management and combating desertification, taking into account the legal framework and mandate of the UNCCD and its role in mitigating the effects of drought.

3.3.4.1 Scaling up and Expanding the Existing E-learning Tools

E-learning is the study of ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources. E-Learning can play a vital role in drought monitoring and mitigation measures. The advantages of e-learning are as follows:

(a) Continuous up-to date information about the forthcoming projected events.
(b) Capability to communicate and collaborate for drought risk reduction through using chat rooms, emails, bulletin boards etc.
(c) Acquiring knowledge from web server with consultation of drought management experts according to the learner own pace.
(d) Can improve the productivity and efficacy of the concerned group.

The WATER CoRe (Water Scarcity and Droughts - Coordinated actions in European Regions) was a project (from Jan. 2010 to Dec. 2013) funded by the EU's European Regional Development Fund. The project provides an exchange platform for water scarcity and drought issues at regional and local level for all European regions (www.unece.org). The WATER CoRe aim was to compile existing policies and practical experiences on the management of water scarcity and droughts and makes it accessible to all regional and local actors in the EU and beyond in order to help countries create their own tailor-made approaches. The WATER CoRe (www.ativizig.hu) e-learning addresses; (i) professionals, working for (regional) governments, (ii) water authorities, (iii) consultants or non-governmental organizations (NGO's), which are looking for practical solutions. It may also be valuable for students and scholars in water management, (spatial) planning, governance and sustainable development and policy makers on the European level.

Seven main e-learning modules related to water scarcity and drought issues highlighted by WATER CoRe are as following:

(a) Water Scarcity and drought - an overview
It deals with the general introduction about water scarcity and drought issues.
(b) Demand-side water management - technical issues
This module deals the partners know-how in management plans, guidelines, software tools and research programs oriented towards real and strong solutions on water demand-side management. Main topics under this module are; (i) alternative sources to freshwaters, (ii) treated wastewaters recycling, (iii) efficiency in the distribution network and leakage reduction, (iv) water-saving equipment, (v) sustainable irrigation, and (vi) metering and re-use.
(c) Demand-side water management - economic aspects
The main focus of this module is on the selection of economic and financial instruments focused on water demand side management through monetary mechanisms.
Main drivers are; (i) taxing and pricing, and (ii) return on investment.
(d) Handling drought periods and mitigate drought effects
This covers the communication and information to drought events; technological and infrastructural measures; planning, management and monitoring.
(e) Climate change effects on water management
This part discusses the existing policy frameworks on different levels of governance, relating to different sectors for the implementation of adaptation and mitigation strategies.
The factsheets selected deal with four different concepts; (i) forecasting, (ii) adaptation strategies, (iii) mitigation strategies, and (iv) implementation and governance.
(f) Public awareness and participation
This part shares several experiences collected: awareness raising and education; information and dissemination as well as public participation programs and stakeholder involvement tools.

(g) Roadmap to the implementation of regional action plans
Providing guidelines to the implementation of local and regional plans to cope with water scarcity and drought.

The UN-SPIDER (United Nations Platform for Space-based Information for Disaster Management and Emergency Response) Regional Support Office (RSO) in Iran is hosted by Iranian Space Agency Office for Outer Space Affairs (UNOOSA). In June 2014, the RSO started to choose E-learning considering it as a key factor in knowledge promotion at the field of drought monitoring. The targeted objectives of RSO from this E-learning program (www.un-spider.org) were:

(a) Increase the knowledge of participants about drought and its impacts.
(b) Increase the knowledge of participants about role of remote sensing in drought monitoring and risk assessment.
(c) Fill the technical gaps between different sectors working in the field of Space Technology and Disaster Management.
(d) Teach a simple methodology using free of charge archived satellite imagery for drought monitoring and risks management.

The target groups were:

(a) Professionals with skills on the use of GIS and RS background who requires knowledge for drought monitoring.
(b) University students, researchers interested in the field of geosciences, geo-information, and drought monitoring,
(c) Staff working in the disaster management organizations and space technology.

3.3.4.2 Merging Latest Technology and Traditional Knowledge to Minimize Future Droughts

As vulnerability to drought has increased globally, greater attention has been directed to reducing risks associated with its occurrence through the introduction of planning to improve operational capabilities (i.e., climate and water supply monitoring, building institutional capacity) and mitigation measures that are aimed at reducing drought impacts. This change in emphasis is long overdue. Typically, when a natural hazard event and resultant disaster has occurred, governments and donors have followed with impact assessment, response, recovery, and reconstruction activities to return the region or locality to a pre-disaster state. Historically, little attention has been given to preparedness, mitigation, and prediction/early warning actions (i.e., risk management) that could reduce future impacts and lessen the need for government intervention in the future. Because of this emphasis on crisis management, society has generally moved from one disaster to another with little, if any, reduction in risk. This concept is expressed in the Cycle of Disaster Management. If more emphasis is placed on the risk reduction portions of this cycle, the impacts associated with drought and other disasters, and thus the need for government interventions in the form of emergency relief measures, will be reduced (Wilhite et al. 2014).

Space-based data is a vital complement to ground-based information in combating drought. However, there is a lack of resources and capacity to perform such analysis in many drought-prone developing countries. A major drawback of operational drought forecasting systems is their inability to make reliable predictions regarding the location, magnitude and the kind of assistance needed in the medium to long term, i.e. several months in advance. Yet in some situations where predictions were made, e.g. warnings of extreme drought conditions in the Horn of Africa during 2010/2011, there was still insufficient response on the ground (Enenkel et al. 2014). Moreover, the predictions of large-scale droughts even fail in industrialized and developed countries such as the United States (Schiermeier. 2013). This has proved that fact that there is no commonly accepted definition of drought (Belal et al. 2012) and climate change impacts on global drought patterns (Trenberth et al. 2014). At the same time the consideration of teleconnections, for instance the impact of anomalies in the sea surface temperatures of the Indian Ocean on drought events in the Horn of Africa (Tierney et al. 2013) add complexity to already sophisticated models. Finally, there are different kinds of drought (i.e. meteorological, agricultural and hydrological) that have different socio-economic implications so it is not possible to have a single physically measurable "drought-parameter" for all of these situations.
How can science play an efficient supporting role in the decision-making process is the crucial question, which

needs an answer. One promising and logical solution is the integrated combination and adaptation of existing technologies, including different satellite-based systems. Organizations such as NOAA (National Oceanic and Atmospheric Administration) or EUMETSAT (the European Organization for the Exploitation of Meteorological Satellites) provide a vast variety of satellite-derived datasets that are available operationally, on a near real-time basis and free of charge (or with a minimal and low-cost receiving station). In addition to some of the more commonly used remote sensing products, datasets derived from microwave sensors can be provided at a spatial resolution that is worth to complement or replace in-situ measurements. These datasets mostly used to compensate for weaknesses of local measurements such as poor coverage and the lack of spatial consistency. Although a spatial resolution of 25 kilometers (e.g. for soil moisture derived using a radar sensor) does not allow investigations at a field scale, such datasets can nonetheless provide an added value, particularly in areas with incomplete or biased rainfall measurements. Monthly weather predictions are available, for instance from the European Centre for Medium-Range Weather Forecasting (ECMWF). However, seasonal forecasts are extremely complex due to uninterrupted chaotic processes in our atmosphere (e.g., wind speed and direction, variations in air pressure or heat transfer) and only available to scientific users. All of these products require an in-depth understanding of atmospheric and biophysical processes along with the technical knowledge to deal with large datasets–an understanding and capacity that many users do not have (Enenkel et al. 2014).

The interaction of environmental drought-inducing key parameters (rainfall, temperature, soil moisture, vegetation, evapotranspiration) is fairly well understood. One major problem is that large-scale preparations require reliable forecasts several months in advance, which are currently not certain enough. Another issue is that agricultural drought constitutes just one possible root cause of food insecurity. In many cases, famine is promoted by high levels of vulnerability caused by interacting socio-economic issues, such as political unrest, and increasing or unstable food prices. In fact, the methods for monitoring environmental anomalies and their socio-economic manifestations hardly overlap. In order to create a holistic monitoring system it is recommended that researchers collaborate more closely with end users in a multi-disciplinary approach. Figure 3.7 demonstrates this approach and identifies the current weak connections.

3.3.4.3 Improving Use of Remotely Sensed Satellite and Information Technologies for Drought Risk Reduction

There are a number of ongoing technological developments that could support drought risk reduction. Here, three complementary tasks are focused that could be better integrated to improve decision-support; (a) the improvement of agricultural drought monitoring through exploitation of satellite-derived soil moisture, (b) gaining a better understanding of the uncertainty of long-term weather forecasts and how this information can be integrated with satellite-derived soil moisture, and (c) the integration of non-environmental information via smartphones. These three complementary tasks are discussed in more detail below.

First, the full potential of state-of-the-art satellite-derived soil moisture measurements from space-based microwave sensors needs to be exploited for agricultural drought monitoring. Soil moisture in particular is essential to close the gap between atmospheric processes and land surface interactions. It indicates plant water deficiencies earlier than conventional products estimating the vegetation status such as the Normalized Difference Vegetation Index (NDVI). For example Zribi et al. (2010), have modeled the future vegetation dynamics during rainy seasons in semiarid regions using satellite-derived soil moisture only. Although the soil penetration of space-based microwave sensors is limited to a few centimeters, it is possible to estimate the soil moisture conditions in the root zone (Albergel et al. 2008). Radar measurements are carried out independent from weather conditions and sunlight. Afterwards, they can either be used directly as an input for drought indicators or incorporated into advanced models via data assimilation (Enenkel et al. 2014). Both the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) are focusing on new-dedicated soil moisture sensors. The launch of NASA's SMAP (Soil Moisture Active Passive) mission is planned for late 2014. The first satellite of the new European flagship mission named "Sentinel" was launched in April 2014. Until Sentinel-1a has finished its "commissioning phase" there is only one operational soil moisture monitoring system.

Second, in addition to a large-scale picture of present

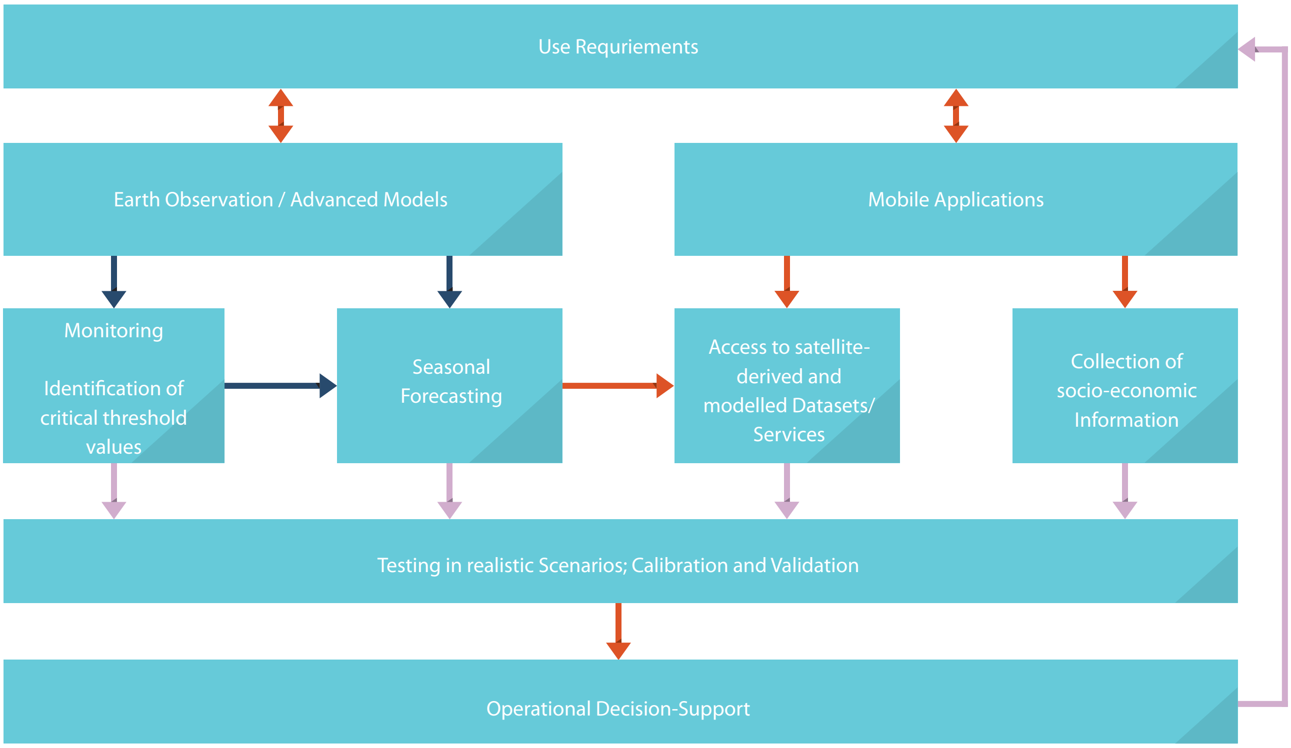

Figure 3.7 Proposed framework for an operational decision-support system that considers state-of-the-art earth observation, advanced models and mobile applications based on user requirements
(Enenkel et al. 2014).

conditions, decision-makers require estimates of future conditions, preferably over the duration of a season. Once the outputs of forecasting models are calibrated to regional conditions (forecasting centers usually provide uncalibrated forecasts), seasonal predictions can then provide an added-value. Therefore, the concept of uncertainty must be well-understood, clearly communicated and visualized. Seasonal forecasts (e.g., of rainfall) are usually based on a multitude of model outputs that ideally agree on a future trend. As a result, it is not recommended to issue warnings for definitive events based only on seasonal predictions. Yet, information such as a "70% risk of rainfall below average during the growing season" can be used as an additional risk parameter. The predicted El Niño conditions for 2014 are a good example for long-range forecasts.

From a user's point of view the retrospective analysis of forecasts, so-called "hindcasts", can help to identify their performance with respect to past drought events. If the forecast of one variable shows an added-value compared to its historic trend, it can potentially be considered as the input for an operational decision-support system. While seasonal forecasts for rainfall, temperature or soil moisture are available from different centers around the world, the vegetation status is not. However, the close temporal relationship between soil moisture and vegetation could allow estimations of the future vegetation status based on soil moisture predictions. Particularly in regions that show a high correlation between crop failure and food insecurity, the predictions of crop health are vital.

Third, mobile applications can directly link end users to drought-relevant information. On one hand, local farmers and aid organizations need to be able to understand and access all the above-mentioned information. On the other hand, these people are indispensable for validating satellite-derived drought indicators, for instance via taking GPS-tagged pictures of crops, or to collect information about socio-economic conditions that cannot be monitored from space. Recent examples of mobile data collection (so-called crowdsourcing) include the activities of the Humanitarian OpenStreetMap Team (HOT) during the aftermath of typhoon Haiyan that struck the Philippines on 8 November 2013 or during the civil unrest in South Sudan in early 2014. In both cases the HOT was activated to provide geographic baseline data for humanitarian response.

Finally, the objective of all new initiatives must be to support disaster risk reduction via individual short-term solutions – also after the media attention is gone. The above-mentioned approaches and technologies are not the ultimate solution, but they can complement the existing knowledge base for decision-support (Enenkel et al. 2014).

The 2014 United Nations/Germany Expert Meeting (UN/GEM 2014) on the Use of Space-based information for flood and drought risk reduction focused on the use of space technologies to improve disaster risk reduction. Floods and droughts served as examples for hazard types that have recently affected countries around the globe. Recent examples are the UK floods in February 2014, floods in Central Europe in June 2013, the floods following super typhoon Haiyan in the Philippines in November 2013, or the droughts in Eastern Africa 2011 and droughts in Bolivia in 2013 (http://www.un-spider.org).

Effective disaster-risk management aims to prevent that events such as floods and droughts become disasters. Space technologies, especially Earth observation and global navigation satellite systems, provide data which can be used for risk assessment. However, the potential contribution of space-based information to disaster-risk management is not yet fully exploited – technical solutions are not tailored enough to the needs on the ground, and space-based information is rarely easily accessible to disaster managers. The United Nations/Germany Expert Meeting on the use of space-based Information for flood and drought-risk reduction focused on the use of space technologies to contribute to disaster-risk reduction.

(a) The outcomes related to this Expert Meeting included:
- The exchange of information on the most up-to-date satellites and Earth observation methodologies to improve flood and drought risk assessment;
- The elaboration of recommendations to improve flood and drought-risk management through the use of space-based information;
- The identification of elements to contribute to the Post 2015 Framework for Disaster Risk Reduction (HFA-2) and to the upcoming World Conference on Disaster-risk reduction to take place in Sendai, Japan, in March 2015.

(b) The Bonn meeting included drought risk reduction related objectives as following:
- To gather lessons learned from on the use of Earth observation in past droughts;
- To identify ways how to enhance the use of the UN-SPIDER Knowledge Portal to support drought risk assessment; and
- To come up with recommendations regarding how drought-risk management can be improved through the use of space-based information.

(c) Tackling the issues like availability accessibility and usefulness of satellite data during recent droughts as well as the suitability of different indices. On the issue of novel satellite sensors, the following conclusions were derived:
- TRMM is an example of an operational satellite-based data source for precipitation monitoring. The Global Precipitation Monitoring (GPM) Core Observatory will ensure data continuity for precipitation monitoring. All GPM products will be released to the public from September 2014. EUMETSAT was also mentioned as a data provider for satellite-based precipitation data;
- The Soils Moisture and Ocean Salinity application (SMOS) is a scientific and experimental sensor which could be used for soil moisture and could complement efforts to predict crop productivity.
- The thermal bands 10 and 11 of Landsat8 resolution were also identified as suitable for soil moisture estimation. With 100m resolution they provide a much higher spatial resolution than SMOS data (35 km), which could be useful for applications in agriculture.

(d) Regarding applications of Earth observation products, the followings were discussed:
- The Famine Early Warning System (FEWSnet) developed by the United States and implemented worldwide with support from the United States Agency for International Development (USAID) is as an operational service that makes use of

vegetation indices (NDVI, EVI), rainfall estimations, evapotranspiration, crop soil water index and other ground-based data to monitor droughts and their effect on food security. Such a system could complement existing efforts to track droughts through standard precipitation and weather measurements carried out by Meteorological Departments. Mexico and Nigeria have used FEWSnet and recommend it as a useful information source for drought monitoring;

- Famers could benefit from the use of precision agriculture, where space-based information is used to optimize agricultural practices. Such practices are used in several countries including the Netherlands;
- A pilot project is being conducted in Pakistan with the objective of providing decision makers near-real-time crop yield forecasting information and a crop-reporting service including statistics on different crops, drought conditions and information on losses due to droughts.

3.3.5 Research and Development Agenda

3.3.5.1 Current Leading Edge Development in the Field of Drought Risk Reduction

To reduce the threat of drought around the world, an increasing number of national, regional, and international entities have begun to take action. Drought risk reduction is also connected with another important international convention, the United Nations Framework Convention on Climate Change (UNFCCC). According to UNFCCC, there are at least two areas where activities related to drought can be undertaken: (a) adaptation to the impacts of climate change, and (b) research and systematic observation. Parties of the convention have committed to close cooperation in responding to drought, desertification, and flood disasters (UNISDR 2007). In 2003, the secretariat of the UNISDR facilitated the creation of an Ad Hoc Discussion Group on drought at the request of the United Nations Inter-Agency Task Force on Disaster Reduction. The endeavor brought together prominent scientists and practitioners from a variety of institutes and UN agencies to propose new paradigms and actions required to reduce global drought risk. The initiative resulted in an integrated approach to reducing social vulnerability to drought, which has been used to promote drought resilient nations and communities around the world (http://www.unisdr.org/droughts-doc).

The drought risk reduction framework proposes the following main elements for consideration, namely:

(a) Drought policies and governance,
(b) Drought risk identification, impact assessment, and early warning,
(c) Drought awareness and knowledge management,
(d) Reducing underlying risk factors, and
(e) Effective drought mitigation and preparedness measures.

The National Drought Mitigation Center (NDMC), established at the University of Nebraska-Lincoln in 1995, providing technical assistance to communities and institutions to develop and implement measures to reduce societal vulnerability to drought, stressing preparedness and risk management rather than crisis management. The NDMC collaborates with many federal, state, and international agencies. A ten-step drought mitigation planning process was developed by the NDMC as below:

(a) Appoint a drought task force or committee
(b) State the purpose and objectives of the drought mitigation plan
(c) Seek stakeholder input and resolve conflicts
(d) Inventory resources and identify groups at risk
(e) Prepare and write the drought mitigation plan
(f) Identify research needs and fill institutional gaps
(g) Integrate science and policy
(h) Publicize the drought mitigation plan and build awareness and consensus
(i) Develop education programs
(j) Evaluate and revise drought mitigation plans

Based on a review of drought related World Bank projects, a number of important design elements summarized as following (Esikuri 2005):

(a) Nonstructural measures such as management of water and other natural resources
(b) Structural hydraulic infrastructure that increases buffering capacity through capture and storage and through inter-basin transfers
(c) Appropriate infrastructure (access roads, crop storage and processing) and technologies, such as drought-

resistant crops and efficient irrigation

(d) Market mechanisms such as drought insurance, destocking in advance of droughts, buying from producers at competitive rates, and establishment of food reserves

(e) Early warning and information systems; community awareness campaigns

(f) Appropriate land use and agriculture policies and institutions and responsive drought disaster

(g) governance systems.

A special issue on drought risk reduction; "Africa Informs" (UNISDR 2012) outlined the following drought risk reduction framework guiding principles:

(a) Political commitment, high-level engagement, strong institutional setting, clear responsibilities both at central and local levels and appropriate governance are essential for integrating drought risk issues into a sustainable development and disaster risk reduction process.

(b) A bottom-up approach with effective decentralization and active community participation for drought risk management in planning, decision making and implementation, is essential to move from policy to practice.

(c) Capacity building and knowledge development are usually required to help build political commitment, competent institutions and an informed constituency.

(d) Drought risk reduction policies should establish a clear set of principles or operating guidelines to govern the management of drought and its impacts, including the development of a preparedness plan that lays out a strategy to achieve these objectives.

(e) Drought-related policies and plans should emphasize risk reduction (prevention, mitigation and preparedness) rather than relying solely on drought (often turned into famine) relief.

(f) Drought monitoring, risk assessment and other appropriate risk reduction measures are principal components of drought policies and plans.

(g) Institutional mechanisms (policy, legislative and organizational) should be developed and enforced to ensure that drought risk reduction strategies are carried out.

(h) Sound development of long-term investment in risk reduction measures (prevention, mitigation and preparedness) is essential to reduce the effects of drought.

3.3.6 Recommendations

For effective drought management to ensure sustainable water resources and to face hydrological drought risk successfully, shifting from a reactive (emergency management and drought relief) to a proactive and comprehensive approach (prediction, preparedness and mitigation) is necessary. However, change of this paradigm in drought management requires the support of several methods and techniques that can find application both for planning mitigation actions as well as for implementing the measures. As a mitigation tool, water shortage risk should be included as one of the criteria along with economic, environmental or social based ones, within a more general procedure for selection of the best mix of strategic and tactical mitigation measures. Some specific recommendations are as follows:

(a) Drought should be recognized a recurring phenomenon rather than an isolated event.

(b) Developing composite drought indices by including different parameters (e.g., precipitation, evaporation, stream flow, soil moisture, and vegetation etc.) can assess the drought regimes more suitably than assessing with a single parameter like using Standardized Precipitation Index (SPI), which depends only on one parameter.

(c) As a complex natural hazard drought is best characterized by multiple climatological and hydrological parameters. Improving our understanding of the relationships between these parameters is necessary to develop measures to reduce the impacts of droughts.

(d) Prepare national drought management plans and/or risk reduction strategies and invite donors to assist developing countries in their efforts to integrate issues related to drought into national, regional and global sustainable development strategies and plans. The water-related issues should be integrated into sectoral policies to successfully address water scarcity and droughts and to ensure a sustainable water allocation.

(e) Support more proactive drought risk-management approaches.

(f) National drought policies should include integrated drought and water scarcity risk management, disaster preparedness, emergency relief, and recovery and rehabilitation planning. They must also take into account water availability and ecosystem protection and restoration while preserving ecosystems and tackling climate change.

(g) The policies must be based on the best available knowledge and science relevant to the local, national and regional conditions and circumstances.

(h) Invest in research and development, robust data collection, including through remote sensing, and information to assess and identify risk and to predict, plan for and manage droughts across time scales from seasonal to multi-year events, including short-, medium- and long-term events, taking into account traditional knowledge.

(i) Cross-sectoral coordination in the design and implementation of mitigation measures, particularly in the infrastructure, water resources, and agriculture sectors, should be encouraged and promoted.

(j) Resource managers, educators, health department, civil society and non-governmental organizations, the private sector and others should be engaged in developing and implementing policies. This will ensure that risk management, resource stewardship, environmental protection, and public education are fully integrated into drought preparedness.

(k) There is a need for advanced assessment of economic, environmental and social impacts of droughts and of the effects of alternative drought mitigation policies in reducing such impacts, based on multi-criteria tools.

(l) Public awareness is a key condition for any change of behavior. Specific campaigns need to be promoted.

(m) Mobilize and enhance funding and support research and development on the underlying causes and effects of drought, including social, economic and environmental perspectives, as well as for improved techniques and practices that can improve food security and reduce human vulnerability.

(n) Promote the exchange of information, experiences and lessons learned in relation to drought risk management and reduction and increase public awareness about traditional and adaptable practices.

(o) Promote innovative technical solutions and practices, combining them with traditional knowledge, for drought forecasting, impact assessment and early warning information systems and sustainable integrated water management.

(p) Prepare national drought management plans and/or risk reduction strategies and invite donors to assist developing countries in their efforts to integrate issues related to drought into national, regional and global sustainable development strategies and plans

(q) Invite the Conference of the Parties to the UNCCD to continue to include drought risk reduction strategies and drought management plans in its work.

3.4 URBAN FLOOD MITIGATION THROUGH INNOVATIVE TECHNOLOGY AND MANAGEMENT

3.4.1 Background

Urban flooding is a growing issue for developed and developing countries and damages with different perspectives and recently become more serious than ever before due to climate change and fast urban development. Currently a number of technical solutions and management solutions have been developed such as (a) for technical solutions: flood defense system such as flood gates, doors, and barriers as well as flood forecasting and observation technologies and (b) for management solutions: the integrated flood management system and the flood warning system. Since major developments for the solutions of urban flood mitigation are presented, it will be useful for the water managers and policy makers as well as general citizen in order to build the basic knowledge of urban flooding and obtaining the information about the state of the arts about the problems and solutions of flooding.

3.4.2 Framing the Challenges

3.4.2.1 Historical Flood Spatial and Temporal Distribution

A flood occurs from the combination of extreme cases for meteorological, hydrological, and human factors. Critical meteorological factors for floods are heavy rainfall, cyclone storms, and intense convective storms while the hydrological components are wet soil moisture and high groundwater levels prior to storm. The human factors that intensify floods are mainly land-use from dense population and flood plain occupation.

Therefore, flood is a growing issue of concern for both developed and developing nations. In the past twenty years, the number of reported flood events has been increasing significantly. Figure 3.8 illustrate spatial distribution of the number of historical flood events. The flood events in Asia and America are over 60 cases and its casualties and damages are higher in developing nations such as Bangladesh.

A research illustrates that trend of flood events exponentially increases over a 30 year period and this may top $1trillion a year by 2050. The numbers of people affected by floods and financial, economic and insured damages have all increased too. In 2010 alone, 178 million people were affected by floods (Jha et al. 2012). The death toll from flood accounted for 20 percent of total deaths and 33 percent of the total economic losses from natural disasters.

3.4.2.2 Short/Long Term Flood Impact on Environment

The impacts of urban floods can be social, physical, and economic. While in rural areas the damages from floods are mostly direct in terms of loss of agricultural production, the damages in urban context are, however, more complex. Table 3.2 summarizes flood impacts in urban areas for both short and long time scales. The larger water depth and flow velocity of a flood damages greater on people and property.

Floods impact on people and environment including infrastructure and assets directly and indirectly. According to Emergency Events Database (EM-DAT), more than one hundred million people have been influenced by floods over the last three decades. The impact on people from flood is diverse such as death, injuries, and trauma. While direct deaths from flooding may be declining over time, flood deaths in developed countries are still caused generally by water-borne diseases such as malaria and dengue aftermath of flooding. For example, outbreaks of West Nile fever were reported after the flood in Romania 1996-1997, Czech Republic 1997, and Italy 1998 (WHO, 2006)

Floods impact environment such as buildings, animals and crops. The impact of flooding on building such as basement, subways, and utility facilities is often overwhelming. Many buildings may survive the flood but will be suffered long period of time and they require substantial repairs and refurbishment. Floods very often cause deaths and injuries to livestock as well as damage crops. Loss of agricultural production will affect the food supply chain where the population of urban areas are highly dependent.

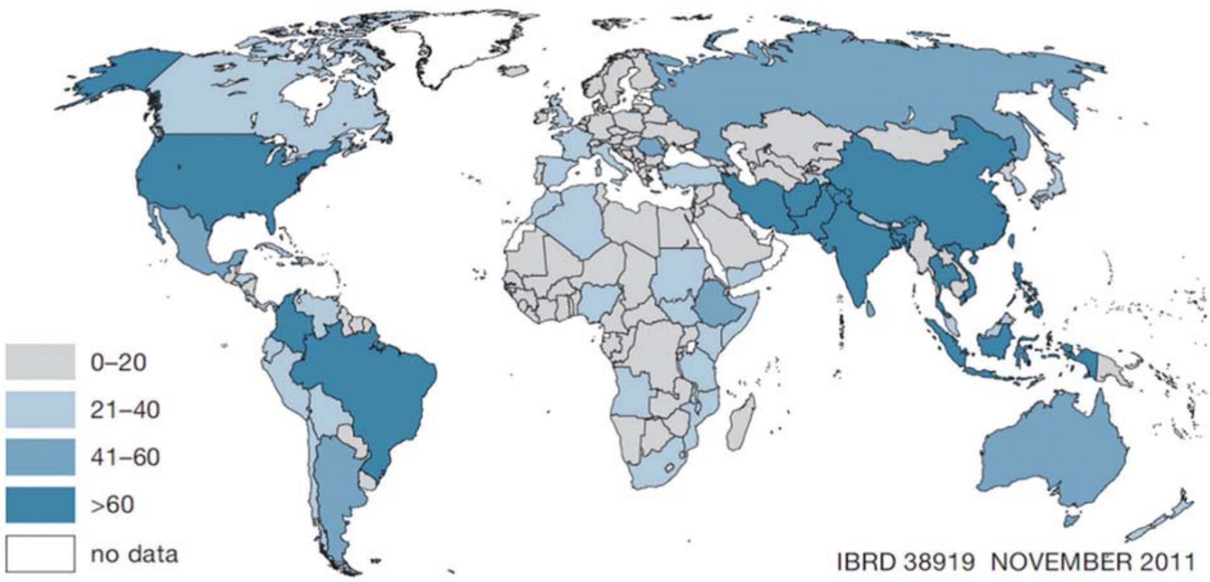

Figure 3.8 Flood Events 1970-2011 (EM-DAT)

3.4.2.3 To Understand Importance of Shifting the Focus from Hazard to Vulnerability/Resilience and Coping Capacity (regarding flood)

Vulnerability can be defined as the degree to which a system is not able to cope with the adverse effects of natural disasters (Barroca et al., 2006). In order to assess vulnerability at different scales, a number of variables must be studied including physical, social, economic, and political conditions of the target area. For developing countries, there are more components that increase vulnerability such as poverty, lack of preparedness and flood management, and limitations in early warning systems. Assessment of vulnerability is necessary to locate the most vulnerable area and prioritize the assistance. Vulnerability mapping can provide a basis for the development of flood risk management plans and help the policy makers and managers to identify which areas has the flood impact. In Figure 3.9, an example of inundation vulnerability map is illustrated in Jinju City in Korea. The map was developed from geomorphic characteristics of the area.

In addition to vulnerability, resilience is a critical measure for flood management, which refers to the ability to cope with flooding and to recover from flooding (Liao, 2012). The measures of resilience involve methods and techniques that reduce flood risks such as elevation, relocation, wet-flood proofing, and infrastructure protection. Maintaining those resilience measures in good order is important for the constant and effective performance of the measures.

3.4.3 Framing the Solution

3.4.3.1 Better Understanding of Dominant Flood Risk Parameters

Floods are categorized as local, river, coastal, flash floods (APFM 2008b). A local flood is caused by very high rainfall under impervious area due to urbanization which leads decrease of infiltration rate and increase of surface runoff, and in some hydrogeological conditions (karst aquifers) due to additional groundwater contribution (Fleury et al. 2013). A river flood occurs when the volume of river runoff exceeds the capacity or when flood control system is badly operated. A coastal flood is caused by high tides and storm surges from tropical cyclones in urban areas particularly at estuaries. A flash flood, a rapid flooding of geomorphic low-lying areas, is resulted from the rapid accumulation and release of runoff from upstream and the discharge quickly reach a maximum following diminishing rapidly. Those different types of floods damage urban areas with different areal extent and time periods.

3.4.3.2 Striving towards Horizontal and Vertical Integration of the Existing Flood Early Warning Systems (working together)

Flood observation and alert system has been widely developed in recent years. Heavy rains or drainage failure are common causes of flood in urban areas, especially a basement flood. To detect a basement flood, Flood Alarm device (Rialco 2014), which is a self-contained electronic device, could be employed. Its water sensor is placed contacting or almost contacting the floor near the lowest drain in basement. Then, the alarm sounds when water caused by flood touches the sensor. Furthermore, this kind of devices (Nexsens 2014, YSI 2014) could be employed to monitor automatically water levels or discharge, precipitation, humidity, and many other parameters used for flood assessment. Radar-based flood alert system (Bedient et al. 2002) can clearly provide information to decision makers before flooding. This system incorporates real time radar data into a GIS grid for a basin. The HEC-1 computer model is employed to predict a hydrograph converted radar rainfall and its duration to peak flows in channel at the point of interest on a basin. Furthermore, this system is automatically delivered through internet to a flood management office. Then, decision makers could determine the necessary step to minimize damage.

In order to integrate those existing early warning system, all the collected information must be interchangeable through web browser of FTP. The data obtained from multi-sensors (radar and satellite images) can be calibrated with a dense network of conventional rain gauges in terrestrial measurements. This combination of the multi-sensor data and classical precipitation data can provide a high spatial and temporal resolution. Employing the combined data, GIS based distributed rainfall-runoff simulation can predict possible flood area. This prediction results can be enhanced with the warning system such as alarm devices.

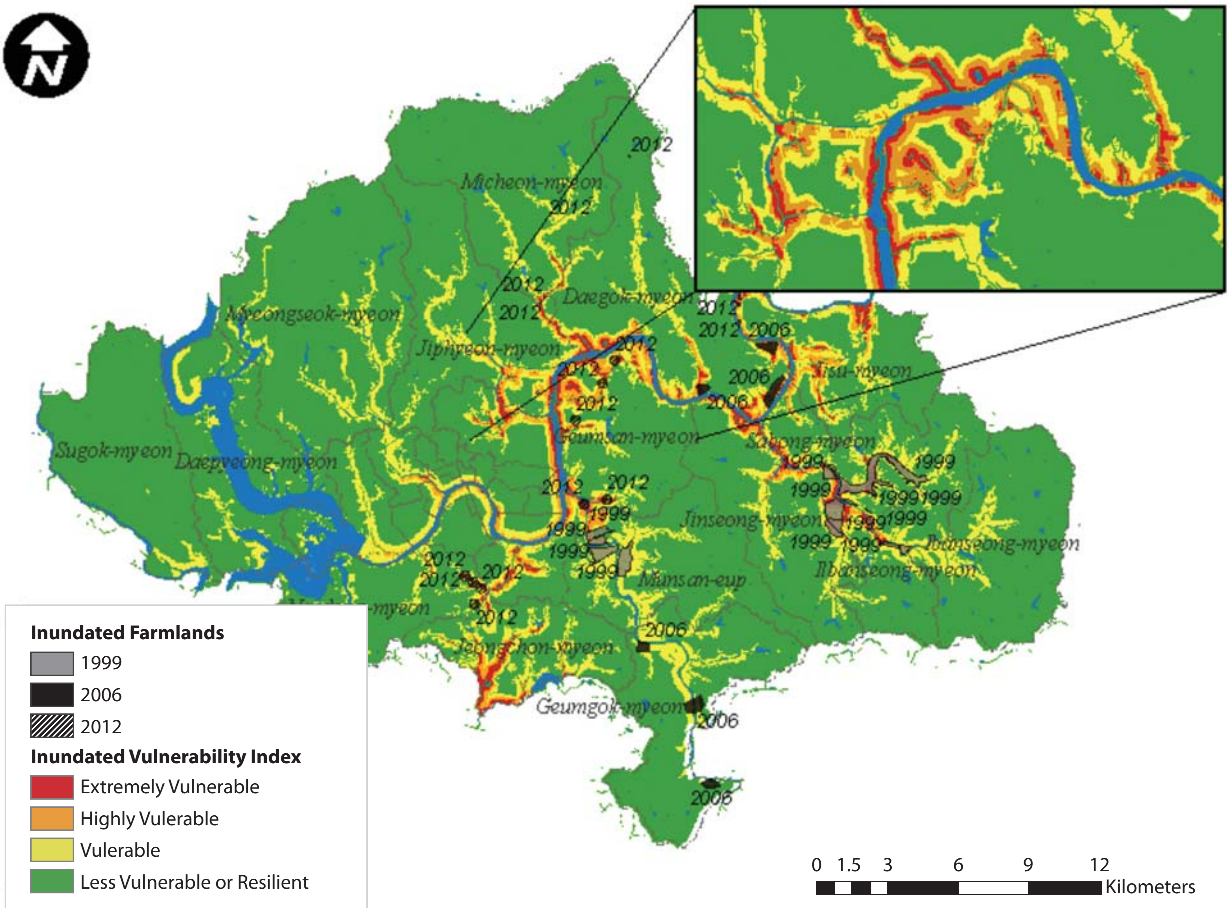

Figure 3.9 Inundation vulnerability map for Jinju City, South Korea(Kim et al., 2013)

3.4.4 Accelerating Innovation

3.4.4.1 Merging Latest Technology and Traditional Knowledge to MinimiseFuture Flood Risk

In order to build efficient flood control, related technologies have been developed as (a) flood defence system technologies; (b) flood forecasting and observation technologies; (b) integrated flood management technologies.

Flood defence system technologies include the structures such as flood barriers, flood gates, and flood doors (Flood Control International, 2014). The flood barrier design varies from a simple modular 'stop-log' water barrier to automatic barriers that operate only when required. There are four types of flood barriers in the field as demountable, glass, and filp-up or drop-down flood barriers.

Demountable flood barriers are manufactured to provide similar levels of protection to permanent defences, but with the advantage of being fully removable when not required. Glass barriers employ high strength structural glass, frames, and structural anchoring system as well as water tight and impact resisting sealing. It requires no operational input and visual intrusion is minimized. Flip-up (or drop-down) barriers are fully recessed into the ground (or on the roof) when not in use in order to provide unrestricted access to pedestrian and vehicle entrances.

Flood gates are designed for dependable flood protection with maximum access ability and operates on a dead level threshold allowing unrestricted vehicles and pedestrians. Three types of gates are popularly employed as lift-hinged, swing-hinged, and pivot flood gates. Flood doors can be clad with a diverse finishes to suit existing finishes and become part of the building aesthetic. Three major types are employed such as secure flood proof doors, sliding flood doors, and heavy duty doors. The secure flood proof doors can achieve full height flood protection depending on the locking mechanism due to steel frame and construction and are ideal for use in unmanned locations, such as utility sites. Sliding flood doors use little space and provide effective flood prevention as well as to incorporate spring wheels to allow an easy sliding operation with the ability to compress seals as well as automation of closure where needed. Heavy duty flood control doors can be used for large openings in flood defence walls with the benefits of any flood protection height or width combination possible and fitting any building or opening.

Furthermore, due to an increasing demand for a n innovative and feasible alternative to sandbags, emergency rapid deployment dam system has been developed (e.g., Tiger Dam System, 2014) to act as an temporary emergency dam suitable for use in variety situations. The system, in general, consists of elongated flexible tubes which may be quickly stacked, joined end to end, and filled with water. It can be assembled within minutes employing floodwater with few manpower and it is easy to repair.

Flood forecasting and observation technologies have been developed in recent years. Flood forecasting is used to evacuate regions at risk by civil authorities, to provide the basis for preparing critical infrastructure for flood to minimize damage, and to inform the operation of reservoirs in minimizing or eliminating the flood downstream from the reservoir. Hydrological and hydraulic simulation models have been commonly used to transform precipitation to channel flow and a number of different hydrological models have been developed from various sectors such as government agencies, universities, and private companies. In addition, statistical models have also been developed employing the statistical relationship between precipitation and discharge. Hydrologic simulation models for flood forecasting can be categorized as lumped and distributed models.

The lumped model is generally based on hydrological equations and relies on the parameters which needs a calibration from field measurements. In this type of the models, runoff is computed from the rainfall with the catchment characteristics (Henonin J et al. 2013). Meanwhile, the distributed model allows compute hydrodynamic flow with two directions based on gridded surface information such as digital elevation model (DEM). In operational systems for flood forecasting, the lumped hydrological models (e.g., HEC-HMS) are slowly but surely giving way to distributed hydrological models (e.g., Vflo and MIKE11- MIKE SHE) along with the development of the detailed space measurements such as weather radar and satellite. A number of approaches for flood forecasting using a neural network model assisted by multisensory precipitation estimates or forecasts as statistical models have been developed. This quantitative flood forecasting consists of three different modules including rainfall occurrence detection module, the classification and decision module, and neural network prediction module (Kim and Barros, 2001).

Furthermore, the time scale of flood forecasting is an

Table 3.2 Flood effects in urban areas (Casale and Margottini, 1999)

Social or human effects	Physical effects	Physical effects
Short term impacts • Fatalities • Injuries • Loss of income or employment opportunities • Homelessness	**Short term impacts** • Ground deformation and loss of ground quality • Collapse of and structural damage to buildings and infrastructure • Non-structural damage loss of ground quality to buildings and infrastructure	**Short term impacts** • Interruption of business due to damage to buildings and infrastructure • Loss of productive workforce through fatalities, injuries and relief efforts • Capital costs of response and relief
Long term impacts • Disease or permanent disability • Psychological impact of injury, bereavement, shock • Loss of social cohesion due to disruption of community • Political unrest where government response is perceived as inadequate	**Long term impacts** • Progressive deterioration of damaged buildings and infrastructure which are not repaired	**Long term impacts** • Losses borne by insurance industry weakening the insurance market and increasing premiums • Loss of markets and trade opportunities through short term business interruption • Loss of confidence by investors, withdrawal of investment • Capital costs of repair

important issue, which changes along the distance where the rainfall occurs. The case is quite different when intensive rains occur in the lower part of basins, or when one wishes to make forecasts in upper part of basins. The lead time of the basin to the rainfall may be short (say 5 hours), then the flood will have propagate on a shorter distance toward the place where the forecast is to be done (say 7 more hours). In this case, only 12 hours is available between the intensive rainfall and the flood occurrence at the considered point to forecast. However, the response time and routing time to the downstream for a large basin (e.g., Colorado River or Mississippi River) might take several days or weeks. In such a case, different forecasting techniques are required including the extensive integration of the current condition of reservoirs and rivers.

Flood risk management aims to reduce the human and social-economic losses caused by flooding while at the same time taking into account the social, economic, and ecological benefits from floods and the use of flood plains or coastal zones (UNESCO 2014). Flood risk management plans shall address all aspects of flood risk management focusing on prevention, protection, preparedness, including flood forecasts and early warning systems and taking into account the characteristics of the particular river basin or sub-basin. Flood risk management plans may also include the promotion of sustainable land use practices, improvement of water retention as well as the controlled flooding of certain areas in the case of a flood event. Therefore, to construct a flood risk management system, following process is needed (Wallingford 2014).

(a) Evaluating hazards and consequences
(b) Developing sustainable spatial planning and flood prevention strategies
(c) Developing preparedness and emergency response action plans
(d) Protecting assets and ensure resilience under climate change and future economic development scenarios

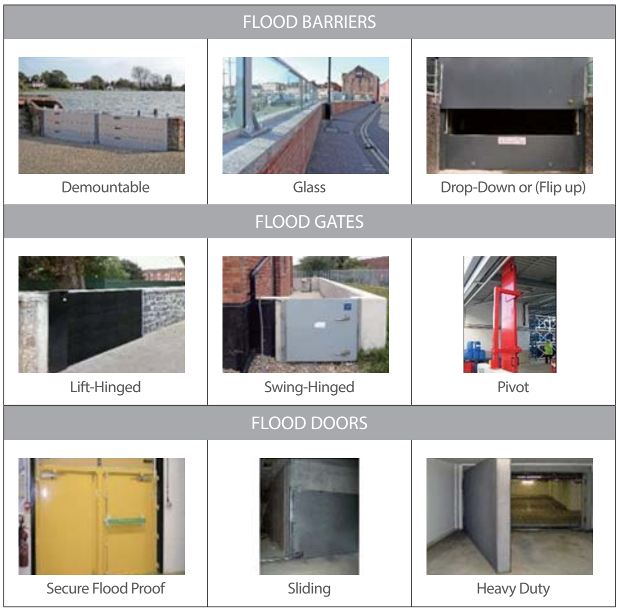

Figure 3.10 Flood defense system
(http://www.floodcontrolinternational.com/)

The concept of integral flood management (IFM) all lay emphasis on appropriate use of land for various purposes, particularly those which adversely impact the objectives of development, prosperity and well-being. This leads to calls for a closer integration or coordination between flood management plans and land use plans. Even though varying in emphasis in different locations such plans would usually contain elements on community infrastructure (schools, hospitals, civil defense, etc.), transportation, housing and location of neighborhood development; protection of cultural heritage, environmental assets and conservation sites, and economic development. All of them do have a specific component on flood hazards and risks. The regulations and by-laws concerned with land use planning should consider the flood risks that are likely to be faced by various uses and efforts should be made to minimize them. The planning process should involve local disaster management authorities (APFM 2008b).

Such a combination of approaches and measures may lead to secondary benefits, i.e. measures whose function consists not only in flood risk management but also in supporting water supply, groundwater recharge, providing space for recreational activities etc. In this sense, the application of IFM concept is also meant to be a contribution to the general improvement of urban living conditions. However, many countries are struggling to devise appropriate policies and administrative mechanisms that would facilitate the integration. A number of fundamental considerations are presented elsewhere (APFM 2008a) those provide insight into the complexity of the issue of integration and harmonization.

3.4.5 Research and Development Technologies

3.4.5.1 Current Leading-edge Development in the Field of Flood Risk Reduction and Bringing Closer Scientist and Decision Makers in the Field of Flood Risk Reduction

Recently, an innovative flood reduction program, Flood Control 2015 (Flood Control 2015, 2014), was executed by a consortium of 9 participants including institutes, engineering consultants, and industry as part of the Dutch governmental subsidy for the object of a substantial improvement in operational flood protection worldwide with cohesive development and application of new knowledge and tools to limit the probability and impacts of floods. Flood Control 2015 integrates three aspects of dikes, decision-maker, and their environment in advanced forecasting systems and decision supporting systems with help of innovative sensors. It starts with information of monitoring waves and water levels in dikes including sensor networks providing real-time information as well as satellite that permanently monitor the flooding in large areas. Based on the collected information, Flood control 2015 integrates all the information into a single whole by means of smart link and this leads a reliable forecasting system. To act and mitigate flood, dashboards that relevant information is presented in a clear way and decision-supporting tools that ensure right decisions can be taken at the right time. In order to transport and process data as well as to present them to various stakeholders, modular systems are developed.

Furthermore, the CORFU project (http://www.corfu-fp7.eu/), Collaborative Research on Flood Resilience in Urban areas, is a major project involving 17 European and Asian institutions, funded by a grant from the European Commission, Seventh Framework Programme. The project is aiming to enable European and Asian partners to learn from each other through joint investigation, development, implementation and dissemination of short to medium term strategies that will enable more scientifically sound management of the consequences of urban flooding in the future. CORFU has brought novel methodologies and models into a unique frame work, called DPSIR as Drivers-Pressures-States-Impacts Response, which were implemented for seven cities – Barcelona in Spain, Beijing in China, Dhaka in Bangladesh, Hamburg in Germany, Mumbai in India, Nice in France and Taipei in Taiwan. Application in the case studies illustrated variations in focus and level of detail, according to specific flooding problems, data availability and development scenarios. The results from the project provide a sound basis for flood damage analysis and the evaluation of mitigation measures (CORFU Consortium, 2014).

After flooding in southern Alberta in June 2012, Insurance Bureau asked what actions the Government of Alberta could take to reduce the risk of flood damage (Kovacs and Sandink, 2013). According to the results, it was revealed that most disaster damage can be prevented through the application of existing and emerging knowledge about building disaster resilient communities. They presented the following recommendations as prohibiting new development in the flood ways with developing structural developments in flood defense, creating a provincial flood damage reduction strategy on the existing stormwater management guidance. The report conclude that achieving flood risk reduction should include a comprehensive flood management strategy such as risk mapping, flood forecasting, land use planning, defensive infrastructure, and public awareness.

Kuala Lumpur, the capital of Malaysia, is situated in the mid-upper reaches of the 120 kilometer long Klang River which drains a catchment of some 1,288 square kilometers. In the 1970s, a flood mitigation master plan was developed incorporating a number of engineering options, including upstream storage, poldering, pumped drainage, and improvement of the drainage capacity of the Klang River and its major tributaries (Wilson 2005).

The Stormwater Management and Road Tunnel (SMART) project was designed both to divert stormwater and to re-route traffic away from the inner city. The scheme consists of a 9.7 kilometer long tunnel, nearly 12 meters in diameter, which runs to the east of the city center of Kuala Lumpur. During moderate storms, the bottom section of the tunnel channels excess water without stopping the traffic flow. In case of severe storms, all traffic is evacuated and automatic watertight gates opened to allow floodwater flow. The tunnel has combined storage capacity of three million cubic meters (Krause et al. 2005). A diagram of the SMART system is shown in Figure 3.11.

The construction cost of the SMART Tunnel project was approximately US$515 million. As it was recognized that as well as the need to mitigate flooding there was an equally urgent imperative to relieve traffic congestion in the city, an innovative solution was proposed in which a tunnel would be used to carry road traffic except during flood events. Part of the total cost of the stormwater relief was offset by tolling the traffic congestion relief. Through this approach, one tunnel will provide flood and traffic improvements to Kuala Lumpur at a cost that is far less than two separate measures. The case demonstrates the potential of flexible, multi-purpose approaches to infrastructure design (Wilson 2005; Krause et al. 2005).

Since conventional flood warning systems have been only focused on discharge predictions in main rivers, local floods may root a large amount of damage especially in urban areas. The DHI developed a warning system based on existing and newly developed components of MIKE CUSTOMED by DHI framework. The system employs a large variety of input data, complex mathematical models, and advanced hydrological analysis processes as shown in Figure 3.12.

3.4.6 Recommendations

Based on the current state of research and practice, the future direction for strengthening science and technology aspects to reduce flood risks is suggested as follows:

(a) Balance applying the technology between common sense approaches such as maintaining (as well as building) existing flood mitigation infrastructure and far-sighted approaches which anticipate and defend against future flood hazard by building new flood mitigation infrastructure or by radically reshaping the urban environment.

(b) Improve further in forecasting and warning systems up to the point that pubic can be relied on. Distributed hydrologic models with adapting the gridded rainfall information from radar and satellite might be a good solution including the accuracy of the information.

(c) Make relevant flood visualization data for current and forecasting status in electronic map format available online for public.

In addition to strengthening the above mentioned science and technology aspects, the further development of science is required including atmospheric science for more accurate and longer forecasting, hydrology for better understanding of flood mechanism. Also, the advances in technologies are critical such as observations and measurements including satellite and radar systems, drainage and low impact development system, and flood management system.

Stakeholders include not only the government ministries and agencies of agriculture and fisheries, water resources management, public works, transport, communication and broadcasting, military and police force, land management and urban planning, disaster management offices at national, state, and district levels, landowners or farmers, rural and urban residents, fishermen and water resources associations. In order to promote innovation of science and technology and stakeholder involvements are needed through providing clear objectives and showing benefits and pitfalls. Employing integrated flood management system under involvement of stakeholders can be a possible alternative with the following action points:

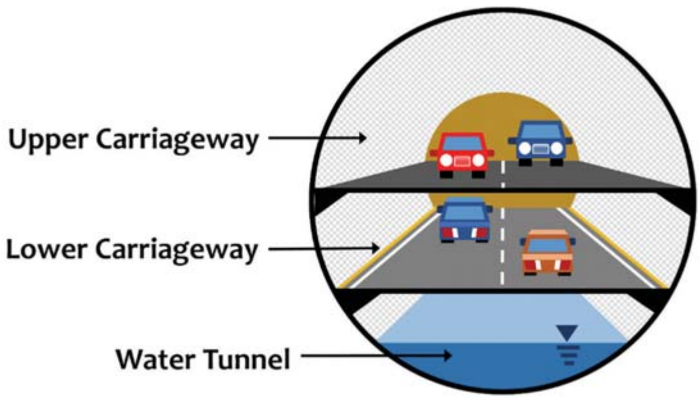

Figure 3.11 Flood defense system in Malaysia (http://www.smarttunnel.com.my/)

(d) Develop sustainable flood mitigation policies with a long-term outlook.
(e) Apply existing knowledge and research results directly to mitigate flood impacts.

Government department should work with infrastructure operators to identify the vulnerability and risk of assets to flooding and maximize the usage of available information and technology.

3.5 ICT AND GIS BASED WATER RELATED DISASTER RISK MANAGEMENT

3.5.1 Background

Innovative technologies, especially Information and Communication Technology (ICT), space technology including remote sensing technology and Geographic Information System (GIS) applications, play important roles among policy-makers and decision-makers to apply their knowledge and experience in building resilience to disasters such as floods, droughts, landslides and typhoons. These applications can be effectively used in all stages of disaster management: preparedness, mitigation, response, relief and recovery. Space-derived and in-situ geographic information and geospatial data are extremely useful during times of emergency response and reconstruction, especially after the occurrence of major flood events (UNOOSA, 2013). In the case of large urban areas with a high population density, the use of these technologies can provide crucial information such as the number of damaged buildings, affected populations and hazardous sites that can trigger secondary disasters. GIS are also utilized for urban planning, development and management of infrastructure and civil services for disaster risk reduction. There is an urgent need to promote the applications of such technology by urban planners, engineers, and decision-makers to innovate and improve resilience of the urban environment which can help us prevent loss of lives, reduce chance of injuries and minimize

Figure 3.12 General scheme of the architecture of the flash floods solution system (DHI 2013)

property and economical losses.

Despite tremendous technological advances and infrastructure development, we are not well prepared for devastating events such as 2011 Tohoku earthquake and tsunami and the nuclear accident triggered by the said events and also for disasters such as Joplin MO tornado, Virginia earthquake and Seoul city flood in Korea. Over the past few decades, ICT, space technology and GIS applications have become indispensible parts of the traditional disaster management. Advanced weather radars and warning systems enable accurate predictions of paths and severities of tornados and hence deliver warnings in a matter of minutes (SSRC and Coulter and Phillips, 2011). Accurate monitoring by remote sensing technology including satellite, CCTV, etc. and GIS-based DB system and information analyzing technologies enables fast estimation for disaster risk and assessment of damages and losses.

This section may help engineers to develop the new technology on ICT, space technology and GIS regarding disaster risk management. A better understanding for these technological trends and challenges will surely help in the improvement of managing big and complex disasters caused by climate and social structural diversities. This will also help the decision-makers to understand the technology on disaster risk management and select the key technologies that can be used for each disaster management phase such as prevention, preparedness, response and recovery.

3.5.2 Framing the Challenges

In the disaster risk management process, the ICT such as radio, satellite radio, subscription radio, amateur radio, television, telephones, electronic bulletin boards, Short Message Service (SMS), Internet, e-mail, instant messages airmail and sirens are widely used to share information and create Early Warning Systems (EWS). The EWS may be used in more than one ICT media in parallel and these can be either traditional (radio, television, telephone) or modern (SMS, cell broadcasting, Internet). The only possible drawback of radio and television media is that their effectiveness is significantly reduced at night, when they are normally turned off. Telephone penetration in many areas is still not satisfactory – particularly in rural and coastal areas which are at high risk. The other problem is the congestion of phone lines that usually occurs immediately before and during a disaster, resulting in many phone calls in that vital period that cannot be completed. While the internet can play a prominent role in a developed country, where nearly half of all homes and almost all offices have internet connections, this is not the case in the developing countries. In many developing countries, less than 5 percent of the population uses the internet and even those who are users do not use it on a regular basis. In such a situation, it is difficult to expect internet and email to play any significant role. In spite of that drawback, many disaster-related activities are already underway within the internet community. For example, a new proposal for using the Internet to quickly warn large numbers of people of impending emergencies is currently being drafted by the Internet Engineering Task Force. The strengths of each information and communication technology and the challenges in using them are summarized in Table 3.3.

There are number of GIS and space-based information technology implementation barriers at local administrative levels, where a strong disaster management initiative is required. These barriers include, but are not limited to: (a) a lack of financial resources, (b) a lack of spatial data, (c) political/institutional instability and iv) a lack of local GIS and space-based information technology knowledge/expertise. The financial aspect is especially significant from a GIS and space-based information technology perspective, since the former and the latter are expensive and therefore becomes an implementation barrier. Developing countries and the least developed countries, small islands developing states and landlocked developing countries and Africa require predictable, adequate, sustainable and coordinated international assistance, through bilateral and multilateral channels for the development and strengthening of their capacities, including financial and technical assistance, as well as technology transfer on mutually agreed terms.

3.5.3 Framing the Solutions

3.5.3.1 Radio and Television

Considered as the most traditional electronic media used for disaster warning, radio and television have a valid use. The effectiveness of these two media is high because even in developing countries and rural environments where the tele-density is relatively low, they can be used to spread a warning quickly to a broad population. After the Indian Ocean tsunami in 2004, many radio manufacturers considered introducing new digital radio alert systems that react even if the set is switched off. In order to trigger this alarm, a special flag integrated into the received signal from a terrestrial transmitter or a satellite would be used and the set would automatically tune to the emergency broadcast channel. Korea also uses TV disaster warning broadcasting system, which is based on automatic TV turn-on/off functions. Since night time is the most critical time for disaster occurrences, these systems enable TV systems to turn on or even change the channel with automatic volume-up so people receive urgent disaster information even if they are sleeping or watching other channels. This system broadcasts urgent disaster information as sound or screen messages using the equipment of broadcasting station and a special receiver connected to the home TV set. Korea has also developed the Radio Disaster Warning Broadcasting System Using RDS and is similar to the TV disaster warning broadcasting system. The system can be applied to any facility that has an internal speaker system, such as a movie theatre or shopping center. The system has three main sub-systems such as control, transmission, and warning broadcasting panels. These panels provide emergency power supply and is resistant to lightning damage.

3.5.3.2 Telephones

Telephones can play an important role in warning the communities about the impending danger of a disaster. Korea has developed the Cell Broadcasting System (CBS) mobile phone disaster message notification system which broadcasts disaster information to mobile phone users with a special receivable ID at the base station transceiver subsystem. Unlike the short message service, which is a point-to-point individual transmission, the CBS system can transmit messages nationwide or to local areas, simultaneously or independently. Serviceable telecom companies and targeted areas were selected in November 2004, after user response were analysed and an interactive system was set up in Korea's National Emergency Management Agency (NEMA) in 2006. This system has several advantages: (a) Information reception via an equipped CBS module without additional hardware for nationwide broadcasting; (b) The system is suitable for real-time warning services because multi-user transmissions are available; (c) The service cost is low and is independent on the number of users; and (d) Users can easily select, confirm, and delete information. This system, however, has some weaknesses: (a) It is terminal-oriented without a

Table 3.3 The summary of strengths of each technology and the challenges in using them (Chanuka, 2007)

Channel	Benefits	Challenges
Radio & Television	- Widespread	- Takes time to get the warnings - Limited use at night
Telephone	- Messages can be delivered quickly	- Problems in authenticity - Does not reach non-users - Congestion
Electronic bulletin boards	- Can be checked for accuracy of information	- Does not reach non-users - Local language problems
SMS	- Quick - Messages can be sent to groups	- Congestion - Does not reach non-users - Local language problems
Cell Broadcasting	- No congestion - Can address a group simultaneously	- Does not reach non-users - Local language problems
Satellite Radio	- High reachability	- Cannot be used to educate masses - Only good specific points
Internet/Email	- Interactive multiple sources can be checked for accuracy of information	- Not widespread
Amateur/Community Radio	- Excellent for rural, poor and remote communities	- Not widespread - People lose interest if used only in case of disaster
Sirens	- Can be used even at night - Good in rural area	- Maintenance of the system - Cannot disseminate a detailed massage

mobile terminal or CBS module therefore information cannot be received; (b) If the terminal is turned off, no information is available even with a CBS module; and (c) The disaster information is not available in radio-dark areas and there is no automatic confirmation method to check whether or not the users have received disaster information.

3.5.3.3 Short Message Service

Short Message Service (SMS) is a service available on most digital mobile phones that permits the sending of short messages, images and movies between mobile phones or other handheld devices and even landline telephones. During the 2005 Hurricane Katrina disaster in the US, many residents of affected coastal areas were unable to make contact with relatives and friends using traditional landline phones. However, they could communicate with each other via SMS more easily when the network was functional. This is because SMS works on a different band and can send or receive even when phone lines are congested. SMS also has another advantage over voice calls for example, the use of group messages. Most of today's wireless systems support a feature called cell broadcasting. A public warning message in text can be sent to the screens of all mobile devices with such capability in any group of cells of any size, ranging from one single cell (about 8 km across) up to the whole country if necessary. CDMA, D-AMPS, GSM and UMTS phones have this capability. Federal Emergency Management Agency (FEMA) of USA developed the Integrated Public Alert & Warning System for public safety officials to alert communities in the event of natural or man-made disasters. This system also offers emergency alert notifications through mobile phones. The National Disaster Management Institute (NDMI) of Korea has started a project, Smart Big Board (SBB) that will make an effective monitoring and warning system for multi-complex disaster situations by maximizing the utilization of real-time field-oriented information and crowd sourcing from text, photos and movies via SMS etc. The only possible disadvantage to cell broadcasting is that not every user may be able to read a text message when they receive it. In many Asia-Pacific countries, majority of phone users cannot read or understand a message sent in English. Thus, it is essential to send warning messages in local languages. However, these messages would still be inaccessible to those who cannot read, even in their own language. The Dutch Government plans to start using cell broadcasting for emergency warnings. The infrastructure is already in operation with the operators KPN, Telfort and Vodafone. It will to be the first multi-operator warning system in the world, based on cell broadcasting with government use.

3.5.3.4 Internet

The role of internet, e-mail and instant messages in disaster warning entirely depends on their penetration within a community as well as the way it was used by the professionals such as first responders, coordinating bodies, etc. Without direct communication among the decision-makers and without a free flow of reliable information among all persons involved, the effective contingency planning and emergency response are at risk (Putnam, 2002). The Internet has a drastic increase in the access of spatial data, as numerous websites now offer free access to a wide range of data. However, there has been little attention paid to the aspects of quality, including newness, lineage, regional accuracy, completeness, and overall usefulness (Engler & Hall 2007, p. 345). This is unfortunate, because the quality of spatial data is particularly important when it is used for disaster management, especially when lives are at stake.

3.5.3.5 Sirens

Though not necessarily an ICT-based solution, sirens can be used in tandem with other ICT media for final, localized delivery. Korea has developed the automatic voice notification equipment which is situated in the local disaster management headquarters which issue warnings using fixed or mobile telephones, village broadcast amplifiers and any available communication tools when inundation and other disasters are imminent. When precipitation, river level, or any emergency data in a specific area are analysed, persons to be informed are chosen and a disaster warning is issued using 32 exclusive emergency communication networks. The system database covers more than 550,000 people such as emergency managers and local residents in 234 central and regional districts in Korea. For an effective response, call sequencing has been set up. The first call goes to the village amplifier in a disaster-prone area so that people in the vicinity can obtain general information about the imminent disaster situation. A second call goes to the village chief, who can personally deliver the information and encourage people to evacuate to a safer place. The final call goes to the related public organizations and officers in the targeted area.

3.5.3.6 Geographic Information System

GIS can be used for scientific investigations, resource management and development planning. A GIS is a key component of any effective and comprehensive disaster management strategy, and can be used to display, integrate, map, analyse, and model data and the information derived from satellites, and other spatial data sources (Kumar et al., 1999). Perhaps, the greatest strength of GIS is its ability to integrate a wide range of data types, including geographic, social, economic, and political data into a single system. However, utilizing GIS requires not only the software, but also the hardware, the data and the trained personnel. As disaster management works usually involve a large number of different agencies working in different areas, the need for detailed geographical information in order to make critical decisions is high. By utilizing GIS, agencies involved in the response can share information through databases on computer-generated maps in one location. Without this capability, disaster management workers have to access a number of department managers, their unique maps and their unique data. Most disasters do not allow time to gather these resources. GIS thus provides a mechanism to centralize and visually display critical information during an emergency. There is an obvious advantage to using a map with remote sensing or GIS inputs instead of a static geographical map. On the other hand, a vulnerability map with GIS provides dynamic information with cause and effect relationship.

3.5.3.7 Remote Sensing

The potential of remote sensing (RS) to provide critical earth observation information for disaster management (e.g., hazard assessment, disaster mitigation, preparedness, response and recovery) has repeatedly been emphasized (Becking, 2004; Chen et al., 2005; Jayaraman et al., 1997; Mansor et al., 2004; Rivereau, 1995). Showalter (1999) provided that the RS technique is i) primarily used to detect, identify, map, survey and monitor existing hazards and/or their effects; ii) secondary goals of RS focus on damage assessment, improved planning, or the provision of data for disaster management functions. Also, space-based information and products are effectively being used for early warning and monitoring of slow onset disasters as well as rapid onset disasters.

3.5.3.8 Digital Elevation Model

Remotely sensed digital elevation data often termed digital elevation model (DEM) is a digital representation of surface topography and are frequently used in the study of natural hazards. DEMs are critical data input for assessing landslide susceptibility (Guinau et al., 2005), delineating flood risk potential (Dewan, Kabir et al., 2007), flood hazard mapping (Dewan, Islam et al., 2007; Sanyal & Lu, 2003) and for a variety of coastal hazard and disaster assessment purposes. DEMs are also commonly used to derive new data that are required for specific types of disaster management-related analysis or visualization. The types of new datasets that can be generated include, but are not limited to: slope, aspect, contour lines, flow direction, flow accumulation, watersheds, and many others. The most important factors that determine the suitability of a DEM for any particular disaster management-related application are the spatial resolution and vertical accuracy.

3.5.4 Accelerating Innovation

3.5.4.1 Proactive Step

GIS has much to offer in the pre-disaster management phases of prevention and preparedness which analyse the developments in the immediate aftermath of a disaster, evaluating the damage and determining what facilities are required to be reinforced for construction or relocation purposes. To effectively prevent and prepare for a disaster requires not only a detailed knowledge and information about the expected frequency, characteristics, and magnitude of hazardous events in an area, but also the vulnerability of the people, buildings, infrastructure and economic activities (Van Westen & Hofstee, 2001). GIS allows the synthesis and analysis of such data information to help determine risk levels, assess vulnerability, model scenarios, plan evacuation routes, determine resource requirements, and create a variety of useful information to aid in the decision-making. For example, if we collect data such as land use of the parcel (residential, industrial, commercial, etc.), building material, building age, number of floors and damage occurrence and make GIS database combined with historical data on previous disasters, such as flood depth, those can be used to generate a variety of vulnerability and risk maps. Guinau et al. (2005) used a GIS to create a hazard susceptibility map to help mitigate landslide risk. They digitized present and past landslides from aerial photographs to create a landslide inventory, which was then overlaid on terrain data, such as lithology, slope, soil characteristics and land use analysis of terrain conditions in areas affected by landslides. These helped determine the zones with similar characteristics and through further analysis the delineation of low, medium and high susceptibility zones.

Dewan, Islam, et al. (2007) integrated GIS and remote sensing techniques to analyse the flood hazard and risk levels in Dhaka, Bangladesh. A major impediment was the unavailability of digital geospatial data, and as a result, a number of the required data layers had to be created. Flood-affected frequency and flood depth were estimated from multi-date Synthetic Aperture Radar (SAR) data (Dewan et al., 2007a, p. 1602) which were based from previous flood events. Uncontrolled and informal housing development is a recurring problem in cities in developing countries (Thomson & Hardin, 2000), and such development practices contribute to increasing natural hazard vulnerability. To address this problem, Thomson and Hardin (2000) used GIS and satellite imagery (LANDSAT TM) to identify potential low income housing sites in the eastern portion of the Bangkok Metropolitan Area, where flood risk was a concern. The National Remote Sensing Centre (NRSC) of Mongolia has been developing local capability for drought monitoring by using modern space science and remote sensing technology. The National Remote Sensing Center has scientific agreement with NASA on 1km Advanced Very High Resolution Radiometer (AVHRR) data archive. The remote sensing data are being used successfully for the Drought Assessment and Monitoring System by combining satellite and ground data collected over the past 10 years in Mongolia. In the coming years the NRSC will also develop new products for drought monitoring such as MODIS drought map and develop new indices such as crop moisture index and aridity index (NEMA, 2010). With the help of ESCAP'S Regional Cooperative Mechanism for Drought Disaster Monitoring and Early Warning, Mongolia is now working towards developing the methodology in using the moderate resolution imaging spectro-radiometer (MODIS) for making drought maps which will include an increased number of parameters such as vegetation health, soil moisture content, and precipitation. Mongolia has also established a prototype Geo-portal with the help of ESCAP's training and capacity building program.

Based on the information provided by GIS, it is also possible to estimate the quantity of food supplies, bed space, clothes and medicine that will be required for each shelter based on the number of expected evacuees. In addition, GIS can display real-time monitoring for emergency early warning. Remote weather stations can provide current weather indexes based on location and surrounding areas. Wind direction, temperature and relative humidity can be displayed by the reporting weather station. Wind information is vital in predicting the movement of a chemical cloud release or anticipating the direction of wildfire spread upon early report. The WEB GIS-Based Typhoon Committee Disaster Information System (WGTCDIS) was developed by National Disaster Management Institute (NDMI) of Korea utilizing the information from the members of 14 Working Group on Disaster Risk Reduction of Typhoon Committee. In the WGTCDIS, the nearest neighbour method was used to find similar typhoon trajectory and the kernel density function was used to estimate the damages caused by typhoons.

The Cambodian Red Cross and the American Red Cross developed early warning system in Cambodia. Floods affect parts of the country every year. The project aims to reduce the risk of vulnerable communities to floods that are greater than normal through improved flood warnings. Flood forecasts and warnings from the Mekong River Commission and Cambodian government's Department of Hydrology and Rural Water Supply are circulated to communities, which sends back information about water levels to forecasters. Communities identify flood alarm stages and work together to develop response mechanisms (IFRC, 2001). The Automatic Rainfall Warning System shown in Figure 3.13 developed by NEMA of Korea can be considered as one of the most directly connected early warning system with 'now casting' concept. This system is for localized rainfall warning. After a one night flash flood which killed 95 campers and hikers in the Jiri National Park in Korea in 1998, the local observatory system need to be expanded to monitor local torrential rains which cannot be easily observed at regional level. The automatic rainfall warning system can measure rainfall in the upper stream, analyse discharge and velocity of river flow in a specific basin and calculate the water level downstream. When the water level exceeds a certain criteria, early warnings and evacuation orders can be issued. When rainfall is actually measured in the observation station in the upper stream, which is powered by batteries and sunlight, the runoff and time of concentration can be determined using a computer program verifying various parameters.

Korea has adopted an integrated water related disaster management approach that leverages the country's strong early warning systems (EWS). These EWS monitor information pertaining to potential natural disasters. This is captured in the Integrated Control Center (ICC), which includes four sub-systems to monitor and disseminate information before and during a disaster. Through the Disaster Prevention and Meteorological Information System, the ICC monitors satellite images, radar images and the contents of special weather reports. Specific monitoring systems such as CCTV real-time monitoring are also established for floods, rainfalls and tsunamis. In the event of an emergency, the ICC acts as a disaster management control tower to support response measures in a 10-minute maximum lapse-time.

The World Bank has been supporting the modernization of early warning systems in many countries (including Mexico, Mozambique, Nepal, Poland, Russian Federation, Vietnam, and Central Asian countries). In each project, the aim has been to modernize the National Hydro-Meteorological Service (NHMS), building institutional capacity, modernizing the observation and forecasting systems, and improving the delivery of services. This approach is a departure from many earlier efforts to assist NHMSs, which focused on enhancing capacity on a limited scale, usually in the area of in situ observations. The new approach is expected to be more sustainable because it is built on strengthening specialized public institutions (NHMSs), which will address a growing social demand to get access to better quality of hydro-met services for economic sectors and communities including timely, accurate, and actionable warnings. It also recognizes that national investment alone is not enough—that partnerships and pairing arrangements with more capable NHMSs through the World Meteorological Organization (WMO) are also essential to ensure sustainability. The World Bank plans to scale up its support to global weather and climate enterprises working closely with the WMO and other partners.

In case of certain hazards such as floods and droughts, for example, the MODIS Aqua and Terra products are available free of charge and can be used to improve the monitoring and forecasting services. Applications of space technology and GIS can provide accurate warnings of impending disasters, help map out hazards and vulnerabilities for evidence based policy-making and planning and help in disaster impact assessments for effective disaster risk management at the regional, sub-regional and national levels. Vietnam Government has been promoting research and application of space technology for natural resource, environment and disaster management. Space Technology applications are successfully being used for wildfire

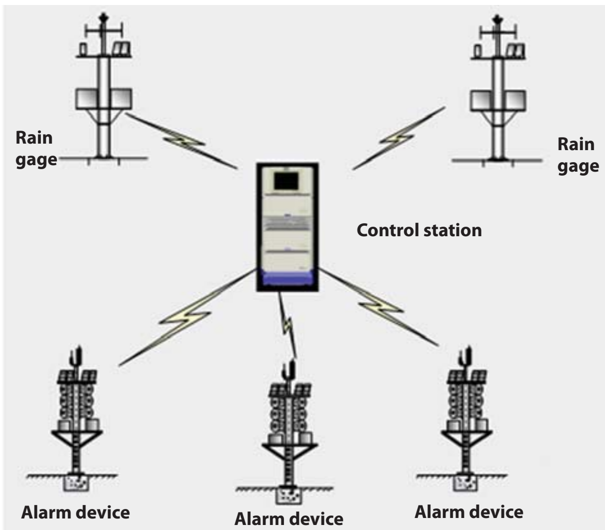

Figure 3.13 Automated rainfall warning system to disseminate early warning massage which help people to escape from lowland and mountain valley in Korea

detection, soil erosion, natural resource management and disaster monitoring such as floods. The VNREDSat-1 project, one of VAST's prioritized projects, is a stepping stone to form the Vietnamese system of earth observation small satellite systems in order to realize the "National strategy for research and application of space technology until 2020". The success of VNREDSat-1 project will contribute efficiently to respond to Vietnam's natural disasters and global weather changes and hence accelerate economic development in the country. To operate the VNREDSat-1, Vietnam has built three ground stations and sent 15 engineers to Toulouse, France, to be trained in operating related systems (APRSAF, 2012). The VNREDSat-1 project utilizes all the existing infrastructure of the satellite image receiving, archiving and processing system of the Ministry of Natural Resources and Environment, that builds up, for the first time in Vietnam, a complete monitoring system from the satellite to ground receiving stations together with a processing and distributing center of remote sensing data. Vietnam is also using EO small satellite data (VNREDSat-1) and physical methods for water quality research and management in Mekong River at the mouth of Vietnam.

3.5.4.2 Reactive Step

Following the initial response period, and once the situation has been stabilized, a GIS can be used to analyse disaster impacts and help plan the rehabilitation process in a way that reduces potential vulnerabilities. The following few examples demonstrate the value and necessity of GIS during the post-disaster management phases. Disaster impact analysis can assist response efforts by identifying those areas that are most in need, and can help guide reconstruction efforts in a way that will minimize the potential for future disasters; for example, through improved land use planning that takes into account local hazard vulnerabilities. In conjunction with IKONOS panchromatic images, De La Ville et al. (2002) used GIS to evaluate the distribution of landslide erosion scars and their effects on several urban areas situated among six mountain catchments in Venezuela. Disaster impact assessment system in Korea aims at fundamentally eliminating potential causes of disasters inherent in various development projects in advance and ultimately protecting the life and property of the people. This program is one good example for implementing sustainable development. The disaster impact assessment system is implemented when the area of targeted development is not less than 300,000 m^2. With respect to small- and medium-sized development projects (150,000 m^2 to less than 300,000 m^2 in size), each city and province has performed a local disaster impact assessment system. To protect lives and properties in downstream areas from the impact of large-scale development, facilitating disaster prevention facilities such as retention reservoir in the development area, the disaster impact assessment has been introduced since 1996 and the coverage of disaster impact assessment has been expanded in 2001. Currently, disaster impact assessment is applicable to 24 categories in 6 fields such as urban development, industrial area development, tourism attraction development, and mountain area development.

Following the Indian Ocean tsunami in 2004, and after evoking the International Charter on Space and Major Disasters to acquire pre- and post-disaster high resolution satellite imagery, most country used a GIS for rapid damage assessment. The GIS was used primarily to combine different data types and to support a visual analysis of building damage. QuickBird multi-spectral imagery and a 1:5000 scale vector layer of buildings obtained from the Survey Department were overlaid in a GIS to accurately identify construction that existed prior to the disaster. Global Positioning System (GPS) was used in conjunction with ground photographs to accurately record the location and building damage, respectively. This allowed for a comparison between the damage level in the photographs and satellite imagery. Results indicated that heavily damaged buildings can be easily identified, but partial damage, particularly if the roof was still intact, was difficult to determine from the satellite imagery alone.

Since 2007, the Netherlands National Safety and Security Strategy has promoted a holistic approach to risk management. It has determined five vital areas for the country, which are territorial, physical, economic and ecological safety, and social and political stability. The main objective of the Netherlands National Risk Assessment (NRA) is to define priority risks for which the Netherlands should prepare and plan capacity development accordingly. The NRA consists of two parts: analysis and impact assessment. The analysis phase is managed by a network of independent experts who operate under the leadership of the steering committee of National Security, which is composed of ministries, businesses and intelligence services. The NRA method is scenario-based. Risk scenarios have assigned scores for their likelihood and impacts according to 10 criteria related to vital safety and security interests. The results are given according to low and high estimates. The impact assessment permits the Netherlands to determine which capabilities are needed for each type of risk. In this way, high estimates contribute to the development of resilience capacities and preparedness. The NRA develops estimates for a five-year period. This NRA is then used to assess capacity gaps and identify where capabilities should be reinforced.

For the effective national disaster management, NEMA, Korea has established the database system and the information-based risk management systems which include a variety of data such as GIS data, spatial information, CCTV images, disaster risk maps, water resources, etc. To manage these information effectively, NEMA developed the National Disaster Management System as shown in Figure 3.14 in which all information are integrated and systematized with numerical models to simulate flood inundation area, estimate flood risk and assess damages. The analysis and assessment results are forwarded to the central government, regional municipalities, and related agencies which can help each of these entities to provide detailed response plans and mitigation plan for sustainable development and disseminate warning information to the public through ICT such as TV and radio stations. The system also can support decision making for quick response and emergency recovery for the damaged facilities by advanced C4 (Command, Control, Communication and Computer Integration) concept, data mining using disaster cases and statistics DB, on-site analysis using GIS/GPS information and various disaster monitoring sensor applications. In addition, satellite or aerial photograph information were collected to identify a disaster, and these related information were also gathered and delivered to the central disaster and safety measure headquarters for analysis. This system is included in various up-to-date telecommunication technologies to use the wireless communication network by way of precaution against failure of the wired network.

In other examples, GIS has been used to determine the extent of a disaster and estimate damage (Ranyi & Nan, 2002), organize resource inventories and their geographic distribution (Hussain et al., 2005), monitor shelter/refugee camp status and the state of transportation infrastructures (Gunes & Koval, 2000) and integrate disparate spatial data sources that may be required to guide response (Amdahl, 2001). GIS can help with search and rescue for providing medical services, debris removal, sheltering, and infrastructure repairs. Sahana, a free and open source software (FOSS)-based system developed by Lanka Software Foundation, Sri Lanka, is a suite of web-based applications that provides solutions to the problems arising in a post-disaster situation. One objective of Sahana is to assist victims in connecting with their families and friends as soon as possible. Sahana's Missing Person Registry is an electronic version of a bulletin board of missing and found people. It can capture information not only on the people missing, but also about those who seek details about the missing persons, thus increasing their chance of reuniting. Even if the victims or families do not have access to this information themselves, it is quite easy for any authorized NGO or civil society group to connect to the central portal and provide that service in the areas they are working. Also it keeps track of all the relief organizations and civil society groups working in the disaster region. It captures information on both the places where they are active and the range of services they are providing in each area to ensure that there is no overlap.

The applicability of remote sensing for disaster management is perhaps best exemplified in the case of flooding, and many researchers address its use for this disaster type. Satellite imagery can be used to assess the extent of past flood events (Dewan, Islam et al., 2007) and aid in the development of flood hazard potential maps. Jayaraman et al. (1997) highlight the potential of RS technology to drastically assist flood response and relief operations by providing inundation mapping and damage assessment. Disasters resulting from floods are a logical choice for RS analysis because: (a) floods generally cover large areas, and thus occur at spatial scales much larger than the spatial resolution of most satellite imagery, and (b) water has a unique spectral reflection which makes it clearly discernable from other ground features (Showalter, 2001). In contrast, earthquakes, for example, may cause significant damages to buildings and infrastructures, but without high resolution imagery or change of detection capabilities, it can be difficult or impossible to identify.

3.5.5 Research and Development Agenda

The Asia-Pacific region has been suffering from multiple exogenous shocks in the past few decades. The overlapping and interlinked nature of these shocks call for a comprehensive approach to build resilience. Regional and sub-regional cooperation has become increasingly critical especially in the sharing of good practices and enhancing the capacity of member states in the active use of space-based information, near real-time satellite imagery and data, including scale, geographic coverage and maps, as well as learning from good policy practices. The disaster-prevention-related agencies must pursue the joint use of disaster prevention information and must work to build a system capable of integrating, acquiring, and managing spatial data segments of the disaster prevention information from the public sector. In addition, the deployment of a ubiquitous-application software development environment must be considered in light of the advances in information technologies. On top of these, the standardization of disaster management affairs, the continued increase in the number of agencies jointly using the available disaster prevention information, the enrichment of shared contents, the expansion of public disaster information service contents, the enhancement of real-time disaster information gathering, the development of disaster-forecasting simulation capabilities, and the enhancement of satellite- and wireless-network-based situation reporting must be realized to come up with a truly advanced disaster information management system. It is important to enhance the scientific and technical work on disaster risk reduction through the mobilization of existing networks of scientific and research institutions at national, regional and international levels in order to strengthen the evidence base in support of the implementation and monitoring of this framework.

3.5.6 Recommendations

Space-based information and products and services play a crucial role in strengthening the much needed cross-sectoral linkages in support of disaster risk reduction, response, recovery and long-term development planning. There are

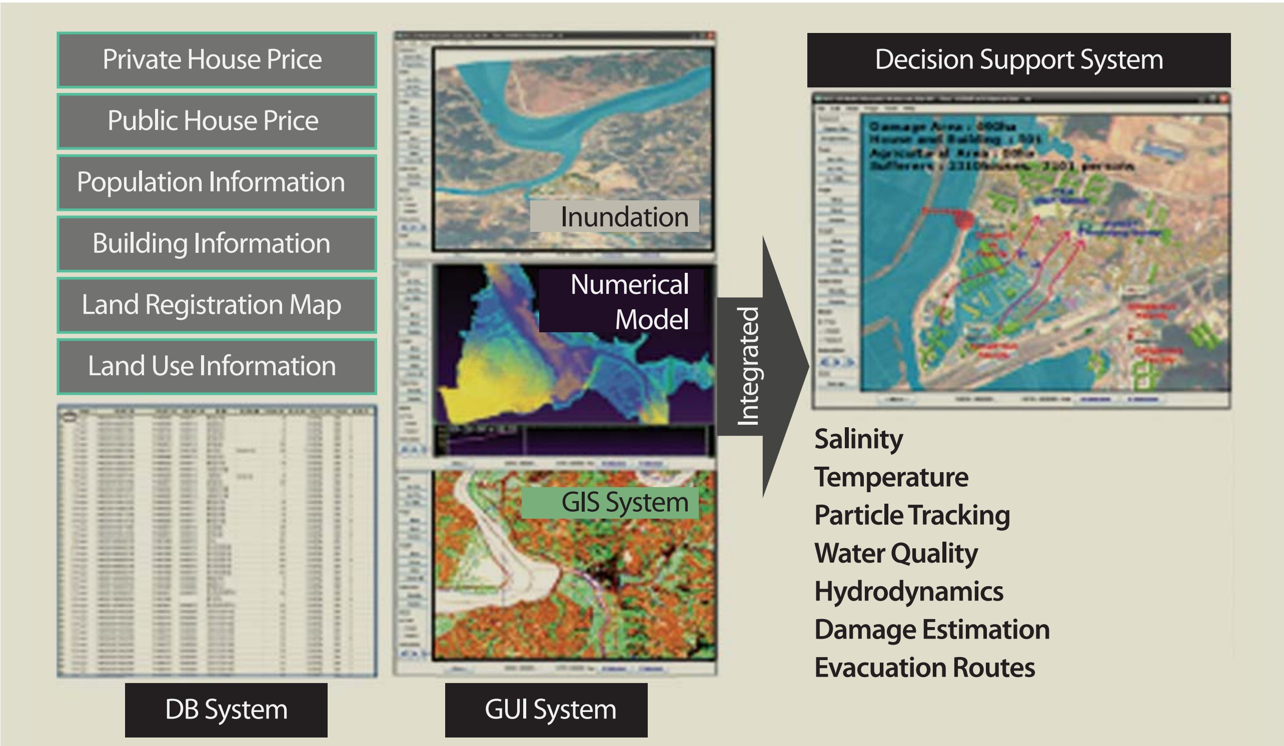

Figure 3.14 Design of decision support system for flood disaster management in Korea (Cheong, 2012)

many good practices in the developed countries for effective application of space technology and GIS and it is imperative to enhance and facilitate the sharing of information and good practices. The ability of GIS and space-based information technology to acquire, interpret, analyze, map and disseminate information, are essential during all phases of the natural disaster management cycle. Since disasters are spatial phenomenon there is a strong relationship between disaster management capacities and decision support capabilities offered by GIS and space-based information technology. The United Nations Office for Outer Space Affairs has been implementing a Space Technology and Disaster Management Program to support developing countries in incorporating space-based solutions in disaster management activities. It is important to ensure real-time access to reliable data, and use Information and Communication Technology innovations to enhance collection, analysis and dissemination of data.

To overcome barriers for GIS and space-based information technology level, in improving the overall disaster management capacity at the local level especially in the case of the developing countries, many researchers have highlighted the particular opportunity that free and open source software (FOSS) provides. Attractive characteristics of FOSS from a developing country perspective include: costfree, freedom, accessibility, customizability, compatibility, software and technical capacity development opportunities. For supporting the development and strengthening of DRR capacities of developing countries, an international platform to share and transfer space and GIS-based information is needed. Also further extension in cooperating with NGO and related institutes for information sharing or developing open platform is essential for disaster risk management.

3.6 DISCUSSION AND CONCLUSIONS

Climate change is a crucial issue for our future already affecting climate, people, and resources in this world. These impacts are projected to increase and thereby pushing the urgent need to address water related disasters due to the climate change, especially, in developing countries. Therefore, we need to mitigate negative impacts and take advantage of possible opportunities. Also, the adaptation strategies are crucial with recognition of both local experiences and innovative technologies to provide decision makers with cutting edge information on the vulnerability to climate change. However, while, we may need the reduction of greenhouse gas emissions to manage changing climate change and natural disasters. It is undisputed that the devastating consequences of climate change cannot be reversed in the short term and therefore, we need international collaborations and cooperative action in the long term associated with both mitigation and adaptation.

Drought that is associated with deficit in available water is an extreme climatic event and cause potential long-term impacts on water resources, agricultural production, economic activities and ecosystems. The occurrence of recent severe droughts and their respective vulnerabilities in the context of climate change have warned communities and governments across the globe to take initiatives for better future planning to mitigate its impacts to the possible extent. A better solution is to mobilize and enhance funding and support research and development on the underlying causes and effects of drought, including social, economic and environmental perspectives, promote the culture of information exchange as well as introducing innovative techniques and practices that can improve food security and reduce human vulnerability.

As discussed, urban flooding has been a growing concern for developed and developing countries and flood events may increase in the future due to climate change and land development especially in urban areas. The vulnerability assessment and resilience measure can help to identify and prioritize weaker area from urban flood. Scientific and technical solutions for mitigating the urban flooding has been developed such as flood defense system and integral flood management including flood observation and alert system as hardware and software tools. We conclude that those tools must be further developed and balanced between common sense and far-sighted approaches to defend against future flood hazard. In addition, improving further forecasting and warning system up to the point public can be relied on is one of the major goals that science and technologies must reach as well as visualize current and forecasting flood status.

ICT and GIS applications, especially space-based information and mechanism were introduced and their crucial roles in strengthening the much needed cross-sectoral linkages in support of disaster risk reduction, response, recovery and long-term development planning were discussed. And it was issued that developing countries and local communities in the advanced countries have barriers for real-time accessing to reliable data, and using ICT innovations to enhance collection, analysis and dissemination of data. To solve this problem, free and open based global platform for information sharing and technology transferring was suggested. This global platform extended to NGOs and related institutes should be empowered to incorporate technology into real practice which also can help to realize evidence-based policy making on disaster risk reduction to be practiced globally.

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Smart Technology

Main Focus 4

Smart Technology for Water

Smart Water Management is a next-generation water management process using intelligent-integrated technologies and water information generated in the process of the whole water cycle. It can maximize the efficiency of water management in terms of water resource management, treatment & distribution system control, and energy consumption management.

Smart Technology for Water

4.1 INTRODUCTION

Smart technologies are considered to be intelligent in that they enable quick and accurate responses to changes and may predict and optimize for future events to provide improved outcomes. Smart water management (SWM) refers to the systematic and pervasive collection and use of data generated from water systems using information and communication technologies (ICT), which enables greater internal and external integration and provides enhanced system control. It can be considered to contain three components: technology, integration, and modelling. Arguably, the key feature is integration or interconnection, as people, systems, and objects interact and communicate with each other in new ways (IBM, 2010).

SWM is a rapidly evolving approach to improving whole system management by exploiting performance data gathered from water systems at various scales. The data can come from many sources including users, infrastructure, meterology/hydrology, and the environment. When processed, the data can be used for automated real-time control or as part of a decision support system (Figure 4.1). The potential benefits are many and include greater operational efficiency, reduced costs, and enhanced system resilience and sustainability. The potential is so great that SWM can be reasonably described as an emerging paradigm shift in the water sector, with applications throughout the water cycle.

SWM can be applied to different parts of the water cycle, such as urban water and water resources, and at different scales. Within urban water management, for example, smart technologies can be implemented independently in each sub-system (e.g., wastewater treatment, urban drainage and water distribution systems), but it is also possible to utilize data from multiple sources in an integrated manner to provide intelligent operation and smart decision-making through the use of smart grids. The term “smart” can also be applied to technologies providing greater integration with external systems, such as energy, to provide further all-round benefits. Applications of SWM are widespread and developing continuously. In the urban environment, topics addressed include water conservation and efficiency, leakage detection and control, energy consumption, and water quality improvements. At river basin scale, applications include approaches to ensure the efficient production, transmission, and distribution of various water resources (e.g., surface water, groundwater). This includes addressing geo-temporal imbalances in water supply and demand, including inter-basin transfers. Other objectives can include flood risk management and management of the quality of surface and ground waters.

This paper is subdivided into four main parts, focusing on (a) the urban scale, (b) the river basin scale, (c) smart water grids (SWGs), and d) big data. Each part addresses current approaches and future trends, case studies/applications, and development challenges. Examples are drawn extensively from the Korean water industry experience and practice, but also from case studies worldwide.

4.2 URBAN WATER MANAGEMENT

4.2.1 Role of Smart Technologies

4.2.1.1 Financial Context

Today's water industry is challenged by many imminent problems (e.g., aged water infrastructure, water supply and demand inbalances, water pollution issues, rising energy prices). The key question to be addressed by water service providers worldwide is not only how to address these issues but also how to finance them. Although approximately US$210.0 billion per year is spent globally on provision of water supplies, there is a still a serious funding deficit. Many water utilities have tried to develop persuasive business models for replacing aged water supply infrastructure and improving inefficient water supply systems. Unfortunately, many have difficulty in securing budgets and the private or governmental funding required to do so (Growing Blue, 2011). This lack of investment has, in turn, put pressure on water utilities into taking epochal cost-saving measures. However, these supposedly cost-saving measures have, according to GWI (2010) often been unsuccessful because of the following:

(a) Difficulties in acquiring sufficient status data about water leakage, of pipes and quality, etc.
(b) Lack of data exchange and knowledge integration among different operation divisions.
(c) Difficulty in analysing information for decision-making. And
(d) Lack of automatic technologies to analyse information about water distribution networks on a real-time basis and make reasoned decisions.

Other significant budgetary pressures include non-revenue water (typically pipe leakage), as high as 40% of the water put into supply in some places, which clearly does not generate any income (Growing Blue, 2011). Also, some 25–30% of the operating costs of most water utilities (USEPA and GETF,

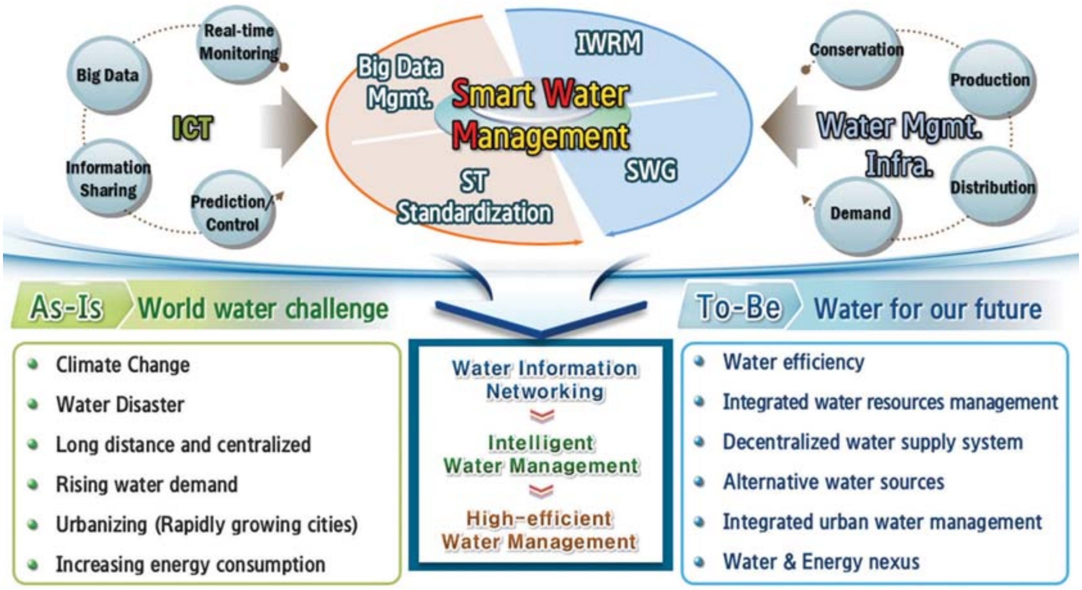


Figure 4.1 Conceptual components of "Smart Water Management"

2008) relates to energy consumption. World energy prices therefore have a significant and variable impact on ongoing operational costs

4.2.1.2 Need for Smart Technologies

The need for cost-effective and efficient approaches to address these multiple challenges is therefore evident and water utilites and others are looking to smart technologies to deliver these needs. The potential benefits to be delivered include the following.

(a) Real-time monitoring and diagnosis, determination of maintenance priority and historical data management.
(b) Remote monitoring and control of the whole water supply and distribution process.
(c) Compliance with regulations and policy requirements for water conservation.
(d) Provision of information to consumers (e.g., water use patterns).

According to a recent survey by Walsby (2013), it was estimated that it would be possible to save US$7.1 billion to US$12.5 billion per year through implementing smart water solutions to improve the efficiency of operating water supply infrastructure and optimize capital investments (Table 4.1), and to reinvest at least 5% of current operational and investment budgets in improving water distribution networks or to transfer them to end users, as through lowered water tariff.

4.2.2 Case Studies

This section gives examples of the development and application of smart technology in five example applications: (a) smart water networks (SWNs), (b) smart control of leakage, (c) smart operation of water quality and energy, (d) pipe condition assessment, and (e) smart control of wastewater treatment and urban drainage.

4.2.2.1 SWNs

According to the Smart Water Network (SWAN) Forum, SWNs can be subdivided into the layers shown in Table 4.2, at each of which it is possible to advance intelligence by adopting appropriate smart components.

Successful cases of smart water networks can be found in Barcelona, Copenhagen, and Dubuque, which have evolved themselves into the so-called “smart cities” or “smart water cities” by introducing and applying smart technologies across a range of public services.

Smart City Barcelona seeks to provide urban services efficiently at multiple levels to all citizens by harnessing ICT through developing and implementing the Barcelona Smart City Model. The model identifies 12 key areas: environmental, ICT, mobility, water, energy, matter (waste), nature, built domain, public space, open government, information flows, and services. Currently, the city has 22 major programmes and 83 separate projects that fit into one or more of these 12 areas (Figure 4.2).

The city of Copenhagen has adopted innovative technologies and policies (prevention of leaks, pricing mechanisms to reduce wasteful consumption, engineering solutions and better management of storm water), which allows a reduced

Table 4.1 Estimated global savings by smart water technology (source: Walsby, 2013)

Category	Potential savings (US$ billions)	Saving (%)	Description
Leakage and pressure management	2.3–4.6	3.5	Predictive modelling to estimate potential future leaks and pressure management
Strategic capital expenditure prioritization	3.5–5.2	12.5	Improved dynamic assessment, maintenance, replacement, planning and design of network to optimized spending on infrastructure needs
Water quality monitoring	0.3–0.6	0.4	Automatic water sampling, testing and quality monitoring reduction in costs from labour and transportation costs for manual sample
Network operations and maintenance	1.0–2.1	1.6	Real-time, automated valve/pump shutoff to facilitate flow redirection and shutoffs; more efficient and effective workflow planning
Total smart water savings opportunity	7.1–12.5	7.4	

consumption of water, while protecting the groundwater resources.

To expedite the development and application of smart water technologies together with other cities, Copenhagen has sought a way to collaborate with private utilities. It plans to form a partnership with public agencies (Copenhagen and Jakarta) and all other utilities of water technologies related to energy and water efficiency, IT infrastructure, and solutions, etc. The city of Dubuque, a city of 60,000 residents announced its partnership with IBM in September 2009 to make Dubuque the first "smarter" sustainable city in the USA. The initial focus was on water consumption analysis and leak alerting. The city has established sustainability as one of its top priorities since 2006. Starting in 2010, the city started replacing existing water meters with smart meters produced by Neptune Technology Group for about 23,000 homes and small businesses. The city's aim was to establish a new baseline for water consumption (using smart water meters), educate citizens about water conservation, and reduce overall water usage.This collaboration between the city of Dubuque and IBM has made the smart water pilot to be successful and the city to be sustainable for water.

Smart Metering

There is a trend in much of Europe for water utilities to move towards smart water metering, driven by the need for efficiency improvements (Stedman 2014). For example, Thames Water (a UK water provider) will have installed 43,000 smart meters by March 2015 and aims to have 80% of its customers metered by 2025; it is planned that this will help address a predicted shortfall of 414 million litres per day by 2040 if current demand is maintained (Thames Water 2013).

Smart metering provides remote, automatic collection of real-time consumption data from consumer water meters and has many potential applications and benefits when implemented in an SWN. These include leak detection, improved demand forecasting, greater flexibility in tariffs and improved network operations (McKenna et al., 2014). When smart meters are used, customers can be encouraged to alter consumption habits by the introduction of variable water pricing, which in turn can mitigate peak demands and reduce stress on the water distribution network (Temido et al., 2014). It has also been suggested that smart water metering may enable companies to defer, downsize or eliminate capital expenditures by providing demand management (Temido et al., 2014).

Use of smart meters can also benefit customers: for example, constant high water usage may be indicative of a leak in the customer's pipes and, if detected, the supply can be switched off, thereby saving the customer money (Stedman, 2014). Furthermore, smart metering can improve customer satisfaction due to the ability to produce bills based on accurate meter readings and prevent over-estimation of consumption (Temido et al., 2014).

Table 4.2 SWN functions

Layer	Technological components
Physical layer	Includes the physical components of water distribution networks (e.g., pipes, pumps, valves, reservoirs, end users)
Sensing and control layer	Includes hardware equipment and monitoring components to measure water delivery and distribution parameters (e.g., flow, pressure, vibration, energy use, water quality)
Collection and communication layer	Includes responsible technologies for storage and transmission of information
Data management and display layer	Integrates acquired data into information, and thereby implement them with SCADA (supervisory control and data acquisition), GIS or other network display tools
Data fusion and analysis layer	Provides data analysis and modelling software interface tools using supervisory communication channels and sensing devices within the network

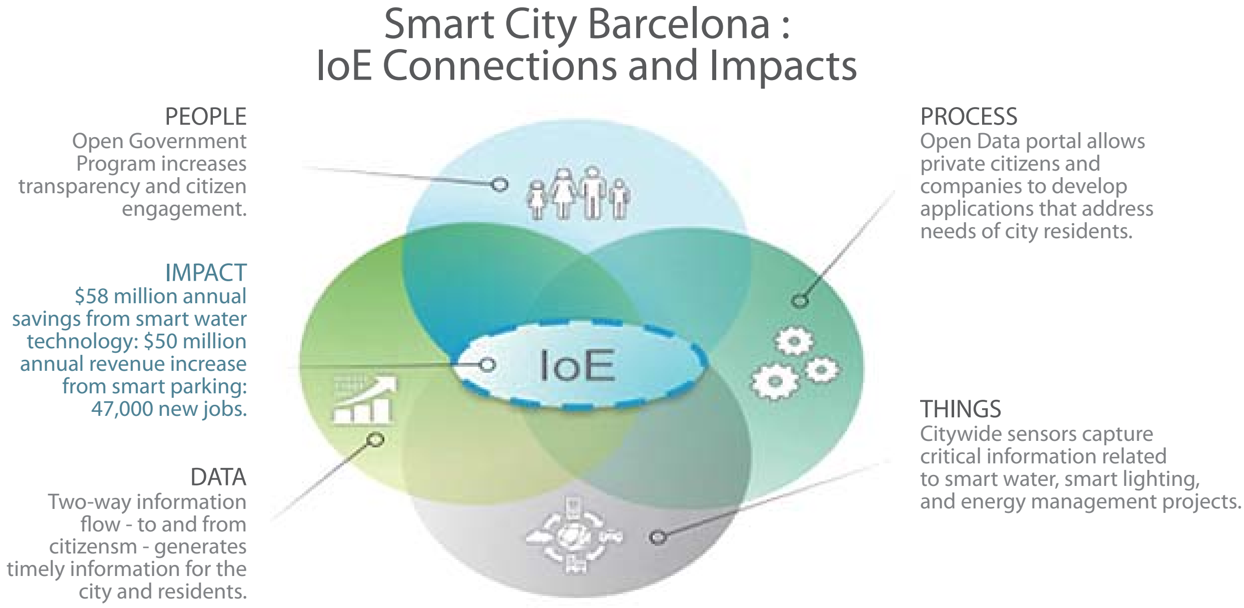


Figure 4.2 Smart city Barcelona (source: Cisco Consulting Services, 2014)

4.2.2.2 Smart Control of Leakage

Water leakage resulting from ageing water infrastructure is among the most important causes of water shortage. Water utilities are faced with increasing operation and maintenance costs, for example to repair or replace pipelines with water leakage and produce and convey treated water. Water leakage management involves four key components: proactive leak detection, pressure management, infrastructure management, and improved leak repair time. Major leak control technologies include electronic listening sticks, leak noise correlators, STEP tests, etc. However, these kinds of leak control technologies require much time and expense for their application.

Acoustic leak monitoring markets are growing as part of efforts to resolve this problem. With acoustic leak monitoring technologies used to detect water leakage effectively in water distribution networks, it is possible to identify leakage very difficult to detect in a short time, which, in turn, will be helpful in managing water shortage more efficiently. Automatic monitoring systems for water distribution networks are designed as to acquire data via online sensors. The acquired data will be perceived and embodied not to only inform about the current state of target water supply infrastructure, but also to respond appropriately to, or prevent, its various problems, including water leakage, pipe damage, flow meter errors, and other malfunctions.

Water leakage is directly related to system pressure, and can be lessened by lowering it. In a practical sense, however, it is difficult to control pressure accurately because most water supply systems are subject to substantial variations in water demand depending on time, day, and season. Still, recent efficient pressure-management practices have made it possible to do so with pressure control valves and variable speed pumps equipped with a control program. With automatic pressure optimization technologies, which are among advanced pressure management technologies, it has become possible to automate the optimization of pressure using data acquired through sensors that are installed throughout water distribution networks. These kinds of technologies send a command to pressure control valves and pump control systems on a real-time basis considering current demand patterns and operational characteristics of target distribution networks, and thereby control pressure immediately. Other leak detection and control technologies are shown in Table 4.3.

Table 4.3 Summary of leakage detection and control

Category	Models and methods
Active leakage control	Leak detection technologies Leak localizing Correlating noise loggers Leak pinpointing Leak noise correlator Ground penetrating radar (GPR) Signal analysis Correlation using low-frequency hydrophones Gas injection In-pipe inspection technology Automatic Meter Reading (AMR) and intelligent meters Acoustic monitoring and advanced meter infrastructure (AMI)
Hydraulic-based leakage detection	Model-based leak detection methods Volume-based demand calibration Pressure-dependent demand calibration Pressure-dependent leakage detection (PDLD) PDLD constraint handling Integrated solution methods Using the fast messy genetic algorithm (fmGA)
Transient analysis-based	Inverse transient analysis Other transient-based leak detection methods Time domain methods Frequency domain methods
Online monitoring	Conventional alert systems Using minimum night flow (MNF) method Conventional alert systems Time series-based alert systems Artificial intelligence alert systems
Pressure management-based	Pressure management model Using pressure dependent demand (PDD) model Intermittent supply model Pressure modelling with pdd
Pipe renewal planning-based leakage control leakage control	Pipe condition rating Point-score protocols Fuzzy theory-based techniques Data-driven approaches to predict condition rating based only on inferential indicators Water main deterioration models Physical/mechanistic models Statistical/empirical models Hydraulic capacity deterioration models Decision support models and methods

4.2.2.3 Smart Operation of Water Quality and Energy

Recent statistics indicate that 30–60% of water quality incidents result from abrupt flow variations due to pipe damages or sudden control of valves or pumps installed in a distribution network (de Graaf et al., 2012). Pollutants from industrial, commercial, and residential areas can enter the distribution network system through damaged pipes or with wastewater overflow. Poor water quality monitoring can lead to serious consequences in terms of public health, cost burden, and reliability.

With the development of smart technologies, the focus of development and application in monitoring and controlling water quality started at water treatment plants, but has begun to be expanded to distribution networks. Conventionally, water quality has been managed manually. That is, in situ and laboratory analyses are made on collected samples as per different scales. More recently, however, genetic sensors, which can detect a wide spectrum of water quality variations, have been used to analyse water quality at multiple levels (ACT, 2005). Also, the strengths of online water quality monitoring systems installed in water distribution networks have been recognized. With these genetic sensors, it becomes possible to transmit water quality data to such a software platform as an early warning system on a successive, real-time basis, and thereby track and identify source pollutants in a timely fashion.

The US Environmental Protection Agency (USEPA, 2005) evaluated the applicability of online water quality monitoring equipment to field practices and assessed the practicability of early warning systems with large amounts of data, which had been accumulated using a methodology to track and identify the sources of water quality problems. There are also cases where the associated operation of online water quality monitoring equipment with a rechlorination system and an automatic flushing system to control the quality of water supplied to end consumers contributed to the improvement of water quality and rate of drinking water (K-water, 2014). Figure 4.3 highlights examples of water quality monitoring and control systems for the water quality management of target distribution networks.

(a) Online monitoring station (b) Rechlorination equipment (c) Automatic flushing equipment

Figure 4.3 Water quality monitoring and control systems in Korea (K-water, 2014)

As mentioned, electricity expenses occupy a substantial portion of all costs incurred by water utilities to produce and supply water, and most of the electricity expenses (90%) correspond to pumping expenses for raw and treated water (Bunn and Reynolds, 2009). Pumping facilities are closely linked among components in them, which indicates that some problems in one specific component may have substantial influences on the efficiency of other pumps within the same system. It is difficult to determine how to operate pumps more efficiently since they are subject to a high level of daily, seasonal variations. Accordingly, it is important to determine optimal pump efficiency by measuring the performance of each pump under various conditions or scenarios. In general, it is possible to do so by performing a simulation analysis based on a calibrated hydraulic model. Pressure and flow per pump should be tracked real-time in the process of such simulation, and an optimization algorithm prediction technique can be used to select optimal pump type through hydraulically analysing all states of flow and pumps. This implies that, along with energy efficiency, the performance of relevant infrastructure can be improved with a hydraulic model and an energy prediction system. Software programs such as InfoWater, KY Pipe, H2OMap Water, HydrauliCAD, WaterCAD, Water-NET, Aquadvanced, and others have been used to determine optimal pump operation conditions with the combined use of hydraulic modelling and energy optimization system.

4.2.2.4 Pipe Condition Assessment

Considerable technological progress has been made, even at this stage, to evaluate accurately the state of aged pipelines and determine when to rehabilitate and replace them. Non-destructive inspection technologies to measure various structural criteria without causing any damage to pipelines are being introduced. Technologies applicable to pipelines include a liquid penetrant testing method (to check for any crack), X-ray inspection, acoustic emission testing, acoustic leak detection, remote -field eddy current testing, magnetic flux leakage inspection, ultrasonic wave velocity, the guided wave method, and seismic methods. (However, the non-destructive testing method for pressure pipes has not been widely used, except for the acoustic leak detection method and the acoustic detection method for steel-wire defects in pre-stressed concrete cylinder pipes). Despite the many methods available, Dingus et al. (2002) indicate that non-destructive inspection technologies are applied to as few as 10% of water mains in the USA. This limited usage results from various causes, such as high expense, disruptiveness, and insufficient track records for most relevant methods and techniques. Thus, limited growth technologies in the area of water pipelines may result from a small market scale, difficult testing conditions, or a lack of understanding of, or interests in, pipeline inspection requirements. However, it is anticipated that the technological development of non-destructive inspection methods will improve when linked to practical sensors, sensor networks, communications, data analysis, and computing.

Many decision support tools have been developed to determine the priorities for investment, maintenance, and replacement of pipelines. Table 4.4 shows the major components of the five decision support models for pipe renewal and their associated capabilities addressed by Ammar et al. (2010). They evaluated the models according to the functions: ability to process condition assessment and defect data; contains an extensive method database; performs a technical evaluation of the project conditions and characteristics; performs a costs analysis; and performs a final method ranking.

Table 4.4 Decision support models for pipe renewal

Models, year	Defect data?	Extensive database?	Technical evaluation?	Cost analysis?	Method ranking?
M-PRAWDS, 2001	Yes	No	Yes	Yes	Yes
Debetal, 2002	No	Yes	Yes	Yes	Yes
CARE-W, 2005	Yes	No	Yes	Yes	No
Ammar et al. 2010	Yes	Yes	Yes	Yes	Yes
AWWA, 2001	No	No	Yes	No	No

4.2.2.5 Smart Control of Wastewater Treatment and Urban Drainage

There are widespread concerns over the condition and functioning of ageing wastewater systems, many of which have exceeded their design lives and are unable reliably and adequately to deal with current conditions let alone future needs. When systems lack capacity, the traditional solution is to build more capacity; however, this can be expensive and sometimes problematic. An alternative approach is to improve performance by optimization of operations, and it is recognized that integrated, system-wide control of the sewer system and wastewater treatment plants can provide cheaper solutions and improved environmental protection (Fu et al., 2008). There are increasing opportunities as technologies for instrumentation, control, and automation become more powerful and less expensive (Breinholt et al., 2008), and recent advances in SWNs are helping to improve efficiency due to improved management and control of the sewer system.

Integration of system dynamics and analytical tools with geographical information systems (GIS) and supervisory control and data acquisition (SCADA) systems, for example, can help optimize operations and performance in real time. Real-time control (RTC) of wastewater treatment plants and urban drainage systems can be considered smart, since this involves continuous monitoring of process variables in the system and data processing to determine the operation of system components in real time to minimize adverse effects. Potential benefits of such approaches include greater operational efficiency, improved preparedness for emergencies, shortened response times, reduced system vulnerability, and mitigation of sewer overflows (Boulos 2013). Cost savings may also be achieved, and Kebir et al. (2014) found smart operation of wastewater treatment plants, using a fuzzy logic controller to provide optimal control of pumps, to reduce energy consumption by up to 40%, extend service life of pumps, and reduce problems and costs associated with maintenance.

Many simulation studies have demonstrated the potential benefits of RTC. Langeveld et al. (2013), for example, found impact-based RTC using an integrated model to be capable of significantly improving the quality of receiving waters in the River Dommel (the Netherlands), although they also noted that the improvements were insufficient to provide compliance with water quality requirements without additional measures. Based on the study results, it is reported that the Water Board De Dommel intend to perform full-scale testing and further develop the impact-based RTC concept proposed. In another study, strategies for water quality based RTC that could be included in the existing global control strategy for the Lynetten catchment in Denmark were evaluated (Vezzaro et al., 2013). Among the successful outcomes of this strategy was the elimination of overflows of “first flush” waters, thereby reducing combined sewer overflow loads.

There are also examples of RTC being successfully implemented in practice. The Québec Urban Community, for instance, has a global optimal predictive RTC system which has been in operation since 1999: this uses optimization to determine flow setpoints which will minimize the value of a cost function, subject to physical and operational constraints. The system includes nearly 70 measurement locations and controls five moveable gates using a non-linear programming algorithm to solve the optimization problem every 5 minutes (Schütze et al., 2004). Key observations and lessons learnt from this implementation of RTC include the following.

(a) Costs of planning and setting up the RTC can be high, but RTC can still result in significant savings by eliminating the need for additional infrastructure to extend the capacity of the system.
(b) RTC can provide significant and quick environmental benefits.
(c) Electronic and mechanical devices are prone to failure in the harsh sewer environment, so measures must be taken to ensure the reliability of the system. These may include multi-channel communications, providing redundancy for critical sensors and actuators, and undertaking data validation.

The RTC system must adapt to varying conditions, and should be designed with capabilities to adapt to unexpected situations.

4.2.3 Challenges and Solutions

As addressed earlier, many attempts to integrate smart technologies into urban water supply systems have already been made. With all their strengths, however, the smart technologies have been challenged by various technological or cost-related problems and limitations of their own, and many efforts are still needed to overcome these challenges. Accordingly, section 4.1.3 attempts to identify relevant challenging problems and suggest solutions to them.

4.2.3.1 Building SWNs

SWN technologies have multiple constraints to address and overcome in terms of accessibility at a level of rural areas, capital investments, security threats to physical assets and data, supply rate of mobile phones, scope of mobile networks, etc. SWN technologies also currently lack optimization capabilities or prediction network models to evaluate the effects of system performance and integrity or their physical change, along with the functions of prediction and analysis required to analyse and manage data use patterns and trends. This, in turn, increases dependency on experience and intuition, and consequently serves as an obstacle to the production of information that can function as a reference in managers' decision-making.

As part of efforts to resolve these problems, many of the current system dynamics and analysis models show a tendency to ensure integration among GIS and SCADA systems, smart measuring and detecting systems, and advanced metering infrastructure (AMI) technology so that operators may optimize network operation and performance on a real-time basis (Figure 4.4).

The integration of SWN technologies into hydraulics and water quality network modelling can provide a powerful tool to evaluate system responses to various operation and maintenance strategies for meeting specific goals. A network model can function to provide water utilities continuously with information about water network performance. The continuous provision of data, coupled with the functions of prediction, can make operators identify potential problems for their timely estimation to ensure a prior response to specific risks or minimize their subsequent impacts, to operate target networks more cost-efficiently and cost-effectively, to achieve a higher level of network integrity, and thereby to improve network maintenance, repair practices, and customer services.

A detection model allows a SWN to monitor and evaluate the dynamics of water quality continuously, and operators acquire water quality data about regulatory requirements for water utilities (e.g., maximum limit of water pollution) and recognize water quality variations and problems. The major functions of this detection model lies in the timely detection of potential hazards so that an operator may respond appropriately. The SWN pursues the formalized network modelling of public services ranging from planning and engineering design to emergency maintenance and repair, remote leak detection, prediction of damages against pipelines, optimization of energy expenses, emission mitigation, and water quality management. Figure 4.5 shows a blueprint for a smart water city where the SWN is combined together with a network model, an event detection model, a decision support model, and an optimization model.

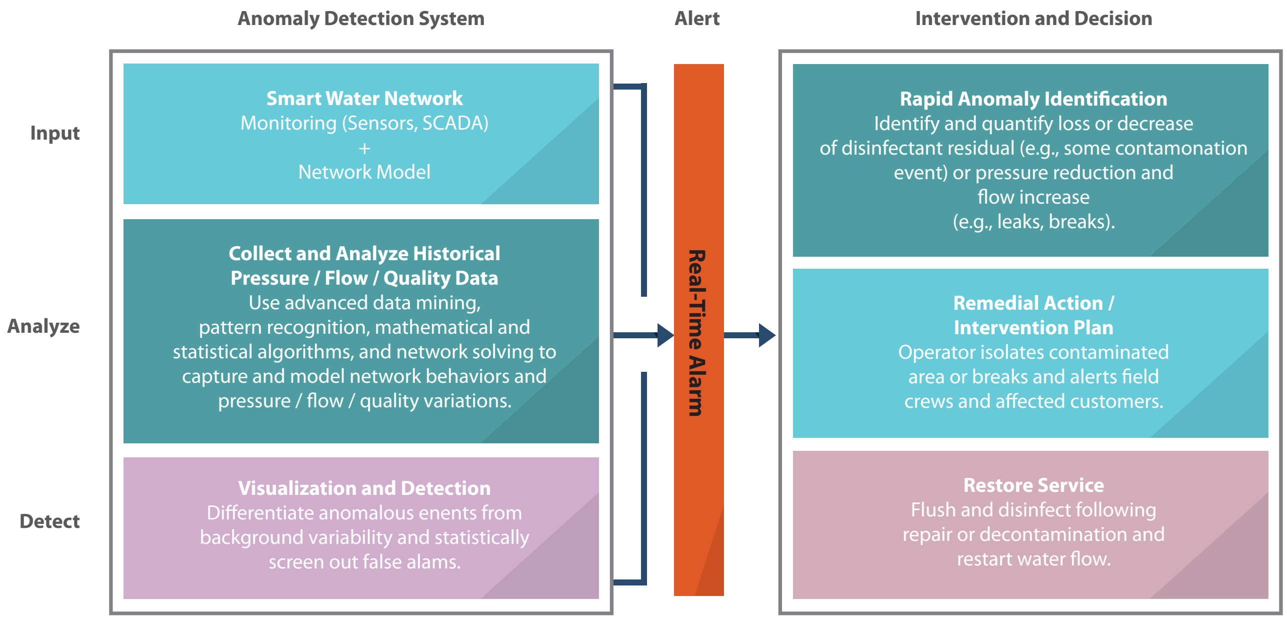


Figure 4.4 Real-time anomaly detection and decision support system (source: Boulos, 2013)

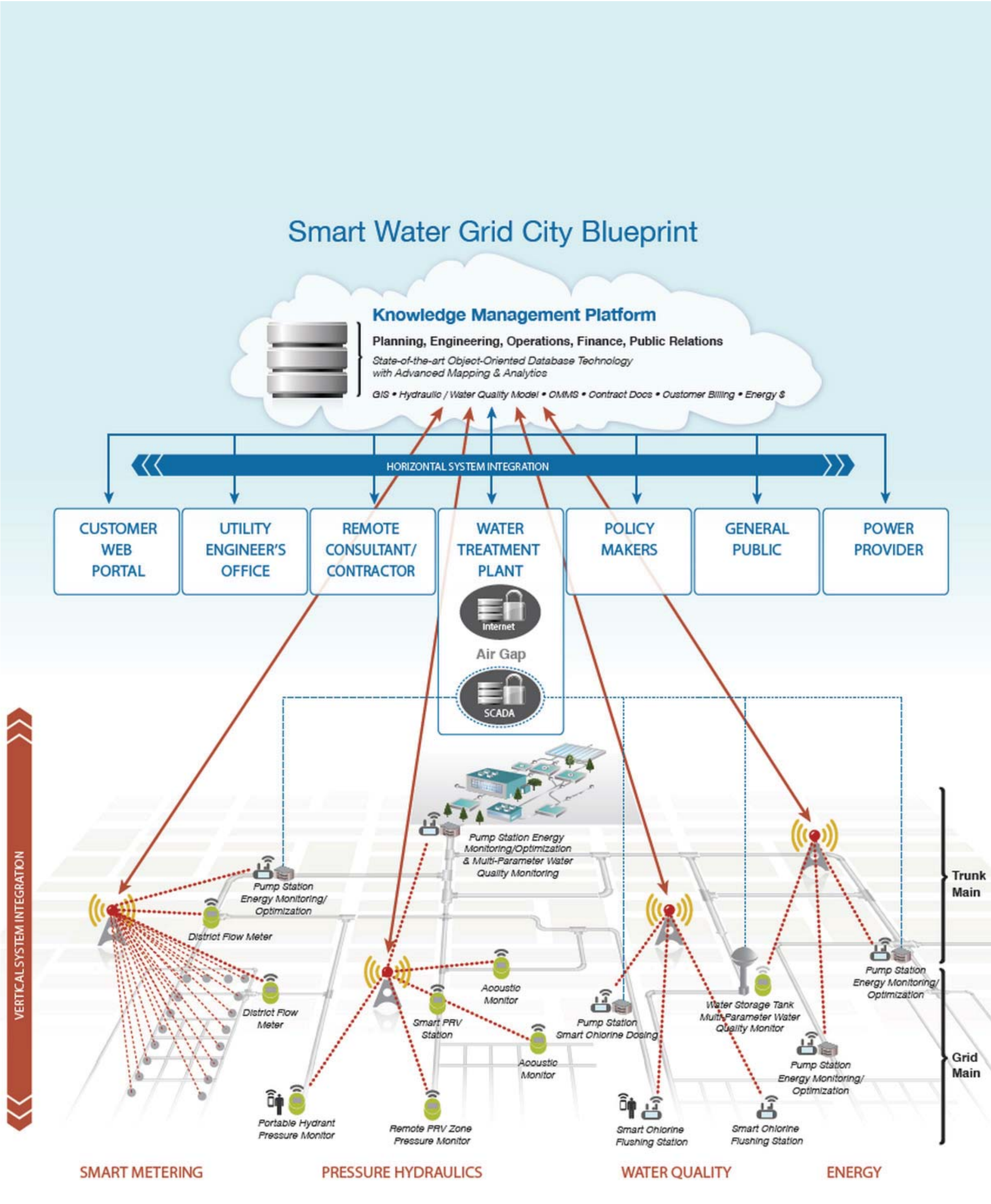
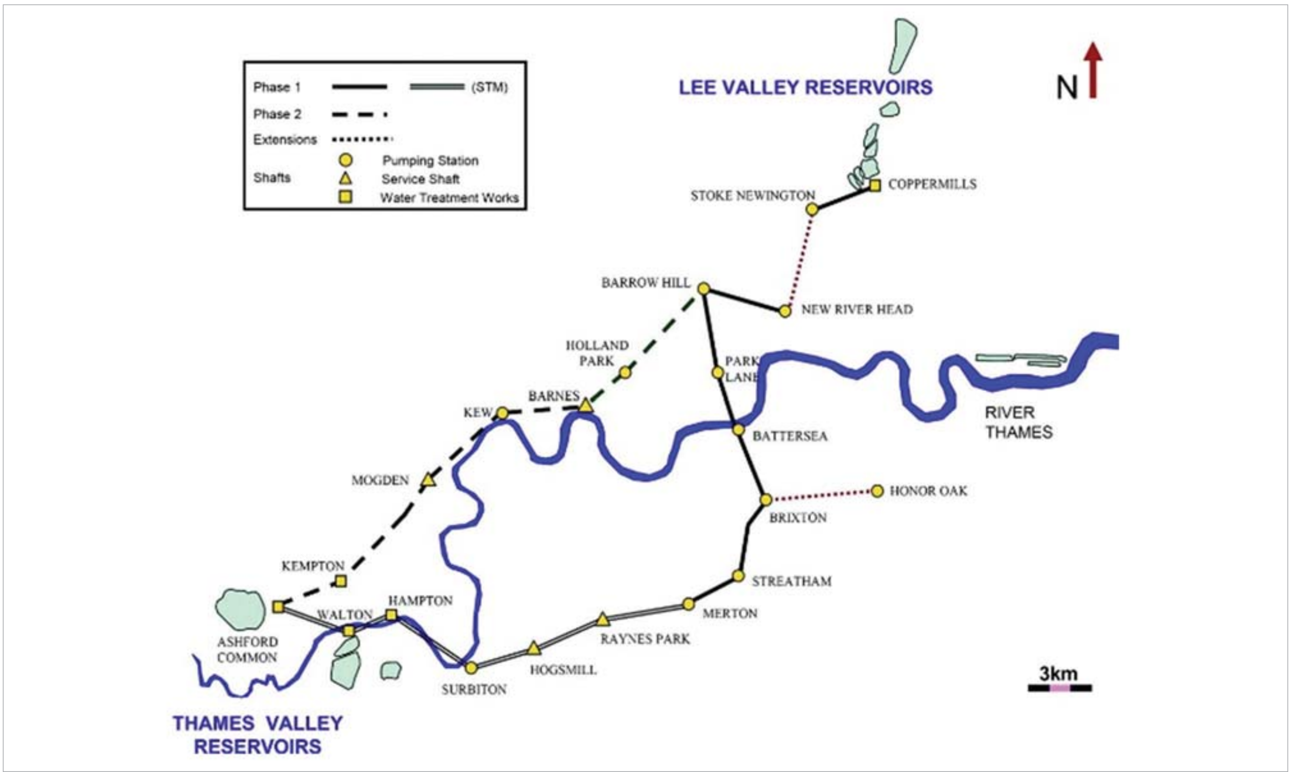
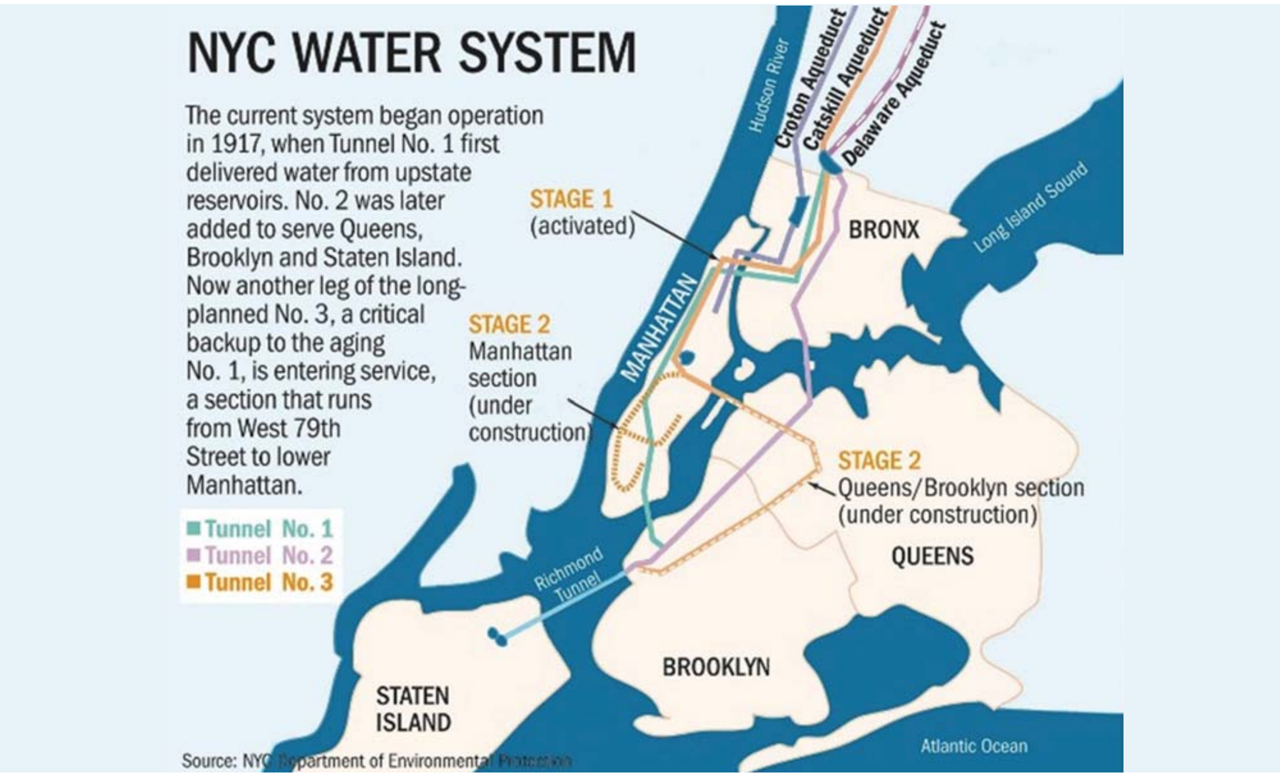


Figure 4.5 Blueprint for smart water city
(source: http://www.newfields.com/sites/default/files/pictures/SWG_City_Blueprint.pdf)



(a) Thames Water Ring Main



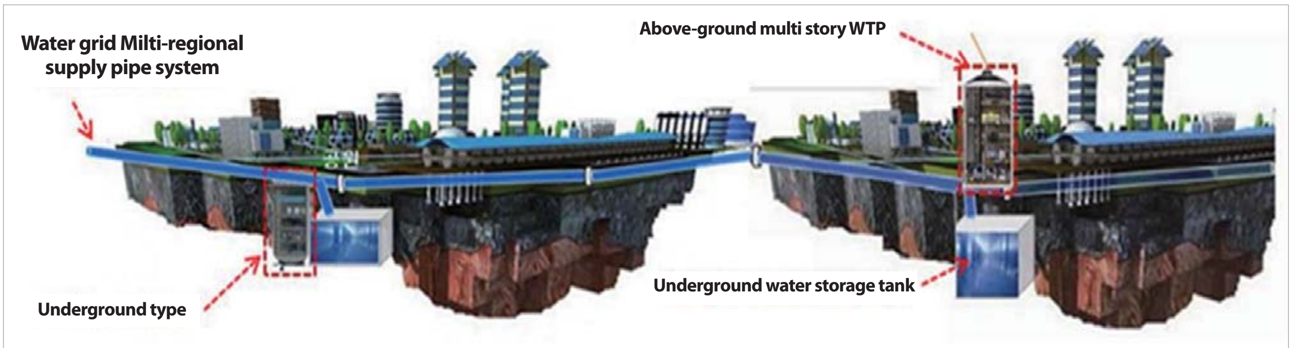
(b) New York City Water System

Figure 4.6 Examples of decentralized water supply systems

4.2.3.2 Planning a Decentralized Water System

A decentralized water system used for water supply can be understood as a system where intensively concentrated urban water load is mitigated, a water grid connecting different water supply systems is provided, and a sufficient amount of storage capacity to provide against any emergency situation is secured.

Efforts to improve the reliability of urban water supply for next-generation cities can be found in many cities, including London and New York. For example, the Thames Water Ring Main (Figure 4.6a), a concrete pipeline whose diameter and length are 2.54 m and 80 km, respectively, is the core of water supply infrastructure for London to transfer water from the Thames and River Lea catchments and supply treated water for the city. The Ring Main functions as an alternative to the water main, in which the frequency and risk of water leakage and bursts have been increasing. That is, it was so designed as to extend the service life of the water mains to a substantial degree through reducing flow in the pipeline, and enabling its maintenance without water supply interruption through pipeline dualization (Institution of Civil Engineers, 1994).



(a) Decentralized water system

(b) Towered water treatment plant

Figure 4.7 Decentralized and towered water supply system

Another example is the New York City Water System (Figure 4.6b), which is one of the largest water supply systems in the world. This system was designed to meet its routine water demands in harmony with relevant tunnels, channels, and reservoirs in the city. One of strengths in this system is that 95% of total water supply comes from gravity flow, but its remaining 5% used to increase when reservoirs comes to stay below their ordinary level in the dry seasons (Galusha, 1999).

In Korea, for example, studies are ongoing to meet end users' various needs for water consumption through securing storage capacity, which is among the strengths of the conventional decentralized water supply system, and installing a towered water treatment plant near end users (K-water, 2014). Aiming at building a water supply system to improve the qualitative, quantitative reliability of water supply and developing core element technologies and demonstrative test facilities to save energy requirement for producing and supplying water, this study has the following goals.

(a) To improve the rate of drinking water supply through securing the reliability of water quality
(b) To secure emergency water and improve water security to reduce water supply incidents to a zero degree
(c) To develop engineering design techniques for towered and decentralized WTPs with 20,000–30,000 m3/day in installed capacity
(d) To secure technologies for the water quality incident and disaster system And
(e) To develop new and renewable energy technologies for increasing the efficiency of consumed energy in the water supply system to at least 30% (Figure 4.7)

4.2.3.3 Assessing Water Infrastructure

According to the technical review of Thomson and Wang (2009), current barriers to the condition assessment of water-related infrastructure are related to:

(a) database quality
(b) regional variations
(c) inspection data requirements
(d) current condition assessment methodologies
(e) current inspection technologies
(f) physical difficulty and cost of inspection
(g) gap between required information and present inspection techniques and
(h) the relationship between outcomes and costs

With the significant advance of capabilities to provide information required for condition assessment, many innovative, effective assessment technologies have been developed. One example is fixed or portable hydrophones for water leak detection, which are inserted into a target pipeline and moved forwards or backwards by the pressure. One of their strengths is that they can be used to detect even very small water leaks. Another example is the broad-banded electromagnetic (BEM) method to inspect iron-contained pipelines. In this method, eddy current is induced in flow most closely approaching a transmitter. One of the strengths of this method is that it is possible to inspect the pipe body without damaging its lining and coating. Other examples include the magnetic flux leakage (MFL) method to inspect the external condition of small- and medium-sized steel pipelines, and the linear polarization resistance (LPR) method in which a supersonic wave is used. Table 4.5, which is summarized in tabular form from the description of Thomson and Wang (2009), shows major condition assessment technologies for water mains.

Thanks to a progress in sensor and electronic technologies and information science, electrical and computer engineering is giving birth to new high-tech assessment technologies applicable to the condition assessment of buried water supply pipes. Also, the development of sensor networks and multi-sensor technologies has enabled the real-time acquisition and monitoring of data about the state of the water supply pipes. Recently developed sensor technologies include corrosion sensors, sensor networks, magnetic strain sensors, flexible ultrasonic transducers, damage sensors, microwave back scattering sensors, optimal fiber sensors for corrosion monitoring, optimal fiber acoustic monitoring networks, wireless sensor networks for pipe monitoring, multi-sensors, smart pipelines, etc. More details of emerging sensor technologies and sensor networks can be found in Liu et al. (2012)

4.2.4 Recommendations

Although smart water infrastructure may be the future of urban water systems, its implementation is a considerable challenge. Still, its strengths and potential have sufficiently been demonstrated, and its technological development will make its application easier than ever. The following recommendations are made.

(a) Develop multiple pilot programmes involving all the key sectors (e.g., IT, communications) can play an important role in improving the functions and effects of the smart water city concept through creating cooperation among the various stakeholders, including research institutes, academic world, government authorities.

(b) Hold regular workshops, seminars, and forums to exchange information and discuss best practice on government policies and regualtions, operational experiences, outcomes, etc. among various stakeholders, including industrial and academic partners. Also, the publication of papers of case studies of smart water cities in prominent journals will be helpful in raising awareness and thereby strengthening cooperation between the academic and industrial worlds.

The appropriate strategy for formulating a smart plan to develop an urban water scheme varies depending on the local context and there is no "one size fits all" solution. Water utilities should therefore carefully review available options and develop solutions appropriate to the local circumstances. The following general principles are recommended.

(a) Place an emphasis on the pursuit of efficiency and conservation. Water utilities should make efforts to optimize the efficiency of the existing water supply system before proceeding with infrastructure investments to secure new water sources, and preferentially invest in the development of operation and maitenance programmes that may have affect end users' piping decisions and water use behavior.

(b) Develop various water supply portfolios. Flexible portfolios of water supply options are most important in terms of urban water security. Water utilities can improve the flexibility and elasticity of water supply through developing various water sources rather than building a large-scale water supply system depending on a single water source.

(c) Formulate a long-term plan considering the impacts of climate change. In general, water utilities formulate plans based on historical extreme drought data, etc. They should consider the impacts of climate change to come in formulating and coordinating the long-term forward

Table 4.5 Condition assessment technologies for water mains

Category	Models and methods	Category	Models and methods
Pit depth measurement	Measure the pit depth of ferrous pipes due to corrosion	Seismic pulse echo	Used to assess the condition of pre-stressed concrete cylinder pipes
Visual Inspection	Man entry and visual inspection Closed circuit television inspection Videoscope 3D optical scanning Laser-based pipe surface profiling Handyscan 3D	Pipeline current mapper	Pipe current mapper is a technology intended to locate leakage of electrical current in cathodically protected pipes.
Electromagnetic inspection	Magnetic flux leakage Remote field eddy current Broadband electromagnetic Pulsed eddy current system Ground penetrating radar Ultra-wideband pulsed radar system: P-scan	Radiographic testing	Show variants and thickness changes in material and structures, also applicable to inspection of valves
Acoustic inspection for structural condition	Sonar profile system Impact echo Acoustic emission	Thermographic testing	Detect material loss of relatively thin structures
Acoustic inspection for leak detection	SmartBall® LeakfinderRTTM Permalog® MLOGTM STAR ZoneScanTM Sahara®	Using soil properties to infer pipe condition	Linear polarization resistance of soil Soil characterization Pipe to soil potential survey
Ultrasonic testing	Guided wave ultrasonic testing Discrete ultrasonic measurement Phased array technology Combined UT inspection	Supplemental information on inspection platforms, intelligent pigs, and robotic survey systems	Computer-aided approach : augmented reality Intelligent pigs and robotic survey system

plans, thereby ensuring the sustainability of water supply services.

(d) Make investments in the development of provincial water sources. Next-generation urban water supply systems should aim to target local water sources under the control of local communities. Also, water utilities should try to ensure the balanced distribution of water demand for providing against possible water shortage, so that they may reliably supply not only municipal water for service areas, but also municipal and industrial water and instream flow for other cities beyond the service areas.

(e) Have interests in decentralized water supply systems. The integration of the decentralized and multi-regional water supply systems provides new opportunities to improvef urban water security and quality. Decentralized supply opens up the possibility to supply water differentially, depending on water uses, spatial scale, and serviced population.

4.3 RIVER BASIN MANAGEMENT

4.3.1 River Basin Management and Smart Technology

Integrated water resource management (IWRM) is a process to ensure the most efficient use and conservation of limited water resources while meeting various requirements of water uses. Hence, IWRM will have different objectives and approaches depending on relevant factors, including water quantity and quality or other water-related issues faced by a country or a river basin, reliability of relevant institutions, relative superiority between the public and private sectors and their respective characteristics, and cultural background (Global Water Partnership, 2000). Smart technology has an important and developing role to play in IWRM. Several opportunities present themselves.

(a) Smart technology enables the systematic management of basin-wide water managment information and data that are currently independently collected for different purposes (e.g., reliable water demand and supply, disaster prevention, water quality management). This can be used to support diverse stakeholder needs and address potential conflicts.

(b) Comprehensive, accurate basin-wide data make it possible to identify vulnerabilities present somewhere in the water cycle system, and thereby stabilize the water cycle and manage a river basin in an integrated manner in which such factors as water quantity, quality, and ecosystem are considered.

(c) Smart technology (e.g., intelligent sensors, wireless communications, code-division multiple access (CDMA), satellite images) can be employed to maximize the efficiency of water use and manage water resources considering such complex factors as water quantity and quality, sediment and flooding, contributing to the efficient use of limited water resources.

(d) Rapidly available and highly accurate data enables the equitable distribution of available water and the minimization of geographical discrepancies in water supply through ensuring interbasin river diversion and distributing water supply among different hydraulic structures in an appropriate way.

Further detail of the application of smart technology is given in IWRM is given section 4.3.2.

4.3.2 Smart IWRM

4.3.2.1 Data Acquisition and Processing

Variations in hydrological conditions due to the impacts of global warming and climate change have made it even more difficult to have IWRM in place. One of the most important countermeasures is to acquire high-quality data on hydrological conditions continuously to understand and support the management of floods and drought events, and efficiently manage water resources as a whole. A system to monitor, acquire, and process data on water level, rainfall, and water quality on a real-time basis can help support rapid and effective decisions. Data acquisition and processing systems have evolved from conventional PC- or UNIX-based data monitoring systems into real-time data processing systems based on client/server networks. These systems have been becoming more sophisticated to acquire more reliable data on hydrological conditions and to manage the data more efficiently by taking advantage of relational databases or web-based systems. The features of a smart data processing system are the following.

(a) Real-time data processing system with client/server network.

(b) Communication network configured with dual-network satellite, VHF, CDMA, etc.

(c) 24/7 web-sharing of video clips for real-time monitoring (of water level <or stage>, rainfall, water quality, etc.) and closed-circuit television footage from major areas; and text message services to smart phones for risk alert.

Relevant data are collected from sensors installed in monitoring facilities, and transmitted to a communication room, or control room, through either wired or wireless communications technologies. The communication room is equipped with servers to acquire and store hydrological data. A communication network in use is either a wired network—the public switched telephone network, or leased lines—or a wireless network using satellite, VHF, CDMA, etc. To guarantee secured data acquisition and transmission, a dual network is typically provided. Transmitted data are stored in communication drivers and databases so that administrators may check the hydrological data in the databases on a real-time basis. Raw data as stored in the databases can be utilized for systematic IWRM, and either acquired or processed data can also be shared with relevant RBOs (river basin organizations) for the implementation of IWRM in a target river basin. This can help facilitate a centralized national-level response to or prevention of natural disasters as well as a coordinated IWRM. Residents can benefit from these services by provision of relevant information through web sites or smartphones. Smart data acquisition and processing systems enable a prompt response to any incident at major areas—of a dam, a weir or a river stream—by setting an alarm or providing short message services, depending on the severity level of an incident.

In Korea, K-water, the government agency with responsibility for developing and managing water resources, has implemented and operates a real-time information system to provide data about hydrological conditions (Figure 4.8). The system functions to combine real-time data (covering water level, rainfall, water quality, etc.) and video footage of closed-circuit televisions from major dams, weirs, or river streams in the country for 24/7 monitoring services. K-water shares the data with the Korea Meteorological Administration, the Ministry of Land, Infrastructure and Transport of Korea,) and other relevant entities, and supports its own employees in checking hydrological information through smart phone applications anytime and anywhere. The website of K-water provides real-time data about hydrological conditions and closed-circuit television footages from dams and weirs to satisfy the public with better services.

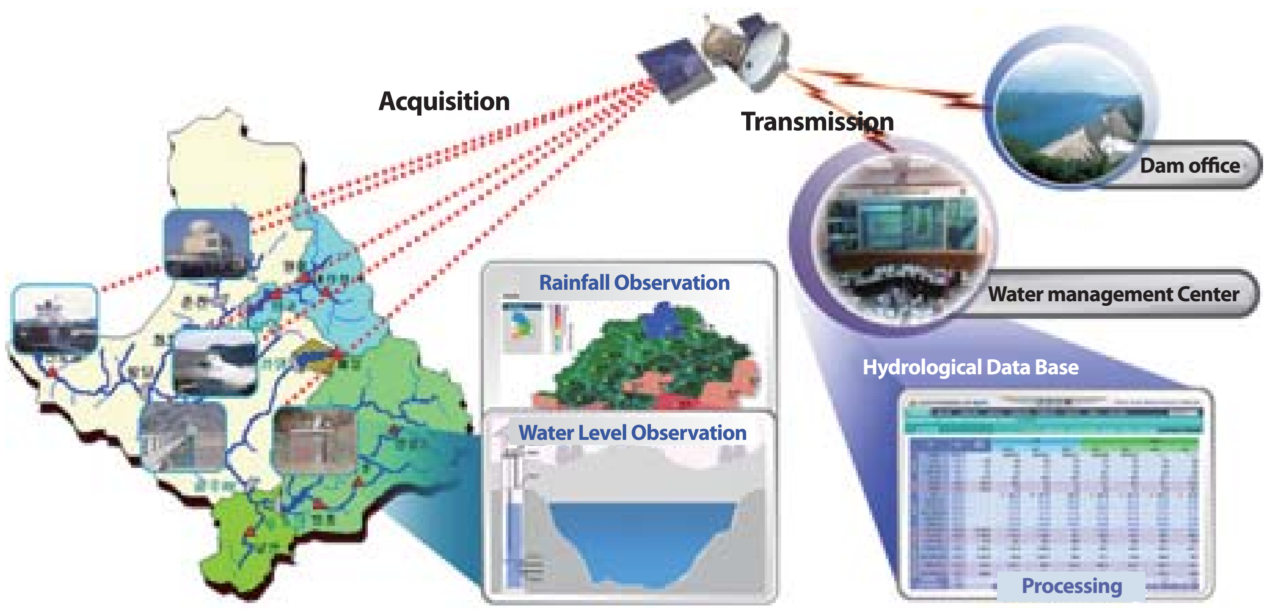


Figure 4.8 Korean communication satellite network (satellite + CDMA dual communication network)

4.3.2.2 Linking Hydrological and Meteorological Data

The successful planning and integrated management of water resources depends on the efficient use of mid- and long-term meteorological forecasts, including observed meteorological data. Smart technologies play an important part in generating and utilizing accurate meteorological and hydrological data and coupling them together to proactively predict and respond to water-related disasters and meteorological hazards. More specifically, the key roles for smart technologies include supporting:

(a) collection and acquisition of meteorological data including the sharing of data among relevant organizations;
(b) the management of data quality;
(c) a reliable analysis and forecasting system;
(d) a decision support system that combines all the above elements including wider datasets.

Satellites and the data they produce currently do play and will increasingly play an important role. The use of video footages from satellites, which can be acquired periodically and repetitively, enables the fast observation of wide-ranging regions. Satellite video data are particularly useful in analysing large-scale flood or drought damage occurring over a wide area. In Korea, for example, extensive use has been made of the Chullian satellite for precipitation prediction, their Satellites-2 and -3 to collect data covering the Korean peninsula, and more recently Satellite-5 to monitor flood-affected areas without the interference of cloud by utilizing X-band synthetic aperture radar (SAR) videos.

Radar is also widely used for for weather forecasting and increasingly as a tool to forecast flood conditions. It can be utilized to assess the risk level of possible water-related disasters and other natural disasters in advance, take mid- and long-term countermeasures against such natural disasters (e.g., master plan to mitigate flood damages, purchase of disaster insurance), and design investment projects to develop hydraulic structures. If the concept of potential flood damages consisting of potential factors (e.g., hydrological, social, and economic factors) risk factors is applied, it would be possible to understand the water control characteristics of each mid- and large-scale zoned area, prioritize investment projects, and identify the level of natural disaster hazards in advance.

An example of how meterological data from various sources can be combined and used is K-water's Precipitation Prediction Model (K-PPM), which was developed to make an objective, precise forecast of precipitation in target dam watersheds. A supercomputer with a capacity of 400 central processing units and 100 terabytes was introduced and dedicated to meteorological forecasts to provide customized 5-day-per-week forecasts for better water resource management in 30 dams, 16 weirs in the four major rivers, and 58 different watersheds around the country. K-PPM was designed to provide a high resolution of 3 km grid spacing. To enhance accuracy, an "ensemble method" was introduced to use ten different models in combination to minimize dam operation risks attendant with inevitable uncertainties (Figure 4.9).

4.3.2.3 Telemetering and Control Systems

Telemetering and control systems are widely used in water resources management for remote monitoing and control of, for example, hydraulic structures. A system is typically configured with communication lines to connect equipment to equipment so that a central control unit (i.e., master) may communicate with a remote unit (i.e., slave). Communication lines can be subdivided into web-based line type, leased line type, private leased circuit (PLC) line type, wireless communication type, and satellite communication type. With this type of system, it is possible to monitor remotely any unauthorized access to onsite facilities or their operational status. The system can turn generators on or off during the night-time when there are no staff on duty or when it is not possible to have access to generators because of natural disaster. The system also enables the acquisition of basic data to inspect or check remotely for any failure or response without the need for onsite visits, thus ensuring more reliable operation and maintenance.

Newer developments include synchronization through a smartphone application allowing the monitoring of onsite facilities anytime and anywhere; and operations staff in charge can monitor onsite facilities without any contact from a field staff member on duty, which, in turn, will reduce human error and enable prompt, effective responses in any emergency situation. Water gates, when controlled in the field, often require frequent manipulations to ensure accurate discharge. With the telemetering and control system, however, it is possible to fine-tune and control them effectively by minimizing waste discharge and saving gate control time

4.3.2.4 Decision Support Systems

Decicion support systems are a key part of any smart system, and that is equally true for IWRM. The US Bureau of Reclamation, for example, has worked with the US Geological Survey since 1993 on the development of analysis tools to manage river basins, and proceeded to develop relevant programs to be applied for basins in San Juan, Colorado from 1995. The Watershed and River Systems Management Program is an analysis tool to support basin-wide water and environment resource management. The program was developed as the combination of a river system model to simulate physical, hydrological behaviors, a reservoir simulation model (where the quantity of water uses in downstream areas is considered), and a biochemical simulation model for each zoned area (customized for upstream flow regime and other riverine hydraulic conditions). This program has been used for water resource planning and management (i.e., decision-making for water distribution) for dam reservoirs operated by the US Bureau of Reclamation, and much support has also been provided in developing relevant software or models required for ensuring connection with other models (Frevert et al., 2001).

The Tennessee Valley Authority system has been used to operate a total of 60 dams, including 45 dams—out of which nine are located in the mainstream and 36 in its tributaries—under its control and others owned by the US Army Corps of Engineers and power companies. Their storage capacity totals up to approximately 16.9 billion m3, which accounts for 30% of mean yearly runoff. The most important operational use of the Authority's dams and reservoirs is related to flood control, waterway transportation, and hydroelectric power. Their other operational uses include recreation, protection of fish and wild animals, water preservation, water supply,

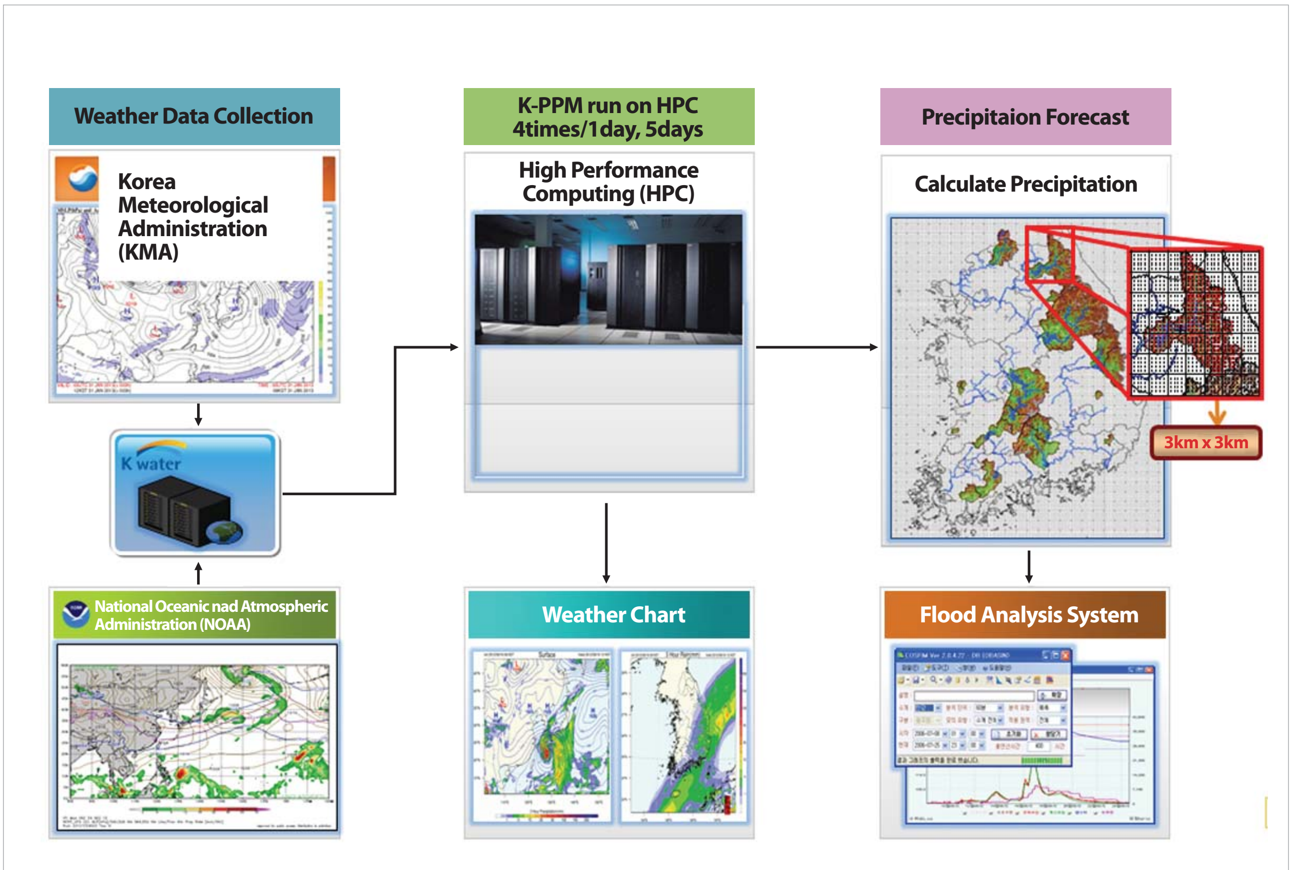


Figure 4.9 How meteorological and hydrological data can be linked for water management

and containment of insect breeding subject to water level (or stage) conditions. The Tennessee Valley Authority system consists of WaterView, RiverWare, and Terra, all of which are interconnected. WaterView is a SCADA system for water management, and RiverWare is a decision support model to ensure the better operation of target reservoirs and rivers. Terra plays a role as a water management web portal to share water management information via the Intranet (Zagona, 2013).

Waterware is the product of the EUREKA European Union 487 Project, which had been implemented for 5 years from 1992 jointly by experts from the UK, Italy, Ireland, and Austria. It was so designed as to support a combination of GIS, database technologies, modelling techniques, optimization techniques, and expert systems. With Waterware, modelling techniques such as simulation models are used to predict the results of various alternative analyses, and intelligent techniques such as the combination of optimization techniques and expert systems help select an optimal alternative (ESS GmbH, 2015).

In Korea, K-water's Hydro Intelligent Toolkit (K-HIT) has been operated on a real-time basis. This IWRM system accommodates a wide range of water management technologies to provide rainfall forecasts and real-time hydrological data, facilitate decision-making for flood control and water supply and enable the remote control of hydroelectric power plants. This system platform also provides guidelines to identify nationwide water status on a real-time basis and make relevant decisions, and integrate functions into which flood control, reliable water supply, water quality and dam management are embodied.

4.3.3 Challenges and Solutions

In this section, one specific area of challenge is used as an example. The particular challenge is that of controlling and managing flood disasters. The specific context is that of how Korean municipal governments can be helped to enhance their capabilities in an integrated and effective manner aided by smart technologies. The particular need is that over 98% of all flood damage in Korea originates in provincial or small-scale rivers.

The mitigation of this flood damage requires the integrated collection and analysis of hydrological data (covering rainfall, water level, dam discharge, etc.) from many relevant river basin organizations and municipal governments connected together along the relevant river system, which should be followed by timely decision-making. In most cases, however, the municipal governments have difficulty in managing rivers and basins under their respective jurisdictions for various reasons such as the absence of reliable data transmission systems to ensure the sharing of hydrological data, a lack of trained personnel involved in disaster prevention, and ageing hydraulic structures. There are also frequent conflicts between municipal governments or residents in upstream and downstream areas over water supply and the causes of the flood damage related to the operation of hydraulic structures at issue.

A particular issue in this case is that each river basin organization and/or municipal government has its own independent data transmission system, making it difficult to share data among themselves on a real-time basis. Thus an approach is needed to standardize their different data transmission systems. The SmartTM program has been developed as a standardized real-time water management data sharing system with which it is now possible to acquire data, which, in turn, are stored in a database and analysed on a single platform with no separate communications drive. The system can function to analyse and monitor on a real-time basis expected rainfall or maximum water level in downstream areas after dam discharge. This will also make possible more cost-efficient and cost-effectively responses to flood disasters by minimizing evaluation and response times, thus minimizing flood disruption, property damage, and loss of life.

4.3.4 Recommendations

As we have seen, IWRM is an approach to maximize the benefits of water management in which not only factors interconnected under each of the same categories (e.g., hydraulics, hydrology, water quality and ecosystem; relationships between upstream and downstream stakeholders; water managers and consumers; and laws and regulations, institutions and governance) but also connectivity among different categories are considered. To this end, there is a need to ensure that water information can be readily shared, ideally at a national level, probably requiring reforming governance. Technical development is still needed to sort, analyse, and provide optimal data specific to water management delivered by real-time monitoring technologies and big data produced by various institutions.

A standardized water management (data) platform should be developed to generate, process, provide, and share big data for practical applications, especially where stakeholders are involved in different areas and fields of water management. This would make it possible to more methodologically collect and understand data coming from the entire water cycle, and thereby make an optimal decision about water management in terms of time and cost. Each player participating in water management typically already has their own system to monitor, acquire, and provide those data, so this leads to the need to develop an information system that can function to integrate databases from these individual systems into a single one. Further, to do this requires tehnologies to be developed to enable the production and acquisition of reliable and standardized data across the entire water cycle, which encompass hydraulics and hydrology, water quality, and ecosystems.

The challenge of climate change is calling for a new approach to water management. As part of preventive initiatives, smart technologies should be developed to utilize limited water resources efficiently and to respond to hydrological variations or disasters proactively and flexibly, thereby maximizing people's water welfare. To this end, the development of monitoring and prediction technologies to understand the entire water cycle system more methodologically, and technologies to minimize uncertainties inherent in nature, should be pursued. This, in turn, should be backed up by building research and development infrastructure so that fundamental knowledge and new technologies may be developed and applied.

4.4 DESIGN AND IMPLEMENTATION OF A SMART WATER GRID

4.4.1 Technology Development Overview

A smart water grid (SWG) is a next-generation water management system that manages real-time data from water resources and supply/sewerage systems using state-of-the-art ICT. Although the concept of smart grids is well established in the energy sector, they are less mature and have only recently started to gain popularity in the field of water management (Mencarelli et al., 2012). The ultimate purpose is to minimize water consumption, ensure high water quality, provide consistent operation of the system, and maintain and operate the system as efficiently as possible, using an increased level of intelligence and enhanced integration of information, sensors, communication, and control technologies throughout the entire system (Olsson, 2011).

The potential benefits are numerous, and can include improved regulatory compliance and enhanced contamination warning (Thompson and Kadiyala, 2014). Components of an SWG include the following (Hill and Symmonds, 2013):

(a) AMI;
(b) customer information systems;
(c) SCADA systems;
(d) computerized maintenance management systems;
(e) GIS;
(f) analytics engines.

Systemized and intelligent systems are implemented in areas including water resource management, water production and delivery, as well as the processing and recycling of used water. Targets and scopes of technologies range from interactive water use management at a household level to national management of water resources (Figure 4.10). In addition, the SWG concept embodies a wide range of topics, including the following:

(a) efficiency improvement;
(b) cost and energy saving for water production and processing;
(c) utilization of multiple water qualities;
(d) systematic and preventive facility management;
(e) water resource management;
(f) solution of regional imbalance and achievement of water security.

The industrial development and application of SWGs in the USA has been led by IBM but water companies such as Siemens and Suez have growing interest in the field. IBM is promoting SWG as part of its "Smarter Planet" campaign, which consists of three SWG characteristics: instrumented, interconnected, and intelligent. SWG in the USA typically focuses on four main areas:

(a) water supply management centred on AMI;
(b) optimization of energy consumption for water management facilities using a smart electricity grid;
(c) implementation of a sensor network for water resource and quality management; and
(d) implementation of an efficient water resource management system.

Additionally, another important attempt at optimization of energy consumption for water management facilities focuses on the implementation of regulation network technology used on a smart electricity grid. Moreover, companies are trying to provide tools for nationwide management of water resources by proposing a large-scale project based on the plan for the National Smart Water Grid™ to utilize excessive water resources in the central region during flood seasons by collecting and moving them to the US West Coast, which suffers from water scarcity.

European companies also have growing interest in SWG, and IBM is expanding its SWG business in Europe. Veolia and Suez are enthusiastic about SWG, and Siemens recently announced a roadmap for SWG. Table 4.6 gives an overview of SWG research and development (R&D) in major regions.

Korea launched a study group for "Smart Water Grid (Water Grid Intelligence)" in 2012. The technologies to be developed by the group are those for spatiotemporal stability of water resource acquisition and supply, water demand and supply evaluation and management technology based on the demand/supply evaluation and automation among grids in consideration of climate change, convergence technologies including interactive and real-time operation technology, and integrated water management technology by utilizing ICT infrastructure and technologies.

Figure 4.11 illustrates SWG's start and progress, showing that the work initiated in the USA in 2009 became the foundation for starting research on United Nations ITU-T standardization in 2012. Several themes and approaches are emerging (Tables 4.7 and 4.8).

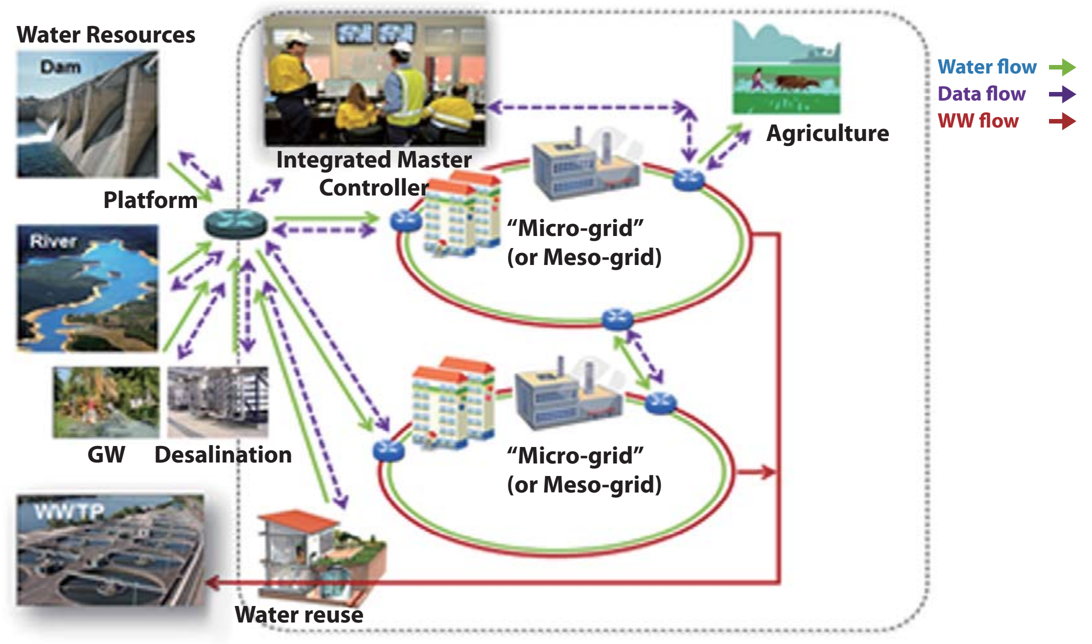


Figure 4.10 Example of SWG system implementation with hierarchy structure

Table 4.6 Overview of SWG R&D in major regions

Country	SWG research and devlopment	Notes
USA	• Started Smart Water Grid Initiative • Implemented water supply management system focusing on AMI • Optimized energy consumption or water management facilities using smart electricity grid (Pecan Street Project, Texas) • Used sensor network for water resource and quality management • Implemented efficient water resource management system at national level (Proposed National Smart Water Grid: transferring excess water from the US central region to West Coast)	Billing and leakage detection using AMI
Australia	• Started SEQ Water Grid Project • Set long-term plan to secure water resources (US$9 billion budget / 2008) • Formed five supply chains • Integrated water source management for source and processed water • Integrated management of large-scale water transfer • Implement infrastructure for greater distribution efficiency • Improved sales via integrated management of water reservoirs	First introduction of water grid concept Relatively fewer cases of AMI applications or integration with Smart Grid
European Union	• Aim to introduce smart meter to all households by 2020 • IBM expanding SWG business throughout Europe • Siemens Germany announces Smart Water Grid roadmap • Other water-related R&D activities in progress • Carried out by FP7(Framework Program, 2007–13) • Established Environmental Technology Action Plan (ETAP) • SWITCH (Sustainable Water Management Improve Tomorrow's Cities' Health)	Introduced AMI later than USA
Israel	• TaKaDu leads SWG business • Developed SWG technology using data on climate, existing sessions, GIS, sound, others	Cooperate with IBM and Thames Water, UK
Other cases of water resource vancement	• Singapore provides industrial water with recycled sewage and waste water • UK runs facility management for uncertainty in future via "Resilient Infrastructure" project • California has integrated water management from Water Plan Update 2009 to resolve water issue • Korea is developing four SWG technologies listed below via convergence of IT technology: • Technology for spatiotemporal stability of water resource acquisition and supply • Water demand and supply evaluation and management technology based on the supply and demand evaluation and automation among grids in consideration of climate change • Interactive and real-time operation technology by utilizing ICT infrastructure and technologies • Integrated water management technology	

Table 4.7 Future (smarter) city and application of SWG (1) (Brook, 2011)

Smarter City Theme	Application of Information and IT
"Leakage is a service failure"	• Permanent in situ leak and pipe condition monitoring • Optimization of pumping activity to avoid scouring, pressure bursts
"Energy costs are a major issue"	• Routine dynamic optimization of energy consumption system-wide
"Decentralized water and wastewater treatment"	• Centralized management of distributed water and waste-water plants • Reduced capacity requirements – optimization enables same level of demand to be met through smaller capacity
"Ecosystem services …"	• Monitoring of ecosystem health and service "performance"

Table 4.8 Future (smarter) city and application of SWG (2) (Brook, 2011)

Smarter City Theme	Application of Information and IT
"Manage the future"	• SPC, modelling and optimization
"Sensing"	• Sensor networking on a massive scale, plus data analytics
"Wastewater is a resource"	• Management systems, oversight, application of SPC to extraction processes, management of residue and discharge
"Water recycling is the norm"	• Management and assurance of localized water treatment, injection, and recovery facilities • Water quality monitoring
"Demand is malleable if water is priced effectively"	• Demand modelling, management, and prediction • AMI for water

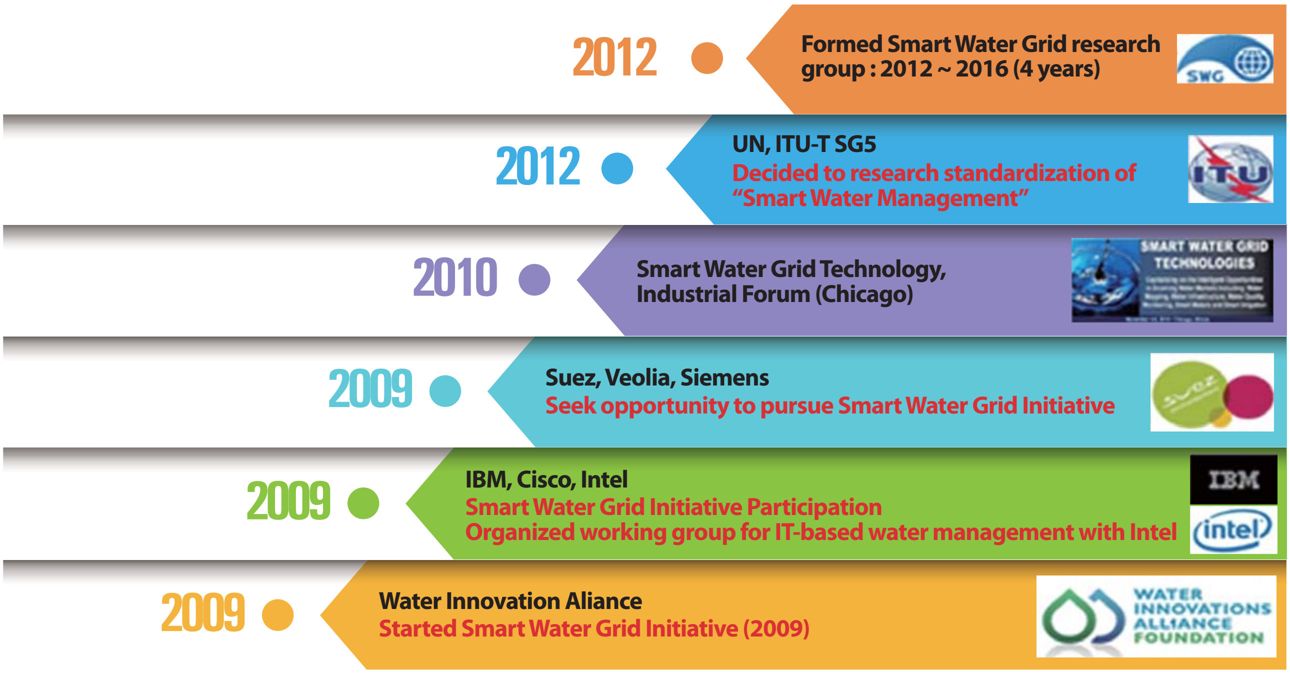


Figure 4.11 SWG initiative

4.4.2 Case Studies

4.4.2.1 Cucamonga Valley Water District: AMI

Cucamonga Valley Water District (CVWD) is a region in Southern California that has run a fixed network since 2005 and services 32,000 AMIs covering 124 km2 in area. With Itron "Water SaveSource"™ for water leakage detection, the service provides not only the metering of water consumption but also detailed real-time information on water consumption, leakage detection and reports, and follow-up and prevention of incidents. Moreover, AMI facilitates more accurate detection of leakage through an acoustic sensor, reducing cost and energy, and improving efficiency for water production by time-of-use data (Poulsen, 2010).

4.4.2.2 Hudson River: Integrated Sensor Network

In 2007, IBM and Beacon Institute implemented a real-time monitoring system by applying integrated sensor network and robot and computer analysis technologies in the Hudson River of New York. They built an integrated sensor network called the River and Estuary Observatory Network in a 315-mile-long river district to collect information on the influence of global warming, behavior of fish, route of pollutants, and other phenomena (Sullivan, 2009).

4.4.2.3 Malta (Island Type)

Malta is a Mediterranean island south of Italy. Its water sources are dependent on groundwater and seawater desalination. The island is suffering from a water shortage, and environmental changes such as global warming will lead to growing scarcity of water resources. So Malta has applied SWG at the national level to improve the efficiency of water and energy utilization. Since 2009, it has implemented a €70 million project in collaboration with IBM to implement national AMI and SWG in water and energy over the next 5 years. IBM has introduced a system for water and electricity management. Especially for water management, the company has implemented smart water metering that supports remote management, allowing users to check water consumption via the Internet (IBM, 2012).

4.4.2.4 Singapore (New City Type)

Singapore's water industry promotion project has come through the collaboration with its Public Utilities Board and private companies. The city-state has secured an independent foundation for water resources by using sewage and wastewater filtered with advanced membrane technology (consisting of pre-processing—micro filter—reverse osmosis concentration and ultraviolet sterilization) to supply drinking and industrial water. Singapore is trying to build independent water resources via the so-called NEWater system to miminize water imports from its neighbour Malaysia. The Singaporean government has promoted SWG to secure a stable water supply to predict and respond to rapid changes in the global water situation. Despite high rainfall in the region, Singapore has experienced a water shortage given lack of enough land to store rain, and has tried to resolve this problem through large-scale projects for long-term securement and a stable water supply. Singapore, as part of a national project, established an R&D center for water processing technology in 2004 to collaborate with top universities across the world, and is fostering international and domestic water companies to become the world's leading water hub.

Singapore's development of its water business is being done through strategic collaboration with think-tanks and companies. For instance, about SGD300 billion has been invested in R&D for water processing technology since 2007, and the Singaporean company Hyflux has invested SGD50 million on the R&D centre. The key project, the NEWater system, purifies half of the city-state's sewage and produces cleaner water than general drinking water. Four factories produce 29 million litres of water daily, which covers 15% of Singapore's demand. All consumed water is recycled and reused as industrial and gardening water through intensive sewage processing using advanced membrane technology consisting of pre-processing - microfilter - reverse osmosis concentration, and ultraviolet ray sterilization. About SGD1 trillion has been spent on the facility over the past 8 years, and 29 global companies, including GE and Siemens, and about 300 partner vendors have participated in the project. Based on the success of this government-led promotion of the water industry, Singapore has established the third phase of its SWG R&D project plan to obtain optimum solutions for water resource management: it has completed its own SWG roadmap to implement infrastructure for water supply and sewage, and an IT-based interactive network for supply and demand of water resources (Allen et al., 2012).

4.4.2.5 Pecan Street Project: AMI (MICRO-WATER GRID)

Pecan Street in Texas is the site of a project for implementing a demonstration complex for smart electricity grid and SWG for 4,900 households over 2.8 km^2 in area, and applying AMI, sewage recycling technology, and smart irrigation for gardening (McCracken et. al., 2010).

4.4.2.6 SEQ Water Grid (MACRO-WATERGRID)

This SWG project in Australia has been implemented in South East Queensland (SEQ). The state was affected by serious drought between 2004 and 2007, which led to strong demand to restructure its water resource management system. As a result, the SEQ Water Grid project for long-term securement of water resources started in 2008. The key goal of the project is implementation of a pipeline network (535 km) to transfer water to areas with water shortage from water-rich regions with a budget of about AU$9 billion (about KRW10 trillion). Water processing plants and a large-capacity transfer network have been implemented in sources of water supplies, and organizations such as Seqwater, WaterSecure, LinkWater, and SEQ Water Grid Manager are sharing roles. SEQ Water Grid operates the project for resolving water imbalance and stable water supply in the territory at minimum cost. In case of growing water scarcity in a specific region, SEQ will increase water supply from sewage treatment plants or seawater desalination and move water to the region needing it. In addition to SEQ, Queensland has classified regions by characteristics to agriculture, mining, and tourism regions to apply a phased strategy of water supply based on each region's attributes (Figure 4.12).

4.4.3 Challenges and Solutions

Most important in the application of SWG is political feasibility. Several government organizations and private or semi-private companies are involved in the process from water intake to production and supply, and many other organizations perform information sharing and communication as well. An urgent requirement is to establish related regulations and policies for integrated SWG management before application of technologies. The political atmosphere for water management might be different in each country and conflict could arise between grids. Therefore, clearly identifying the issues of each country and conducting advanced research in considering future forecasts are crucial.

The next step is to work out the standardization issue for management, and sharing information and materials produced by participating organizations. Each organization or company that provides data creates and manages information in favour of their needs, and duplicated investment and different decision-making often result

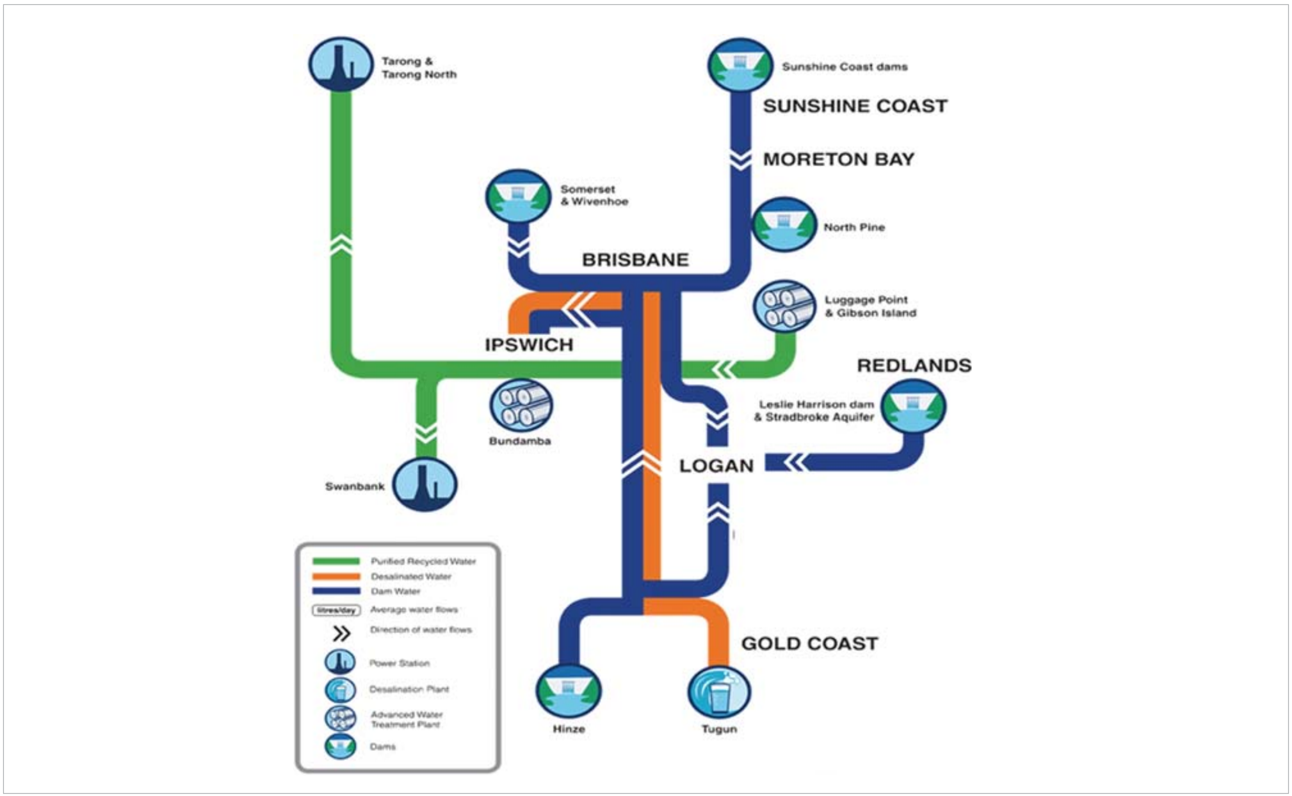


Figure 4.12 Conceptual diagram for SEQ Australia

in problems that could hinder the application of SWG technology.

To remove this hindrance and standardize SWG, the International Telecommunication Union (ITU), a leading international standardization institute, identified the standardization needs of SWM and started research from 2012. The Union went on to form a SWM group (ITU-T SG 5) and made three working groups. The scope of the working group research is given in Table 4.9.

Table 4.9 ITU-T FG-SWM working group task scope (Kim, 2012)

WG	Task scope
WG1	• Identify main national or industrial agents in the introduction of the SWM system • Build industrial eco-system in the SWM system
WG2	• Discover international standardization trends and additional items in the SWM system • Analyse KPIs for the SWM system
WG3	• Identify and build partnerships with organizations involved in the SWM system • Perform activities for introducing and promoting the SWM system

Furthermore, in considering the standardization of component SWG technologies, a plan is needed for measurment and data integration for water sources, households, water production, communications, and networks related to ICT, interfaced for sharing interactive user information and sensors related to AMI.

A sound understanding and participation of end users in SWG technology are other important factors in implementing technology for SWG decision-making via interactive information sharing. Data collection and control using smart water metering based on AMI, and efficient operation of information sharing system via apps or the Internet, enable users to save water and control demand themselves.

4.4.4 Applications

SWG can be classified by source and condition of location as described in Table 4.10. The most commonly considered areas are urban and non-urban regions that are located inland or in coastal areas. Such regions have their own surface or underground water and can utilize rain and recycled water at the same time. In coastal areas, additional water resources like seawater or brackish water can be used, but supply or sewage pipelines in the area might be inadequate for SWG implementation, necessitating a retrofit plan to implement an efficient pipeline network. Additionally, a real-time smart management system is worth considering in accordance with selected intake, optimum distance, and supply and demand for efficient and cost-effective use of existing and alternative resources. From a long-term perspective, a system for water shortage risk assessment and forecasting is suggested to implement assessment systems for regional water shortage risk and forecasting to ensure water supply in an emergency situation as well as systems that can evaluate the influence of climate change on water resources.

Table 4.10 Classification of SWG type

Type	Condition	Usable water resources
Inland	Existing urban or non-urban inland areas separated from sea	Surface and underground water, rain, recycled water
Coastal	Existing urban or non-urban coastal areas	Surface and underground water, rain, recycled water, seawater or brackish water
Island	Island needing to autonomously secure entire or part of necessary water resources	Surface and underground water, rain, heavy and recycled water, seawater or brackish water
New town	Newly constructed urban areas	Surface and underground water, rain, recycled water

In certain cases, island areas can obtain all necessary water resources themselves from surface or underground water but, if not, desalination of seawater or brackish water must be considered. As desalination requires more cost and energy and different maintenance than other sources of water, a plan is needed to resolve the issues. SWG technology based on real-time management of water and energy consumption is proposed as a promising solution to secure and supply such diverse water resources. It can provide not only a desalination facility but also a solution for integrated water resource security by accurately identifying available water resources in island areas and balancing supply and demand. Because leakage in the existing pipeline causes resource loss in island areas, a solution can be found through the implementation of a smart pipeline, smart water metering, and AMI.

Taking a long-term prospective, SWG technology should be included as routine in the design and implementation of new city water management systems. If such an approach is considered from the initiation of the project, and if real-time water management and an AMI system are implemented in connection with ICT infrastructure, the SWG system can be efficiently implemented without increasing the cost to build the water infrastructure. In addition, safe systems can be utilized that minimize water shortage and water supply failure caused by natural or accidental incidents by incorporating systems to improve customer self-reliance and emergency readiness.

SWG is a distributed system technology applicable on a small scale as well as medium to large scales. For instance, for a small scale of SWG, the Smart Water Micro Grid can be applied to regions with restricted water supply or facilities in need of highly stable water supply. The grid is a microcosm of a medium- and large-scale SWG and aims to minimize water resource dependency by maximum utilization of regional resources and recycling water within the region. Therefore, it is possible to apply a package containing a system to select and combine types of water resources and supply them in accordance with demand, demand-sensitive supply management technology, real-time water information collection, and an analysis and decision support system based on the analysis. If such technologies are applied to an industrial complex, for example, in which failure of water supply can cause critical damage, the results and effects will be maximized.

At the larger scale, it is recommended that, when implementing such facilities, a system with a hierarchical structure linked to such smaller-scale SWG facilities is applied. Building with water self-reliance or small- (micro-grid) or medium-scale system (macro-grid) by district or region and large-scale system (mega-grid) by basin or country should be connected seamlessly to maximize efficiency. The important thing here is data and information integration between different SWG systems and implementation of an integrated decision support system based on the integration. Such integration of information facilitates smart system operation that maximizes the cost effectiveness of an SWG system.

SWG and smart power grids are interrelated and not independent of each other. This is because water production requires energy, and energy production needs water as well. Thus, when implementing SWG, the implementation plan must be reviewed with consideration of the connection to the smart power grid. A precedent exists in the utilization of technology for power management optimization for water supply and sewage facility using electricity demand control technology from a smart power grid (Poulsen, 2010). The smart system linked to water resources and energy can be a solution that resolves problems caused by the water–energy nexus as well as an excellent opportunity for extensive SWG application.

SWG technology is also a possible alternative for developing countries with water supply problems due to poor and deteriorated water resource infrastructure. A system can identify and secure available water resources and process and supply them in a cost-effective way by combining component technologies of SWG. Moreover, a locally developed smart integrated management system can not only help resolves difficulties of domestic operation and management, but can also be seen as an export business opportunity.

4.5 WATER MANAGEMENT AND BIG DATA

4.5.1 Using Big Data to Create New Value

4.5.1.1 Emerging Big Data Technologies

The London Summer Olympic Games, which was the first held since the sweeping popularity of smartphones, was called the first Big Data Olympics, where a huge amount of data was generated from social media (e.g., Twitter, Facebook). NetApp, an American computer storage maker, made a perfect prediction on the result of the US presidential election by producing its infographic, "The Big Data and 2012 U.S. Presidential Election", which was made of the data collected from emails, Twitter, video, and mobile devices. As the amount of digital data has increased overwhelmingly over the past 10 years, large-scale data have emerged as an important issue, and big data are now being recognized, across the world, as a core resource that can generate a significant amount of new value. It is anticipated that big data will have considerable impacts not just for the survival of businesses but also for their future competitiveness. It is also predicted that the efficient use of newly produced data will hold sway over the competitive edge of firms and nations.

In particular, companies such as IBM, EMC, and HP have realized the importance of big data management since 2009, and embarked on the acquisition of high-performance data warehouse businesses to secure competitiveness in analysing the data. Currently, they are focusing on strengthening their capability for big data analysis. As interests have increased dramatically since 2012 and they are utilized in various fields, big data are rapidly emerging as a methodology for solving social issues and moving ahead towards a new society

A promising emerging approach related to the big data agenda is that of the Internet of Things (IoT). The IoT refers to the intelligent interconnection of embedded sensors or computing devices across the existing internet. Sensors can be embedded in virtually any device, allowing a degree of automaric control or data collection (Figure 4.14).

Sensors used in the IoT encompass not only those conventional ones to detect temperature, humidity, gas, heat, and illuminance, but also a variety of new ones which function to detect remote things, position, motion, and videos. Recently, multi-functional high-precision sensing technologies have been developed, including smart sensors in which standard

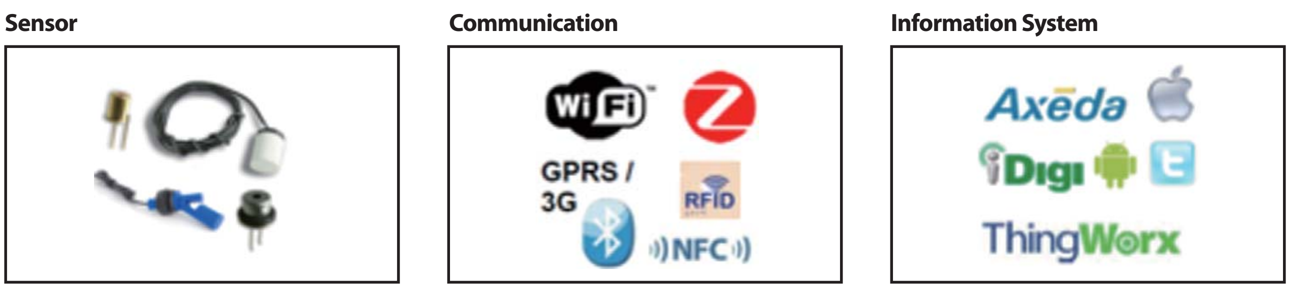


Figure 4.14 Components of Internet of Things (IoT)

interfaces and communications technologies have been embedded. Standardization of vendor equipment is a key issue to overcome in promoting the widespread application of the IoT in the water sector (Robles, 2014). Typical emerging applications include smart water metering and leakage detection (Vieira et al. 2014; Loureiro et al. 2014).

4.5.1.2 What is "Big Data"?

Big data exist in various forms (e.g., corporate information, Webs, images, videos, storage network solutions , and sensor streams). Thus, the term "Big Data" refers to a large amount of digital data whose forms are so various and whose velocity is so rapid that they are difficult to store, manage, and analyse just with a traditional database. The key benefit is the ability to be able to search and analyse the raw data to abstract of required trends and patterns. Key big data properties can be summarized by the six Vs: volume, velocity, variety, veracity, visualization, and value (Figure 4.15). Ultimately, the core properties of the big data can be described as data that can produce valuable information by efficiently analysing and processing data in areas where a huge amount of unprocessed data are produced and consumed rapidly and in various forms (KCA, 2013):

4.5.1.3 Prospects for Big Data

From an economic and industrial perspective, the size of the global market for big data is forecast to reach US$53.4 billion in 2017 (KISTI, 2013). Furthermore, big data in the public sector are closely related to the improvement of the national

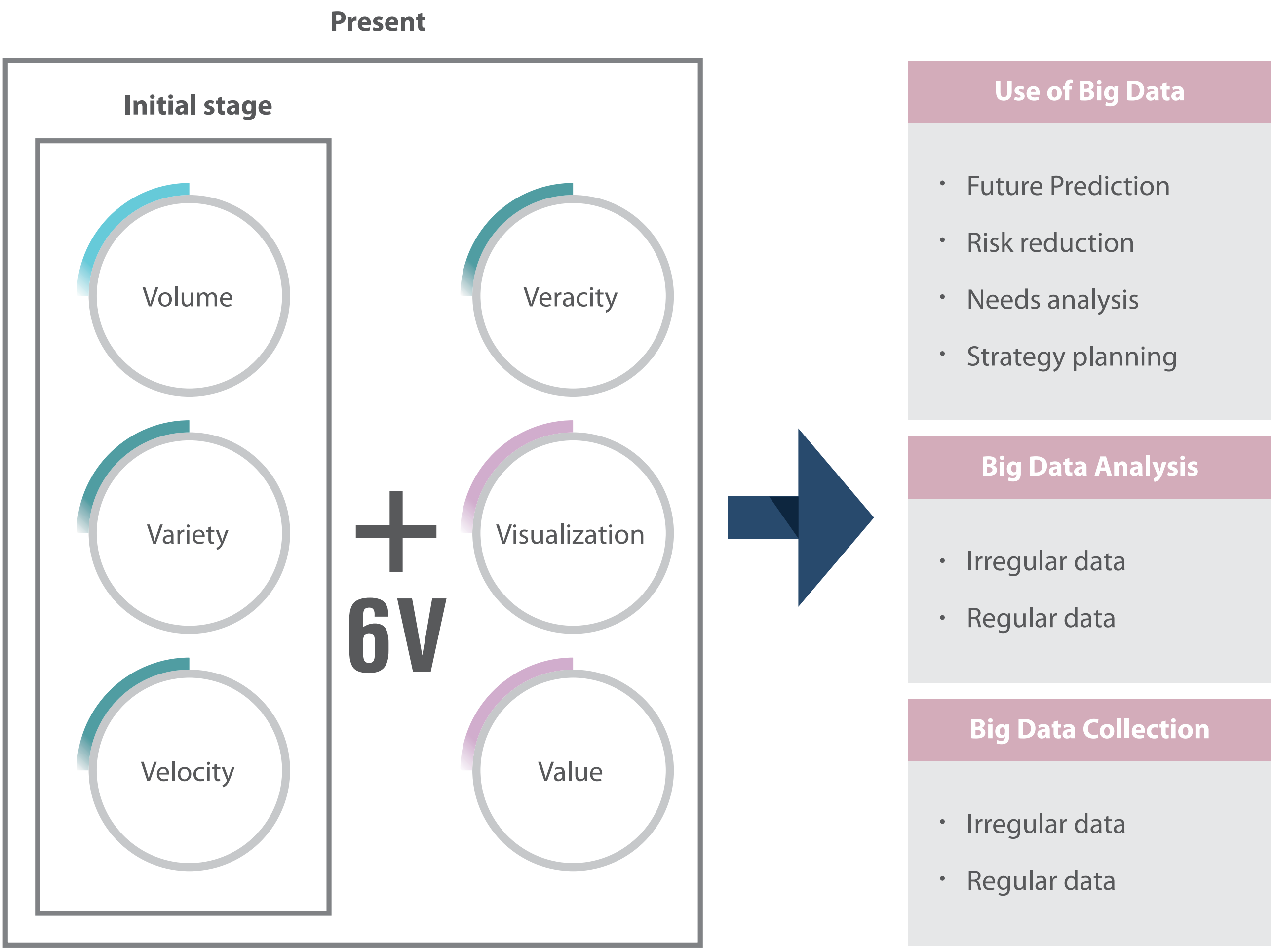


Figure 4.15 The six Vs composing the big data technologies

competitiveness, because it has been shown that they can be used to increase the work efficiency of the private sector, unearth new industries, and achieve the optimization of decision-making. Hence, the use of big data in the public sector has constituted worldwide trends, along with the so-called "open data" in the socio-cultural sector. The European Union and the USA have already realized the value and importance of information from the public sector and, to enable the common sharing and use of information, they are implementing policies based on such data platforms as CKAN and Socrata.

In the USA, if big data are utilized in such sectors as the medical industry, public administration, retail, manufacturing, and personal information, it is possible to add 1% to productivity, and each sector can see economic benefits varying from US$100 billion to US$700 billion. In particular, it is anticipated that the economic benefits of the medical industry will amount to US$330 billion dollars, and the retail industry is expected to enjoy a 60% increase in its profits (McKinsey Global Institute, 2011). In the case of the UK, it is reported that the introduction of big data would bring some GBP216 billion of economic benefits across the whole economy by 2017 (Center for Economics and Business Research, 2012), and they would also help the public sector save cost of GBP16 billion to GBP33 billion (NIA, 2012).

4.5.2 Big-Data-Based Water Management Practices

Compared with other industries, the use of big data in the water management sector shows relatively slow progress. However, there are some case study examples to consider.
IBM's SWM

IBM has developed a water management system built for the efficient supply and monitoring of water in metropolitan areas run by the Bangalore Water Supply and Sewerage Board based on the exploitation of big data sets. This system provides not only the functions of GIS-based real-time monitoring based on information (collected with flow meters), but also key performance indices, including recent flow, total mean flow for the past 7 days, total flow, geographical location, time, etc. It is composed of solutions based on IBM's Intelligent Operations Centers (IOC), and it enables users to evaluate the current state of water supply in the city, predict the amount of future water supply, and control it on a real-time basis.

It also helps minimize unaccounted-for water loss. The IOC monitors water flow by connecting 284 flow meters (out of 784 large-scale flow meters) within the metropolitan area. It also provides a monolithic view on flow indicated in each of the individual flow meters, flow supplied from each distribution system, and water level in tanks at each water supply station. Data provided by each flow meter is reported on a single executive dashboard. Users can operate control valves remotely and obtain real-time feedback on variations in a previously set amount of water supply. The IOC ultimately enables its users to ensure the efficient control of water supply, and obtain relevant information timely through a real-time alarm system and take necessary measures when pre-set target water supply has not been met.

Water Supply Management of the HydroPoint Data System

The HydroPoint Data System (HDS), a water management system developed by the California-based HydroPoint, provides its users with an automated system that functions to prevent and monitor water waste and damage caused by leaks or run-off. To this end, it uses real-time two-way wireless communication technologies based on the AT&T's M2M (Machine-to-Machine) network, and big data and cloud technologies. The HydroPoint platform connects its integrated management framework with data from various sources including onsite water systems, spring coolers, master valves, flow sensors, historical water tariff, water supply plans, and location-specific meteorological data. It helped its 25,000-strong customers cut US$137 million in expenses by saving 20 billion US gallons of water and 7,700 kilowatt-hours of electrical energy in 2013 alone (HydroPoint Data System Inc., 2015).

K-water's Data Management for Water Resource Management

Korea's K-water has created and managed a large amount of data with its own database system, including measured and observed hydrological data and other data about the operation of relevant structures and facilities. In the field of water resources, various data have been produced and managed to ensure IWRM, and various decision support systems based on those data have been developed and operated. Accumulated data are stored in the RHDAPS

(Real time Hydrological Data Acquisition and Processing System) database first, and then used for various IWRM practices, including real-time water management analyses. Furthermore, the RHDAPS database is used for managing various facilities through its nationwide network with 887 gauging stations, flood and disaster monitoring systems, dam integration, and earthquake monitoring systems.

K-water also operates its own flood decision support system. It is an integrated system which uses data, as mentioned above, along with data about meteorological conditions, water supply, flood control, and water quality. The system provides support for decision-making by clients and operators as well as information sharing services. The flood decision support system consists of three modules dealing with meteorological conditions, water supply, flood control, and water quality. Its services are provided through the integrated database and a server dedicated to numerical analyses.

SURIAN (SUpercom based RIver Analysis Network), an integrated water quality prediction system, functions to collect data from independently operating models for such factors as meteorological conditions, drainage basins, rivers and reservoirs, conduct an integrated simulation on each drainage basin, and provide applicable operators with data to support their decision-making. In the system, databases are constructed with data covering hourly meteorological parameters (e.g., rainfall, temperature, solar radiation), flow and water quality (in each sub-basin), point and non-point pollution sources, real-time flow and water quality (of each river system), topographical parameters (corresponding to each of target dams and river systems), etc. All of these are used for various analyses, including water quality analysis, two-dimensional cover flow analysis, and three-dimensional animation analysis, and the values of forecasts on each of target dams and river systems are paired with each corresponding river basin. In the case of the water utility sector, the nation is divided into seven regions, with an integrated operation centre set up in each region. The operation centres are responsible for carrying out the remote monitoring and control of 40 water treatment plants, 24 intake stations, and 82 pump stations. Measured data are sent to database servers in the seven regional headquarters. They are processed and sent through the Real-time Water Information System (RWIS) to 18 systems in and out of K-water.

4.5.3 Challenges and Solutions

In this sub-section, hurdles and problems in introducing big-data-based water managment systems will be addressed with suggested solutions. A plan to introduce the system will also be described by showing some relevant examples.

4.5.3.1 Hurdles

Unification of Diversified Water Information Management Systems

This hurdle or challenge is similar to the one already identified earlier. Water management systems produce a vast amount of data about meteorological conditions, water quality, water availability, and so on, but they not currently integrated systematically. Most water-related data are individually created and managed by independent agencies with their own different goals. Furthermore, relevant data also exist in different formats such as databases, Web pages, or documents, and the cycle of data acquisition varies, ranging from minutes and hours to months or years.

Accordingly, data sharing and cooperation among information management organizations is essential for the efficient integration and management of water-related data, which are sporadically and interruptedly created by different, independent agencies . To this end, it is necessary to establish a data hub or a control tower for their integrated management.

Improvement of Data Reliability

Most data related to water management, which is created on a real-time basis through such automatic measurement tools as sensors, are used as they are or go through further processing. However, the creation of data with 100% reliability is not possible because of numerous mis-measurements, which, in turn, are attributable to the malfunctions of sensors, operators' negligence, and flaws in communication systems. Accordingly, a solution for improving data reliability should be found.

To this end, it is necessary to build a redundant communications network, and thereby ensure the stable transmission of relevant data. A real-time monitoring system is also needed for the management of data quality. In some cases, the construction of an automated platform should be considered if necessary.

Improving data protection and security

As with other cyber environments, the dysfunction of big data lies in the fact that they are highly likely to infringe on personal information and privacy. Accordingly, measures to tighten cyber security should be arranged before introducing big data technologies. Damages and losses are irrevocable if information is destroyed or spilled out due to lax management or cyber-attacks. Although no cyber fields are free from security problems, cyber security measures in the area of big data technologies are all the more important because their use has been increasing dramatically.

The most important security challenge faced by the big data technologies is about how to protect personal information. It is likely that some information related to water supply contains confidential information. Accordingly, so-called privacy-preserving data processing technologies (e.g., data encryption) are necessary to protect information in the big data system. According to the Korea Internet and Security Agency, the following technologies are required to improve big data security: technology for obtaining a consent at a phase of data acquisition, technology for denying data collection, technology for encrypting data at a phase of data storage, technology for controlling access to data, technology for data anonymity at a phase of data processing, and technology for data deletion. Still, care should be taken to address all of these technologies which are inevitably required in terms of data security.

When deciding what data should be shared, a priority should be placed on their industrial importance (in terms of their usefulness and commercial values) and ease of use (in terms of accuracy and openness). Data to be shared are selected by adding up all points of each evaluation item with different weights. Then data sharing should proceed on a step-by-step basis and according to the given priority.

4.5.3.2 Plan

K-water's road map for introducing a Big-Data-based IWRM system

K-water is working on the development of a management system that secures the systematic flow of data in and out of the organization, a data quality management system to improve data reliability, and a standardized platform enabling the integrated analysis and operation of the big data. For efficient sharing of water data, the method, frequency, and measuring unit of data acquisition are coordinated depending on specific needs. K-water has a plan to conclude a memorandum of understanding with relevant organizations to facilitate data sharing with them. In addition, it is also planning to facilitate data distribution through disclosing (i.e., sharing) the water data, and building a cooperation system with other relevant organizations by asking them to create necessary but unavailable data.

A single data hub is built in which not only existing data collected as described above but also new data acquired through a status analysis are all managed together, and a quality management system is developed to ensure the efficient management of data quality and reliability by adopting tools based on statistical methods. Also, a tool for analysing standardized and non-standardized big data is developed so that their systematic, integrated analysis may lead to the meaningful creation of valuable outputs, and thereby support decision-making.

The integrated water information platform based on the big data consists of a data platform, analysis platform, and service platform. The data platform functions to sort out standardized data collected in and out of K-water and non-standardized data collected from the private sector, and manage their quality. The analysis platform analyses the big data on an on-site, real-time basis. The service platform ensures the sharing of customized information. That is to say, the big data collected at the data platform proceed to the analysis platform where they are stored and analysed. Then, they are finally expressed at the smart water board or smart water portal of the service platform.

The analysis platform supports decision-making by acquiring meaningful outputs from methodologically analysing standardized and non-standardized big data in an integrated way. Tools continuously developed to analyse the big data and support decision-making within the analysis platform create a new growth engine. The service platform is built for the standardization of data shared in and out of the integrated database.

4.5.4 Recommendations

Under the IoT-based water management system, data are collected through sensors and networks. The sensors should have such features as low price, low electricity, high precision, diversity, and reliability, while the networks should have redundancy. The associated data management platform should meet such requirements as two-way data sharing, and standardization and unification of overlapping systems. The big data should include status of facilities, operational information, space information, risk information, and information about water tariff, civil complaints, and so on.

In addition to hardware needs, a model for maximizing the efficiency and reliability of water resource management is required. From the aspect of water managment in river basins, multiple implementation among meteorological forecasts, basin-wide runoff, reservoir operation, and river management is to be realized.

Further, the successful construction of the system requires real-time monitoring of information on water cycles in river basins; the building of information-sharing governance by national water management agencies; the collection of information on water cycles and its provision to the public, where relevant; and the upgrading of water management technologies through ensuring timely, precise predictions. The following prerequisites are needed to achieve this: analyse convergence data for making policies on water supply; construct a one-stop analysis system by converging data about meteorological conditions, water quantity, quality, etc.; cope with disasters through ensuring the proactive associated operation of dams and weirs; and introduce a decision support system for water sectors based on the big data collected through IoT.

4.6 CONCLUSIONS

We have seen in this paper the significant potential for smart water technologies and smart water management (SWM). Not until recently has it been possible to exploit the opportunities derived from being able to interconnect water users, water objects or things, sensors, and systems together with intelligent data analysis in a myriad of applications. Benefits include cost savings and operational efficiencies, improved performance, additional flexibility and the possibility to "sweat" existing assets. Despite a late start in the water sector, the pace of change is rapid and is set to increase with interest and involvement of large multinational companies.
However, use of smart technology and SWM is not an automatic "fix" and will need to be considered in conjunction with other strategies such as building increased capacity or greater use of blue-green infrastructure. There is no "one size fits all" solution, and available options in each case must be reviewed to identify the best for each situation.

There are still barriers to overcome before SWM can be used more widely, including a lack of reliable data about existing water system infrastructure and its upgradability, the need for standardization of protocols and equipment, long-term operational experience, and updating of the regulatory system. Generation of data and reliance on it can also cause potential issues which still need to be addressed, including the need for cyber security. It also has to be realized that data cannot be generated with complete reliability: sensors will fail, inaccurate measurements may be made, and communication flaws will occur. It is important, therefore, that redundancy is provided and that data quality management is properly addressed.

It is no exaggeration to say that SWM will have a major role to play in addressing the global challenges of climate change, population growth and rapid urbanization, natural disasters, and environmental degradation. As a result, we can see major shifts taking place in the structure of the water industry, with a need for new ways of working, new skills, and new water management policies. All this points towards a bright future for the smart water sector and the ushering in of a new water paradigm, with applications and potential throughout the urban water cycle.

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Ecosystem Services

Main Focus 5

Understanding and Managing Ecosystem Services for Water

It is time to fully realize that our societies and economies are integral parts of the biosphere, and to start accounting for and governing natural capital. Poverty alleviation and future human development cannot take place without such a wider recognition of nature's contribution to human livelihoods, health, security and culture.

Understanding and Managing Ecosystem Services for Water

5.1 INTRODUCTION

Ecosystem services are defined as various benefits that ecosystems provide for humans. Lately, deterioration of water quality and quantity has caused significant damage to freshwater ecosystems, resulting negative impacts in the provision of ecosystem services. This study examines three aspects of managing freshwater ecosystem services: (a) the conceptual linkage between economic valuation and ecosystem services, (b) technology of low-impact development (LID) and green infrastructure (GI), and (c) the resilience of ecosystem services.

For the conservation and sustainable use of biodiversity/ ecosystem services in the policy arena, the measurement of biodiversity/ecosystem services, in monetary terms in particular, is crucial for policy implementation and assessment. In this paper, starting with introducing the concept and classification of freshwater ecosystems , the linkages between classification of ecosystem services, total economic value (TEV), which is a well-recognized typology of economic valuation exercises, and relevant economic valuation methods are examined to assist communication among various stakeholders.

Urbanization distorts natural water circulation systems by causing changes of land use in watersheds, and affects water quality and aquatic ecosystems by discharging various pollutants. Therefore, it is necessary to reduce the hydrological and environmental impacts of urbanization to secure healthy water resources and aquatic ecosystems. The proposed alternative is to apply low impact development (LID) and green infrastructure (GI). LID/GI is a method of analysing environmental impacts that may occur from the planning to the operation stages, and minimizing those impacts. It refers to establishing a land use plan wherein it secures green spaces that could imitate the natural water circulation, reducing impervious surface, preserving low lands with water as much as possible, and maintaining natural water circulation functions. GI may establish natural water circulation systems, prevent floods, provide biological habitats, purify pollutants included in stormwater runoff, and may preserve and recover vegetation such as trees.

The resilience and transformation to cope with the challenge of balancing water for humans and for nature are important. Resilience includes delivery of ecosystem services in the face of climate change and urbanization, and contributions of ecosystem services to sustainability for humans and nature. Water management cannot be based on scientists' knowledge and understanding alone: the social, economic and managerial dimensions have to be understood and accounted for. To strengthen the water resilience of intertwined human and ecological systems, humans and ecosystems must share the same water without partially

5.2 FRESHWATER ECOSYSTEM SERVICES AND ECONOMIC VALUATION : CONCEPTUAL LINKAGES

5.2.1 Background

The Millennium Ecosystem Assessment (MA, 2005) and The Economics of Ecosystem and Biodiversity (TEEB, 2010) have significantly contributed to the recent rise of studies on the benefits that ecosystems provide to human beings (i.e., ecosystem services). The primary purpose of the MA (2005) and the TEEB (2010) was to provide scientific evidence to support decision-making processes based on the relationship between ecosystems and human well-being. However, the important contribution of the MA (2005) was, in a way, to shift the focus of discussion from ecosystem functions to services in policy areas by acknowledging that the issues of interest are the benefits ecosystems provide to human beings in decision-making processes.

This section has two purposes. One is to introduce the concept of ecosystem services from anthropocentric perspectives and to suggest a classification of freshwater ecosystem services. The other is to present how the values of ecosystem services are interpreted and measured in the economic valuation framework by linking the classification of ecosystem services, types of TEV, and valuation methods. Note that this section is designed to illustrate the conceptual linkages between ecosystem services and economic valuation to enhance communications among various stakeholders, rather than providing case studies on how to utilize the concept of ecosystem services in practice.

5.2.2 Concept and Classification of Ecosystem Services

The concept of ecosystem services was introduced by Westman (1977) using the term "nature's service" and further developed by Daily (1997) and Costanza et al. (1997) (Table 5.1). Although these early developments share common characteristics, the definitions of ecosystem services can be differentiated according to their emphases. Daily (1997) concerns the conditions and processes of ecosystems that support human life, while Costanza et al. (1997) focuses on the benefits derived from ecosystems and consumed by humans. The concept of ecosystem services was further elaborated by de Groot et al. (2002), the MA (2005), and the TEEB (2010). Currently the definitions by the MA (2005) and the TEEB (2010) are commonly used in the literature.

Table 5.1 Definitions of ecosystem services

Definitions	Ecosystem services vs. benefits[1]
"…the conditions and process through which natural ecosystems, and the species that make them up, sustain and fulfil human life" (Daily, 1997)	Ecosystem Services » Benefits
"…the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al., 1997)	Ecosystem Services = Benefits
"…the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirect." (de Groot et al., 2002)	Ecosystem Services » Benefits
"…the benefits people obtain from ecosystem" (MA ,2005)	Ecosystem Services = Benefits
"…direct and indirect contributions of ecosystems to human well-being" (TEEB, 2010)	Ecosystem Services » Benefits

1 The arrow indicates that benefits are derived from ecosystem services; equals signs indicate that ecosystem services and benefits are used interchangeably in the corresponding study.

Note that the definitions of ecosystem services introduced in Table 5.1 are human-centred because the services are recognized only when they provide something useful to humans or society, which leads to anthropocentric instrumental values in value typology. Another feature is that the terms "services" and "benefits" are often used without distinction. For instance, Daily (1997), de Groot et al. (2002), and the TEEB (2010) distinguish ecosystem services and benefits where the benefits are derived from the services. In contrast, Costanza et al. (2002) and the MA (2005) use both terms interchangeably.

Rather unclear and confusing definitions of terminologies in the literature have caused significant difficulties in communication among stakeholders. The TEEB (2010) proposed a pathway from biodiversity/ecosystems to social-economic systems, which shows clear linkages between biophysical structure/process, functions, services, benefits, and values. It also includes feedback from institutional and human domains (Figure 5.1). A clear delineation between ecological functions, their direct and indirect contribution to human welfare (i.e., ecosystem services), and the welfare gains they generate (i.e., benefits) is useful in avoiding double counting that might arise because supporting and regulating services are often inputs for the production of other services (TEEB, 2010).

Costanza et al. (1997) suggested a classification of ecosystem services with 17 sub-items based on the idea that ecosystem services are closely related with ecosystem functions. Therefore, early studies on classification of ecosystem services tend to use "functions" rather than "ecosystem services". For example, de Groot et al. (2002) classified ecosystem functions into production, regulation, habitat, and information functions with 23 sub-items.

The MA (2005) replaced "functions" with "ecosystem services" and categorized them into provisioning, regulating, cultural, and supporting services with 25 sub-items. The provisioning services are the products people obtain from

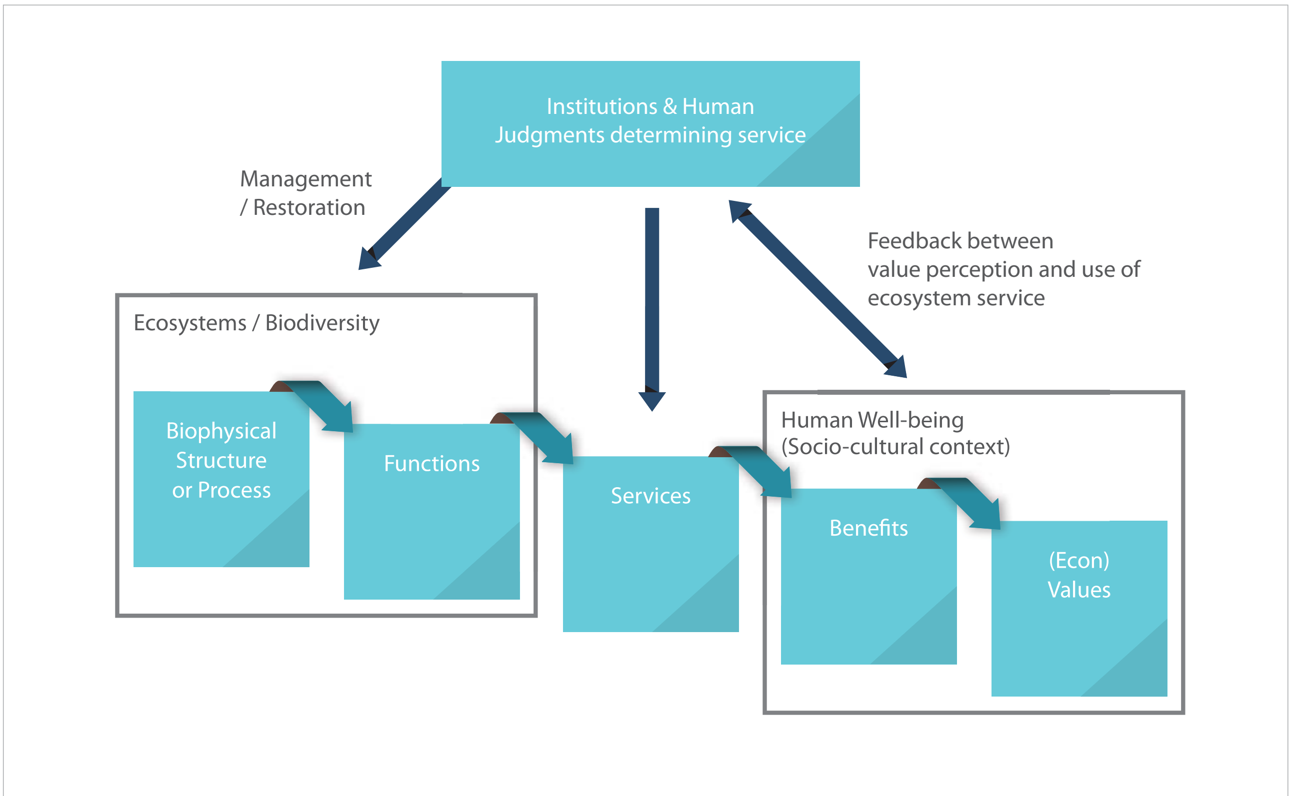


Figure 5.1 Pathway from ecosystem structure to human well-being. Source: modified from TEEB (2010)

ecosystems such as food and fibre. Most of these products are traded in markets. The regulating services are the benefits obtained from the regulation of ecosystem processes that indirectly support social and economic activities. Air quality maintenance, climate regulation, erosion control, regulation of human diseases, and water purification are included in this category. The supporting services refer to those necessary for the production of all other ecosystem services. In other words, the supporting services are indispensable in generating the provisioning, regulating, and cultural services, and they correspond to the concept of ecosystem integrity. For this reason, the supporting services are presented as the bedrock in Figure 5.2.

Building on the MA (2005), the TEEB (2010) established a classification of ecosystem services (see second column of Table 5.2). The main difference between the classifications by the MA (2005) and the TEEB (2010) lies in supporting services and habitat services. The habitat services in the TEEB (2010) roughly correspond to the supporting services in the MA (2005). However, the habitat services are confined to the maintenance of life cycles of migratory species and maintenance of genetic diversity. Here “genetic diversity” is different from “genetic resources” in the provisioning services where the potential commercialization is implied. In addition, some of the supporting services in the MA (2005), such as soil formation and primary production, are re-classified as the regulating services in the TEEB (2010), indicating that there is no clear distinction between the regulating and the supporting services. The MA (2005) and the TEEB (2010) are the most commonly used classifications of the ecosystem services.

Based on MA (2005) and TEEB (2010), there have been efforts to develop the classifications of ecosystem services further. One line of work is to classify ecosystem services in relation to analysis purposes. Wallace (2007) for natural resource management, Fisher and Turner (2008) for economic valuation, and Haines-Young and Potschin (2013) for environmental accounting are such examples. Another line

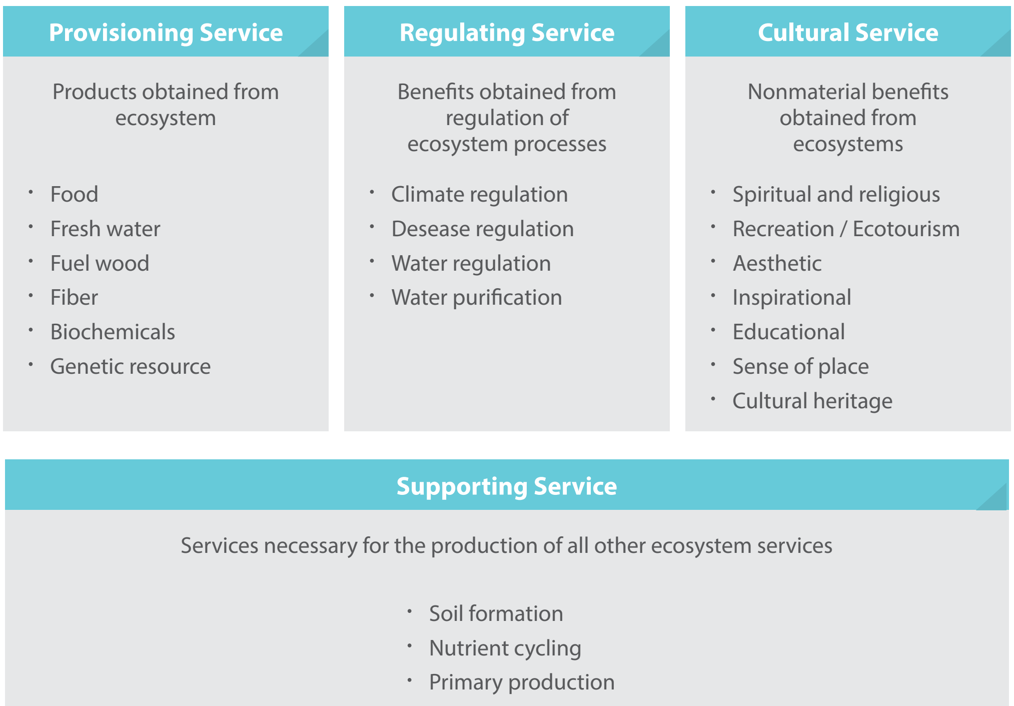


Figure 5.2 Classification of ecosystem services by the MA (2005)

of work is to develop classifications of ecosystem services for regional/national assessment. They try to differentiate the classifications according to important ecosystems in regions, such as forest, wetland, freshwater, etc. This line of study includes the UK National Ecosystem Assessment (NEA 2011) and the RUBICODE (Rationalizing Biodiversity Conservation in Dynamic Ecosystems, 2008).

For freshwater ecosystems, refer to the third column of Table 5.2. Examples of classification include the NEA (2011) for UK, Harrison et al. (2010) for Europe, Gutierrez et al. (2013) for Spain, and Ahn et al. (2014) for Korea. Note that the priorities and importance of sub-items within a service category can vary according to regional and national circumstances. For instance, food and raw material provisions could be regarded as important items in a region where the local economy depends on these products from the rivers, while renewable energy production could be regarded as more important in other regions where hydro-power generation is active.

5.2.3 Ecosystem Services, Total Economic Values, andValuation Methods

5.2.3.1 Ecosystem Services and Total Economic Values

The economic concept of values has its foundation in neo-classical welfare economics. The basic premises of welfare economics are that the purpose of economic activity is to increase the well-being of the individuals (Freeman III, 2003). The welfare of individuals depends not only on the consumption of private goods but also the ecosystem services which are not traded in the markets and, therefore, the objective measurement of values (i.e., prices) cannot be observed. In these cases, the value-measures can be expressed in terms of people's willingness to pay or

Table 5.2 Definitions of ecosystem services

	Items[1]	Definitions relevant for freshwater ecosystem[2]
Provisioning services	1.food	Fish and shellfish products including freshwater aquaculture; other edible/dietary animals, plants and fibre
	2. Water	Freshwater consumption by irrigation, drinking and industrial use
	3. Raw materials	Fibre, wood, etc.
	4. Genetic resources	Materials that are potentially useful or can be commercialized
	5. Medical resources	Material that can be commercialized as medical sources
	6. Ornamental resources	
Regulating services	7. Air quality regulation	
	8. Climate regulation	Local climate regulation through evapotranspiration
	9. Moderation of extreme events	Floods, droughts, fires prevention and mitigation
	10. Regulation of water flows	Water cycle/flow regulation
	11. Waste treatment	Biotic water self-purification
	12. Erosion prevention	
	13. Maintenance of soil fertility (including soil formation) and nutrient cycling	
	14. Pollination	
	15. Biological control	Breeding of flora and fauna, non-native species control
Habitat services	16. Maintenance of life cycles of migratory species	
	17. Maintenance of genetic diversity	Biological diversity within and between species; habitat, habitat continuity and connectivity
Cultural services	18. Aesthetic information	Aesthetic value of scenic river or lake
	19. Opportunities for recreation and tourism	Recreational activities (fishing, swimming, etc.); river eco-tourism
	20. Inspiration for culture, art and design	Historical, cultural identity
	21. Spiritual experience	Religious experience and activity based on river or lake
	22. Information for cognitive development	Educational and scientific value of freshwater ecosystems

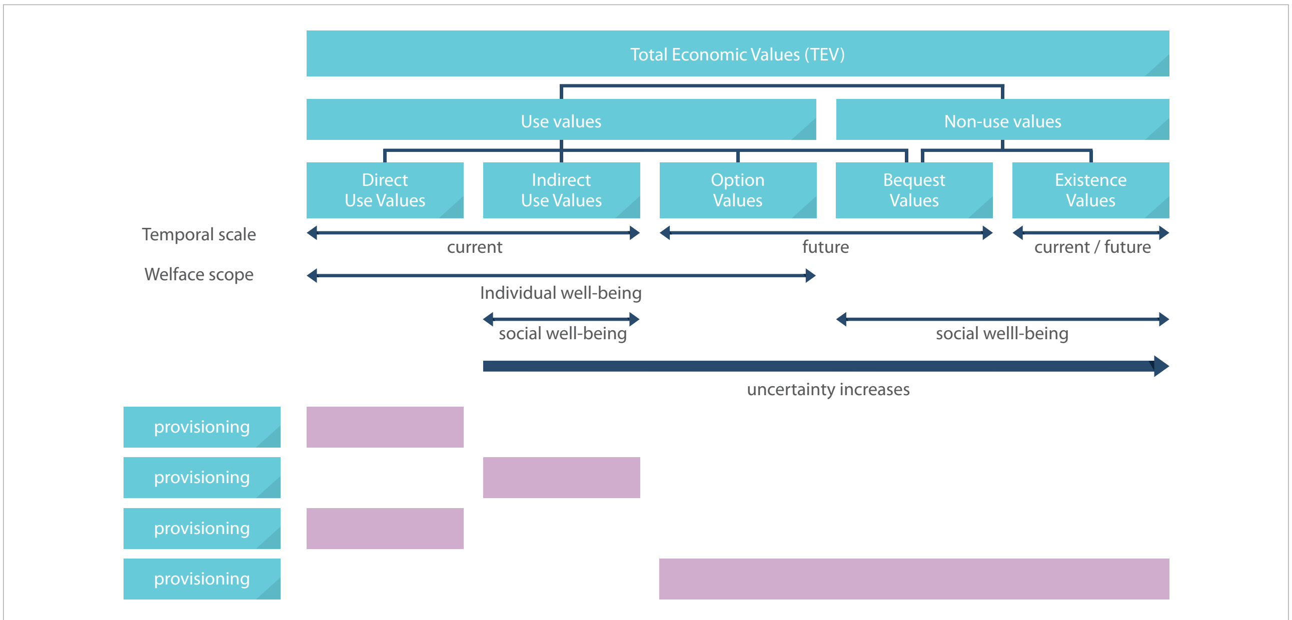
[1] Adated from TEEB (2010).
[2] Adapted and modified from UK NEA (2011), Harrison et al. (2010), Gutierrez et al. (2013), and Ahn et al. (2014).

willingness to accept compensation for the welfare changes associated with the changes in quality and quantity of the ecosystem services consumed.

Given the economic concept of values above, the typology of TEVs is a well-recognized framework for looking at the utilitarian values of ecosystems (see top panel of Figure 5.3). The TEV is disaggregated into use and non-use values. The use values comprise direct use, indirect use, and option values. The non-use values are grouped into bequest and existence values. While the direct use values are associated with the actual consumptions of the services (e.g., harvesting of food products, timber for fuel or construction, medical products, etc.), the indirect use values refer to the benefits obtained from the indirect consumption of the services where the ecosystem services are used as intermediate inputs for the production of the final goods (e.g., water, soil nutrients, and pollination, etc.). Most regulating services have indirect use values. Both direct and indirect use values involve the current consumptions of the services.

Once we expand the temporal scale, we can assign values on having options to ensure the existence of ecosystem services in the future. Similarly, the bequest values are the use and/or non-use values people place on securing future generations to have ecosystem services. Existence values refer to the values people attach to simply knowing that ecosystems exist regardless of the possibility of use in any forms. Existence values are difficult to quantify owing to their lack of instrumental elements to human benefits. In terms of sustainability, the option values concern sustainability within a generation; the bequest values concern sustainability between generations; and the existence values are likely to concern sustainability both within and between generations.

Figure 5.3 illustrates practical links between the ecosystem services and the TEV (see bottom panel of Figure 5.3). On the basis of the definitions of ecosystem services described in the previous section, it can be inferred that provisioning services are associated with direct use values, and most regulating services correspond to indirect use values. Although cultural services include non-material benefits, they are more likely to be linked to the direct use values as they are directly consumed by individuals. Conceptually, both provisioning and cultural services correspond well with direct use values; however, the value-magnitudes of cultural services cannot



Note: The links shown between the ecosystem services and the TEV types are not necessarily one-to-one relationships. For example, the regulating and cultural services can also be related to the option, bequest, and existence values. The purpose of this figure is to indicate the main conceptual links between ecosystem services and TEV types.

Figure 5.3 Ecosystem services and TEV. Source: Ahn et al. (2014)

be easily estimated owing to the lack of market. Therefore, the difference between provisioning and cultural services, in terms of measurement, comes from whether their values are observed in the market.

Supporting services are fundamental to the production of all other services and are not likely to be associated with direct and/or indirect consumption in the current period. Therefore, it is more appropriate that they are considered and interpreted in the context of sustainability as the supporting services maintain and secure sustainable flows of ecosystem services. With this context, supporting services encompass the option, bequest, and existence values.

Provisioning and cultural services are likely to be associated with the welfare of individuals, and regulating and supporting services are more likely to affect social welfare. Provisioning and cultural services are directly linked to human well-being and relatively easy to quantify and monetize. In contrast, estimating values of regulating and supporting services is inherently challenging, owing to the lack of markets and direct linkages to human well-being; accordingly, the uncertainties associated with measurement increase.

To sum up, Figure 5.4 illustrates an example of the relationships between ecosystem structure/process–functions–services–TEV for wetland ecosystems. It shows the interlinkages between the disciplines of ecology and economics.

5.2.3.2 Methods to Estimate the Values of Ecosystem Services

The valuation methods can be categorized into four groups: (a) market analysis, (b) preference-based approaches, (c) cost-based approaches, and (d) value transfer. The preference-based approaches are further divided into revealed and stated preference approaches, where both are based on the individual preferences. The revealed preference approaches elicit values from observed behaviours of

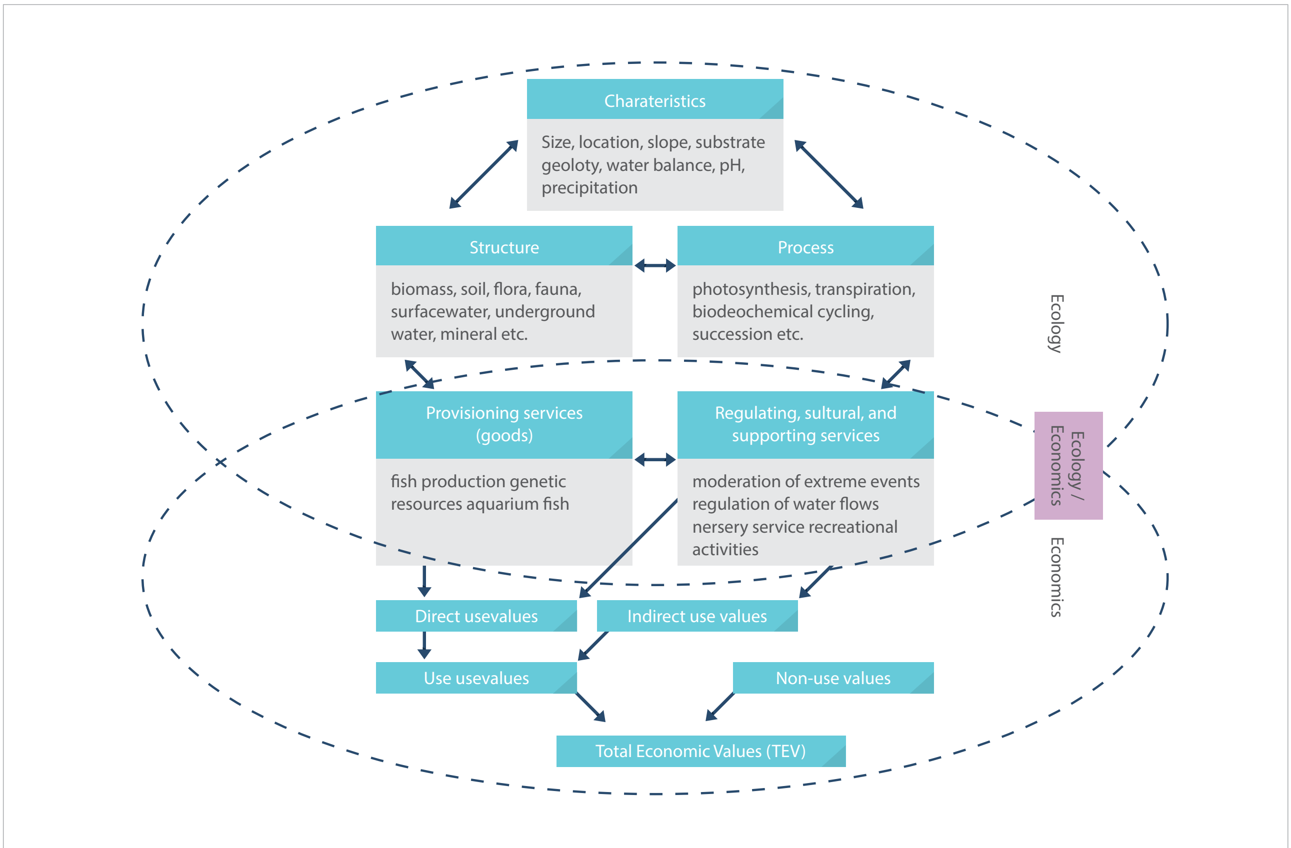


Figure 5.4 Wetland ecosystem structure/process, functions, services, and total economic values (TEV). Source: modified from Turner et al. (2003)

individuals embedded in the related markets, whereas the stated preference approaches infer values by estimating individuals' willingness to pay through conducting surveys with hypothetical scenarios. The principal difference between the revealed and the stated preference approaches is that the latter draw their data from people's responses to hypothetical questions rather than from observations of real-world choices. The revealed preference approaches include the travel cost method and the hedonic price method, where the actual and time costs involved in trips and amenity premiums in real-estate values are used in the proxies for willingness to pay, respectively. Sated preference approaches include the contingent valuation method and the choice experiment.

The cost-based approaches include replacement and restoration cost methods. The replacement cost methods estimate the costs of replacing particular ecosystem functions lost with manufactured facilities. The restoration cost methods estimate the costs of restoring foregone ecosystem functions. Both methods tend to use unit-cost estimates incurred by either replacing or restoring ecosystem functions, which correspond to supply-side cost estimates, and do not take into account individual preferences reflected in the willingness to pay of the demand-side.

The value (or benefit) transfer is a terminology referring to the various techniques and/or procedures of estimating the value of ecosystem services by utilizing existing information or knowledge from previous studies (i.e., study site) in a new but similar context (i.e., policy site). From a practical point of view, applying value transfer techniques is generally less expensive and less time-consuming than conducting original research (EEA, 2010). Value transfer has advantages in providing value estimates, through relatively easy and quick procedures, for decision-making processes in the real world. Therefore, in theory, any value estimates from the market analyses, preference-based approaches, and cost-based approaches can be used for value transfer.

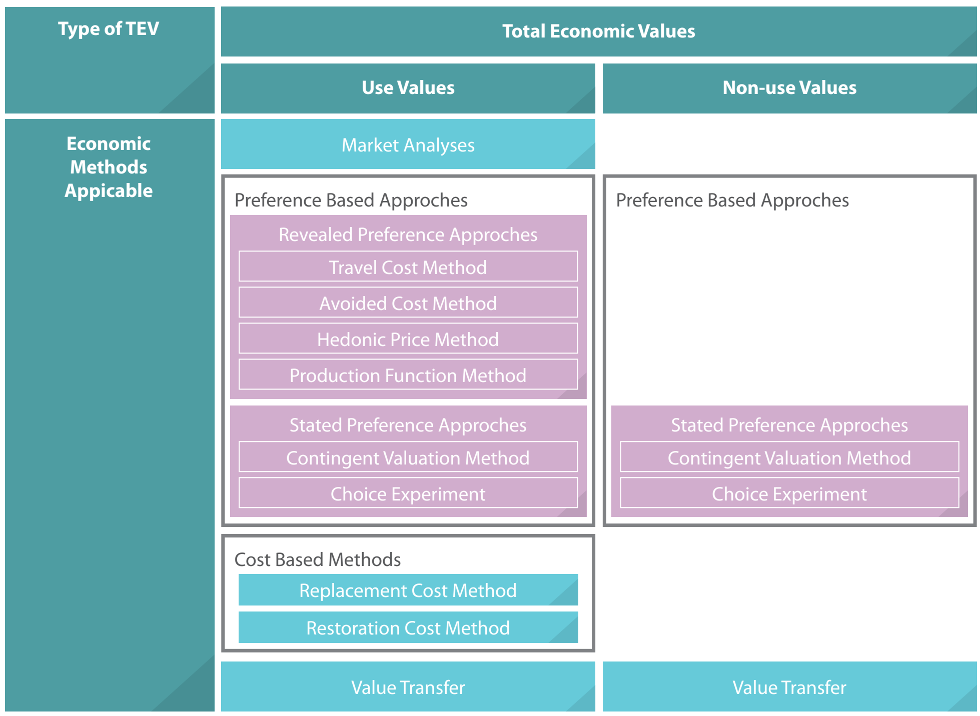


Figure 5.5 TEV and valuation methods. Source: Ahn and Bae (2014)

Associating ecosystem services and TEV can provide important information to select valuation methods suitable for each ecosystem service. Figure 5.5 shows that market analyses, the revealed and stated preference-based approaches, and the cost-based methods can be used to estimate use values; however, only stated preference approaches can be used to estimate non-use values. Because use values are derived from direct and/or indirect consumptions of ecosystem services, thus the evidence from human consumption of ecosystem services can be found in actual and/or surrogate markets. The selection of methods largely depends on data availability and characteristics of ecosystem services. Various methods have been developed based on these. They are all applicable in principle. However, non-use values lack any instrumental component to humans and, therefore, the only method to derive willingness to pay in these cases is to use surveys based on hypothetical circumstances.

Linking the characteristics of the ecosystem services, the TEV, and valuation methods is critical for proper valuation exercises. For example, if the purpose of valuation is to estimate the direct use values associated with eco-tourism, then the proper valuation methods applicable are confined to travel cost methods. If the purpose of valuation is to estimate the indirect use values associated with the regulating services such as water purification, then, theoretically, all of the avoided cost method, the contingent valuation method, the choice experiment, and the replacement cost method can be considered. In this case, the final choice of valuation method should be determined according to valuation purpose, data availability, and other surrounding circumstances.

5.2.4 Discussion

As indicated throughout section 5.2., the economic valuation of ecosystem services is not an easy task. One difficulty comes from the inherent complexities of the ecosystem process, which are the basis of providing ecosystem functions and services to humans. Unless we understand the systematic pathway from ecosystem structure/processes to ecosystem services/benefits more clearly, the economic valuations are likely to lose their scientific foundations. In practice, however, a clear boundary between ecosystem functions and services does not exist because they are characterized and defined depending on their roles or uses in the socio-economic system. For instance, water purification can be defined as either a function or a service. An important distinction relevant to economic valuation is whether it is an intermediate or final service, because the subject of economic valuation should be confined to final services to avoid double counting. In this respect, a reverse pathway analysis beginning from benefits/services, via functions, to ecosystem process/structure can be a practical and useful alternative.

This section has dealt with the scoping issues for conducting valuation studies of ecosystem services. Establishing clear linkages between the characteristics of ecosystem services, classification, TEV types, and valuation methods is a prerequisite for economic valuation exercise and communication among stakeholders as well. Needless to say, integrated and multi-disciplinary approaches are

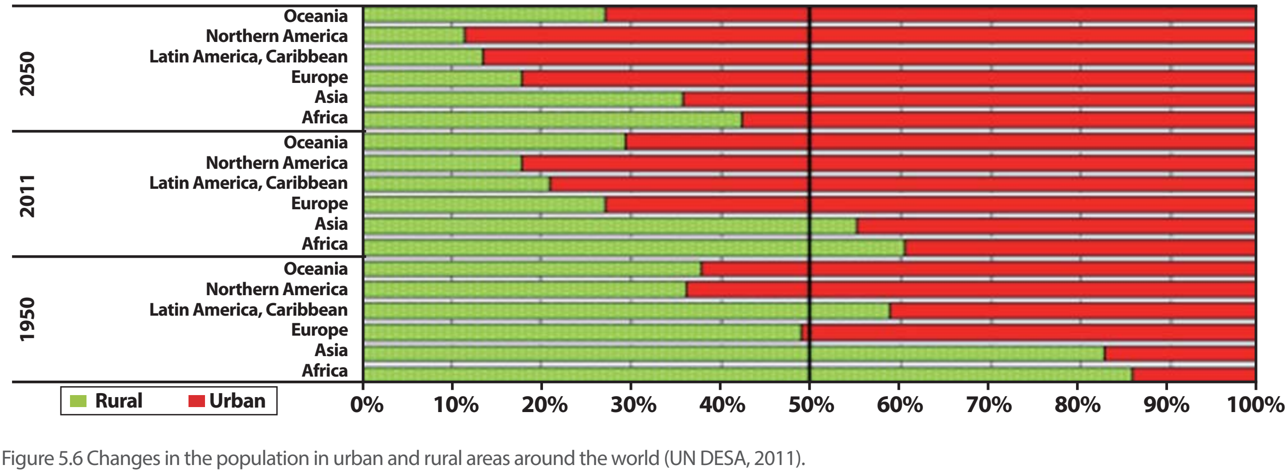


Figure 5.6 Changes in the population in urban and rural areas around the world (UN DESA, 2011).

essential in conducting economic valuation studies and developing science-based policy tools for the conservation of biodiversity/ecosystem services.

5.3 SCIENCE AND TECHNOLOGY OF NATURAL AND GREEN INFRASTRUCTURE MANAGEMENT

5.3.1 Background

The United Nations Department of Economics and Social Affairs (2011) reported that all continents, including Asia, have been experiencing rapid population concentration in urban areas since the 1950s; it is expected that by 2050, at least 80% of the world's population will be living in urban areas (Figure 5.6). Urbanization is the transition of inherent natural landscape (e.g., meadow, forests, etc.) into a highly developed environment of impervious surfaces (e.g., roadways, building rooftops, parking lots, etc.). Generally, urban areas consist of various land uses (i.e., commercial, industrial, residential, recreational areas, etc.) to provide supplies and spaces necessary for human life. Population concentration due to urbanization has severe impacts on settlements, transportation, water quality and resources, energy and ecosystems. Specifically, the increase in impermeable surfaces and upsurge usage in vehicles cause hydrological and water quality effects that eventually affect the entire ecosystem. Therefore, this section will deal with the impacts of urbanization on the ecosystem in terms of water circulation and water pollution.

5.3.2 Challenge

5.3.2.1 Hydrological Impacts

Vegetation cover intercepts and absorbs rainfall and stormwater runoff. However, as shown in Figure 5.6, impervious surfaces decrease the infiltration and evapotranspiration capabilities and increase stormwater runoff. According to Schueler (1994), the volume of stormwater runoff is directly proportional to the amount of impervious surface in a catchment area. In addition, the obstruction of rainfall infiltration results in increased runoff velocity and peak flows. Most runoff from impervious urban areas drains directly to a stream or stormwater collection system that discharges into a water body without treatment. Several studies have indicated and examined the specific hydrological effects of an urbanized area. According to Rose and Peters (2001), the peak flows in an urbanized area were most probably 30% to more than 100% greater than the non-urbanized land use. In addition, Cook and Dickinson (1985) have examined the hydrological response of urbanization and found out that, regardless of rainfall intensity or duration, the runoff coefficient increased by at least 50%, and the lag time of concentration and peak flow was decreased three-fold.

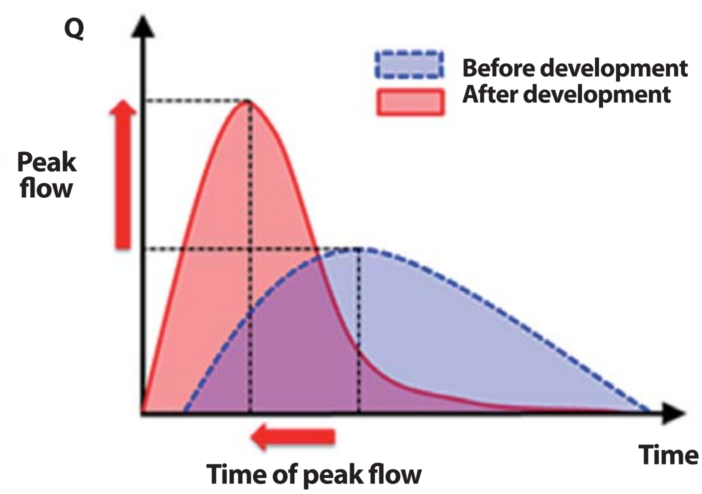


Figure 5.7 Change of natural water circulation system by urbanization (Kim, 2014)

5.3.2.2 Non-point Source Pollution

Watershed change in Korea caused by rapid industrialization and urbanization is making an impact on the water quality and ecosystem of the four major rivers (i.e., Han River, Nakdong River, Guem River, Youngsan and Sumjin Rivers). Among the average discharged mass of biochemical oxygen demand (BOD) from the four rivers, the contribution of pollutants discharged from land use due to urbanization of watershed, or pollutants discharged due to stormwater runoff, exceeds 64% (Table 5.3; Korea MOE, 2012). However, in the case of heavy metals, sediments, and toxic chemicals mostly discharged from non-point sources (NPS), the contribution turns out to be extremely high (Kim, 2002).

Table 5.3 BOD concentration and percentage contribution in the four major rivers in Korea in 2010 (Korea MOE, 2012)

Watershed	BOD (kg/day, %)		
	Total	Point source load	Non-point source load
Han River	618,760 (100)	209,672 (33.9)	409,088 (66.1)
Nakdong River	446,378 (100)	158,804 (35.6)	287,575 (64.4)
Guem River	304,014 (100)	72,434 (23.8)	231,580 (76.2)
Youngsan and Sumjin Rivers	270,571 (100)	79,386 (29.3)	191,185 (70.7)
Total	1,639,724 (100)	520,296 (31.7)	1,119,428 (68.3)

Among the NPS pollutants discharged in the watershed, the chemical oxygen demand (COD) was found to increase during rainfall events. Figure 5.8 shows the annual average concentration change of BOD and COD in the four major rivers from 1993 to 2012. BOD shows a decreasing or stable trend, whereas the COD is increasing. This is reported as an impact of non-biodegradable matter originating from non-point source pollutants in watersheds (Korea MOE, 2012). BOD is similar in function to COD, in that both measure the amount of organic compounds in water. However, COD is less specific, since it measures everything that can be chemically oxidized, rather than just levels of biologically active organic matter. Heavy metals are toxic materials, which can affect to ecosystems by bio-accumulation processes.

Stormwater runoff from urban areas can discharge various types of NPS pollutant that had accumulated on surfaces during the dry season into the water system and cause great impacts on water quality and aquatic ecosystems (Kim & Kang, 2004; Kim, 2007). As shown in Figure 5.9, urban stormwater runoff has a first flush phenomenon, which means the first part of the runoff during rainfall is highly polluted by NPS pollutants. It is an important phenomenon in determining the volumes to be treated for rainfall harvesting.

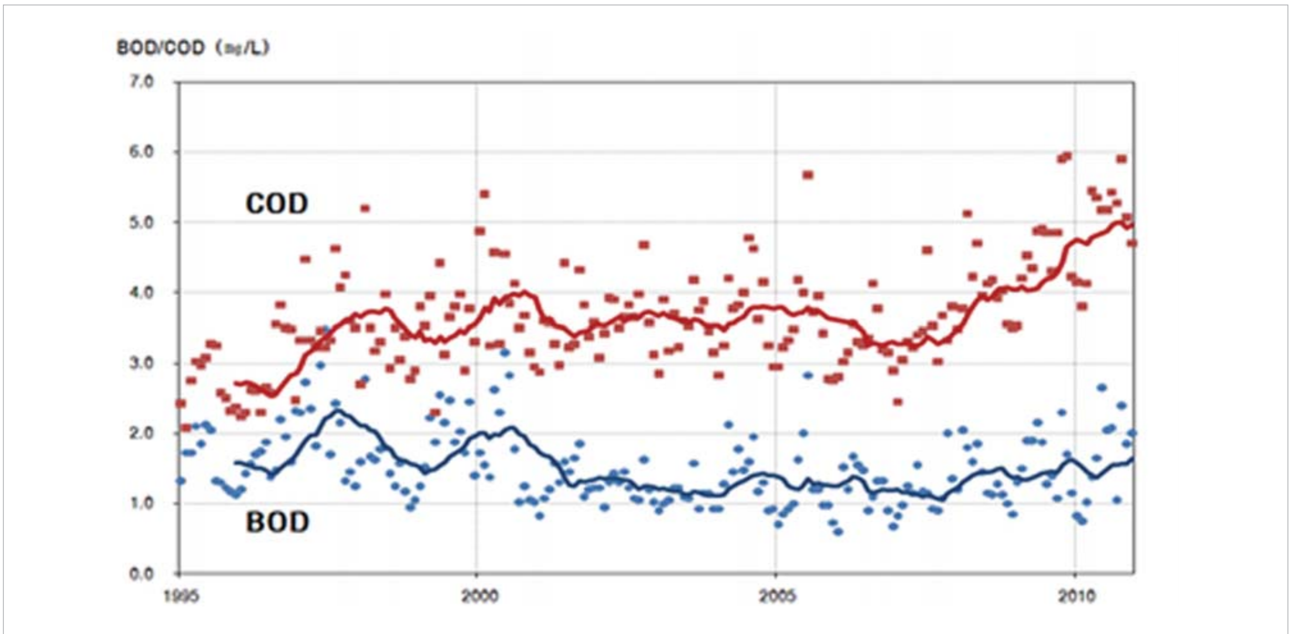


Figure 5.8 Annual average concentration changes of BOD and COD in the four major rivers in Korea (Korea MOE, 2012)

Table 5.4 shows the average concentration of NPS pollutants discharged during rainfall events from various land uses in urban areas for several countries. The concentration of pollutants varies among the countries, but the discharge of sediments, COD, and metals turns out to be high in roads and parking lots because of vehicular activities. The amount of COD is significantly higher than that of BOD, which indicates that a great deal of biodegradable organics originate from NPS. Along with roads and parking lots, industrial complex areas are also considered as sources of many NPS pollutants that affect water quality and aquatic ecosystems.

5.3.2.3 Ecosystem Impacts

Changes in the hydrological characteristics of watersheds damage the habitats in the water system. Moreover, various pollutants that originate from watersheds cause the decline of dissolved oxygen (DO) in the water, a rise in water temperature, and respiration complications to fish and other living aquatic creatures because of sediments and increases in toxic substances; thereby they have negative impacts on aquatic species' assemblages, biomass, and organisms. Figure 5.10 shows the impacts of urbanization and imperviousness to aquatic ecosystems and fish.

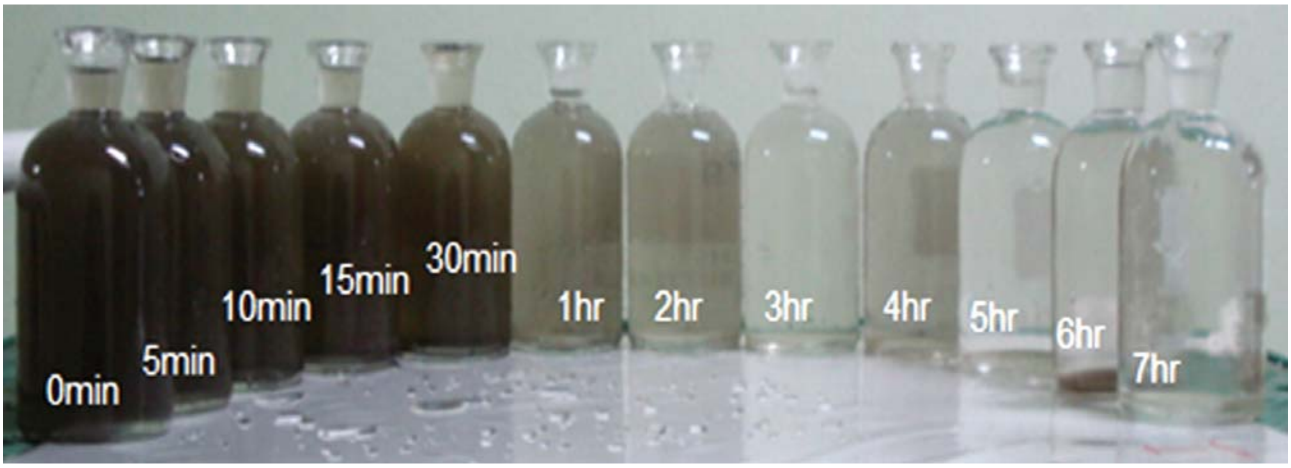
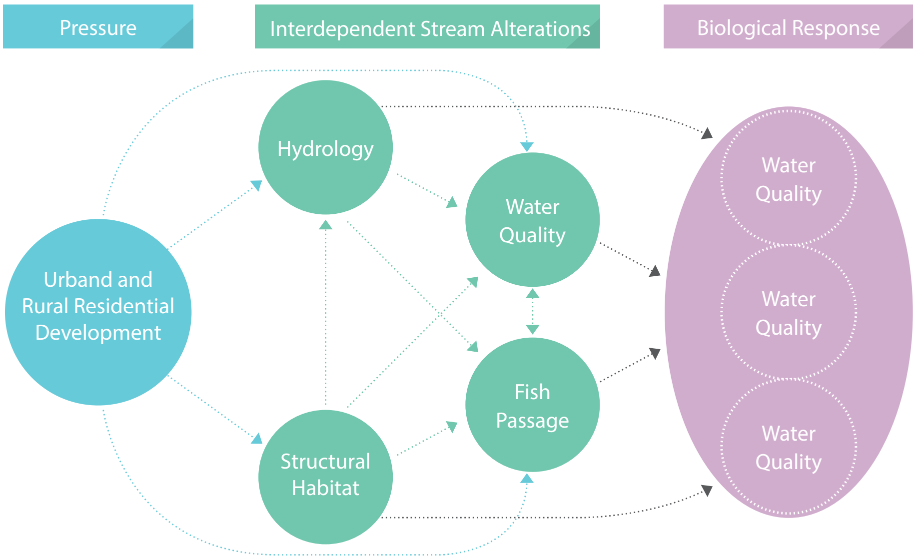


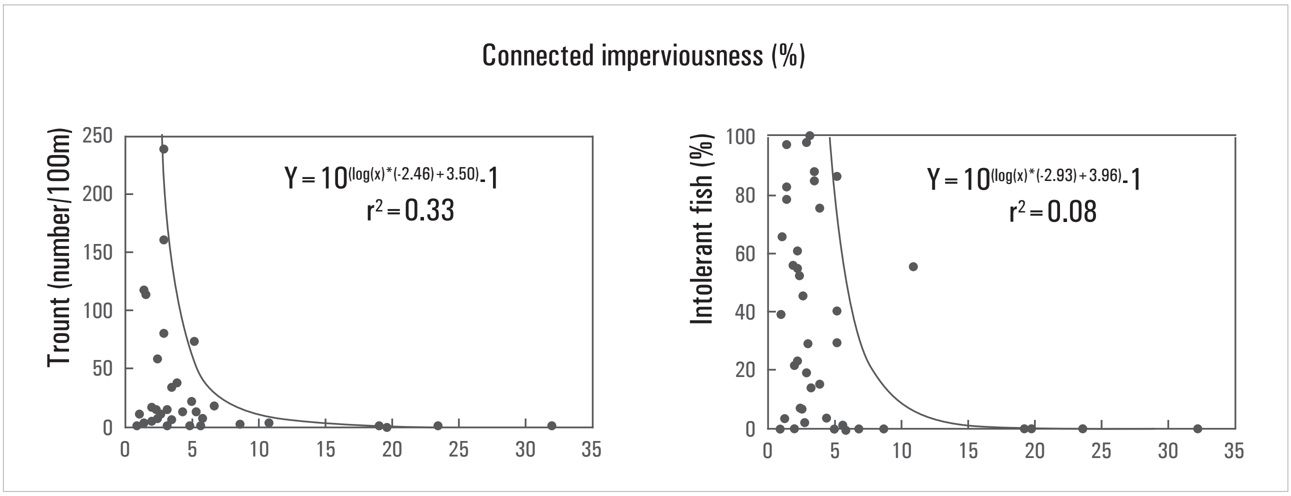
Figure 5.9 Hydro- and polluto-graphs in urban areas and the first flush effect (photograph: Lee-Hyung Kim)

Table 5.4 Average concentration of typical constituents in urban stormwater runoff studies in different countries (Mercado et al, 2012)

Country	Germany	Macau, China	Italy	USA	South Korea	
Reference	Gobel et al., 2007	Huang et al., 2007	Gnecco et al., 2005	Brezonik and Stadelmann, 2002	Mercado et al., 2012	
Average Annual Rainfall (mm)	837	2120	1323	788	1352	1352
Parameter Unit	Mean Concentrations					
TSS mg/L	12	318.6	140	184	119.1	425.1
BOD mg/L	2	-	-	-	10.3	25.9
COD mg/L	19	201.4	129	169	136.7	222.3
Cu μg/L	19	201.4	129	169	136.7	222.3
Zn μg/L	80	3.2	81	-	213.3	145.9
Pb μg/L	9	55	13	60	116.4	77.0



(a) Impacts of urbanization and increased imperviousness on aquatic ecosystems



(b) Fish changes with respect to increasing connected imperviousness

Figure 5.10 Fish changes by increasing connected imperviousness rate (Wang et al., 2003).

5.3.3 Solution

5.3.3.1 Principles of LID/GI for Reducing Urbanization Impacts

To reduce the impacts of hydrological changes and discharge of pollutants due to urbanization, it is necessary to consider techniques to reduce these impacts through planning each stage of various development projects. Many countries have thus adopted the environmental impact assessment (EIA) to reduce various environmental impacts on ecosystems. However, this was mostly to provide countermeasures rather than precautionary measures. Therefore, application of the LID and GI is required for an eco-friendly EIA from the start of planning and until the detailed construction of each development project. Figure 5.11 summarizes the differences between conventional and LID approaches. LID includes a development plan to overcome hydrological, environmental, and ecological problems caused by urbanization so that humans can coexist with the ecosystem. LID development also refers to an approach that minimizes the negative impacts of development by increasing green areas, reducing impervious areas, protecting low lands, and restoring the natural water circulation. This development can be done by incorporating into development plans and construction technologies the technique of managing stormwater runoff where it occurs, harmonizing with nature, and processing NPS pollutants accumulated in impervious areas.

5.3.3.2 LID Techniques for Landuse Planning

The LID approach is a development method that minimizes various environmental impacts due to urbanization. It is effective for water resources, water quality, atmosphere, ecosystems, and humans. A development project can change the natural surface into an impervious area, increasing runoff in rainfall and discharging various types of NPS pollutant. Therefore, the LID approach secures the green spaces wherein it reduces the impervious area, and preserves low lands with water as much as possible, while maximizing the natural water circulation function. Through this approach, it is possible to establish a land use plan with low runoff of NPS pollutants.

LID development has various environmental benefits. First, it establishes a good water circulation system, assisting with flood prevention, providing habitats for organisms, purifying pollutants included in stormwater runoff, and preserving and recovering vegetation such as trees. For developers, LID techniques can suggest new alternatives for site plot plans and stormwater runoff management. LID can also reduce the costs of construction and maintenance of drainage facilities. Furthermore, it provides benefits for developers by allowing them to use the properties required for large-scale retention basins in the development projects for production of other diverse values. LID development also offers various benefits to the community and local governments. It can prevent floods, protect biotic habitats, maintain drinking water

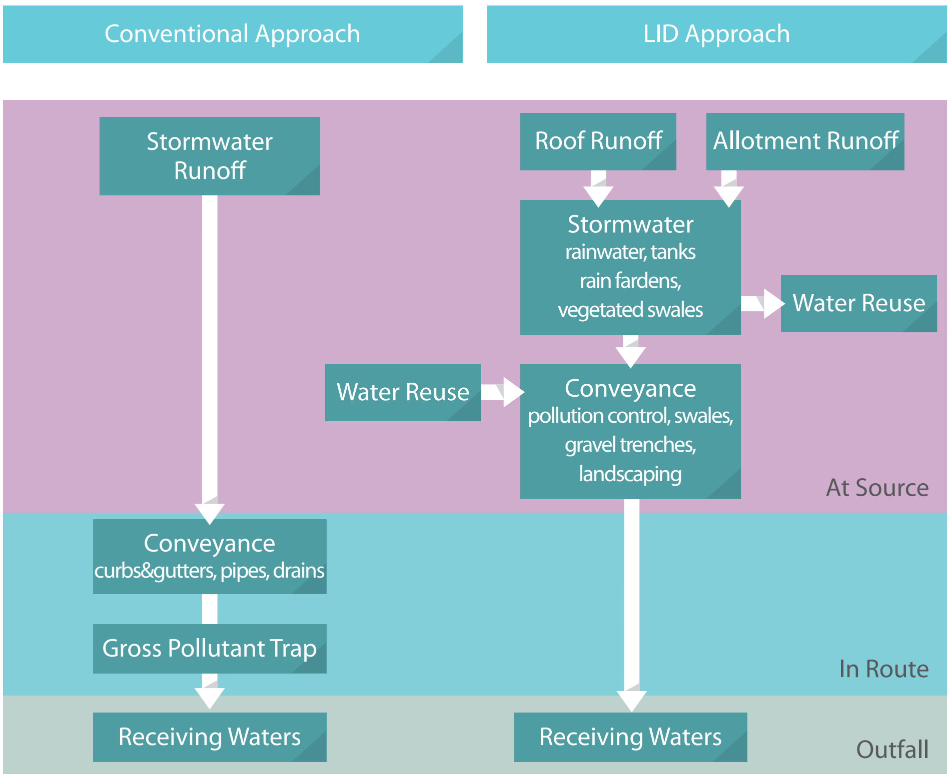


Figure 5.11 Comparison of conventional and LID approaches

supply, reduce maintenance costs of facilities for stormwater management, reduce NPS pollutants, and save costs of other social infrastructures such as roads and curbs. In addition, it improves the exterior and aesthetic value of the community, thereby increasing the property cost of the site and building while reducing the costs of wastewater treatment plants. Approaches for LID development can be carried forward by implementing the following strategies.

Figure 5.12 shows a comparison of conventional development and the LID approach presented in the LID manual of the USA Puget Sound Action Team (Washington State). The LID approach increases the ratio of green area connected to water and reduces impervious area, thereby reducing environmental impacts of urban development. Moreover, the arrangement of buildings, adjustment of drainage area considering topography, and connection to green spaces and

Table 5.5 Strategy for LID approach (NIER, 2012)

Type	Content
Preservation and regeneration of vegetation and soil	• Preserving vegetation on the original soil as much as possible while maintaining the natural drainage pattern, topography, sinking place, etc. • Selecting types of plants and planting them again to recover native vegetation • Preserving hydrological soil type Group A and B with good drainage as much as possible • Minimizing soil consolidation and disturbance • Using fertilizers to recover the health of soil consolidated by construction • Maintaining natural drainage system and topography of property and considering them in property design • Reorganizing property to delay surface runoff and increase infiltration function using the existing topography of the property • Using open vegetated swale and natural vegetation drainage pattern for extension of water ways and flow distribution • Blocking the flow by using detention systems of nature such as vegetated swale or rain garden • Minimizing curbs or bypass drainage systems and designing so that impervious surface areas are not continued • Extending rainwater's detention time in the sources by connecting impervious areas and vegetated areas • Maintaining low slope
Preservation and regeneration of vegetation and soil	• Need common value or consensus based on cooperation of property designers, planners, engineers, landscape planners and architects • Maintaining land cover type, imperviousness rate, connectivity, hydrological soil type, natural flow pattern and retention characteristics • Minimizing disturbances, preserving open vegetated swale and soil with high infiltration rate, establishing nonpoint source treatment facilities in soil with high infiltration rate, etc. • Minimizing impervious surface areas such as roofs, roads and parking lots • Installing impervious areas such as buildings, roads and parking lots away from soil with high infiltration rate • Disconnecting so that impervious areas are not continued • Distributing stormwater runoff to hydrological soil type A and B
Managing from stormwater runoff sources	• Applying IMP(Integrated Management Practices) (Different with centralized BMP) • Integrating stormwater management functions into property design to create an attractive landscape that preserves the environment • Creating a landscape that delays stormwater runoff and increases rainwater retained inside the property • Designing so that retention and infiltration are possible in the phase of stormwater runoff source • Integrated stormwater management combining small wetlands, permeable pavements and green roofs • Distributing pollution reduction facilities such as rain garden, infiltration trench, roof cistern and ponds in runoff points • Improving reliability of stormwater management system and reducing possibility of failure by comprehensively using various facilities • Reducing dependence on stormwater drainage pipes, sewer pipes and ponds used in conventional stormwater runoff management • Avoiding installation of stormwater drainage pipe, curbs, and runoff bypass pipe between roads and sidewalks • Preventing pollution by installing BMPs in runoff sources
Maintenance and training	• Important for all stakeholders to understand and be educated • Important to understand the system in which runoff is controlled by integrating with landscape and scenery with LID and to know how to manage it • Need to train housing or building owners and designers for appropriate maintenance of LID facilities • Property owners must believe that these landscape elements enhance their property value, feel rewarded for contributing to environmental protection, and be willing to pay the costs required for landscape maintenance • Need to develop long-term maintenance plans with clear and practicable guidelines

water spaces are also important elements to consider in LID planning.

Roads have the highest pollutant discharge among all urban land uses owing to vehicular activities and pavement degradation. Therefore, linear-type development projects like roads must apply the LID approach to fundamentally minimize the impacts on water quality and aquatic ecosystem. In applying LID systems for roads, it is necessary to plan on keeping the roads at a certain distance from streams and rivers, and to create a bypass for regions that need preservation of water quality and aquatic ecosystems. If those roads need to cross streams and rivers, the number of bridges and their length must be minimized.

(a) Conventional approach (b) Advanced approach (c) LID approach

(d) Conventional approach (e) LID approach

Figure 5.12 Comparison of conventional and LID approaches (PSAT, 2012).

5.3.3.3 Ecological and Environmental Mechanisms of LID and GI Technology

LID is a small-scale, decentralized-type technique that establishes natural water circulation with integrated retention and infiltration. These technologies also treat and manage the urban stormwater runoff while promoting water pollution reduction, groundwater recharge, and water reuse. Stormwater runoff management using LID refers to managing the pollutants through infiltration and retention from overland flow or drainage systems, not through end-of-pipe structures. Meanwhile, GI technology refers to the facilities and techniques that link the natural features (e.g., green areas, parks, wetlands, etc.) to each other and provides ecological services that are helpful for humans. However, it is perceived as a similar concept to LID. LID/GI has the function of recovering natural water circulation and reducing water pollutants by using the physico-chemical and biological principles of soil and plants. Complex biological and ecological processes occur in the rhizosphere through ecosystem-level interactions among roots, microorganisms, and soil fauna. The contribution of the rhizosphere effect generated by microbes and roots appears in the improvement of soil nutrient acquisition and bioabsorbable and biotransformation efficiency (Figure 5.13).

Particulate matter included in stormwater runoff is reduced by sedimentation and filtration of the soil. Organics change their form through biodegradation by the microorganisms within the soil. Among all the nutrients, nitrogen is reduced by microorganism synthesis, nitrification and de-nitrification processes, and plant uptake. Meanwhile, phosphorus is reduced by microorganism synthesis and absorption as well as plant uptake. Heavy metals are reduced by means of physico-chemical filtration and absorption of soil. Plants

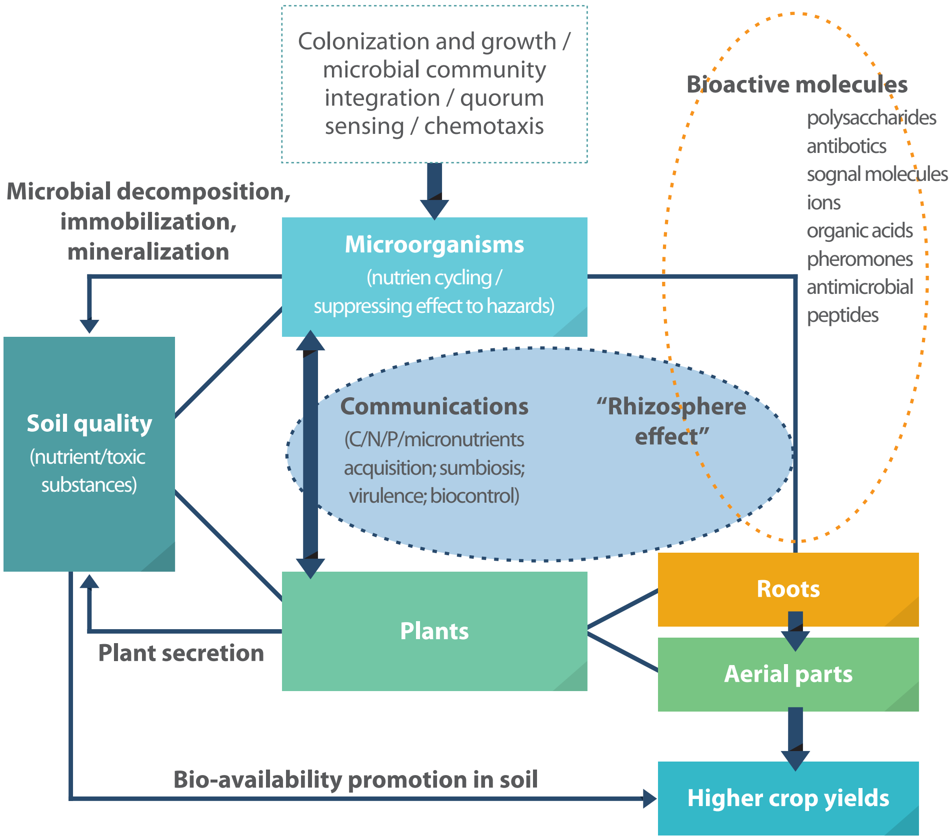


Figure 5.13 Net structure of rhizospheric interactions between microorganisms and plants (Zhuang et al., 2013)

and soil microorganisms are considered one of the effective maintenance mechanisms in reducing various pollutants such as organics and nutrients through photosynthesis and respiration. In other words, applying LID/GI approaches indicates that maintenance costs can be reduced more than by applying regular reduction facilities.

Using plants in LID/GI approaches may lead to a reduction in NPS pollutants through photosynthesis and respiration, as well improving water retention and infiltration by the roots of plants. In general, approximately 70% of water exists up to 50% of root depth. In LID/GI elements, increased infiltration and retention quantity by establishing water circulation contribute significantly to the reducing NPS pollutants. Therefore, the types of soil used are important in the application of LID/GI. Sand has high infiltration and retention but lacks pollutant absorption ability, whereas clay has outstanding pollutant absorption ability but does not contribute to water circulation. Owing to these characteristics, sand and clay cannot contribute greatly to the growth of plants, and thus it is desirable to combine sand with humus soil that has high cation exchange capacity. Moreover, since LID/GI handles stormwater runoff from the pavement, it is necessary to apply plants that can resist the high water content and salt.

LID/GI technology is classified into infiltration, vegetation, retention, and constructed wetlands (Table 5.6). This technology can be applied to landscapes, green areas, parks and flowerbeds in urban areas, and is determined by the available space, amount of stormwater runoff, and pollutants that occur. Furthermore, it can be applied in various forms, from small scale to large scale, depending on the amount of stormwater runoff and available space.

To secure the maintenance of all these facilities and their respective continuous efficiency, it is necessary to include a sedimentation deposit in the design to remove particulate matter that occurs early in stormwater runoff.

5.3.4 Research and Development

5.3.4.1 Effects of LID Application

LID application in urban areas plays the role of recovering natural water circulation and reducing pollutants discharged from pavements. Recovery of natural water circulation can be done by increasing the infiltration ability of soil and the evapotranspiration of plants. Recovering natural water circulation through LID installations is possible by delaying the runoff time after or during rainfall, reducing runoff volume and peak flow, and delaying peak flow occurrence time. Reduction of stormwater runoff volume through LID applications may reduce the outflow of pollutants. Also, pollutants are reduced through physical reduction mechanisms (such as biochemical reduction mechanisms), filtration, and absorption by microorganisms and plants inside the soil (Figure 5.14).

Of the LID/GI technologies, bioretention (e.g., rain garden) is one that is diversely applied in the USA, Germany, and Korea. LID can reduce the peak flow by retention and infiltration. The infiltrated outflow is supplied as ecological water for the ecosystems of streams and rivers in the dry season by being sent to underground water, thereby using it to improve water quality and ecosystems. Peak flow reduction and delay to occurrence time have the effect of improving water quality and aquatic ecosystems by supplying ecological water to streams and rivers, while also reducing flooding of urban areas. Developed countries including the USA and Korea have

Table 5.6 Classification of LID/GI technology

Type	Content	Types
Infiltration	Facility infiltrating stormwater to the ground, which is removing the pollutants with filtration and adsorption	Infiltration trench, Infiltration basin, Permeable pavement
Vegetation	Facility providing green spaces and habitats, which is removing the pollutant with filtration and adsorption in soil and vegetation uptake	Vegetated swale, Vegetated strip, Bioretention, Tree box filter, Planter
Retention	Facility retaining stormwater, which is removing the pollutants by sedimentation and others	Retention basin, Underground retention tank
Constructed wetlands	Facility retaining stormwater and treating with plants, microorganisms and media	Free water surface constructed wetland (FWS), Subsurface flow constructed wetland (SSF), Hybrid constructed wetland

recently considered using LID/GI technologies as disaster prevention facilities to reduce urban flooding. LID facilities may contribute to reducing the heat island phenomenon in urban areas through infiltration and retention of stormwater runoff. Retention and infiltration of urban water using such LID facilities will produce a variety of effects such as reduction of pollutants, recovery of water circulation, provision of ecological habitats, prevention of urban disasters, and reduction of energy use.

5.3.4.2 Examples of Applied LID and GI Technologies

The USA, Germany, UK, Austria, Australia, New Zealand, and Korea are countries in which LID/GI is most actively applied. Germany is applying decentralized stormwater management and LID principles to reduce various environmental problems that may be caused by urbanization.

Germany

Germany applies various small-scale decentralized types of vegetated swale, infiltration basin, bioretention, and constructed wetland in urban land uses (Figure 5.15). Also, landscape is considered significantly along with water circulation and the ability to reduce environmental pollutants in applying the LID technique. Freiburg is a city located near the River Rhine in the southwest, and is regarded as an emblem of an ecological city with worldwide recognition.

- Freiburg is acknowledged as the environmental capital of Germany, with various environmental technologies applied to the city, embracing everything such as energy, water reuse, rainwater management, and LID.
- Freiburg is a city with high environmental awareness among all residents, and major policy directives include green transportation, low carbon energy, low carbon housing, ecological green spaces, and circulation of water resources.
- Preserving water quality and aquatic ecosystems is also an important policy for the city, since Freiburg is located near River Rhine; thus, the city is successfully applying the management of NPS pollutants by establishing water circulation.

Munich, located in the south of Germany with a population of 1.3 million, is a major economic city. Riem, located in the east of Munich, is formerly where Munich Airport was located. It was newly developed as an integrated green city after the airport was relocated. Riem was remodelled into an integrated business and residential area as well as a logistics complex. It is a typical water circulation complex developed with various types of LID technology. Water circulation in Riem includes a variety of facilities for stormwater runoff, such as rainwater use, retention, infiltration, vegetation facilities, and green roofs. LID technologies installed in Riem include infiltration trenches, permeable pavements, bioretention, constructed wetlands, retention basins, green roofs, and cisterns.

(a) Bioretention (b)Permeable pavement

(c) Small retention basin (d) Vegetated swale

Figure 5.15 LID/GI applications in Freiburg, Germany (photograph: Lee-Hyung Kim)

Figure 5.14 Water quality change after LID application (photograph: Lee-Hyung Kim).

Korea

Korea has been through urbanization on a national scale, and thus has adopted LID/GI as a national project since 2008; it is currently organizing and implementing various systems and laws. On the basis of the 'Act of Water Quality and Aqua-ecosystem Protection', the Ministry of Environment formed LID/GI technology at a similar level to that advanced countries on the national road that connects Asan, Chungcheongnam-do and Sejong, where Korea's Government Ministries are gathered together (Figure 5.16). There are six facilities installed here: vegetated swale, small-scale constructed wetlands (i.e., horizontal subsurface flow and free water surface flow constructed wetlands), infiltration trenches, and rain gardens (i.e., bioretention). Research findings drawn from this project are used in the design guidelines for NPS pollutant reduction facilities on roads, and as a plan to expand LID to manage road stormwater runoff in Korea. Figure 5.17 shows applications of LID/GI inside a university campus (Kongju National University). Bioretention, planters, infiltration trenches, and hybrid constructed wetlands are used as educational resources for students while also improving environmental and hydrological functions.

(a) Small-scale constructed wetland

(b) Vegetated swale

(c) Bioretention

(d) Infiltration trench

(e) Horizontal subsurface flow constructed wetland

(f) Free water surface flow constructed wetland

Figure 5.16 LID/GI applications in Chungcheongnam-do, Korea (photograph: Lee-Hyung Kim)

Figure 5.17 Various types of LID/GI application on the campus of Kongju National University, Cheonan, Korea (photograph: Lee-Hyung Kim)

UK

The UK is installing sustainable urban drainage systems to efficiently manage the amount of stormwater runoff and NPS pollutants in narrow urban areas. For sustainable functional maintenance of these systems, the UK effectively connects constructed wetlands, retention basins, and infiltration trenches. Sustainable urban drainage systems are designed with an emphasis on landscape by adding various designs along with the functions of stormwater runoff retention, infiltration, and pollutant reduction. Moreover, the systems are applied to urban areas by valuing ecological mechanisms that connect water and green spaces. Recently, the UK has expanded the establishment of various LID facilities that can

(a) Retention basin

(b) Infiltration trench

(c) Free water surface flow constructed wetland

(d) Infiltration trench at aroundabout

Figure 5.18 LID/GI applications in Kirkcaldy, Scotland, UK (photograph: Lee-Hyung Kim) manage stormwater runoff while also having scenic value in accessory structures of roads such as rotaries and junctions. Figure 5.18 shows some common LID/GI applications in Scotland. To this end, the UK is increasing ecological and scenic characteristics by adequately combining flowering plants and shrubs.

USA

The application and implementation of LID/GI in the USA has been rapidly expanding in several states. Specifically, cities and states near waterbodies and coastlines like Maryland, Oregon, Washington, California, etc. are actively pursuing the adoption of LID/GI. The US Environmental Protection Agency is legalizing the application of LID/GI in various development projects to reduce the problems of urbanization through efficient management of stormwater runoff, to improve water quality and health of aquatic ecosystems, and to create a city where humans coexist with ecosystems. Generally, the concepts of environment and ecology must be taught to students from elementary school for them to realize environmental concepts in daily life, even after they become adults. Therefore, the USA is expanding eco-friendly LID/GI facilities from elementary schools to university campuses to familiarize the students (Figure 5.19) with these concepts. Moreover, students learn to perceive that maintaining the surrounding environment is not difficult, by voluntarily participating in the maintenance of these facilities. LID/GI application is also active in public institutions to expand the application of this technology, where various programs and policies are implemented and where there is a high traffic of residents. Public institutions such as the business operators, occupants, and technicians adopt these LID/GI systems to show environmentally friendly development conditions. Accordingly, the USA has installed various LID/GIs in public institutions for use in publicity and policy education.

Commercial areas and industrial complexes are places where various businesses are located and where there is high traffic of people and vehicles. Of the two, commercial areas lack a wide area of space for LID and GI, so small-scale decentralized facilities are established. However, in industrial complexes, LID/GI technologies are installed in connection with retention basins to prepare for the possibility of toxic chemical outflow (Figure 5.20).

Stormwater runoff in residential areas requires management since it contains pollutants emitted from vehicles as well as pollutants like manures and fertilizers sprayed on gardens. Figure 5.21 shows common LID applications in a residential area. Eco-friendly facilities in residential areas require maintenance by residents since they can contribute to the regional economy by improving the land value of the region. Residents must make efforts to wash cars in places with proper drainage to enhance the ecological property of the community, always clean the flowerbeds and streets in front of their own houses, prevent sediment discharge from landscape spaces, and lead the runoff of impervious areas to landscape spaces for treatment.

5.3.5 Recommendations

Urbanization distorts natural water circulation systems in rainfall by causing changes of land use in watersheds, and causes bad impacts on water quality and aquatic ecosystems of the water system by discharging various pollutants.

Therefore, it is necessary to reduce the hydrological and environmental impacts of urbanization to secure healthy water resources and aquatic ecosystems: the proposed alternative is to apply LID and GI. LID is a method that analyses environmental impacts that may occur from the planning stage to the operation of various development projects and minimizes those impacts. The following development methods are required to recover water circulation and minimize discharge of pollutants through LID applications.

(a) LID refers to establishing a land use plan wherein it secures green spaces that could imitate the natural water circulation, reducing impervious areas, preserving low lands with water as much as possible, and maintaining natural water circulation functions.

(b) LID development has the functions of establishing natural water circulation systems, preventing floods, providing biological habitats, purifying pollutants included in stormwater runoff, and preserving and recovering vegetation such as trees.

(c) It is necessary to establish and apply technological methods for runoff reduction purposes because, despite the establishment of LID land use plans, NPS pollutants may still leak after development.

(d) Soil applied to LID facilities must have good infiltration and retention functions, wherein absorption of pollutants and attached growth of soil microorganisms are possible.

(e) Plants applied in LID should have high amount of pollutant absorption, have strong tolerance to salinity, and can grow in both dry and rainy seasons.

(f) Any road is a type of land use where all stormwater runoff and NPS pollutants in urban areas are gathered; thus, it is necessary to consider water circulation and pollutant reduction functions in planning and creating any road. Extra sites must be secured in road plans to implement infiltration trenches or vegetative swales, and stormwater runoff must pass through green spaces (e.g., street trees, landscape spaces, etc.) before flowing into storm sewers.

(g) The central part of the crossroad is a space that can be used for treating stormwater runoff, and thus must be created into a green space where stormwater runoff can flow in when designing it.

All urban land uses have various types of green area, or landscape space, to reduce environmental impacts of urbanization. However, improper design of landscape space and management that does not consider the environment may only increase the discharge of NPS pollutants in urban areas. Therefore, it is necessary to pay close attention to construction and management of a landscape space to secure its function in reducing, not discharging, NPS pollutants (Kim et al., 2008).

(a) Green areas around facilities in urban areas (e.g., schools, buildings, cultural properties, and public buildings) such as street trees, central part of roads, median strips, and plazas are important landscape spaces that can handle NPS pollutants occuring in paved areas.

(b) NPS pollutants can be removed by changing landscape spaces or urban areas into concave type instead of convex type, and making stormwater runoff that occurs on roads and parking lots flow in and undergo infiltration and retention.

(c) When dead plants in landscape spaces in urban areas are discharged to storm sewers in rainfall, they act as organics that cause water pollution; thus, they must be removed by managing the vegetation regularly.

(a) Northwestern High School and University of Maryland (Maryland)

(b) Public agency (flood control agency, Riverside, California)

Figure 5.19 LID/GI applications in schools and public agencies (photograph: Lee-Hyung Kim)

(a) Commercial area (California

(b) Industrial area (Ohio)

Figure 5.20 LID/GI applications in commercial and industrial areas (photograph: Lee-Hyung Kim)

Figure 5.21 LID/GI applications in a residential area in Hyattsvile, Maryland (photograph: Lee-Hyung Kim)

5.4 RESILIENCE AND TRANSFORMATION

5.4.1 Background

Resilience is the capacity of a system, be it an individual, a water body, a city, or a country, to deal with change and to continue to develop. Ecosystem resilience is the capacity of an ecosystem to cope with change and perturbation, such as storms, droughts, and pollution. Loss of resilience in an ecosystem leads to more vulnerable conditions, and possible shifts to undesired states that provide fewer services like water supply, flood control, and water purification. Such loss of resilience can be caused by pollution, climate change, altered freshwater flows, and biodiversity deterioration. Ecosystems show that human-induced stress and over-exploitation of species reduce the resilience capability to storms, droughts, or other events that they have coped with before. When resilience is lowered, even minor disturbances can cause a shift to a state that is difficult, expensive, or even impossible to reverse.

Human-induced environmental changes, from the local to the global scale, have serious impacts on water flows and on the ecosystems. The latter is particularly noteworthy because our earlier perceptions about the stability of ecosystems, and that change is possible to control, have proved false. Today we know that freshwater systems are complex, adaptive, but vulnerable systems. Aquatic ecosystems often do not respond to gradual change in a formulated manner; rather, a stressed ecosystem can suddenly shift from a seemingly steady state to an undesired state that is difficult to reverse (Moberg et al., 2005). The challenge is to live with change without losing important structures and functions in life-supporting ecosystems and in societies. Water is a key element in terrestrial and aquatic ecosystems, and a resource that supports human health, industry, and energy generation. Planetary constraints limit the functioning of a resilient global water system, and there is a reason for a new level of concern over water resources.

5.4.2 Challenge

We have entered a new era, the Anthropocene, in which humanity is the largest driving force for global change. In the past 50 years, trends show a rapid acceleration of human enterprise: wealth, population, globalization, agriculture, and industry. Stress on the biosphere may cause collapses and major shifts on all scales. The ability to generate social and economic well-being for an increasing population is now threatened. Water is at the centre of this change, where events on local scales could be either contributors or receivers of impacts on a regional and global scale shifting (Rockströom et al., 2014).

Despites immense technological development and progress, our economies and societies still fundamentally depend on ecosystems to provide us with a hospitable climate, clean water, food, and numerous other goods and services. It is time to realize fully that our societies and economies are integral parts of the biosphere, and to start accounting for and governing natural capital. Poverty alleviation and future human development cannot take place without such a wider recognition of nature's contribution to human livelihoods, health, security, and culture.

The issue at stake extends beyond climate change to a whole spectrum of global environmental changes that interplay with interdependent and rapidly globalizing human societies. Science and technology has a great responsibility in this aspect to provide a better understanding of the multiple challenges facing humanity and to explore solutions for sustainable development in an increasingly unpredictable world. Resilient thinking is an important part of the solution, as it strives at building a flexible and adaptive capacity rather than attempting to achieve stable optimal production and short-term economic gains. It is time for a new social contract for global sustainability rooted in a shift of perception: from people and nature seen as separate parts to interdependent social–ecological systems (Stockholm Resilience Centre, 2013). This provides exciting opportunities for society's development in collaboration with the biosphere: a global sustainability agenda for humanity.

5.4.3 Status

Resilience is the capacity of a system both to withstand pressures and to rebuild and renew itself if degraded. On a simplistic level, resilience is the ability of a system to maintain its structure and function when subjected to disruptive forces and to have adaptive capacity wherein it could successfully accommodate the impacts of change. Issues of resilience are discussed in the following cases.

Case 1 : Small-scale Water Innovations Break Dry Land Poverty Traps in Tanzania (Stockholm Resilience Centre, 2013)

Improved water management in rain-fed agriculture can build resilience to cope with water-related risks and uncertainties. Conventional solutions have been developed into large-scale irrigation systems, but recent studies in Makanya, Tanzania, have shown that small-scale innovations (e.g., rainwater harvesting, conservation tillage, etc.) have enormous potential for increasing on-farm productivity and ecosystem service output in areas where people live in poverty and are vulnerable to climate change.

Case 2 : Natural Capital Investments in China (Stockholm Resilience Centre, 2013)

Ecosystem service investments in China today are remarkable in their goals, scale, duration, and innovation. Following severe droughts in 1997 and massive flooding in 1998, China implemented several national forestry and conservation initiatives, exceeding US$100 billion over the current decade. Targeted investments aim to secure natural capital and alleviate poverty through wealth transfer from coastal provinces to inland regions, where many ecosystem services originate. Over 120 million farmers are directly involved in programmes with the intention of reducing the loss of soil, reducing desertification, and protecting biodiversity and ecosystems, for example flood control, more productive agriculture, and ecotourism.

Case 3 : Northern Ireland Countryside Management Scheme (NICMS) (NIDARD, 2010)

The NICMS is an agricultural–environmental scheme that began last 2008 under the European Agriculture Fund for Rural Development. It is a voluntary programme that provides financial support to farmers and landowners for adopting farming practices that enhance the countryside to improve biodiversity; improve water quality; climate change mitigation; improve soil quality; and enhance the landscape. Annual payments vary according to farm size and specific natural attributes of farms. The programme aimed to have 50% of agricultural lands under enhancement agreements by 2010. A total of GB£219 million was allocated to this programme for 2008–2013.

Case 4 : The Netherlands Farming for Nature Pilot Program (Voor Natuur, 2010).

This pilot programme is based on the precept that in rural areas there are several ways to unite agriculture, nature, and landscapes. One of those is that farmers who are compensated for managing their land for the benefit of ecosystem services and the natural landscape. One online document reported in October 2008 that water quality was noted as one of the objectives of the pilot project, although it is not clear if this programme would evolve into a fully functioning payment for watershed services programme. As of the publication of this report, there were two operational sites with efforts to bring together the researchers, farmers, civil servants, local residents, and regional planning experts.

Case 5 : The WWF's Danube PES Project (Tracy et al., 2010)

The WWF's Danube–Carpathian Programme has been at the forefront of efforts to promote payment for ecosystem services (PES) as a river basin management policy framework in Europe linked directly with the European Union's Water Framework Directive . Starting in about 2002, WWF began building its capacity in the Danube and using PES as one tool to conserve rural environments and improve rural livelihoods in the Danube Basin, with a focus on the lower Danube and the Danube Delta (Bulgaria, Moldova, Romania, and Ukraine). After a multi-year and multi-stakeholder process, the project's activities began in 2007. The programme is being closely watched by researchers and decision-makers for lessons on how to bring PES programmes to scale such that they deliver actual conservation benefits and economic improvements to the stewards of the region's invaluable ecosystem services.

Case 6 : Korea's "Four Major River Restoration Project"

The "Four Major River Restoration Project" has been initiated to cope with climate change and water security in Korea. The project is prepared to achieve the following five core tasks: a) securing water supply, b) flood control, c) water quality improvement and ecosystem restoration, d) development of spaces for cultural and leisure activities, and e) regional development around four major rivers. After the "Four Major River Restoration Project", the flood management capacity against climate change increased by 920 million tonnes. The expanded water-flow and water-storage areas and reinforced levees make it possible to withstand a 200-year frequency flood. Rivers and streams can have environmental flow (maintenance water) during dry periods of the year by secured water resource. The ecological environment will be improved by eco-river restoration and riparian eco-belts. The project will serve as a guide for the river systems to cope with climate change and to enhance their resilience.

5.4.4 Solution

An ecosystem with low resilience often seems unaffected by human-induced stress and environmental change, until a disturbance causes it to exceed a critical threshold. Such a shift to a less productive state tends to be difficult, expensive, or even impossible to reverse. Water management should be based on the resilience of intertwined human and ecological systems. Humans and ecosystems have to share the same water, so we have to build a society that resiliently adapts to climate change and to develop adaptive co-management.

5.4.4.1 Humans and Ecosystems Sharing the Same Water

Water is a key resource for social, economic, and cultural development. When discussing the looming water crisis, people often focus on the amount of liquid water drawn from lakes, rivers, or groundwater aquifers. However, the water cycle is not only affected by this increased demand for water. Changes in land-cover and climate also affect the amount of water available for drinking, irrigation, and industrial uses (provisioning services), as well as recreation (cultural services), flood control (regulating services), and maintenance of healthy ecosystems (supporting services). As human activities and ecosystems depend on the same water, trade-offs are inevitable. For example, upstream consumption patterns and pollution loads affect aquatic ecosystems and people downstream.

The role of water in global sustainability is a key part and is analysed both in terms of securing water for local development and for the impact of water on tipping points in the earth system. New multi-level, polycentric governance structures and systems are needed to put this perspective into practice. Water needs to be further integrated into human development by including the "ecosystem" component in new water governance. To this end, sharing the water between humans and ecosystems should be strengthened further.

5.4.4.2 Building a System That Resiliently Adapts to Climate Change

The climate will continue to change in the future. No projection of climate change will ever be free from uncertainty. It is essential to build a resilient system that can sustainably adapt to such a changing and uncertain climate. Climate change will have complex and multidimensional implications for the water cycle, water use, and floods. Comprehensive and integrated actions are required, with attention given to all water-related subsectors, including flood management, water use, and water environments; and stakeholders at all levels, including central and local governments, the private sector, non-govermental organizations, and local communities. Such action should be reviewed as appropriate to cope better with a changing climate.

A society's vulnerability will depend not only on a changing climate but also on what type of development is pursued. It is essential to pursue environmental conservation and development in tandem, and put into action the principle of sustainable development that meets the needs of the present without compromising the ability of future generations to meet their own needs. In other words, what is required is long-term sustainable water management that incorporates adaptation to climate change.

5.4.4.3 Developing an Adaptive Co-management

Water quality and ecosystems are the most common natural disturbances affecting human development in recent years. Their effect has been greatly exacerbated by human-induced changes of water flows and ecosystems, as well as by development in vulnerable areas. Moreover, the climate advisory body of the United Nations (the Intergovernmental Panel on Climate Change) has warned that global environmental change will entail increasing climate variability and increasing occurrence of extreme weather events. Instead, new water management strategies are needed that minimize the undesirable effects of climate change and enhance the resilience of vulnerable social and ecological systems.

Movement of freshwater in the landscape, water availability in soils, moisture recycling from forests, and recharging of groundwater are fundamental for the resilience of terrestrial and aquatic ecosystems. Most ecosystems develop around freshwater flows in a process that generates natural resources and ecosystem services in a complex, ever-changing, and unpredictable manner. The realization that this inherent change and uncertainty in nature exists calls for more flexible governance with the ability to respond to environmental feedbacks. That is, we must learn to live with change through an active, adaptive management approach that is diversified and open for renewal.

To develop adaptive co-management, the following factors should be considered. (a) Scope of management widened from a particular issue (floods) to a broad set of issues related to freshwater flows and ecological processes across scales. (b) Management expanded from individual actors to groups of actors. (c) Organizational and institutional structures evolved as a response to deal with the broader set of water and ecosystem issues. (d) Knowledge of ecosystem dynamics developed as a collaborative effort and became part of the organizational and institutional structures. (e) Social networks developed to connect institutions and organizations and to facilitate information flows, identify knowledge gaps, and create nodes of expertise of significance for adaptive co-management within the catchment. (f) Social networks mobilized for knowledge management, which complements and refines local practice and improves the capacity to deal with future uncertainties and surprises (Moberg et al., 2005).

5.4.5 Recommendations

The human imprint on the planet's environment is now so vast that the current geological period should be labelled the 'Anthropocene'—the age of man (Stockholm Resilience Centre, 2013). Human pressure has reached a scale where the possibility of abrupt or irreversible global change can no longer be excluded. We are the first generation with the knowledge of how our activities influence the Earth as a system, and thus the first generation with the power and the responsibility to change our relationship with it. Formulation of new sustainable water management goals can be guided by the 'planetary boundaries' concept, which aims to create a scientifically defined safe water environment within which humanity can continue to evolve and develop.

In the next two to three decades, the world will have to feed another billion people. This will require enormous amounts of water to produce food for an acceptable nutritional level. Clearly, the challenge is to balance water for food and water for nature. Hence, ecosystems must be included in water practice and water included in ecosystems practice to reach sustainable development (Moberg et al., 2005). The overall challenge is to actively strengthen the resilience of ecosystems and local communities – namely their capacity to cope with disturbances and global environmental change – and explicitly recognize the role of freshwater. The key recommendations to enhance water ecosystem resilience are as follows.

(a) Freshwater policy and management should be based on recognition that water systems are complex and adaptive wherein the changes should be in a formulated manner, rather than sudden shifts to both irreversible and less productive states.
(b) Freshwater policy-makers should promote cross-sectoral water management that shifts the focus from human uses of water as a technical issue to the role of water in catchments for the generation of ecosystem and societal services.
(c) Policies should provide incentives for stakeholder participation and incorporate their local ecological knowledge into institutional structures in a multi-level governance system.
(d) Social networks with a wide scope of actors should be developed, aiming to connect institutions and organizations across scales to build trust, facilitate information flows, identify knowledge gaps, and create nodes of expertise for resilient water management.

5.5 DISCUSSION AND CONCLUSIONS

Human activities have caused the significant deterioration of natural assets, resulting in negative impacts on the status of biodiversity/ecosystems and in the provision of ecosystem services. The Global Biodiversity Outlook 4 (CBD, 2014) and OECD Environmental Outlook to 2050 (OECD, 2012) concluded that biodiversity at the global level is declining and will decline with the "business-as-usual" scenario.

Decision-makers demand ever-more information on the economic implications of losing biodiversity/ecosystem services to develop policies and strategies to conserve those services at local, national, regional, and global perspectives. Section 5.2 has tried to establish a classification of freshwater ecosystem services, capture the conceptual links between the different types of total economic value (TEV) and ecosystem services, and examine applicable economic valuation methods. This could provide information for practitioners to understand the conceptual linkages between ecosystem services and economic valuation, and assist in forming common bases for communication among various stakeholders.

Population concentration due to urbanization has severe impacts on settlements, transportation, water quality and resources, energy, and ecosystems. Urbanization distorts natural water circulation systems in rainfall by causing changes of land use in watersheds, and causes high impacts on water quality and aquatic ecosystems by discharging various pollutants. In particular, changes in the hydrological characteristics of watersheds by urbanization damage habitats in the water system. To secure healthy water resources and aquatic ecosystems, it is necessary to reduce the hydrological and environmental impacts of urbanization. The proposed alternative for solving these problems is to apply low-impact development (LID) and green infrastructure (GI). LID is a method that analyses environmental impacts that may occur from the planning stage to operation of various development projects and minimizes them. It refers to establishing a land use plan wherein it secures green spaces that could imitate the natural water circulation, reducing impervious areas, preserving low lands with water as much as possible, and maintaining natural water circulation functions.

LID development has the function of establishing natural water circulation systems, preventing floods, providing biological habitats, purifying pollutants included in stormwater runoff, and preserving and recovering vegetation such as trees. It is necessary to establish and apply technological methods for runoff reduction because, despite the establishment of LID land use plans, non-point source (NPS) pollutants may still leak after development. Soil applied to LID facilities must have good infiltration and retention functions, wherein absorption of pollutants and attached growth of soil microorganisms are possible. Plants applied in LID should have high amount of pollutant absorption, have strong tolerance to salinity, and be able to grow both in dry and in rainy seasons. LID development has various environmental benefits. It establishes a healthy water circulation system, assisting with flood prevention, providing habitats for organisms, purifying pollutants included in stormwater runoff, and preserving and recovering vegetation such as trees. It also can reduce the costs of construction and maintenance of drainage facilities. Furthermore, it can prevent floods, protect biotic habitats, maintain drinking water supply, reduce maintenance costs of facilities for stormwater management, reduce NPS pollutants, and save costs of other social infrastructures such as roads and curbs. It improves the exterior and aesthetic value of the community, thereby increasing the property cost of the site and building while reducing the value of wastewater treatment plants.

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