

Low Carbon Green Growth Roadmap for Asia and the Pacific

[Background Policy Paper]

Water Resource Management:

Policy recommendations for the development
of eco-efficient infrastructure



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Policy recommendations for the development
of eco-efficient infrastructure

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1. Issues on water management

Water is one of the most essential resources for the humans and the ecosystems. However, the continued increase of population due to urbanization is causing a severe decline in the amount of available water resources. Urbanization has had many adverse effects on our environment. Cities replace natural vegetation with pavement for roads, buildings, and other structures necessary to accommodate growing populations. As a result of the urbanization, water and heat cycles are distorted, leading to many problems such as water scarcity, urban flood, groundwater depletion, and heat island phenomena as shown in Figure 1.1 In addition, the temperature of urban area increases, resulting in an increase of energy consumption for cooling. Water management is one of main parts in energy consumption. It was reported that 2 to 3 % of total energy in the world is used to secure and supply of water resources.

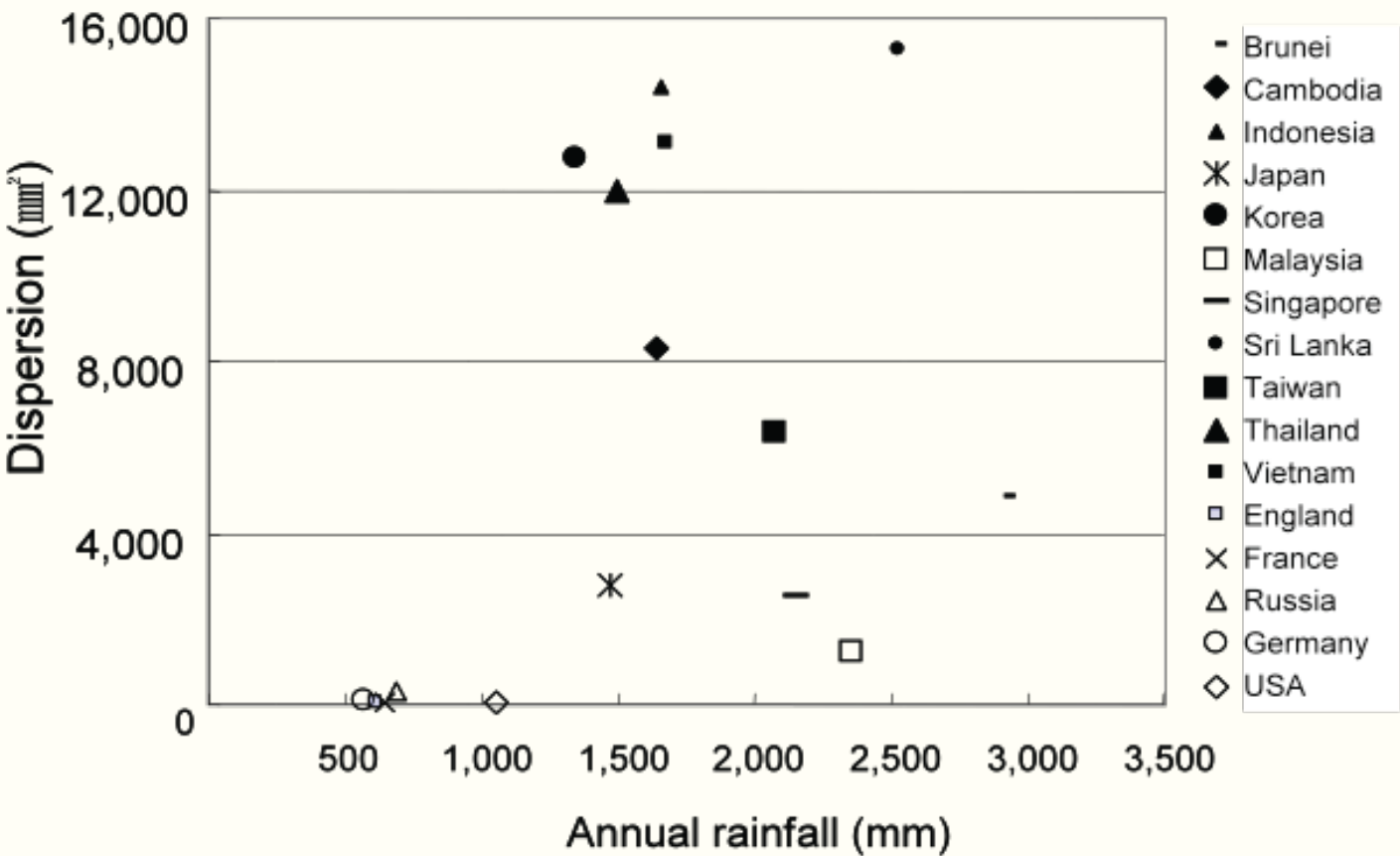
Figure 1.1 Impacts of urbanization on water management



It is also predicted that there is strong impact of global climate change on the availability and variability of water resources. The present experience of many communities in climate variability and the looming climate change has become not just a perceived threat but a real one measured in terms of losses. Consequently climate change results in higher temperature, more rain, extreme weather, and rising sea-levels, which create serious problems in our life.

Figure 1.2 shows the average amount and dispersion of annual rainfall in selected Asia-Pacific, European, and North American countries. Most countries in Asia-Pacific have higher annual rainfall, and the dispersion is higher than in most developed countries. The Asia-Pacific region is home to the majority of the poor and hence plays a pivotal role in the achievement of Millennium Development Goal (MDG) targets. Around 60 % of the world's populations underserved by water live in this region. In Asia-Pacific, 700 million people live without adequate water and at least 1.9 billion people without adequate sanitation under poor water management infrastructure. That means the water management in these areas is more difficult and explains the severe damage occurring in this region each year. We have to be very careful in adapting the technologies and management skills.

Figure 1.2 Average annual rainfall and dispersion for selected countries



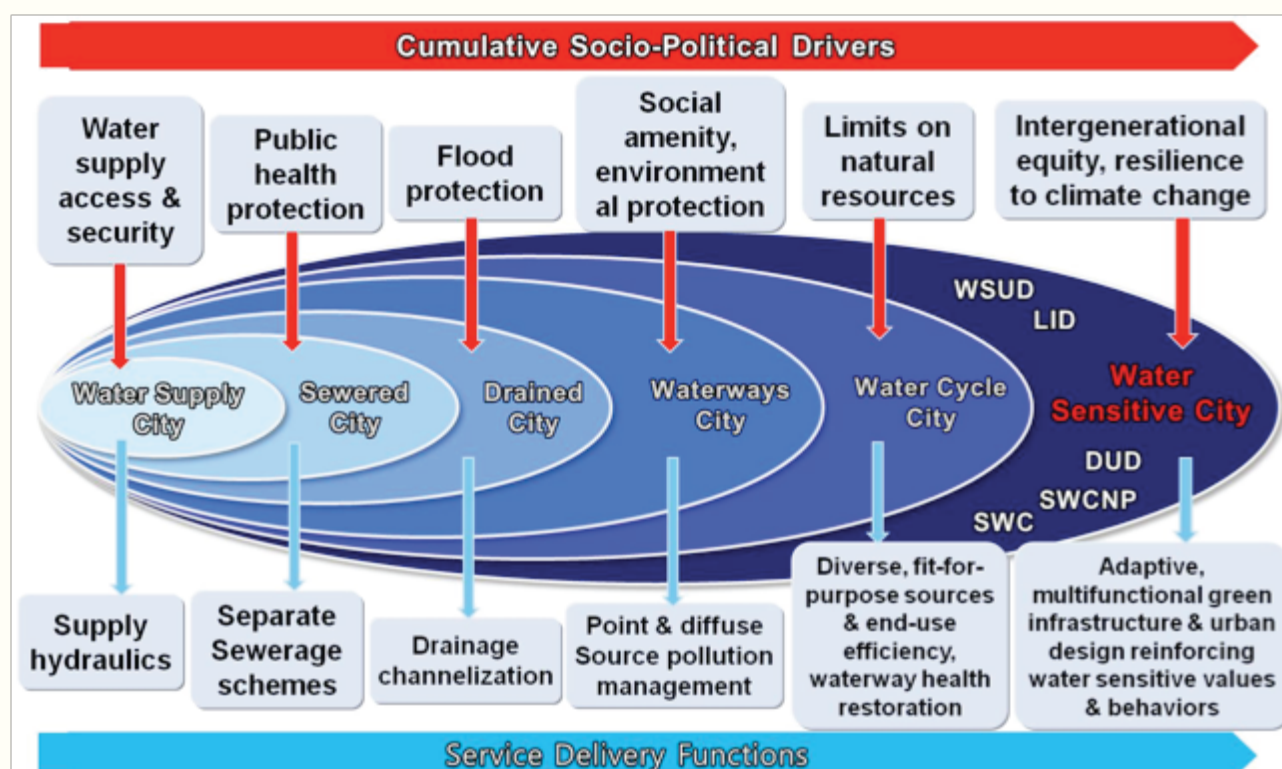
Data from www.worldweather.org (1961~1990)

2. New approaches in water management

2.1 Urban water management transitions framework

The continued increase of population is causing a severe decline in the amount of available water resources. The present experience of many communities in climate variability and the looming climate change has become not just a perceived threat but a real one measured in terms of losses. New approach in water management is urgent to address those water related problems and supplement the limitations of existed water management system. It should have functions to restore water and heat cycles in urban areas, that is, to restore hydrological cycle by promoting infiltration and evaporation, to secure water resources, to alleviate heat island phenomena, to prevent urban flood, and to conserve and restore the ecosystem. Figure 2.1 shows urban water management transitions framework (Brown et al., 2009).

Figure 2.1 Water management transitions framework (Brown et al., 2009)



The transitions framework is composed of six city states such as the “Water supply city”, the “Sewered city”, the “Drained city”, the “Waterways city”, the “Water cycle city”, and the “Water sensitive city”. The first two transition states, the “Water supply city” and “Sewered city” has features such as the effective provision of safe and secure water supplies and public health for a growing urban population. Water supply city adopted the planning, design, construction and management of centralized city water supply schemes including the extraction of large quantities of water through building dams and pipe systems. Sewered city involved the design and construction of a reticulated sewerage system to dispose of waste effluent outside cities, and often to receiving waterways that were perceived as environmentally benign. Drained city has emphasis on rapid and efficient conveyance of stormwater out of cities to receiving waterway environments. In the drained city, from a community perspective stormwater was largely viewed as a nuisance. Services were delivered by the centralized water supply and sewerage authorities and over time also by local authorities. Waterways city considers social amenity and environmental protection by point and diffuse source pollution management. From the waterways city, water began to be integrated into planning functions as important visual and recreational features for communities, and measures were taken to reduce pollutant inputs into waterways. Although the progress towards waterway cities, there remain still fundamental problems that cannot be solved by the centralized technologies due to people’s poor understanding about their ongoing management and operation under dispersed

accountabilities. Water cycle city emphasizes restoration of natural water cycle and integrated water management. Restoration of water cycle involves water conservation and finding fit-for purpose diverse water supplies (from sources of varying quality – rainwater, stormwater, groundwater, sewage, seawater – matched to the most appropriate uses – potable, irrigation, industry, household) at a range of scales that are also sensitive to the energy and nutrient cycles and ultimately contingent on protecting waterway health.

Currently water management emphasize the sound, sustainable and decentralized stormwater and rainwater management such as Low Impact Development (LID) for USA, Decentralized Urban Design (DUD) for Germany, Water Sensitive Urban Design (WSUD) of Australia, Sound Water Cycle on National Planning (SWCNP) for Japan and Smart Watergy City (SWC) for South Korea (See Table 2.1). Those measures have similar concepts with on site rainwater and stormwater management and source control. They also would integrate the normative values of environmental repair and protection, supply security, flood control, public health, amenity, economic sustainability, energy consumption reduction and climate change adaptation, amongst others. The LID is the representative concept among those present water management approaches.

Table 2.1 Current status of water management approach

Classification	Concept	Characteristics
South Korea	SWC (Smart Watergy City, U-Eco City,)	<ul style="list-style-type: none"> ·Water management based on ubiquitous ·Construct of ecosystem using green energy and technology ·Watergy: water, energy & ecology
U.S.A.	LID (Low Impact Development)	<ul style="list-style-type: none"> ·Management of pollution sources and rainwater management based on green land ·BMPs (Best Management Practices) ·WQCV (Water Quality Capture Volume) ·GI (Green Infrastructure) ·Smart Water Grid
Australia	WSUD (Water Sensitive Urban Design)	<ul style="list-style-type: none"> ·Rainwater management adaptable to climate change ·Management and using of stormwater runoff
Germany	DUD (Decentralized Urban Design)	<ul style="list-style-type: none"> ·Decentralized rainwater management by arcology ·Management and using of stormwater runoff
Japan	SWCNP (Sound Water Cycle on National Planning)	<ul style="list-style-type: none"> ·Sound water cycle by rain water management ·Reduction of stormwater runoff ·Detention and infiltration in watershed

2.2 LID approach

2.2.1 Introduction of LID

Low impact development (LID), as defined by Washington State University's Puget Sound Action Team, "is a stormwater management strategy that emphasizes conservation and the use of existing natural site features integrated with distributed, small-scale stormwater controls to more closely mimic natural hydrologic patterns in residential, commercial and industrial settings." LID practices are measures to mitigate the impacts of development and urbanization. LID techniques focus mainly on site-specific hydrology since every aspect of site development affects the hydrologic response of the site. Thus, the primary goal of LID methods is to mimic the undeveloped site hydrology using site-design techniques that store, infiltrate, evaporate, and detain runoff. Key LID concepts are as follows (Emily Ayers et al., 2011):

- ① Mimic natural drainage
- ② Use small scale practices
- ③ Manage stormwater at the source
- ④ Maximize storage, infiltration, evapotranspiration, and detention of runoff
- ⑤ Use simple, natural practices
- ⑥ Make landscape and infrastructure multifunctional

The effects of LID approach is described with hydrographs in Figure 2.2 to Figure 2.5. Figure 2.2 illustrates the hydrologic response using LID techniques to reduce the impervious areas and increase the storage volume. The outermost hydrograph represents the response of a post development condition with no stormwater management. The resultant hydrograph shows a decrease in the time to reach the peak runoff rate, a significant increase in the peak runoff and discharge rate and volume, and increased duration of the discharge volume. The hydrograph just below the outermost one represents the resulting post development hydrograph using the LID techniques to reduce impervious area and increase storage volume. There is a reduction in both post development peak rate and volume. In Figure 2.3, the middle hydrograph represents the effects of the LID techniques to maintain the Time of concentration. This effectively shifts the post peak runoff time to that of the predevelopment condition and lowers the peak runoff rate.

Figure 2.2 Hydrographs in the development with reduced or disconnected impervious areas (Emily Ayers et al., 2011)

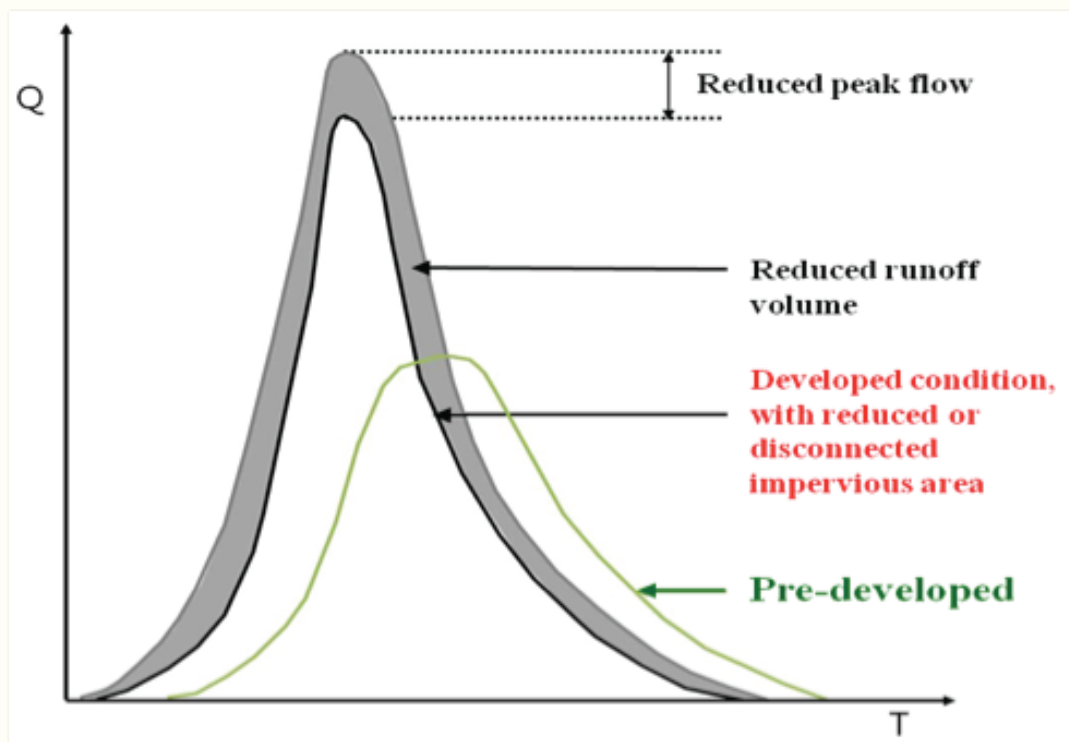
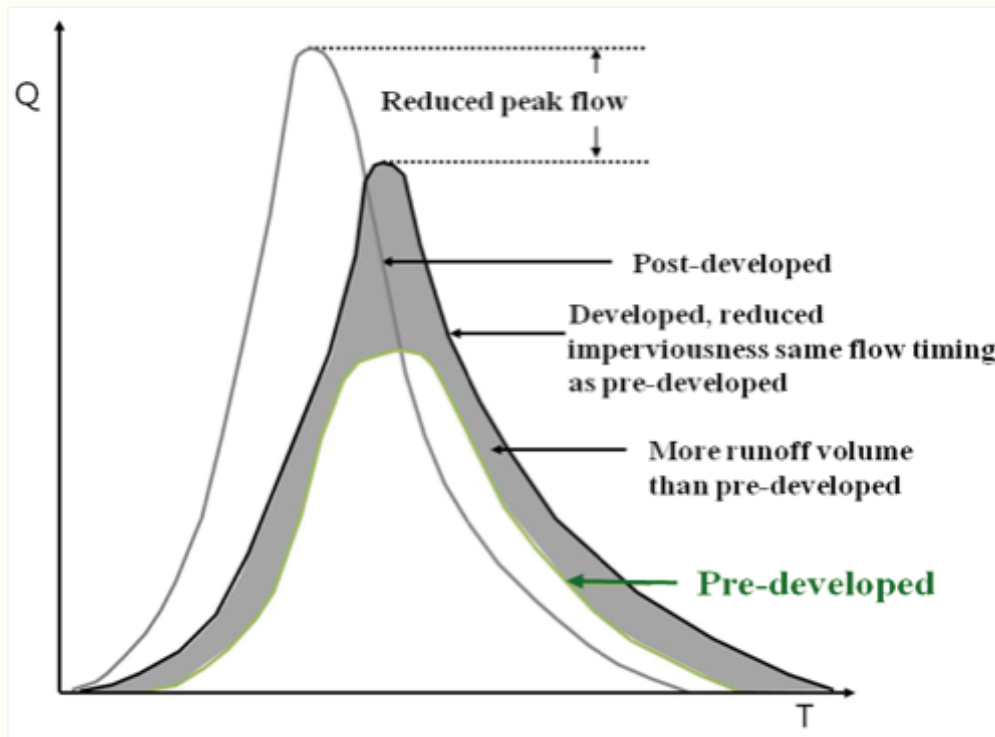


Figure 2.3 Hydrographs in the development with scattering runoff flow (Emily Ayers et al., 2001)



In Figure 2.4, retention storage allows for a reduction in the post development volume and the peak runoff rate. The increased storage and infiltration capacity of LID approaches allows the predevelopment volume to be maintained. Figure 2.5 illustrates the effect of providing additional detention storage to reduce the post-development peak discharge rate to predevelopment conditions.

Figure 2.4 LID with supplemental detention (Emily Ayers et al., 2011)

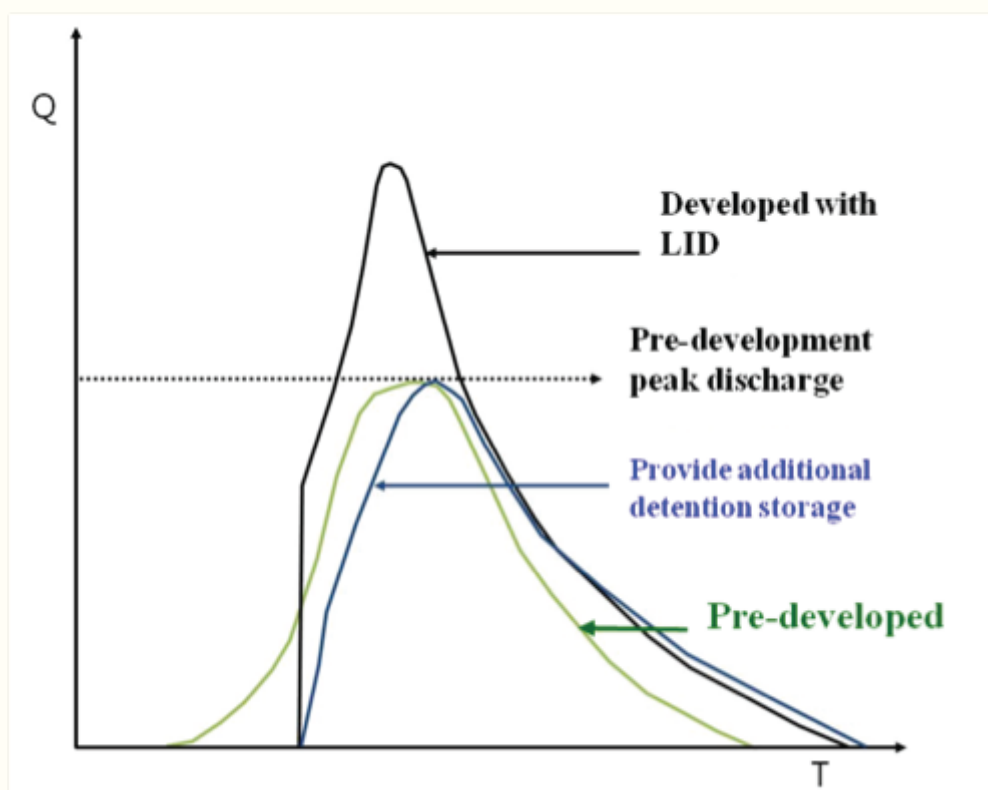
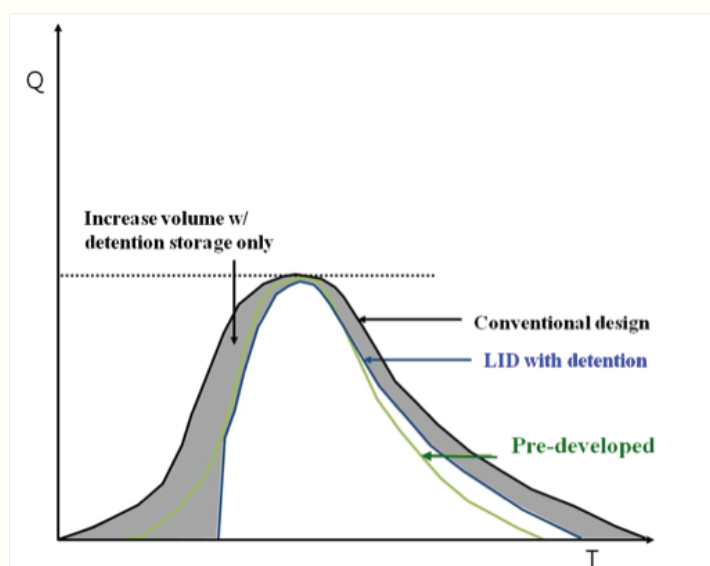


Figure 2.5 Comparison of Hydrographs (Emily Ayers et al., 2011)



2.2.2 Comparison between conventional and LID approaches

LID takes a very different approach to water management as compared to conventional stormwater strategies. Conventional methods aim to move water off-site and into the storm drains as quickly as possible, while LID seeks to do just the opposite—keep as much water on-site as possible for absorption and infiltration. Instead of large, centralized treatment plants and water storage facilities, LID emphasizes local, decentralized solutions that capitalize on the beneficial services that natural ecosystem functions can provide. LID also focuses on controlling urban runoff and pollution right at the source, rather than at the end of the storm drain outlet. For example, a landscaped area may rely on natural soils to simultaneously absorb stormwater, filter out contaminants, and recharge the groundwater supply. The comparison between conventional and LID approach is presented in Table 2.2. A comprehensive approach to LID should include city-wide land development strategies and planning along with the creation of infrastructure for stormwater management.

Table 2.2 Conventional vs LID approach

Category / Characteristic	Conventional approach	LID approach
Project goal	Single purpose	Multiple benefits
Benefits to the ecosystem	Low priority	High priority
Structure	Concrete, steel, human-made, “hard”	Landscape/aquatic features, natural “soft”
Energy source	Fossil fuel combustion, electricity	Solar, gravity, plants, animals
Material movement mechanisms	Pumps, blowers, conveyors	Convection/gravity, plant/microbial process
Process	Human-driven, human-regulated	Natural, self-regulated
Climate and landscape setting	Relatively unimportant	Critical
Useful lifespan	Relatively short	Relatively long
Performance	Controlled	More variable
Robustness	Often low	Usually high
Operation & Management costs	High	Low
Land requirements	Low	High

2.2.3 Current practices

1) South Korea

Green growth is a policy focus for Korean government, which emphasizes environmentally sustainable economic progress to foster low-carbon, socially inclusive development. It implies the conversion to system with low carbon, high efficiency, and clean environment. Framework act on low carbon, green growth was enacted in April, 2010 to promote the development of the national economy by laying down the foundation necessary for low carbon discharge and green growth. Ministries have prepared and implemented green growth plans and strategies. Now that the national initiative is realigned to meet the goals, and the policies of ministries are pursuing those goals as well, we should examine how the roles and responsibilities of participants are defined to ensure the effective implementation. Ministry of Land, Transportation & Maritime Affairs (MLTM) has established 3 objectives and strategies for green growth aiming to take a national leadership for green growth. The ministry has pushed for green house gas (GHG) reduction and major river restoration strategies for the climate change adaptation and energy independence while promoting green transportation and green jobs for creating green growth dynamics.

Ministry of Environment (ME) aims to create green wealth prosperity through environmental innovation, and to promote strategies to reduce carbon emission, develop new environmental technologies and industries, create new jobs and human resources, and promote environment-friendly lifestyle. The government of South Korea suggested LID approach as a national environmental policy to implement these policies (Park et al, 2008). The necessity of LID measures is increasing due to waterside urban development by the special act and guideline on the development of waterfront area.

Table 2.3 Object and action plans of MLTM (South Korea)

Objectives		Action Plans
Climate change adaptation & Energy independence	Low-carbon society	<ul style="list-style-type: none"> · Building emission statistics system · Drawing emission reduction strategies
	Energy independence	<ul style="list-style-type: none"> · Low-carbon, high efficient transportation · Energy-efficient buildings with energy saving in existing building
	Climate change adaptation	<ul style="list-style-type: none"> · River restoration project, eco-friendly dams · Flood maps and advanced dam functions · Sea level prediction & countermeasures · Maritime energy techs & resource utilization
Growth Dynamics	Developing green techs to growth dynamics	<ul style="list-style-type: none"> · Water processing projects · Promoting green transportation industry · Expand green city infrastructure
	Green industries	<ul style="list-style-type: none"> · Green buildings all thru the lifecycle
	Green Economic infrastructure	<ul style="list-style-type: none"> · Green building grades & certification · Creating green jobs
Increasing quality of life & nation's position	Green land & transportation	<ul style="list-style-type: none"> · Urban planning for green city · Low-carbon, eco-friendly new towns · Requirements for energy saving construction · Supplying 2 million green homes · Faster public transportation system · Green port & green airport · Green distribution partnership & certification · Promoting bicycle use
	International leadership	<ul style="list-style-type: none"> · Supporting developing countries develop and manage water resources

Table 2.4 Object and action plans of ME (South Korea)

Objectives		Action Plans
Carbon zerorization	GHG emission control	<ul style="list-style-type: none"> · Recycling wasted resources & biomass · Create environment & energy town · Energy independence & mapping weather resources
	Climate change adaptation	<ul style="list-style-type: none"> · Monitoring national climate change · Developing climate change scenarios and prediction models · GHG emission statistics & evaluation · Climate change maps & impact assessment
Green growth	10 Environmental techs	<ul style="list-style-type: none"> · Water processing & purification techs · Green car & bio-resource/ climate change countermeasure/ eco-friendly products/ GHG substitutes/ environmental techs/ high efficient resource recycling
	10 Environmental industries	<ul style="list-style-type: none"> · Plant business/ soil purification/ green car/ bio resources/ carbon market/ environmental consulting service
	Green infra & green leadership	<ul style="list-style-type: none"> · Education on green growth · Governance for green growth · Hosting international forum & organization · South-North collaborative projects
Green jobs	Green new deal project	<ul style="list-style-type: none"> · Waste water recycling/ BTO/ Blue-green cleantoria projects/ restoring dredging area
	Human resources	<ul style="list-style-type: none"> · Human resource & creating jobs · Establishing university & graduate school
Life style	Environmental & weather service	<ul style="list-style-type: none"> · Increasing urban amenity/ clean and safe water supply/ improving local water supply system/ accurate weather forecast
	Public health care	<ul style="list-style-type: none"> · Preventing disease · Eco-friendly healthcare service · Expanding eco-friendly playground · Improving air quality in subway station

2) U.S.A. (LID)

LID is a term that is used to describe de-centralized stormwater management. Rather than traditional “pipe and pond” practices that capture water from large drainage areas and store it in a large pond, releasing it gradually, LID techniques are smaller scale, on-lot practices distributed across a development site. Previously, LID techniques did not count directly towards the stormwater treatment requirements for a site and were used sparingly by developers. Despite this, several developers have incorporated these practices in Bowie projects, and some of them are profiled here. Initially developed and implemented by Prince George’s County, Maryland, in the early 1990s as an innovative way to handle stormwater runoff, LID techniques have rapidly spread across the country. Prince George’s County, Maryland has pioneered several new tools and practices in LID. The Prince George’s County Maryland Department of Environmental Resources Programs and Planning Division (PGDER) created two publications: 1) Low Impact Development Design Strategies: An Integrated Design Approach (EPA 841-B-00-003), and 2) Low-Impact Development Hydrologic Analysis (EPA 841-B-00-002). These publications describe how LID can achieve stormwater control through the creation of a hydrologically functional landscape that mimics the natural hydrologic regime.

The overall goal of LID stormwater treatment is to mimic pre-development hydrologic conditions through the use of a variety of structural and nonstructural practices that detain, retain, percolate, and evaporate stormwater. This publication is not intended as a comprehensive guide to LID stormwater treatment strategies but merely aims at providing an overview of alternative stormwater management practices and technologies (City of Bowie Low Impact Development Practices, http://www.cityofbowie.org/GreenBowie/documents/low_impact_devel_brochure.pdf).

3) Australia (Water Sensitive Urban Design, WSUD)

WSUD was first referred to in various publications exploring concepts and possible structural and nonstructural practices in relation to urban water resource management during the early 1990s. The emergence of WSUD in Australia is part of a wider movement at an international level towards the concept of integrated land and water management. In its broadest context, WSUD encompasses all aspects of integrated urban water cycle management, including the harvesting and/or treatment of stormwater and wastewater to supplement non-potable water supplies. To date, individual WSUD demonstration projects partially address planning and design issues associated with fully integrating the urban water cycle. Collectively, the projects highlight the full potential for WSUD. WSUD aims to minimize the impact of urbanization on the natural water cycle, and its principles can be applied to the design of a single building or to a whole subdivision. The design of integrated water management systems is evolving towards a practical balance between traditional and WSUD approaches. Whelans et al. (1994) defined the objectives or desirable outcomes of WSUD as:

① To manage a water balance

- Maintain appropriate aquifer levels, recharge and stream-flow characteristics in accordance with assigned beneficial uses
- Prevent flood damage in developed areas
- Prevent excessive erosion of waterways, slopes and banks

② To maintain and, where possible, enhance water quality

- Minimize waterborne sediment loading
- Protect existing riparian or fringing vegetation
- Minimize the export of pollutants to surface or groundwater
- Minimize the export and impact of pollutants from sewage

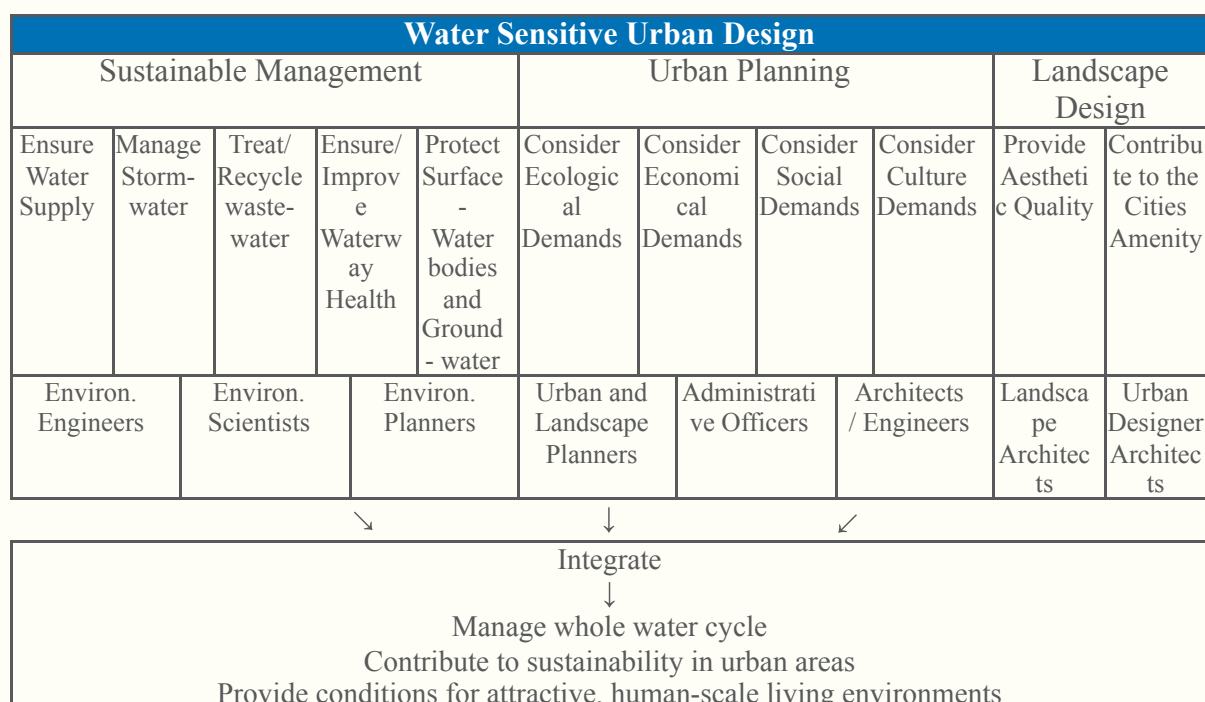
③ To encourage water conservation

- Minimize the import and use of potable water supply
- Promote the reuse of stormwater
- Promote the reuse and recycling of effluent
- Reduce irrigation requirements
- Promote regulated self-supply

④ To maintain water related environmental values

⑤ To maintain water related recreational values

Table 2.5 Components of Water Sensitive Urban Design (Lloyd, 2001)



4) Singapore

Singapore has a unique political driver to ensure that its water consumption becomes self-sufficient and will not have to rely on sources from Malaysia. It has a population of 4.4 million people on an island with a land area of 700 km². High population density and low land area means that it is considered to be a water-scarce country. While it was still a British colony, Singapore signed long-term agreements with the Malaysian Government in 1961 and 1962 to import water. Malaysia committed to sell 350 million gallons per day (MGD) to Singapore at a price of less than one Singapore cent per 3,785 L. This accounted for all Singaporean water demand. The agreements run to 2011 and 2061 respectively. However, the two Governments cannot agree on terms of a new agreement, the main issue being that of price. As a result of the stalemate and other water security issues, Singapore has decided to embark on a program to ensure it will become self-sufficient. This situation means that Singapore has been forced to review all possible sources of new water, coupled with better, more efficient use of water and demand management. The Public Utilities Board (PUB), a Government owned utility, manages the country's entire water cycle and has developed and implemented a holistic policy, referred to as the 'Four National Taps', which covers:

- ① Increasing the water available from the local catchment area, including the construction of the new Marina Barrage to create a freshwater reservoir with a land area of 10,000 ha
- ② NEWater – a reclaimed water plant that was built to take wastewater and treat to a level that can be reused in industry and commerce using microfiltration (MF), reverse osmosis (RO) and UV disinfection. The treated water does not get used directly for drinking, but does feed one of the reservoirs for indirect potable reuse (IPR)
- ③ Imported water – the existing agreements will mean that Singapore continues to purchase water from Malaysia
- ④ Desalinated water – new desalination plants are planned

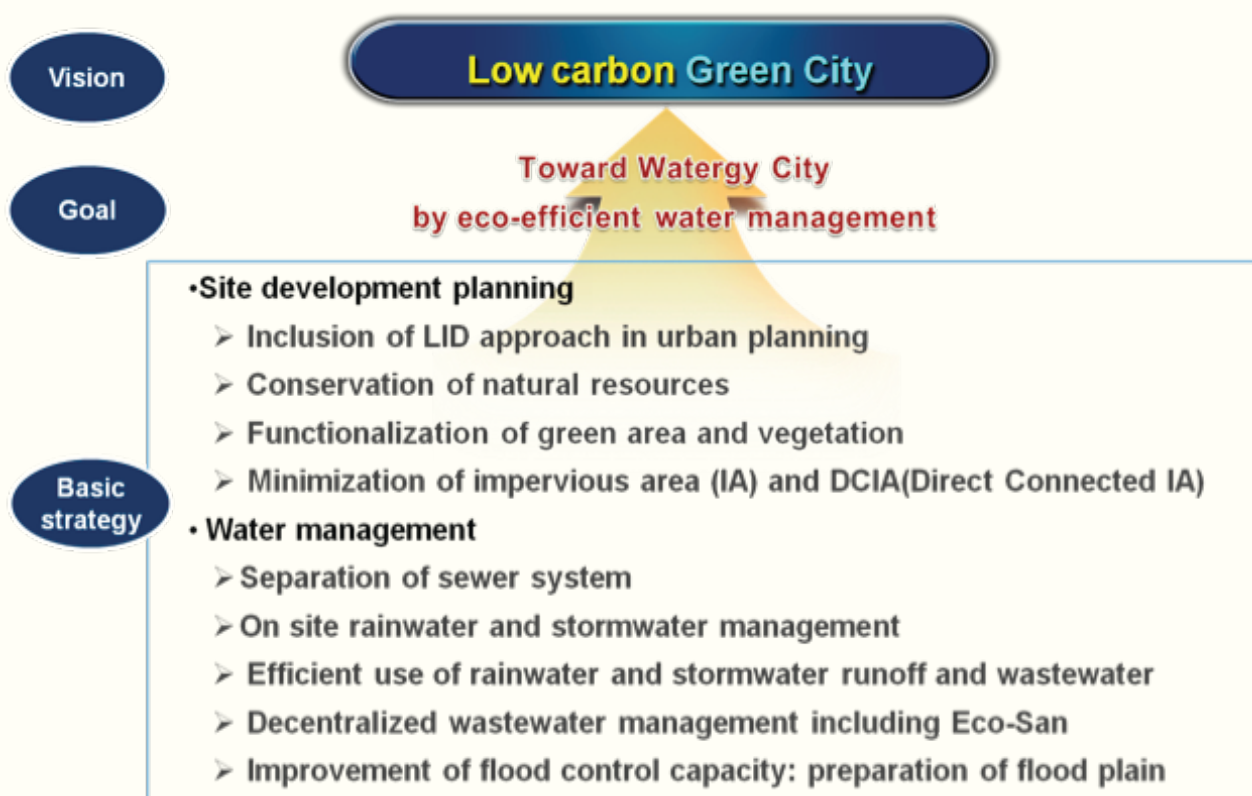
Overlaying all these policies is very active community participation and education and R&D programs. The country is now fully sewerred and has constructed separate stormwater and foul water sewerage systems to facilitate wastewater reuse.

2.3 Eco-efficient water management based on LID approach

2.3.1 Vision and goal

Although LID approach is a representative water management strategy to adapt climate change and mitigate the impact of urbanization, site specific conditions such as climate, social infra structure and public awareness should be considered to achieve the goal, watery city by Eco-efficient water management (EEWM), and the vision, Low Carbon Green City (see Figure 2.6).

Figure 2.6 Vision, goal and Strategy to achieve EEWM for Low carbon Green city



Watery is a word composed of water, energy and ecology. Therefore Watery city pursuits EEWM considering restoration of ecosystem and efficient energy consumption and production. The vision and goal can be achieved by setting a proper strategy related to site development planning and water management infrastructure (also see Figure 2.9). Strategies for establishment of eco-efficient water management system are described in next session of (2) strategy in details.

2.3.2 Strategy

1) Site development planning

① Encourage conservation measures: conservation of natural resources

- Implement Open Space or Cluster Development Regulations to preserve large tracts of the site,
- Implement "Site Fingerprinting" to minimize land clearing & soil disturbance,
- Minimize soil compaction,
- Provide low maintenance landscaping & plant native species which will minimize the use of fertilizers and pesticides,
- Use Source Erosion Control measures.

② Functionalization of green area and vegetation

- Maintain Pre-Development Time of Concentration by long flow paths on vegetated Surfaces,
- Minimize the extent of flow on impervious surfaces,
- Maintain and encourage overland flow conditions across vegetated areas
- Maintain pre-development infiltration rates by preserving those soils with moderate to high infiltrative capacities,
- Maintain existing vegetation to Maximum Extent Practical,
- Remove pollutants from runoff by flow thru vegetated systems, allow natural infiltration to occur,
- Encourage the use of rain gardens for roof runoff,
- Encourage the use of rain barrels or cisterns to collect & reuse runoff.

③ Minimization of impervious area and DCIA

- Compact city to secure more green area and less conveyance of water and energy
- Disconnect impervious coverage to the maximum extent practical to encourage overland flow conditions across vegetated surfaces: runoff from impervious area → pervious area → porous runoff pipe → reservoir → river,
- Reduce pavement widths for local roads,
- Use Permeable Pavement, Porous Concrete, and Open Course Pavers for parking areas and other low traffic areas,
- Use Porous Concrete for sidewalks.

2) Water management

① Strategy by sewer systems

Sewer system	type	Pollution Load	Strategy
No	-	High	Septic tank installation
		Low	Drainage or reuse after treatment through soil filtration, wetland, membrane process, etc.
Combined!	-	High	Conveyance or recovery of nutrient or energy
		Low	Reuse after treatment through soil filtration, wetland, membrane process, etc.
Separated	Sanitary	High	Conveyance or recovery of nutrient or energy
		Low	Reuse after treatment through soil filtration, wetland, membrane process, etc.
	Storm		Porous storm sewer system

* On site rainwater and stormwater management is included in above all cases

② On site rainwater and stormwater management

- Mimic the onsite undeveloped site hydrology using site-design techniques that store, infiltrate, evaporate, and detain runoff
- Improvement of thermal conditions in urban area by enhancing vegetation and evapotranspiration
- Use heat and potential energy from water resources

③ Efficient use of rainwater and stormwater runoff and wastewater

- Stormwater harvesting as well as rainwater harvesting for flood control and water supply
- Greywater and wastewater reuse
- Multi pipe system

④ Decentralized wastewater management including Eco-San

- Distributed wastewater treatment
- No mix or dry toilet

⑤ Improvement of flood control capacity:

- Preparation of flood plain
- Distributed rainwater and stormwater tank installation in the project site to minimize or omit downstream detention basin for flood control
- Combination of infiltration and storage

⑥ Pollution prevention

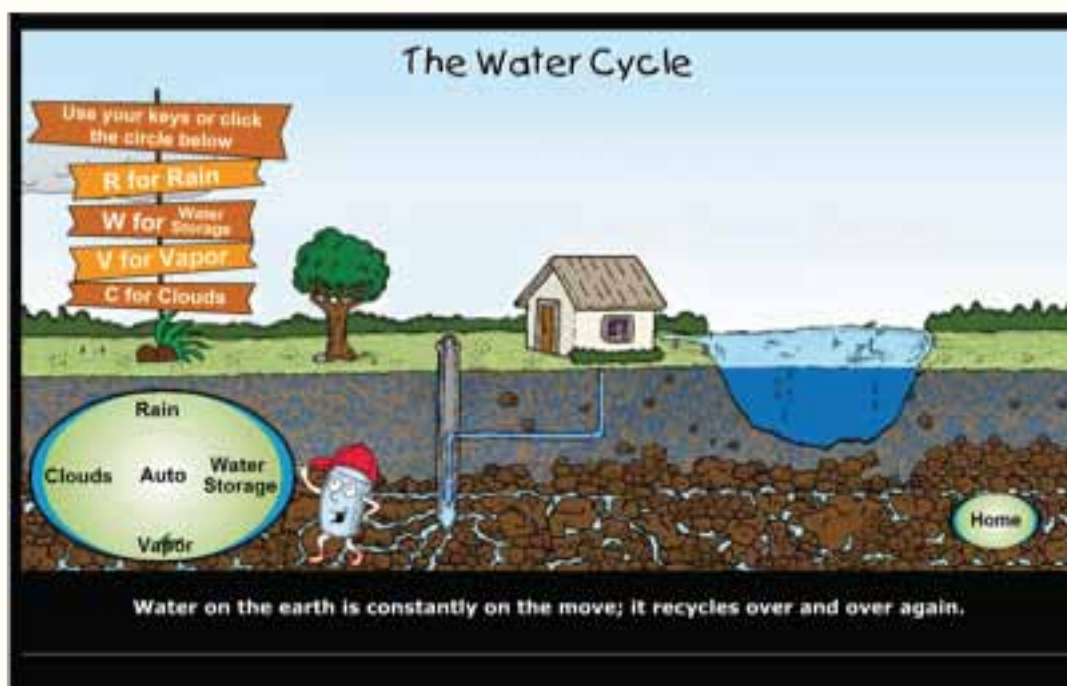
- Minimize applications of sand and salt on roads & parking areas,
- Use “Source Controls” such as weekly sweeping of large impervious areas,
- Minimize application of fertilizers on turf areas.

3) Public involvement (Education program)

- Public awareness is one of key factors to achieve the goal of eco-efficient water management
- (examples of websites) Drinking Water & Ground Water Kids' Stuff | Drinking Water | Interactive water cycle | US EPA (<http://water.epa.gov/learn/kids/drinkingwater/index.cfm>)



- (examples of websites) Drinking Water & Ground Water Kids' Stuff | Drinking Water | Interactive water cycle | US EPA (http://www.epa.gov/safewater/kids/flash/flash_watercycle.html)



3. Policy options

3.1 Rainwater & stormwater harvesting

3.1.1 Key messages

The original concept of rainwater harvesting (RH) is to secure a new water resource in addition to conventional ones. Thus, the primary purpose was to capture and store rainwater for non potable use. The planning and installation of RH system were mainly implemented in individual house or building. Nowadays it has been expended to stormwater harvesting. Recently changes in precipitation, combined with rising temperatures, have impacts on water availability, water quantity, and flooding. Rainwater and stormwater harvesting (RSH) is intended to mitigate urban water flooding, conserve water, control non-point source pollution, restore hydrologic cycle, and alleviate urban heat island phenomena. The RSH have potential to mitigating water problems related to climate changes.

RSH systems capture rain and runoff water over a collection area, channel and store it, either in the soil for agriculture or in containers for household and other use. All stakeholders should be involved using participatory approaches in the planning and implementation of RSH systems. Effective RSH systems can help supply water to beneficiaries throughout an entire year even with minimal rainfall. It is needed to use local knowledge and new technologies for RSH, i.e. RSH is not a new concept for many places in the world, but new technologies may be able to enhance current systems. RSH should also involve local resources, i.e. materials and labor, for the creation of or improvements to RSH systems

3.1.2 Description of the policy

1) South Korea

RSH is one of major technologies for LID implementation because it is an important means for sustainable infrastructure and water-resources. The first law to promote Rainwater harvesting and management (RHM) in Korea is the "Water Law" (2001), which forces sport facilities with roof area larger than 2,500 m² to have rainwater harvesting systems (Han and Park 2005). Under this law, four world cup stadiums in Korea have equipped with rainwater harvesting systems. Since then, a number of RHM projects have been preceded by government authorities together with the development of new policies and regulations. In 2010, the Ministry of Environment announced a new law ("the law to promote and support water reuse"), which enforces the installation of rainwater harvesting system for non-potable use. The paradigm of RHM is continuously changing. Now it is changed to the integrated management of rainwater, which is intended to mitigate urban water flooding, conserve water, control non-point source pollution, restore hydrologic cycle, and alleviate urban heat island phenomena.

As of July 2010, there are 659 RHM systems in Korea, which are currently being operated or planned. Most RHM systems are located near Seoul Metropolitan Area, including 520 facilities in Seoul City and 48 facilities in Gyeonggi-Do. Nearly 30% of total RHM systems were installed in housing complexes and 21% were installed in schools. On the other hand, 26% of total RHM systems were constructed only for stormwater runoff control. Currently, the collected rainwater is used for cleaning, irrigation, firefighting, and toilet flushing. The usage patterns are different for different types of the sites. For example, the purposes of rainwater storage in housing complex are fire-fighting (36%), irrigation and gardening (34%), and cleaning (30%) but those in schools are and gardening (50%), cleaning (19%), toilet flushing (16%), spaying to playground (11%), and fire-fighting (4%). This is attributed to the differences in rainwater catchment, storage, and water usage pattern. Table 3.1 summarizes the activities related to RHM by central government in Korea.

Table 3.1 Activities related to RHM by Korean government

Authorities	Projects and policies
Ministry of Education & Science Technology	Green School Project · Investment of 800 billion won from 2009 to 2012 · Application of environmentally friendly techniques such as green space and rainwater harvesting
National Emergency Management Agency	Project for Rainwater Storage and Infiltration · Investment of 350 billion won to establish facilities for rainwater storage and infiltration during 2009 ~ 2014 · Revised supplementary budget (14.8 billion won) in 2009
	Support on Rainwater Storage System in Busan · Storage size of 45,000m ² in public families and parks · Investment of 12 billion won for establishing the system (total 20 billion won)
Ministry of Environment	Law to Promote and Support Water Reuse (2010) · Widespread application of rainwater harvesting facilities

The policy development by municipalities is much more active than that by the central government in Korea. Before 2003, there was no ordinance for RHM. Total 26 ordinances were adopted between 2004 and 2008 while additional 19 ordinances were adopted between 2008 and 2009. As of July 2010, there are currently 47 ordinances for RHM by the municipalities. This reflects the increasing interest in RHM by municipalities in Korea. Depending on the final purpose, they can be classified into three categories: rainwater use, rainwater use and flood control, and rainwater management for sound water cycle. The early ordinances by the municipalities aim at rainwater storage and use rather than infiltration and runoff control. Other municipalities such as Seoul, Daejeon, and Incheon Cities extended their ordinances to flood control by rainwater storage and infiltration. The main goal of these ordinances is to mitigate the urban water flooding and the secondary one is to conserve water, leading to the safety of a city and the well-being of citizens. The final type of the ordinance, which Suwon City announces in 2009, focuses on the integrate water management for restoring hydrologic cycle. The ordinance promotes the collection and utilization of rainwater in an integrated way to get benefit by increasing reliability of water supply, reducing the risk of inundation by sudden heavy rainfall, reducing energy consumption.

There are various types of incentives in these ordinances. For example, Seoul City provides a financial support for the installation of RHM system up to 10 million won while Jeju Island subsidizes up to 80% of total installation cost. Other municipalities reduce the cost of tap water and/or wastewater treatment for people who use rainwater. Some municipalities give a higher floor space index (FSI) allowances to the buildings with RHM systems.

2) Japan

Japan experienced an abnormal drought in 1994. Also, water supply difficulties after the Great Hanshin-Awaji Earthquake in 1995 raised the importance of securing water supplies from the viewpoint of disaster preparedness. These experiences accelerated a large number of municipalities to re-evaluate importance of RSH in the last decade. Their aims include finding alternative water resources, preventing urban flooding and securing emergency water for disaster-responses. They are settling on the ordinance and the guideline according to the local conditions and are trying to promote the rainwater storage and harvesting positively. More than 60 municipalities subsidize the installation of rainwater tanks, while more than 45 municipalities subsidize the conversion of old septic tank to the rainwater storage tank for flood control. However, the rainwater tanks which are subsidized by almost municipalities are too small, about 0.2m³ in capacity, to realize their domestic purpose of miscellaneous water use. The current state is thought to have an educational meaning for the rainwater harvesting. In case

of Tokyo, most development related to RH started in Sumida City. RH was introduced in Sumida Ward as early as 1982. According to officers in Sumida City Hall, to date, there are 750 facilities with RH system both in private and public buildings. Table 3.2 summarizes the history and development of RWH in Sumida-ku.

Table 3.2 History & Developments of RH in Sumida City (Abdul Rahiman NAFISAH et al., 2010)

Year	RH HISTORY & DEVELOPMENTS
1983	RH was introduced in Sumida-ku (model system is in the building for young children)
1985	National Sumo Arena was completed with utilization of large scale RH
1988	“Rojison” – a communal RH system is installed in Mukojima area in Sumida Ward
1994	International Rainwater Conference was held (8,000 participants from 16 countries)
1995	Planning guidelines for RH promotion, Subsidy system for rainwater tank, Mandatory system for RH, and People for Rainwater (PR) was established
1996	Rainwater Utilization Liaison Council: 125 local government joined the network
2000	· International Association of Local Government awarded Sumida Ward for best RH · Japan Business Association for Rainwater Utilization was set-up
2001	RH Museum was opened in Sumida City (the world’s first museum of its kind)
2005	Tokyo International Rainwater Conference was with Sumida Ward’s coordination
2006	Environmental Local Ordinance: RH promotion by collaboration among stakeholders
2007	Environmental Planning in which RH is stipulated as one of high priority measure
2008	The first congress of rainwater network was constituted

The key elements under policy & planning aspects for Tokyo are the subsidy system, mandatory system and registration system. Tokyo can pride with its well-known subsidy system. The subsidies are given base on tank size. Table 3.3 summarizes the details of the subsidy system. Furthermore, in term of planning for RH, TMG (Tokyo Metropolitan Government) execute registration system, wherein if the company is registered, they receive subsidy for installing RWH tank. Thus, organized database for the RH implementation can be recorded for the purpose of research & developments and future reference. Moreover, starting from 2003 onwards, for the development or construction of new building with floor areas more than 10,000m², TMG encourages the owner to install RH system. Previously, it was not mandatory. However, according to an officer in TMG during the hearing survey, owners of new building especially in Sumida City did not oppose the instruction of the local government to install RH system. The local government proposed to make it mandatory and only recently building with such floor area is enforced to install RH. This mandatory system led to increasing number of RH installation and utilization in Tokyo.

Table 3.3 Details of Subsidy System in Sumida-ku (Abdul Rahiman NAFISAH et al., 2010)

Tank size	Subsidy details
Small Size Tank (less than 1cu.m)	50% of the tank cost; maximum subsidy amount = ¥ 40,000
Medium Size Tank (> 1cu.m to < 5cu.m)	Maximum subsidy amount = ¥ 300,000
Large Size/Underground Tank (more than 5cu.m)	Maximum subsidy amount = ¥ 1million

3) Malaysia (Selangor)

The introduction of RH in urban areas only started in 1999 with the establishment of “Guidelines for Installing a Rainwater Collection and Utilization System” after Selangor faces severe drought in 1998. To date, only some government buildings such as Department of Irrigation & Drainage Headquarters, several pilot projects conducted by National Hydraulic Research Institute of Malaysia, in example double storey terrace house in Taman Melawati and few private buildings for instance One Utama Shopping Complex is equipped with RH system. Table 3.4 summarizes the history and development of RH in Selangor.

Table 3.4 History & Developments of RH in Selangor, Malaysia (Abdul Rahiman NAFISAH et al., 2010)

Year	RH HISTORY & DEVELOPMENTS
1998	Government state the interest in RH after experiencing severe drought in Klang Valley
1999	“Guidelines for Installing a Rainwater Collection and Utilization System”
2004	<ul style="list-style-type: none">·Ministry of Housing & Local Government prepared a cabinet paper to encourage government buildings to install rainwater collection & utilization system· National Hydraulic Research Institute of Malaysia (NAHRIM) was established to conduct research in all water hydraulic & water environment aspects including RH
2006	<ul style="list-style-type: none">·National Urbanization Policy (NUP) was formulated which emphasize on the use of alternative water resources including RH and WWR. For the long term plan, it aims at installing RH system in new government buildings and schools·The government announced to make rainwater harvesting mandatory to large buildings

Up to now, RH practice in Selangor can be concluded as only at policy and planning stage. This is because so far there are only small numbers of RH projects implemented. The new Selangor government had revised the policy of water for the state. Starting from June 2008, the first 20 m³ of water from public water supply is not charged. It is given free to each household. Based on early response of some water experts, i.e. Datuk Randhir Singh Johl, the president of Selangor and Wilayah Water Watch, the Selangor's free water policy could prove detrimental as it encourages waste. He added that conservation should be made priority and efforts like RH should be encouraged (Malay Mail, 2009).

Instead of subsidizing the free water, the state government can alternatively provide subsidy to Selangor citizen for installing RH facility especially the storage tank which is the most costly component of RH system. At present, the amount of money allocated for the free water is estimated roughly at RM1.8million a month which Selangor government has to pay to Syabas, a water concessionaire company. If the money is allocated for subsidizing RH facilities, public will still enjoy the free water but by more sustainable means. RM 1.8million of subsidy for free water paid by the government at the moment is equivalent to giving subsidy for 1,385 tanks if for example, 50% of the tank cost is subsidized as practiced in Tokyo. The 5 m³ tank cost (RM2, 600) is taken from the result of pilot project conducted by NAHRIM for double storey terrace house in Taman Melawati. For mandatory system, although the government openly announced to make RH compulsory particularly for large buildings, nevertheless so far from literature reviews and observation, there is no further significant action taken to realize it. Thus, it is not mandatory for new developments in Selangor to be equipped with RH system. In term of planning, the major step taken to promote RH in Selangor is effort by NAHRIM by conducting pilot projects to study the effectiveness of it in water resources management. Other than that, there are no other measures taken in term of planning such as registration system etc.

4) India

India is facing a water crisis and by 2025 it is estimated that India's population will be suffering from severe water scarcity. Although India occupies only 3.29 million km² geographical area which forms 2.4% of the world's land area, it supports over 15% of world's population with only 4% of the world's water resources. With increased population growth and development, there is a need to critically look at alternative approaches to ensure water availability. To resolve the problem, there is a need to look for alternative water resources. These include rainwater harvesting, wastewater reuse and desalination. The National Water policy 2002 is a cogent and comprehensive document and forms a basis that could be converted into a law.

In India, under the constitutional set up, water is a state subject. In urban areas its governance rests with urban local bodies in their areas of jurisdiction as per the 74th constitutional amendment.

The need for a policy framework for water harvesting systems arises mainly because the prevailing policy statements do not touch extensively upon the issue. There is a clear need to evolve a decentralized legal regime with regard to water, which empowers people and makes them real managers of resources. For promoting urban water harvesting, a policy should include a mix of incentives and penalties. Measures that need to be undertaken include:

- ① RH / recharge of ground water system should be an essential town planning requirement and a pre-requisite for permission for the development of new colonies.
- ② Provision of RH structures in all building plans should be mandatory for issuing of building permission.
- ③ Appropriate rebates on property /fiscal incentives should be granted for effective implementation of RH systems.

A number of state governments have made RH compulsory for new buildings according to their plot sizes in various Indian cities. Some of the measures adopted in different states/cities are highlighted in Table 3.5.

Table 3.5 Legislation on RH in Indian states/ cities

City	RH HISTORY & DEVELOPMENTS
New Delhi	Since June 2001, the Ministry of Urban Affairs and Poverty Alleviation has made RH mandatory in all new buildings with a roof area of more than 100 m ² and in all plots with an area of more than 1000 m ² that are being developed. The Central Ground Water Authority (CGWA) has made RH mandatory in all institutions and residential colonies in notified areas. This is also applicable to all the buildings in notified areas that have tube wells. The deadline for this was March 31, 2002. The CGWA has also banned drilling of tube wells in notified areas.
Indore	RH has been made mandatory in all new buildings with an area of 250 m ² or more. A rebate of 6 % on property tax has been offered as an incentive for implementing RH systems
Kanpur	RH has been made mandatory in all new buildings with an area of 1000 m ² or more.
Hyderabad	RH has been made mandatory in all new buildings with an area of 300 m ² or more.
Chennai	RH has been made mandatory in three storied buildings (irrespective of the size of the rooftop area). All new water and sewer connections are provided only after the installation of RH systems.
Haryana	Haryana Urban Development Authority (HUDA) has made RH mandatory in all new buildings irrespective of roof area. In the notified areas in Gurgaon town and the adjoining industrial areas, all the institutions and residential colonies have been asked to adopt water harvesting by the CGWA. This has also been made applicable to all the buildings in notified areas having a tube well, and March 31, 2002 was fixed as the deadline for compliance. The CGWA has also banned drilling of tube wells in notified areas.
Rajasthan	The state government has made RH mandatory for all public establishments and all properties on plots covering more than 500 m ² in urban areas.
Mumbai	The state government has made TH mandatory for all buildings that are being constructed on plots that are more than 1,000 m ² in size. The deadline set for implementation was October 2002.

(Measures for Ensuring Sustainability of RH, Water for Asian Cities Program, India – UN-HABITAT & Directorate of Urban Administration & Development Government of Madhya Pradesh)

5) Sri Lanka

In 2005 for the first time in Sri Lanka a policy for RH was established and approved by the government. The policy objective is to encourage communities to control water near its source by RH to improve ground water recharge, encourage urban agriculture, reduce energy consumption and recurrent costs, collect run off for crop production, reduce soil erosion and use for drinking with adequate treatment, and also to minimize the use of treated water for secondary use.

The policy proposed to amend legislation (UDA, Urban Development Authority) by Laws) to incorporate RH in new construction. The gazette to amend the UDA by laws was presented to parliament by the Hon. Minister for urban Development and passed on the 25th of August 2007. Legislation which follows will make RH mandatory in all areas under urban Council, Municipal Jurisdiction with in prescribed time period (Tanuja Ariyananda, 2007).

3.1.3 Benefits

RSH provides the long-term answers to the problem of water scarcity. RSH offers an ideal solution in areas where there is sufficient rain but inadequate ground water supply and surface water resources are either lacking or are insufficient. In hilly areas, rainwater can be used by humans, vegetation and animals. RSH system is particularly useful in remote and difficult terrain as it has the ability to operate independently. The whole process is environment friendly. There are a number of ways in which water harvesting can benefit a community – water harvesting enables efficient collection and storage of rainwater, makes it accessible and substitutes for poor quality water. Multiple benefits of RSH are as follows:

- Improvement in the quality of ground water
- Rise in the water levels in wells and bore wells that are drying up
- Mitigation of the effects of drought and attainment of drought proofing
- An ideal solution to water problems in areas having inadequate water resources
- Reduction in the soil erosion as the surface runoff is reduced
- Decrease in the choking of stormwater drains and flooding of roads
- Saving of energy, to lift ground water. (One-meter rise in water level saves 0.40-kilowatt hour of electricity)

RSH helps smooth out variation in water availability by collecting the rain and storm and storing it more efficiently in closed stores or in sandy riverbeds. In doing so, RSH assures a continuous and reliable access to water. A RSH system collects and stores water within accessible distance of its place of use. While traditional sources are located away from the community particularly in peri-urban areas, collecting and storing water close to households, villages or pastures greatly enhances the accessibility and convenience of water supplies (UN-Habitat, 2007).

3.1.4 Barrier

① Regulatory Barriers

- Lack of clarity in rainwater or stormwater management requirements.
- Uncertainty on how to calculate benefits of RSH system.
- Inflexibility of design criteria in ordinances preventing adaptability.

② Technical Barriers

- Overall lack of technical capacity for investigating regional conditions.
- Lack of standardized process for investigations and site remediation.
- Lack of installers' knowledge of new practices, and resistance to implement and learn about them
- Decision-makers lack the knowledge that there are better stormwater management methods out there and what they are

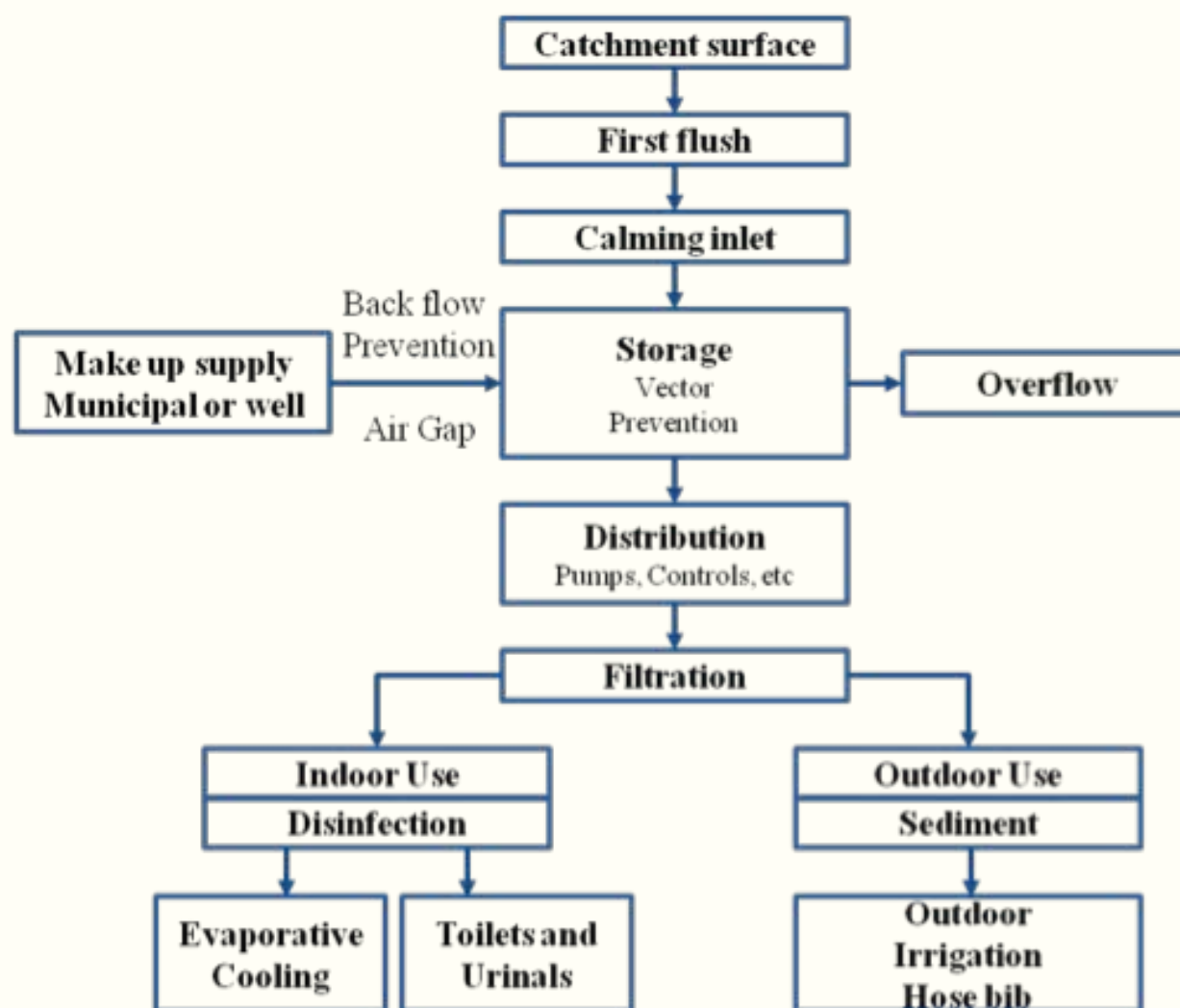
③ Social Barriers

- Lack of engagement in stormwater management issues by public officials
- Communication gap

3.1.5 Implementation strategies

RSH is the capture, diversion, and storage of rainwater and stormwater for a number of different purposes including landscape irrigation, non-potable domestic use, aquifer recharge, and flood control. Understanding how the fundamental components of a RSH system work is crucial when contemplating designing or installing a RSH (Figure 3.1).

Figure 3.1 Rainwater Harvesting Flow Chart (Department of community affairs, Georgia, 2009)



Many factors influence component selection when designing or selecting the right RSH system for a specific end use application. Gutters, downspouts, buried utilities, soil types, soil depths, slopes, site drainage, existing plumbing, electricity, diversion of overflows, local restrictions, neighborhood covenants, and neighbors are some of the many items that deserve attention when sitting RSH systems. Regardless of the complexity of the system, RH systems are comprised of six basic elements:

- Gutters and downspouts: conduits that channel water from the roof to the tank.
- Downspout filtration, leaf screens, first-flush diverters, and roof washers: components that remove debris and dust from the captured rainwater before it goes to the tank.
- Storage: one or more storage tanks, also called cisterns.
- Pumps and controls: devices such as level indicators, makeup water supplies, back flow preventers and or air gaps.
- Treatment and disinfection: for non-potable indoor systems, filters and other methods to make the water suitable for use in toilet flushing, urinal flushing and as cooling tower make-up (Department of community affairs, 2009)

3.1.6 Example

Sumida City Hall, Japan



The capacity of the rainwater storage tank employed by Sumida City Office is 1,000 ! , but usually it stored only 500 ! at most. The other half of the space is saved to control flood. 80% of water to flush toilet is from rainwater (approximately 5,000! /year) and purified kitchen waste water. A small-scale rainwater utilization facility is introduced also to the wall greening corner of the annex building. This building was completed in 1990.

(8UDM & 2RWHM program and abstract lectures, 2009)

Tzuchi Hospital, Taiwan



The hospital has collected the rainwater by roof (1,200 !). After retained and filtered, it is stored in the rainwater trough (85 ") to provide toilet flushing and watering water. The rainwater used per year is over 1,700 " .

(http://www.wcis.itri.org.tw/english/alter_h.html)

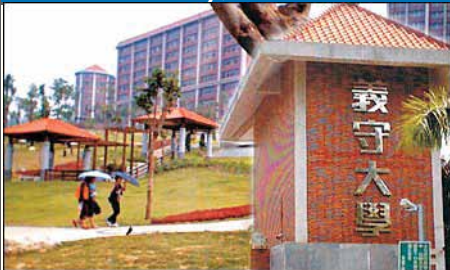
Tainan Hydraulic Laboratory National Cheng Kung University, Taiwan



The rainwater in the Tainan Hydraulic Laboratory has been collected by the roof plate of a big experimental tank and led to a big and circle water storage tank (15,000 !) for supplying whole laboratory experimental water use.

(http://www.wcis.itri.org.tw/english/alter_h.html)

I-Shou University, Taiwan



The school has treated and stored the wastewater of wastewater plant to supply the toilet flushing, fire prevention water, planting water, and landscape water, and decreases the roof temperature. The reuse water used per year is over 70,000 ! .

(http://www.wcis.itri.org.tw/english/alter_h.html)

3.2 Greywater reuse

3.2.1 Key messages

Greywater reuse is a promising strategy in terms of the significant local water, energy, and cost savings that it can produce. Greywater is wastewater that comes from the bath, spa, shower, bathroom wash basins, clothes washing machine, laundry trough, dishwasher and kitchen sink. However, wastewater from the kitchen sink is generally not recycled due to the heavy contaminants it contains. Current water reuse policies in many countries are very restrictive of responsible on-site greywater reuse. Few states and countries have in place supportive policies, particularly in the Middle East. Policy and regulatory frameworks that provide consistent rules and regulations regarding greywater reuse are needed in the region. These policies should balance the public health and environmental risks of greywater reuse with the economic and water saving benefits particularly in regions with inadequate access to freshwater. Appropriate policies should differentiate between different scales and should be tailored to local or regional conditions, e.g., existing plumbing and infrastructure. Greywater policy should be harmonized with World Health Organization standards and local plumbing and building codes in order to avoid contradiction and complication.

There is a clear need for industry standards in the realm of greywater treatment technologies. Standards could provide information to a consumer regarding the ability of different systems to treat particular contaminants that may be present in source water, the length of time that the treatment process takes, the amount of energy required, etc. Finally, Micro finance and public sector incentives should be considered alongside private sector investment and large-scale international aid and development funding. In addition, while greywater reuse is often considered primarily as a benefit in terms of water conservation, it also conserves energy, reduces waste water, and the water savings may, in some cases, be allocated to other uses.

3.2.2 Description of the policy

1) South Korea

There are around 260 greywater facilities installed in commercial buildings, factories, sports complex, and etc on 2008. Total capacity of the facilities is about two million tons per day. The operation rate of the facilities is 26.5 % through supply of two hundred million tons greywater. In 2010, the Ministry of Environment announced a new law ("the law to promote and support water reuse"), which enforces the installation of greywater reuse system for non-potable use.

The law to promote and support water reuse

People who want to build or remodel structures should install and operate Wastewater Reclamation and Reusing System which could reuse more than 10% of used water according to Ministry of Environment law. But, people who gets treated sewage, treated wastewater, retreated water more than 10% of total water use are exception.

2) Japan

Japan is situated in an area of the world that receives an abundant amount of rainfall. On the other hand, Japan's per capita rainfall is actually one-fifth of the world average due to the country's dense population (Japan for Sustainability, 2009). As a result, Japan is strained by rising freshwater demand. Compared to agriculture and industry, where the total volumes of water use have either stayed the same or are decreasing, the residential sector uses a greater share of water. From 1975 to 2002, total household water use increased by 5.0 billion cubic meters. In addition, approximately 40 percent of Japanese have experienced cuts in the supply of water. Fortunately, however, 70 percent of Japanese also support the utilization of rainwater or recycled water. The government of Japan is highly aware of the need to conserve water, so greywater technology is already a popular choice for household water needs.

The Japanese government does not provide incentives for household residents to implement greywater systems in their own living spaces. Nevertheless, many people choose to implement them in urban areas because water

costs are very high. Greywater systems in Japan are less extensive than those in California or Australia because there are very few backyards that would require the use of an extensive outdoor irrigation system. Residents typically limit the use of greywater systems to simple system revolving around the bathroom toilet. Hand washing basins are placed above toilets and are connected to the same water pipes that deliver water to the urinal. When new water is delivered to the urinal, water comes out of the hand-washing basin. The water from hand washing is then used to fill the urinal as greywater. While this system is very simple, it nevertheless promotes the conservation of water for residential use.

On the other hand, the Japanese government is making an effort to implement greywater technology in more extensive urban commercial uses. In the capital city of Tokyo, greywater reuse is mandatory for buildings with an area greater than 30,000 square meters or with a potential non-potable demand of more than 100 cubic meters per day. In order to offset the costs associated with construction, the Japanese Ministry of Construction provides subsidies of up to 50 percent of the capital costs. The government also assists in connecting commercial greywater systems to the public sewerage system. Therefore, while residential greywater use is minor in Japan, commercial greywater use is very extensive (Kevin Chung and Meredith, 2009).

3) India

National Environmental Engineering Research Institute (NEERI) Nagpur and UNICEF Bhopal, Madhya Pradesh have developed, implemented and evaluated greywater reuse systems for small buildings (schools) in rural areas. During 2005 and 2006, NEERI and UNICEF collaborated to investigate the possibility of recycling greywater (bathroom water) in residential tribal schools in rural Western Madhya Pradesh. The water reuse or recycling systems collected, treated and reused bathroom water (shower non toilet/black water) for recycling and flushing of toilets. The drive for this technology was a result of decreasing availability of water, lowering of groundwater table and increase in fluoride concentration in groundwater. Additionally, with the increase in demand for water due to increased coverage of rural areas with toilets under the Total Sanitation Campaign (TSC), there was a need for augmentation through appropriate technologies, to provide water for sanitation. (Pacific Institute, 2010)

3.2.3 Benefits (<http://www.doityourself.com/stry/benefits-of-grey-water-recycling>)

Recycling grey water can yield much benefit to the environment. Once it has been recycled, the water can be used for irrigation. It is one way of countering perennial water shortages. When water is constantly available for irrigation needs, it makes for a balanced ecosystem.

① Recharge of Groundwater: Greywater reuse is a useful source of water for irrigation purposes. When introduced into the landscape, grey water replenishes groundwater. The natural hydrologic cycle is able to keep functioning as it should. It also acts as a backup for groundwater. When levels run low, the presence of grey water enables the ecosystem to function in much the same way as when groundwater is fully available.

② Enhances Soil Fertility: Landscaping activities have a tendency to exert a toll on soil quality. Soil nutrients levels will reduce, depending on soil usage. Still, plants must continue to draw the nutrients necessary for healthy growth from the soil. During recycling the bacteria in the soil breaks down the nutrients in the grey water. Soil fertility is improved due to the supplemental nutrients. The nutrients are also made available to plants, resulting in healthy growth and development of plants.

③ Enables Plant Growth: Water is a fundamental growth requirement for all plants. It is difficult to cultivate plants in drought stricken or water impoverished areas. In the absence of water, minimal plant life can be sustained. Greywater reuse helps to achieve healthy plant cultivation in water deficient soils. Irrigation systems can enable a cultivated landscape in areas where the groundwater deficiency would not allow it.

④ Improves Water Quality: Both surface water and groundwater supplies experience a reduction in quality from time to time. These changes occur from man's various activities on the land, as well as weather patterns. The natural purification processes involved in greywater reuse are a valuable boost to natural water supplies. These processes take place in the top layers of soil directly benefiting surface water. Benefits inevitably flow down to the groundwater as well. Surface and groundwater can be preserved through these processes.

⑤ Allows Diverse Landscaping Activities: Many of the activities undertaken on our landscapes require a good measure of water. The demand on both surface and groundwater can exceed supplies available. This deficit results in the disruption of some activities we would want to sustain. By harnessing grey water, maximum utilization of the land can be realized. A symbiotic relationship is enabled in which we are able to nurture the environment while it also meets our needs.

⑥ Assists Ecological Balance: Pressures exerted on groundwater by both human needs and landscaping activities threaten the survival of the ecosystem. Plants, soil, water, micro-organisms and air all work in concert to achieve a properly functioning system. Should one element fail, the entire system is threatened. Recycling groundwater lends invaluable support to the groundwater supplies. This is vital in achieving a healthy ecological balance.

3.2.4 Barrier to implementation (Sandra Baynes, 2002)

① Water agencies government barriers

- Few demonstration sites
- Unfamiliar with technology
- Reluctant to authorize permits
- Prefer revenues for water supply and treatment
- Costs for water services fixed
- Billing changes

② Financial barriers

- Not mass produced, systems costs are high in multi-res and single family applications
- Technology changing
- Generally cost prohibitive where municipal service exist
- Billing may not be adjusted at wastewater side - sewer surcharge

③ Savings barriers

- Small scale projects do not result in significant savings
- Costs for testing and maintenance outweigh savings
- Urban municipal costs too low
- Unmetered areas do not realize water savings

④ Resident barriers

- Presently do not see financial savings in urban cases
- Lifestyle change
- Multi-res may not have trained maintenance staff
- Homeowners commitment to upkeep
- Costs for maintenance time and repair a concern
- Health concerns with unfamiliar technology
- Partial unit project not cost-effective

⑤ Health unit barriers

- Technology not proven
- Hesitant to take risks to authorize permit

⑥ Maintenance barriers

- Each system currently different

-
- Delegation of tasks: who does what? when?
 - Every time shut off, must be cleaned out
 - Training difficult with residential turnover
 - Time commitment
 - Not many familiar with system

3.2.5 Implementation strategies

Small demonstration projects and new, more flexible, greywater policies have demonstrated the successful use of greywater at multiple scales. However, there are also a variety of challenges to the increased use of greywater in homes, farms, and businesses. Currently, these challenges have hampered broad implementation of greywater reuse. Below, we outline several strategies for overcoming some of the most critical challenges to wider use of greywater.

There are a wide variety of greywater technologies from diversion systems to biological treatment. A clear and consistent categorization of different technologies, matched to appropriate end-uses, is needed. Appropriate technology means choosing a greywater treatment system that follows local greywater codes and matches the quantity and quality of water to its intended use. For instance, when greywater is reused in the toilets of large buildings this requires treatment and storage of large volumes of water before reuse, and appropriate technologies include physical, chemical, or biological treatment and large scale storage systems. On the other hand, small scale systems that provide water for subsurface irrigation are well suited for simple diversion systems that filter but do not treat greywater before reuse. Much of the public concern around greywater reuse is related to a lack of information about the long-term health and environmental impacts of greywater. Multi-year studies with controls are needed to examine the long-term impacts of greywater on human health and soil chemistry. While some long-term studies are currently being completed by the Water Environment Research Foundation, more work is needed, particularly on the long-term impacts of different qualities of greywater on soil and plant health for agricultural applications. Studies conducted by respected academic organizations and international research organizations would be especially useful.

Better public information and awareness of the opportunities, benefits and risks associated with greywater will be necessary to expand greywater reuse. Public perception of greywater as unsafe for reuse, or uncertainty around how to safely reuse greywater, is a major challenge for its increased use. Additionally, greater awareness of the potential water benefits and its cost effectiveness will all aid in the expansion of responsible greywater use. This type of public outreach should accompany new policies and can be done by governments and other organizations interested in promoting greywater, including a new international greywater organization. (Pacific institute, 2010)

3.2.6 Examples

Residential area, China

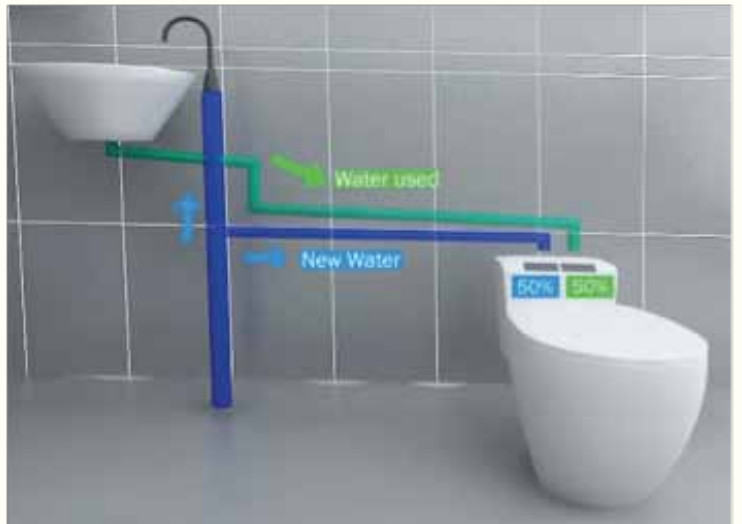
The graywater reuse system was developed within a Chinese/German partnership program. The system has been operated since June 2006 to supply water for toilet flushing (60 apartments, 210 people). Raw water from showers and basins is treated using membrane bioreactor. Treated capacity is 10 m³/day, and capacities of aerobic treatment tank and clear water tank are 6 and 10 m³, respectively.



(http://www.dwc-water.com/fileadmin/user_upload/images/PDF_Files/Grey_water/DWC_Greywater_recycling_case_study_China.pdf)

Eco bath system, South Korea

The “Eco Bath System” (designed by designer Jang, WooSeok) is a new concept that combines the functions of a sink and toilet bowl. Drawing inspiration from the natural flow of water on earth, the Eco Bath System accumulates the water used to wash your hands which further can be reused to clean the toilet.



(<http://www.tuvie.com/eco-bath-system-by-jang-wooseok/>)

Recycled waste water (gray water) is used in rest rooms and gardens at the head office. For customers using recycled waste water, a rate reduction (30% off of water rates) policy is applied to increase the use of recycled waste water and to establish a circulation-type society. In 2010, customers using recycled waste water increased by 28% compared to the previous year, resulting in a rate decrease of KRW 5.7billion won (K-Water, 2011).



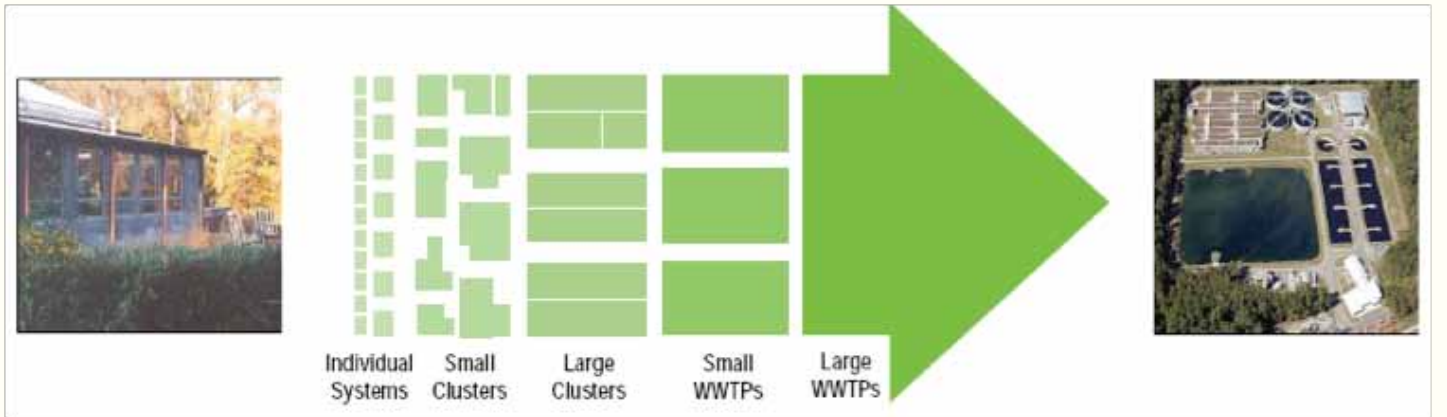
(K-Water, 2011)

3.3 Distributed wastewater treatment

3.3.1 Key messages

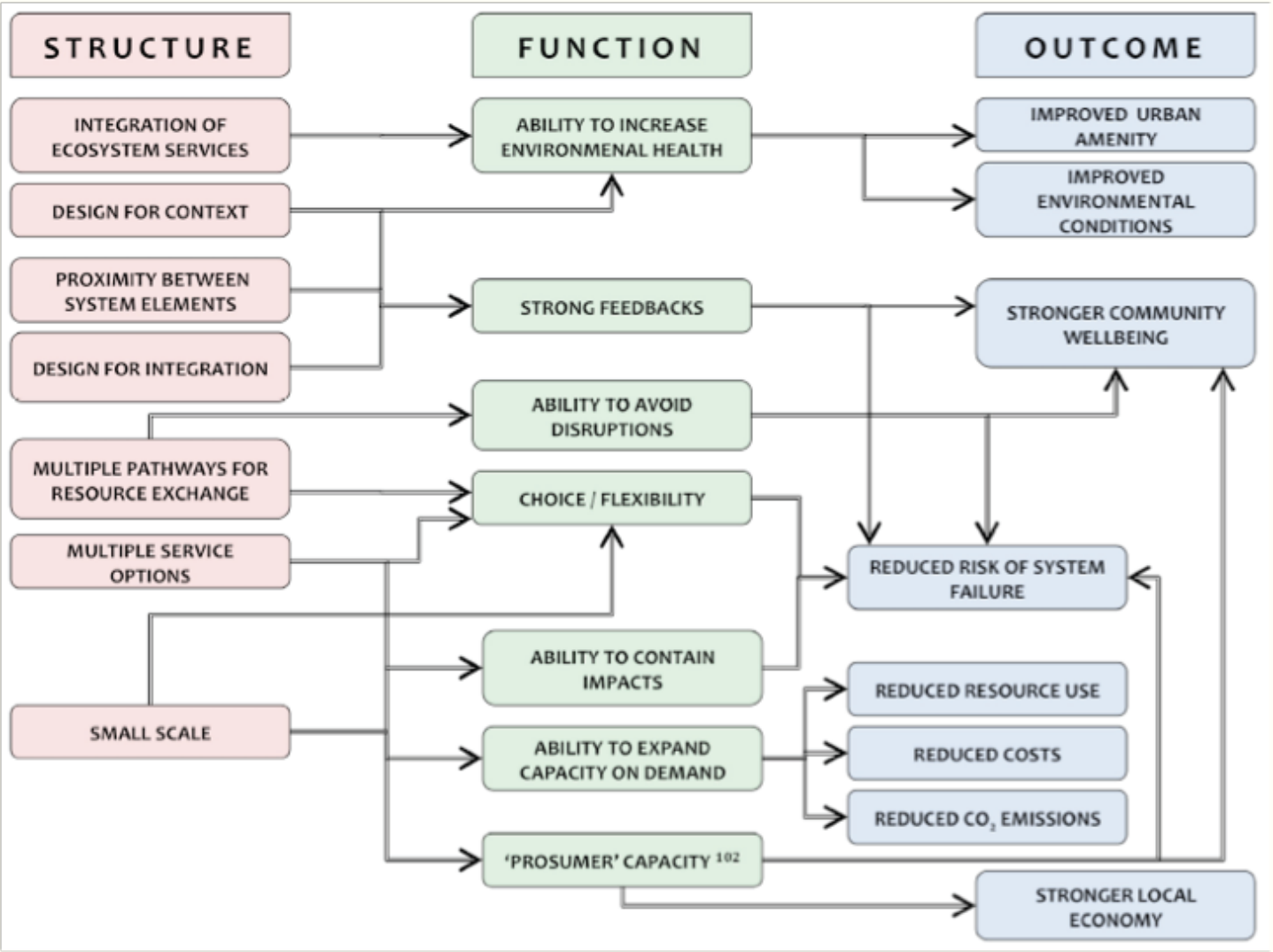
Distributed wastewater management is an approach to wastewater collection, treatment, and disposition (discharge, reuse, dispersal) that uses appropriately scaled systems - which can vary from onsite to cluster to centralized - across a service area, watershed, or other political or natural boundary. The wastewater management continuum from individual systems to large wastewater treatment plant (WWTP) is presented in Figure 3.2.

Figure 3.2 The wastewater management continuum (Water Environment Research Foundation (WERF))



Effectively planned, implemented, and managed distributed water systems are critical elements of sustainable green-to-gray infrastructure. In distributed systems ‘centralized’ infrastructure can play a key arterial role at a regional level, while smaller more tailored systems operate and interact more closely with users at the local level. Figure 3.3 illustrates how factors such as size, design and integration of water systems can influence outcomes as diverse as carbon emissions, business opportunities and community wellbeing.

Figure 3.3 The relationship between key structures, functions and outcomes in distributed water systems (Biggs et al, 2008).



Networked and localized water systems can save costs, water and materials. Developing services close to demand can allow technical systems to be smaller, less complex and built on demand. Greater sensitivity to local conditions also allows systems to take advantage of low-cost, site-specific opportunities. While ‘economies of scale’ may be lost, localized systems that move water short distances and supply water at a standard that matches a specific use can deliver services at lower cost than larger systems. New telemetry and modeling technologies are creating opportunities to down-size water systems.

3.3.2 Description of the policy

1) South Korea

To integrate water and wastewater planning and management more effectively, a National Water Improvement Program was developed at national level in 1990. In 1992, region-specific Catchment Water Quality Master Plans were drafted by the Ministry of Public Works and in co-ordination with other ministries. The plans attempted to avoid resource losses and minimize expenditure. This regional planning and co-financing of infrastructure works is administered by Catchment Authorities that direct and complement municipal initiatives. As a consequence, as of 1994, the cities of Kwangju and Seoul envisaged the application of more modest hydraulic design guidelines, with the full reuse of sewage in nearby agriculture, the avoidance of any nutrient disposal in coastal waters, and with much lower investments in wastewater infrastructure (Helmer and Hespanhol, 1997).

Also, The Eco-STAR plan, which is a part of Eco-Technopia 21 Project developed by MOE, sets mid- and long-term strategies to develop promising environmental technologies by sector. It is focused on projects which can deliver world-class technologies that will compete on global markets. The rationale is to maximize synergistic effects through joint or multilateral R&D on projects unable to achieve targets independently. Projects are selected according to their commercialization and success potential; they are financed through a matching fund system, where the government works with industry. In 2004, two pilot centers were set up: the 'Centre for Environmentally Friendly Vehicle' focusing on developing technologies for vehicle emission reduction (with the investment of 65 billion won by 2010), and the 'Innovation & Integration Centre for 21st Century Water Technology', devoted to advancing sewage and wastewater treatment technologies (with an investment of 65 billion won).

2) China

The revised pollutant discharge fee levy and use policy was put into effect July 1, 2003, and the former Temporary Management Methods on Pollutant Discharge Fee Levy, enacted in 1982, was abandoned. The most significant change in this new policy is the method used to calculate pollution fees. According to the old policy method, if discharged wastewater at the same outlet contained more than two pollutants, the pollutant discharge fee would be calculated and based solely on the single pollutant that incurred the maximum discharge fee. The new policy stipulates that all the pollutants listed on the standard will be calculated into the total pollutant discharge fee. The new policy clearly encourages and accelerates the industrialization of municipal wastewater treatment.

The newly revised management methods were effective Jan. 1, 2004. The management methods enacted in 1985 were abandoned. The new policy emphasizes the monetary value of water and treats water as a special commodity. The new policy also incorporates market-oriented mechanisms into water resource management and changes the behavior of state financing and administration in water resource engineering.

The new policy prescribes a water tariff approach, comprising water production costs, expenses, profit, and tax. Water production costs include labor, materials, capital assets depreciation, repair and maintenance, and water resource pricing. Expenses include administration and operation, selling, and finance costs. Pertinent pricing is expected to be in accord with local market demand. The local or central government must approve the water tariff. The new policy also has a special condition for water resource projects supported by loans or bonds. This condition prescribes that the water tariff level should allow for a rational profit and should contract the operator to pay back the loan or bond over a specified operating term. By enacting this new policy, China expects to promote reasonable exploitation of water resources and provide new investment opportunities, while also promoting needed market reforms in the water resource sector.

Beijing and Tianjin have advanced municipal regulations for water reuse targeted at larger building (up to 30,000m²) that requires on-site greywater treatment and reuse system. China's rapid economic growth (8 to 10%) has created a water crisis that the government is addressing through a number of policies, including regulation requiring greywater treatment and water reuse for large scale institutional buildings and residential developments.

Policies advancing water reuse technology applications have been progressively evolving since the 'Water Law of the People's Republic of China' was adopted at the Twenty Forth meeting of the Standing Committee of the Sixth National People's Congress on January 21, 1988. Water reuse is being addressed at multiple market levels, industrial, municipal (large scale system) and at the smaller scale of commercial, institutional and residential on-site greywater reuse. Early research on reuse applications dates back to Luo's 1994 paper: Prospects for wastewater reuse treatment and reuse in Beijing Municipality. These studies indicate that wastewater reuse has improved significantly over the past two decades rising from 45.3% in the early 1980s to 91.4% in 1996. Beijing factories have either met the standard for water reuse or they have closed or been relocated.

The greywater treatment system in use in China typically incorporate either activated sludge or fixed film (e.g. rotating biological contactor) biological treatment technologies, with limited operational success. While the laws require the provision of greywater reuse technologies, there has been no enforcement to verify their performance. The overall pragmatic objective is to conform to the law and provide equipment at the lowest possible cost. The technologies often do not work. This is changing with as the regulatory authority's capacity to monitor performance increases.

3) Australia

At an urban greenfield site near Townsville, Australia, researchers compared four distributed wastewater treatment system (WTP) designs against a centralized 'base case'⁵⁹. One design, which used four treatment plants and on-site greywater reuse, showed how splitting wastewater streams at their source could cut demand for sewerage treatment services by 65%. In another system design, 32-networked WTP's treated all wastewater and then returned it via a third-pipe return system. This design reduced residential demand for potable water by 33.1% and saved six percent on energy compared to the centralized option. The gain in energy efficiency was due to the lower energy needs of many smaller treatment plants and the use of recycled water (which reduced energy for pumping). A similar option using 315 smaller WTP's proved less energy efficient - suggesting that as the treatment system became increasingly localized (for this site), efficiency increased to a point and then declined.

The strategic- or planning-level tool, known as the Decentralized Wastewater Stakeholders Decision Model (DWSDM), requires stakeholders to define the relative importance of predefined community objectives and then score the attributes associated with each objective in terms of whether they favor centralized or decentralized systems.

More importantly, it provides insight to the values, views, and preferences of stakeholders and provides a transparent framework for the various objective discussions that can, hopefully, lead to resolution. Use of the DWSDM is straightforward—its power lies in its ability to have all stakeholders define their preferences, values, and concerns for the same set of hierarchical project objectives and their associated attributes. The results provide a basis for structured discussions among stakeholders in which all issues and concerns are defined. Although the model cannot ensure that all stakeholders will arrive at consensus for any given project, it can provide transparency relative to each individual's judgment and assist in identifying those attributes that are most important.

4) Palestinian

All treatment and/or reuse systems will be regulated through permits from The Palestinian Water Authority (PWA). The permit should ensure that the system design is done according to approved regulations, specifications, standards, and guidelines fulfills wastewater flows and effluent quality for the designed period, and solves identified and potential environmental and health problems. The minimum acceptable treatment level is secondary treatment (e.g., removal of settleable and suspended solids and biodegradable organics plus disinfection). For regional utilities, this minimum treatment level is expanded to include tertiary treatment. Low cost technology is encouraged wherever it is possible. All wastewater treatment processes should be chosen and designed to consume as little energy as feasible and potential energy in wastewater and sludge must be utilized whenever appropriate. In addition, independent alternative energy sources should be installed, if appropriate (e.g., solar systems, battery, heating exchange pumps, etc.) and farmers should be involved in energy recovery projects thereby benefiting from wastewater sludge and farm wastes. PWA emphasizes that treated wastewater is a

valuable resource that must be utilized and agriculture is given priority for reuse. In order to encourage and promote the use of treated wastewater incentives need to be adopted.

3.3.3 Benefits

(<http://www.pumpzone.com/filters/filters/decentralizeddistributed-systems-as-alternative-treatment-options.html>)

There are several benefits of the distributed wastewater system such as Reduce costs and resource use, improve service security and reduce risk of failure, strengthen local economies, strengthen community wellbeing, regenerate and protect the natural environment and redefine traditional water systems (Biggs et al, 2008). Moreover, benefits for stakeholders are as follows;

1) Benefits for Developers

Developers who consider alternatives to sewer or center-collection systems actually see many reasons to choose decentralized/distributed systems for their homes. For example, a developer looking to build 50 suburban homes can have his project delayed up to five years while the city extends the existing sewer lines to the homes. Plus, the developer is likely going to pay significant sewer tap fees and substantial fees for the cost of extending sewer lines so current sewer customers will not see rate increases. If the developer is charged more, chances are the developer will charge the residents more. Additionally, especially in places like coastal areas, small lots and heavy regulation can tie the developer's hands if he is trying to put in a sewer. The five year or longer timeline is likely to stretch farther.

Because these decentralized/distributed systems are typically composed of modular, interconnected and easily replaceable parts, installation and maintenance is simple. It only takes a few days or weeks to install and start-up a decentralized system. The savvy developer does not have to plan as extensively in comparison to building a neighborhood with a sewer. The developer may also decide to use these systems instead of building out from the central infrastructure because they require less time and money to obtain permits. One of the major benefits of these systems is the developer can build out slowly and add to the treatment system as needed to maintain treatment, so the initial costs are significantly lower.

As an example, small, quick-to-install, wastewater treatment units are available. Modular units can typically treat 500 gallons per day or significantly more using a cluster system treating from 3,000 up to 160,000-plus gallons/day-enough to accommodate an entire community. Fixed activated sludge treatment units are easily upgradable, scalable and fill considerably less space than centralized treatment options. Moreover, these advanced treatment systems offer a water reuse opportunity for community parks, schools, golf courses and other common areas. The developer also has more options in terms of the topography and/or type of land available, which not only increases property value but can lead to a decrease in urban sprawl.

2) Benefits for Residents

Homeowners generally do not like to think about sewage treatment. Frequently, residents who live near a large treatment plant will be irritated by its smell, noise or appearance. Residents will be happy to know that odor is usually less of a concern with decentralized/distributed systems, and they are typically almost unseen because they can be installed below ground.

Since the size of land normally reserved for the drain field on a given property can be reduced by using individual onsite systems or eliminated by using cluster systems, the residual land can be used for other structures like a pool or common areas like parks or green space. Another benefit is that the treated water can be reused for drip tube irrigation of the lawn or other landscaped areas.

Whenever a community has a centralized wastewater system and developments are proposed, questions are likely to arise over how the costs and benefits of the system are to be distributed, which can be avoided when all the costs and benefits go to single homes or clustered developments. It is also important to consider that property values near large centralized systems understandably decrease. Houses with individual or distributed systems have a more equal distribution of value. In addition, distributed/decentralized systems are often much more economical for smaller communities than sewers. In 1995, for instance, Columbus, N.M., had a choice between paying \$4.21 million for sewers with aerated wetlands and ponds, or paying \$1.19 million for new single home treatment systems.

3) Environmental aspects

Properly designed, installed and operated decentralized/distributed wastewater systems have significantly cleaner effluent than centralized systems. Untreated water is sometimes disposed to the environment with centralized systems due to aging infrastructure, water main breaks, flooding or poor operation. Often, minimal energy is needed to create this superior effluent. Using again the example of a modular unit, the blower can be cycled on and off for two reasons: reduced operating cost (up to 45 percent) and improved nitrogen reduction performance (in specific situations).

A great concern of the EPA is the amount of nitrates a system releases into the environment. These nitrates can enter groundwater and under the right conditions are implicit in causing certain birth defects and are thought to cause other disorders like hyperthyroidism. If too many nitrates enter a pond or lake, they create algae, which destroy oxygen in the water and subsequently kill fish. Many centralized systems remove hardly any nitrates, while some distributed/decentralized systems remove an impressive amount of nitrates.

Water table levels and stream base flows can be harmed by the use of centralized systems and are improved or preserved by the use of decentralized/distributed systems. Centralized systems do not discharge effluent anywhere near where homes or businesses use and/or obtain water. Many streams lose water to these systems, but with decentralized systems, the water goes to the nearby leach field and possibly back into the stream. In addition, riparian zones (the area between land and a stream) are less frequently disturbed by the installation and operation of onsite systems than they are by sewer systems.

3.3.4 Barriers to implementation

① Increasing engineer's financial compensation for using decentralized system. The most influential and solvable barriers were found in two categories:

- Demand issues
- Funding availability and conditions

② Engineer's lack of knowledge about decentralized system. The lack of knowledge among engineers about decentralized technology and management is pervasive in the engineering community, including design engineers, regulators, utility engineers, developer's engineers and funding agency engineers. The barriers in this category include:

- Universities have limited or no curricula on decentralized technology and management
- Documented knowledge of decentralized systems and their performance is not widely available.
- Research funding for decentralized systems is scarce, which reduces the amount and quality of university teaching about decentralized system.

③ Unfavorability of the regulatory climate for decentralized systems. Regulations and regulators are often unfavorable to decentralized systems. Quite a number of barriers exist within this category:

- Regulators' perceptions and limited knowledge restrict equitable consideration of decentralized system.
- Regulators need to better define what constitutes system failure and adequate performance.
- A weak regulatory environment can result in inadequate or failure-prone decentralized system.
- Regulations and codes are often based more on regulating growth than good wastewater choices

④ Lack of systems thinking. The following barriers related to the lack of systems thinking in the wastewater facility

planning process:

- Wastewater system planning and water resources planning are often not integrated.
- There is a lack of coordination between local government entities responsible for general planning and those responsible for wastewater infrastructure planning
- Tendencies to focus on short-term costs rather than lifecycle costs hamper consideration of decentralized system.
- Lack of robust alternatives analysis leads to less holistic solutions.
- Systems thinking is not part of the standard engineering curriculum or the typical engineering culture.

3.3.5 Implementation strategies

- ① Engineer's financial reward for using centralized system
 - Increase availability of financial assistance for decentralized system
 - Require consideration of decentralized options in regulatory and funding process
 - Adopt new business models for engineering firm success with decentralized system
- ② Increasing engineers' knowledge of decentralized system
 - Increasing teaching of decentralized system
 - Increasing the amount of real-world data on decentralized technologies
- ③ Increasing the favorability of the regulatory climate for decentralized system
 - Achieve greater uniformity in decentralized system regulations
 - Improve system information management
- ④ Increasing system thinking
 - Require wastewater planning to include relationship to other water sector
 - Utilities encourage integrated water resources approach
 - Train engineers in board systems thinking

3.3.6 Examples

Residents of Lai Xa Hamlet, Vietnam

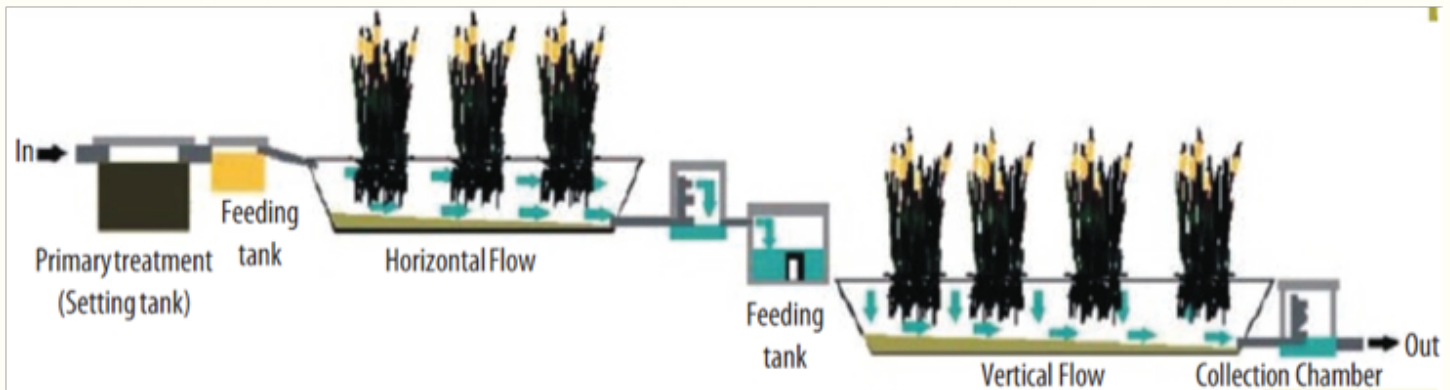
This project in Lai Xa had two sub-projects: a solid waste management project and a liquid waste management project. The liquid waste project in turn had three components: 1) a training of trainers on sanitation issues and solutions, 2) an awareness-raising IEC campaign, and 3) construction of decentralized drainage and treatment systems. This project ran from 2003 until 2009, with the solid waste management portion of the project running in 2003 and 2004 and the liquid waste management portion beginning at the start of 2005. The technology package implemented by this project consists of the following sections, in order of wastewater flow: gravity-fed sewers and drainage canals, five 'wastewater treatment stations' consisting of: primary settling unit, anaerobic baffled reactor, and anaerobic filter, with effluent then draining, depending on the specific station, to one of two waste stabilization ponds and vegetated horizontal rock flow filters or directly to an improved irrigation canal (KOICA, 2009).



(KOICA, 2009).

Dhulikhel Hospital, Nepal

In 1997, Dhulikhel Hospital, a community-based hospital located in Dhulikhel Municipality, set up the first constructed wetland wastewater treatment system in Nepal to treat all the wastewater generated in the hospital and ensure that the people living around the hospital have access to clean treated water for irrigation. The treatment system was originally designed to treat 10 m³ of wastewater m³/day, but it is currently treating about 40 m³/day as the capacity of the hospital has increased significantly over the past 10 years. Also, The Dhulikhel Hospital constructed wetland system consists of a three-chambered septic tank with a volume of 16.7 m³. The area of the horizontal bed and the vertical bed is 140 m² and 120 m² respectively (Singh)



3.4 Low impact design and technologies

3.4.1 Key messages

In recent years, “Low impact design and technology (LID&T)” has become an important concept in the field of urban sustainability. The LID&T presents an alternative approach to improving water quality that integrates green infrastructure, such as swales and green roofs, with investments to optimize the existing system and to build targeted, smaller-scale grey or traditional infrastructure. This is a multi-pronged, modular, and adaptive approach to a complicated problem that will provide widespread, immediate benefits at a lower cost. The Low impact design Plan will achieve better water quality and sustainability benefits than the all-Grey Strategy. The LID&T component of this strategy builds upon and reinforces the strong public and government support that will be necessary to make additional water quality investments. LID&T reexamines traditional development practices and technologies and focuses on identifying project-specific site solutions that benefit the municipality, the developer, the home buyer, and the environment.

3.4.2 Description of the policy

Like many new terms, there is not yet one standard definition, but there is agreement on the principles. The Conservation Fund in Washington, DC states that “LID&T is defined as an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations.” The EPA defines LID&T as a stormwater management strategy that is closely intertwined with natural BMPs. The EPA website says that LID&T uses stormwater “management approaches and technologies to infiltrate, evapotranspiration capture and reuse stormwater to maintain or restore natural hydrologies. At the largest scale, the preservation and restoration of natural landscape features (such as forests, floodplains and wetlands) are critical components of LID&T. On a smaller scale, LID&T practices include rain gardens, porous pavements, green roofs, infiltration planters, trees and tree boxes, and rainwater harvesting for non-potable uses such as toilet flushing and landscape irrigation.”

3.4.3 Benefits

Elements of the LID&T are also known by other names, such as conservation design, environmentally friendly design, resource-efficient design, and better site design. In addition to the fact that LID&T makes good sense, LID&T techniques can offer many benefits to a variety of stakeholders (see Table 3.6).

Table 3.6 Benefits to stakeholders

Developers
<ul style="list-style-type: none">· Reduces land clearing and grading costs· Reduces infrastructure costs (streets, curbs, gutters, sidewalk)· Reduces stormwater management costs· Increases lot yields and reduces impact fees· Increases lot and community marketability
Municipalities
<ul style="list-style-type: none">· Protects regional flora and fauna· Balances growth needs with environmental protection· Reduces municipal infrastructure and utility maintenance costs (streets, curbs, gutters, sidewalks, storm sewers)· Fosters public/private partnerships
Home Buyer
<ul style="list-style-type: none">· Protects site and regional water quality by reducing sediment, nutrient, and toxic loads to water bodies· Preserves and protects amenities that can translate into more salable homes and communities· Provides shading for homes and properly orients homes to help decrease monthly utility bills
Environment
<ul style="list-style-type: none">· Preserves integrity of ecological and biological systems· Protects site and regional water quality by reducing sediment, nutrient, and toxic loads to water bodies· Reduces impacts to local terrestrial and aquatic plants and animals· Preserves trees and natural vegetation

In case of cost, pilot projects of Los Angeles, U.S.A have shown that using LID Technologies instead of conventional stormwater controls can result in considerable capital cost savings. An analysis of LID&T projects from across the nation conducted by the U.S. Environmental Protection Agency (EPA) in 2007 found that with just a few exceptions, the capital costs of LID&T projects were less than conventional water management controls. As shown in the Table 3.7, savings ranged from 15~80%.

Table 3.7 Cost comparisons between conventional and LID&T approaches (City of Los Angeles, 2009)

Project	Conventional development cost	LID&T cost	Cost difference	Percent difference
2nd Avenue SEA Street	\$868,803	\$651,548	\$217,255	25%
Auburn Hills	\$2,360,385	\$1,598,989	\$761,396	32%
Bellingham City Hall	\$27,600	\$5,600	\$22,000	80%
Bellingham Bloedel Donovan Park	\$52,800	\$12,800	\$40,000	76%
Gap Creek	\$4,620,600	\$3,942,100	\$678,500	15%
Garden Valley	\$324,400	\$260,700	\$63,700	20%
Kensington Estates	\$765,700	\$1,502,900	-\$737,200	-96%
Laurel Springs	\$1,654,021	\$1,149,552	\$504,469	30%
Mill Creek	\$12,510	\$9,099	\$3,411	27%
Prairie Glen	\$1,004,848	\$599,536	\$405,312	40%
Somerset	\$2,456,843	\$1,671,461	\$785,382	32%
Tellabs Corporate Campus	\$3,162,160	\$2,700,650	\$461,510	15%

Table 3.8 and 3.9 highlight some of the advantages for water supply and climate change that LID&T has to offer and provide interesting facts about the effectiveness of LID&T.

Table 3.8 Water supply and demand (City of Los Angeles, 2009)

Issues	How LID&T Helps	Supporting Facts
<ul style="list-style-type: none"> ·The L.A. area regularly faces water shortages and does not generate enough water to sustain itself. ·Only 13% of L.A. City's water supply comes from local Groundwater. ·At least 30% of all the water used in the City of Los-Angeles is used Outdoors. 	<ul style="list-style-type: none"> ·Decreases dependence on outside sources of water. ·Reduces the demand for irrigation water. Some methods also capture water for reuse. ·Increases the supply in the local water table. ·Promotes or requires the use of drought-tolerant plants. 	<ul style="list-style-type: none"> ·Widespread use of water infiltration, capture and reuse in L.A.: savings of 92,019,987 – 188,110,562m³ of imported water per year by 2030 (water consumption of 456,300~ 929,700 people.) ·Each lot of 1000m³ in L.A. has the potential to generate 378m³ of stormwater annually.

Table 3.9 Climate change (City of Los Angeles, 2009)

Issues	How LID&T Helps	Supporting Facts
<ul style="list-style-type: none"> ·Fossil fuels are the #1 source of the greenhouse gases that cause climate change. ·World temperatures could rise by between 1.1 and 6.4°C during the 21st century. ·In the summer, central Los- Angeles is typically 2.8°C warmer than surrounding suburban and rural areas due to the heat island effect 	<ul style="list-style-type: none"> ·Increasing the local water supply means that Los-Angeles will use less energy pumping water from distant locations. ·Trees and landscaping counteract climate change by absorbing excess carbon dioxide. ·Shade from trees and evapotranspiration by plants reduce the heat island effect. 	<ul style="list-style-type: none"> ·Water systems account for 19% of the electricity used in the state of California. ·L.A. County could save 131,700~ 428,000 mWh of energy per year if less water was transported from Northern California (Equivalent to electricity use of 20,000~64,800 households). ·Each shade tree in L.A. prevents the combustion of 18kg of carbon annually

3.4.4 Barriers to implementation

Since LID&T is relatively new and unfamiliar concept, implementing this new approach will require a major effort to educate and engage everyone involved – state and local governments; developers; engineers and contractors; as well as homeowners. Effective implementation of LID&T requires reviewers and practitioners to fully understand and accept it. Many of the solutions to these barriers are going to take considerable time to become the status quo, as they require substantial behavioral modifications within the institution of water management.

① Regulatory Barriers

- Lack of clarity in stormwater management requirements.
- Uncertainty on how to calculate benefits of LID&T practices.
- Inflexibility of design criteria in ordinances preventing adaptability.
- Insufficient inspection and enforcement during construction and post-construction Phases

② Technical Barriers

- Overall lack of technical capacity for investigating regional conditions.
- Lack of standardized process for investigations and site remediation.
- Lack of installers' knowledge of new practices, and resistance to implement and learn about them
- Decision-makers lack the knowledge that there are better stormwater management methods out there and what they are

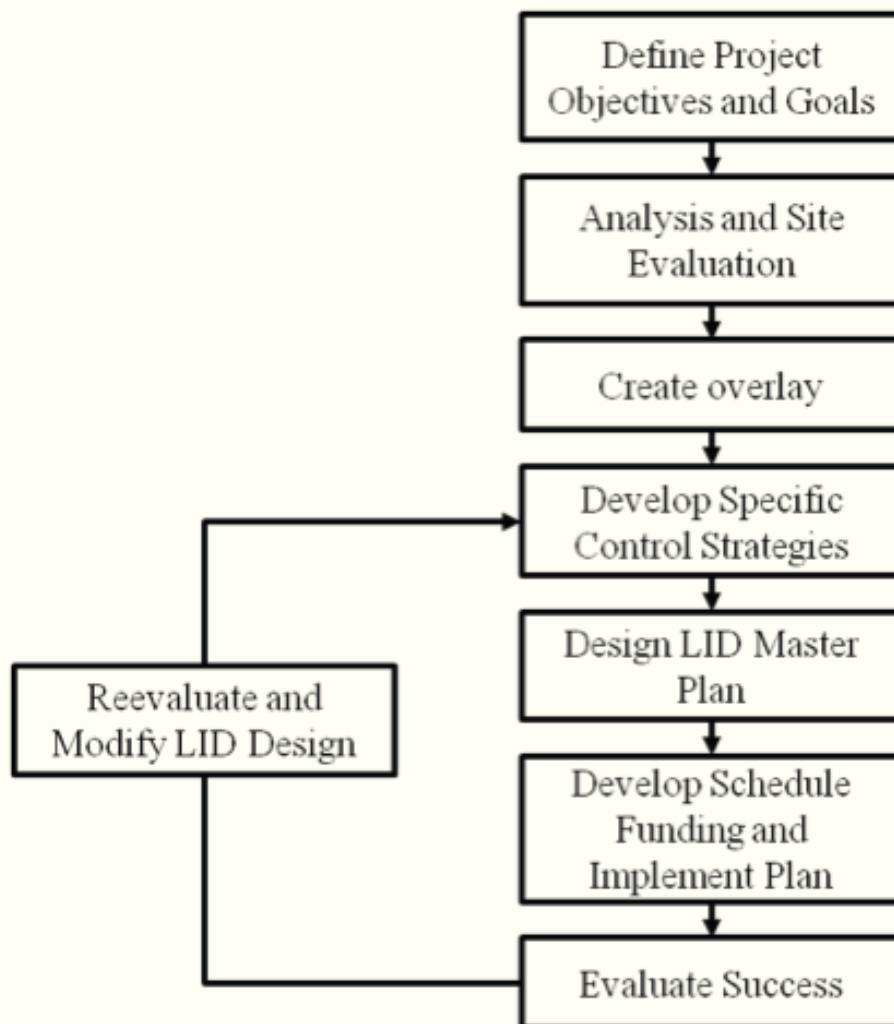
③ Social Barriers

- Lack of engagement in stormwater management issues by public officials
- Communication gap
- Economic benefits of GI not widely known, general scarcity of economic data regarding LID&T.
- Access to finance and security of government budget

3.4.5 Implementation Strategies

It is important to have a clear idea of the sustainability goals in order to develop an effective LID&T stormwater management program. Once strategies and LID&T are identified, a master plan can be prepared. The LID&T Site Planning Process is shown in Figure 3.4 (Guillette, 2010).

Figure 3.4 LID&T Design and Planning Process (Guillette, 2010)



A step-by-step process for LID&T design is described below (Guillette, 2010):

① Define Project Objectives and Goals

- Identify the LID&T objectives for the entire project.
- Determine the goals and feasibility for water quality, water quantity, peak runoff control, and on-site use of stormwater.
- Determine project character/aesthetic. Identify the baseline principles from which LID&T design decisions will be made by defining the LID technologies that support the concept and visual aesthetic. Determine if it is a goal to irrigate open space with captured rainwater, or whether rain barrels are a suitable aesthetic for front or back yards. Determine if it is important to offer residential homeowners the ability to use rain barrels for private irrigation needs, or use subsurface detention facilities for carwashes. Consider whether green roofs or roof gardens are consistent with the envisioned architectural design.
- Prioritize and rank basic objectives.

② Analysis and Site Evaluation

- A site evaluation will facilitate LID&T design by providing infrastructural, contextual, cultural, and community clues that will assist in the development of a LID&T program.
- Conduct a detailed investigation of the site through collected materials such as drainage maps, utilities information, soils maps, land use plans, and aerial photographs.
- Perform an on-site evaluation highlighting opportunities and constraints, such as pollutant hot spots, potential disconnects from Combined Sewer Overflows (CSOs), slopes, critical drainage areas, sunlight, shade, wind, habitat, potential green corridors, circulation, power lines, and storm drains. Make note of potential LID&T practices and areas where water quality and quantity controls could be installed.

③ Create Overlay

- Classify the land use on the project site.
- Review the proposed architectural plan to identify buildings and structures, open or vegetated space, parking lots, parking lot islands, side yards, vegetated strips adjacent to sidewalks, and buffer areas.
- Create an overlay that identifies opportunities for LID&T devices.

④ Develop LID&T Control Strategies

- Develop a list of LID control strategies that potentially fulfill the objectives. Determine the appropriate number of LID&T controls needed. Identify specific LID&T technologies for the project site and determine how to integrate them, keeping in mind the optimum location, to meet their design objectives.
- Specify LID technologies for each land use component.

⑤ Design LID Master Plan

- Sketch a design concept that distributes the LID&T devices uniformly around the project site. Keep in mind that some LID technologies can be used to capture stormwater from adjacent impervious areas. Consider where public recreation areas can be provided, such as networks of open space or green corridors. Take into account using all surfaces (built, hardscape, and landscape). Keep in mind the multifunctional aspect of LID technologies (i.e., parking lot with sub-surface detention facility).
- Develop a master plan that identifies all key control issues (water quality, water quantity, water conservation) and implementation areas. Specify specific LID technologies and any connections they have to stormwater overflow units and sub-surface detention facilities.
- Finalize the plan.

⑥ Develop Schedule, Funding, Construction, and Implementation Plans

- The development process is not a linear or static process but one that is dynamic and adaptable.


⑦ Evaluate Success or Modify Design

- Developing a stormwater management program using LID&T principles and practices is a dynamic process. Evaluate the design to see if it meets project stormwater management objectives.
- Conducting modeling and/or calculations to determine if the master plan meets stormwater control objectives. If the design does not meet the requirements, consider alternative strategies and repeat Steps 4, 5, and 6.
- Periodically reevaluate the plan during the implementation process to determine if revisions need to be made to the stormwater management program.


3.4.6 Examples

1) Technologies for site planning


The most important low impact development often occurs during a project's planning phase, well before any "green infrastructure" features are installed. Properly planning the layout of a site to enhance natural drainage patterns and developing a strategy to preserve the infiltration capacity of the existing soil during construction can make a significant difference in the success of a LID&T project.

Site Evaluation and Planning	
	During the design phase, property owners and designers should evaluate the topographic and hydrologic features of their site and minimize the amount of impervious surfaces. Soil characteristics determine whether the site is best suited for water capture or infiltration. Low impact development should be placed in locations that will maximize infiltration and minimize runoff.


(McGraw-Hill Construction, 2008).

Retaining Existing Trees and Large Vegetation	
	Retaining existing trees and large vegetation that has well developed root systems can help improve the infiltration capacity of a low impact development site.

(McGraw-Hill Construction, 2008).

Proper Site Grading	
	LID sites can be graded to enhance natural drainage patterns by directing water towards rain gardens and infiltration zones. Flat or shallow slopes reduce the velocity of stormwater runoff, allowing for greater infiltration. Moreover, carefully planned grading practices can help preserve valuable topsoil.

(McGraw-Hill Construction, 2008).

Preserving Top Soil and Preventing Soil Compaction	
	Healthy top soil can be a major asset to a LID site because it absorbs water quickly and the vegetation and microbes help filter out pollutants from urban runoff. Compaction can greatly reduce the infiltration capacity of soil. Therefore, strategies should be developed to preserve topsoil and to prevent soil compaction, especially during the construction phase of any LID project.

(McGraw-Hill Construction, 2008).

2) Technologies for landscape

Vegetated Swales



A vegetated swale is a broad, shallow channel with a dense stand of vegetation covering the side slopes and the bottom. Swales can be natural or manmade, and are designed to trap particulate pollutants (suspended solids, trace metals), promote infiltration, and reduce flow velocity from stormwater runoff

(McGraw-Hill Construction, 2008).

Bioswales



Bioswales are landscape elements, very similar to vegetated swales, designed to remove silt and pollution from surface runoff water. They direct drainage with gently sloped sides (less than 6%) and are filled with vegetation, compost and/or rip rap. The water's flow path is designed to maximize the time water spends in the swale.

(McGraw-Hill Construction, 2008).

Rain garden



A rain garden, created in a low spot on a property, captures rain and excess irrigation water from roofs, driveways and yards. Runoff is directed into the rain garden to support landscapes and for infiltration to ground water. In a sense, a rain garden is a "mini-bioretenention" swale that can be particularly well-suited for residential properties. Supplemental irrigation may be required during the dry season.

(McGraw-Hill Construction, 2008).

Infiltration Swales / Basins / Trenches



Infiltration swales are designed for conveyance and infiltration, with less emphasis on growing vegetation. They are depressions created by excavation, berms, or small dams placed in a channel intended to infiltrate the storm runoff from impervious surfaces. Infiltration basins and trenches serve similar purposes as swales, but the tops may be hidden with covers that could range from landscaping to a porous material, such as decomposed granite.

(McGraw-Hill Construction, 2008).

3) Technologies for building

Green building strategies achieve multiple objectives like resource and energy conservation, and environmental quality: Design with nature, and orient buildings to optimize microclimate, landscape with native plants and manage stormwater on site. Green buildings see up to a 9% decrease in operational costs over conventional buildings (McGraw-Hill Construction, 2008).

Green roof



Placement of rooftop planting system that allows for sustained presence of live plants covering a significant portion of a building's roof. Green roofs can provide a range of environmental (stormwater runoff reduction, energy savings), economic, and social benefits.

(McGraw-Hill Construction, 2008).

Cistern



Reservoirs, tanks, or containers can be used to store stormwater for non-potable reuse (such as landscape irrigation). Cisterns are usually placed underground, but can also sit above ground. The cistern system on the left directs rainfall from the roof through a sand pit to filter out impurities; it then collects the water in an underground cistern. Cisterns can vary in size from smaller household units to large underground storage areas beneath outdoor playing fields. These features can also be made into attractive architectural elements. A pump may be required to harvest the water for reuse.

(McGraw-Hill Construction, 2008).

Rain Barrels



Rain barrels are used to store rainwater for later reuse. Gutters and downspouts direct rainfall from rooftops into the barrels. Rain barrels are smaller and less expensive than cisterns, making them more appropriate for residential buildings. Most barrels have spigots so that the water can be easily accessed for irrigation. Rain barrels are made from a variety of materials and can be an attractive landscape feature. They commonly have provisions to prevent mosquitoes from breeding.

(McGraw-Hill Construction, 2008).

4) Technologies for street

Green streets would be able to capture over 90% of street runoff at the Parkade site, inverting stormwater from conventional infrastructure and providing opportunities for reuse. Streets occupy nearly a quarter of the site in the preliminary design for the Parkade site. Because typical streets are impermeable, all the rain that falls on them becomes stormwater that needs to be managed. With street trees, swales, planted medians, and stormwater planters, green streets are able to manage stormwater through interception, evapotranspiration, and attenuation.

Porous Pavement & Sidewalks



Porous/permeable/pervious pavement and sidewalks absorb water, allowing infiltration into the soil layer below. They are especially appropriate for highly urbanized areas where open space is scarce. Porous pavement usually needs to be vacuum swept periodically to keep pores unclogged. Side benefits: (1) reduces danger of hydroplaning for cars, (2) some porous pavements absorb and store less heat, so they can help reduce temperatures in an urban environment.

(McGraw-Hill Construction, 2008).

Permeable and Vegetable Pavers



Permeable pavers allow water to percolate through crevices between paving blocks. They come in a variety of styles, shapes and sizes. Cobblestones are a popular example. And Vegetated pavers help natural infiltration by reducing the overall imperviousness of otherwise paved areas. They can be used for sidewalks, driveways, and parking lots. They address stormwater through small, cost-effective, attractive landscape features located at the lot level.

(McGraw-Hill Construction, 2008).

Curb Cuts



Curb cuts can be used to direct runoff from paved areas into infiltration zones such as bioswales. They allow stormwater runoff to enter a vegetated area and infiltrate the underlying root system or soil medium.

(McGraw-Hill Construction, 2008).

Tree boxes



Tree boxes can be installed upstream of a catch basin to intercept urban runoff from a gutter (up to a certain volume). The runoff is used to irrigate the tree and local landscaping, and provides infiltration. During heavy rains, the excess water beyond the capacity of the tree box flows into the catch basin. Tree boxes are placed below grade so trash is also intercepted, which is then manually removed on a periodic basis.


(McGraw-Hill Construction, 2008).

4. Case study

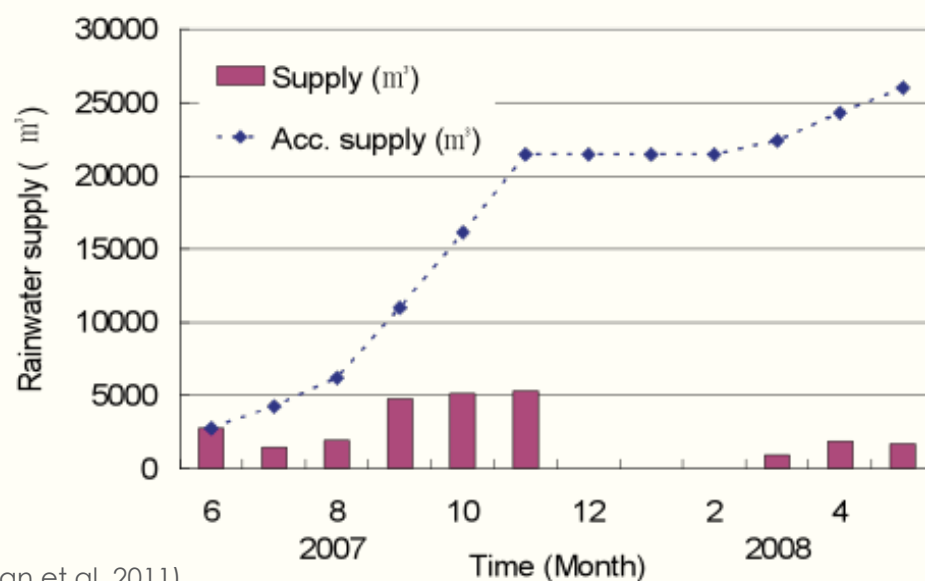
4.1 Rainwater/Stormwater harvesting

Project : Juyeop Elementary School, South Korea

Classification	Contents
Key messages	<ul style="list-style-type: none"> Eco friendly School : Rainwater facilities, Planting trees, roof park, Eco-pond
Background	<ul style="list-style-type: none"> Based on Korea government's Green Growth National Vision (Green School Initiatives) Provide the education to students by installing rainwater and wastewater recycling system and green equipment On-Site Water Supply and reduction of carbon (Green Growth & Low Carbon Business)
What was done	<ul style="list-style-type: none"> Plan for non-point source control <ul style="list-style-type: none"> First flushing of rain below 5 mm per hour Non-Point Pollution Source Control: heavy metal, Phosphorus, Nitrogen, Suspended solid, Oils etc. Plan for Calculating the Size of Rainwater Tanks <ul style="list-style-type: none"> Collecting space (roof space m^2) \times 0.1 ~ 0.15 Simulation analysis based on rainwater data (Rain-Stock & Rain-City Program) Contingency Plan for Full Tank <ul style="list-style-type: none"> Install the butterfly electronic valve in front of rain water tank <div> </div>
Results	<p>Rainwater management system was constructed in Juyeop elementary school, which was established in 2004 year. Rainwater is used for toilet flushing, irrigation, gardening and spaying for playground. Integrated operation and maintenance system based on remote monitoring and control is equipped in this system.</p>

Classification	Contents
Key lessons	<ul style="list-style-type: none"> • The concept of a multipurpose in rainwater harvesting system : the system is used in flood mitigation, water conservation, and emergency response. • The proactive management of flooding: Three different tanks store water separately according to water quality. The risk of flooding is mitigated with a remote control system by emptying or filling the tanks appropriately. • City government's incentive program for the developer to alleviate fear of any economic disadvantage. The developer was permitted to construct three percent more floor space above what would normally be allowed. Considering the price of real estate in Seoul, that is a significant incentive.
Background	<p>Star City, where is located in an eastern suburb of Seoul, South Korea, is a major real-estate development project of more than 1,300 apartments. It comprises four 37–58 story buildings on an ~5 ha site. Star City has a plane area of 62,505 m² and a constructed building area of 16,868 m². The Star City RWHS has been operating since 2007 and is receiving attention as a model water management system that supplements the existing centralized water infrastructure as a CCA strategy (IWA, 2008).</p>
What was done	<p>The catchment area comprises 6,200 m² of rooftop and 45,000 m² of terrace. The entire fourth below-ground floor in Building B is used as a water storage area. Altogether, 3,000 m³ of water is stored in three separate tanks with a total floor area of 1,500 m². The capacity of each tank is 1,000 m³. Two of the tanks are used to store rainwater from the rooftops and the ground. Garden irrigation is achieved efficiently by ground infiltration, which is recycled to the tank for multiple uses. The third tank stores emergency tap water. Fresh tap water is maintained by regular replenishment after decanting half of the old water to the rainwater tank.</p>  <p>(International Water Association, 2008)</p> <p>The quantity of rainwater flowing into the tanks is measured by pipe- and weir-type flow meters. The shock absorber is used to relieve the high flow velocity of rainwater from the top of the building. A screen and a filter are used for pretreatment. The calm inlet and floating suction are installed to mitigate the resuspension of bottom sludge and draw out high-quality subsurface rainwater, respectively.</p>
Results	<p>About 26,000 m³ of water was saved per year from rainwater supply, which is ~47% of the annual amount of rainfall over the Star City complex. The ratios of the volume of water conserved per month to monthly amount of rainfall, ranged widely from 18% in July to over 200% in November. The turbidity of the rainwater in the tanks was below 1.5 NTU and their pH was between 6 and 8.4. The tank volume–catchment area ratio of 5.8 m³/100 m² and 10 year design period for this building would provide protection from a 50 year rainfall flood event. It is also estimated that approximately 8.9 MWh of electricity was saved from June 2007 to May 2008 by using the 26,000 m³ of rainwater.</p>

The Star City approach shows that DRM can be a feasible supplement to the existing centralized system, and CCA in a newly constructed residential complex can be achieved by installing a proactive and multipurpose RWHS.



(M.Y. Han et al, 2011)


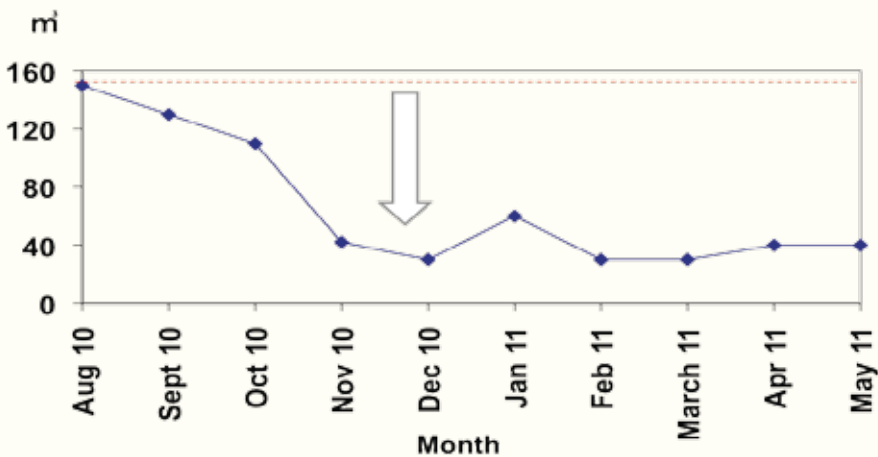
References

- M.Y. Han and J.S. Mun (2011) Operational data of the Star City rainwater harvesting system and its role as a climate change adaptation and a social influence, *Water Science & Technology*, 63(12), pp. 2796-2801.
- International Water Association (2008) Seoul's Star City: a rainwater harvesting benchmark for Korea. *Water* 21, 17–18

4.2 Greywater reuse

Project : Department of Science and Technology (DOST) Region 7, Philippines

Classification	Contents
Key lessons	<p>The project serves as an inspiration to water policy makers in Cebu. The ISWM project provides a “proof of concept” those intending to emulate such facility.</p> <p>The facility also is a potent visual tool for the education of students on rainwater, stormwater and waste water management.</p>
Background	<p>As one of the key actions of the Green Growth strategy, the United Nations Economic and Social Commission for Asia and Pacific (ESCAP) located in Bangkok, Thailand and the Department of Science & Technology – Region 7 (DOST-7) jointly initiated a pilot project “Integrated Stormwater Management” (ISWM) to be implemented in Cebu to address the related water challenges and to support other similar on-going efforts in the country. The project aims to improve the awareness and advocacy on integrated stormwater management as one of the key eco-efficient approaches, to alleviate the impact of stormwater surges to the eco-system, and to promote the reuse of wastewater with green technology developed in Korea.</p> <p>The objectives of the project is to strengthen the capacities of local government officials for the planning and management on the integrated rainwater and stormwater recycling system through the implementation of the pilot demonstration project and, to establish the model for integrated rainwater and stormwater recycling system in the selected building to demonstrate the eco-efficient approaches for water infrastructure</p> <ul style="list-style-type: none"> • Venue: DOST 7 Office Building, The S&T Complex, Sudlon, Lahug, Cebu City, 6000 Philippines • Project cost: US\$45,000 from ESCAP (Construction cost of the tanks by DOST 7, MF system donated by EREDE co. Ltd.) • Project duration: 2009-2010 (12 months) • Information Source: http://www.ro7.dost.gov.ph/ <div data-bbox="531 1406 1447 2016"> <p style="text-align: center;">Needs of combined utilization</p> <p style="text-align: center; color: orange; font-size: 1.2em;"><i>Combined System</i></p> </div> <p style="text-align: right;">(Kim, R, 2011)</p>

<p>What was done</p>	<p>Major Components of the ISWM Facility is consist of Rainwater collection, Primary Rainwater Treatment, Micro-membrane Filtration System, Integrated Rainwater Administration System, Rainwater Drainage against Emergencies, Reuse Water Treatment System.</p> <ul style="list-style-type: none"> • Rainwater Collection: Rainwater from roof and stormwater from porous surface of roads. • Primary Rainwater Treatment (Green Filter): First flushing; initially removes contaminants / pollutants. • Micro-membrane Filtration System (MF System): Metal membranes to reduce microbial and particulate pollutants. • Integrated Rainwater Administration System: Wireless monitoring devices, controllers for pumps/valves, server • Rainwater Drainage against Emergencies: System to divert overflows and excess water. • Reuse Water Treatment System: Uses advanced biological treatment processes that eliminate organic and nitrogen compounds. <p>Figure 4.13 Photo of the DOST regional office and system (Kim, R, 2011)</p> <div data-bbox="480 824 1506 1178">  </div>																						
<p>Results</p>	<ul style="list-style-type: none"> • The consumption of water coming from the Metro Cebu Water District (MCWD) as it is supplied to the DOST 7 was 160 cu. m in August of 2010. When the ISWM facility of the DOST 7 was installed, dependence on MWCD water reduced to 40 cu. m as of May 2011 or a reduction of 75%. <div data-bbox="549 1417 1430 1872">  <table border="1"> <thead> <tr> <th>Month</th> <th>Water Consumption (cu. m)</th> </tr> </thead> <tbody> <tr><td>Aug 10</td><td>160</td></tr> <tr><td>Sept 10</td><td>130</td></tr> <tr><td>Oct 10</td><td>110</td></tr> <tr><td>Nov 10</td><td>45</td></tr> <tr><td>Dec 10</td><td>35</td></tr> <tr><td>Jan 11</td><td>60</td></tr> <tr><td>Feb 11</td><td>35</td></tr> <tr><td>March 11</td><td>35</td></tr> <tr><td>Apr 11</td><td>40</td></tr> <tr><td>May 11</td><td>40</td></tr> </tbody> </table> </div> <p>(Kim, R, 2011)</p> <ul style="list-style-type: none"> • The facility controls flooding at the DOST 7 compound. • Treatment of the wash and “grey” water allows the DOST 7 to comply with the requirements of the clean water law. 	Month	Water Consumption (cu. m)	Aug 10	160	Sept 10	130	Oct 10	110	Nov 10	45	Dec 10	35	Jan 11	60	Feb 11	35	March 11	35	Apr 11	40	May 11	40
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May 11	40																						

	<ul style="list-style-type: none">• Capacity Building Program Component·The training materials (guidelines) were developed in collaboration with DOST 7 officers and ESCAP.·Advocacy and training workshops were held for maintenance &operation and for development of the replication plan to other regions·Site visits were arranged for stakeholders in the region to enhance the awareness and replication of the system into region
References	<ul style="list-style-type: none">• Reeho Kim, Best Practices in Rainwater and Stormwater Management, Training-Workshop on Eco-efficient Water Infrastructure Development for Green Growth in the Philippines, 2011• Reeho Kim, The integrated rainwater and greywater management project in Cebu, Philippines, Low impact development symposium, Pennsylvania. 2011

Classification	Contents
Background	<p>Kuching, the capital of the Malaysian State of Sarawak, is located on the Island of Borneo in the South China Sea. The city is situated along both sides of Sungai Sarawak (Sarawak River), some 40 km from the river mouth. Large parts of the city are situated on flat terrain of unstable peat swamp and soft clay. The city of Kuching is currently lacking a wastewater treatment plant, and the local subsurface conditions make a conventional centralized wastewater system expensive to implement.</p> <p>Most buildings (residential, institutional, commercial, and industrial) in Kuching are equipped with two separate wastewater outlets, one outlet for black water (toilet wastewater) and one or more for greywater (washing, bathing and kitchen), although this is not the required building standard. Black water flows into septic tanks, either within the housing plot or at communal level serving commercial buildings or residential complexes. The septic tanks subsequently discharge their effluents directly into the stormwater drains from where they are conveyed into the nearest aquatic system. Greywater is also discharged into the stormwater network or directly into receiving waters. Some oil and grease traps have been installed at large food outlets at the request of Kuching North City Hall (DBKU) and Kuching City South Council (MBKS).</p> <p>These facilities are, however, generally undersized and often only emptied irregularly. The demonstration project described herewith is based on source separation of black water and greywater from nine residential terraced houses (average of five persons per household) in Hui Sing Garden, Kuching. The treatment facility is located in the adjacent park and operated since December 2003.</p>
What was done	<p>The system treats greywater from nine households, including water from laundry, kitchen, bath, washbasin, and other in-house water outlets excluding toilets. Total greywater production amounts to approximately 225 l/p/d, with an average 6.8m³/day inflow into the treatment system. The grey water treatment system comprises a baffled, septic tank and primary treatment unit to remove oil, grease and settleable solids, followed by a dosing chamber. The greywater then flows into four vertical down-flow, single-pass aerobic biofilters before reaching a subsurface horizontal-flow planted filter. The treated greywater then exit the system into the stormwater drain through an outlet comprising an integrated tip-bucket flow measurement system.</p> <div data-bbox="408 1574 1482 1946" data-label="Diagram"> </div> <p>(Greywater Management in Low and Middle-Income Countries,2006)</p>


Results	<p>The initial purpose of the Hui Sing Garden EcoSan demonstration project was to prove that the concept chosen is a technically viable approach to decentralized greywater treatment in Sarawak. The second and equally important aspect was to ascertain whether the greywater facility would be accepted in an urban residential setting. The Hui Sing Garden EcoSan demonstration project yielded highly promising treatment results and fulfilled its purpose since its operation in 2003. The project provides valuable data and practical experience on decentralized urban greywater treatment.</p> <p>A social survey of the nine families serviced was conducted in 2004. The residents of Hui Sing Garden strongly support the project, indicating both enthusiasm and interest in its future success. An additional social survey was conducted with 108 daily users of the park containing the greywater facility. Eight park users voiced their concern about the occasional odor emissions from the facility. The other hundred users did not pass any comment or make complaints. Occasional odors are believed to be emitted after clogging of the biofilters given the extremely high levels of oil and grease used in the preparation of traditional Malaysian food.</p> <p>The capital costs of this greywater treatment system are high and probably not affordable by single households. Nevertheless, this system can be a suitable solution for neighborhoods, as per capita costs decrease with increasing household connections. Since system performance is extremely high due to the low-strength inflowing greywater, the need for a vertical-flow and a horizontal-flow filter unit should be questioned.</p>
References	<ul style="list-style-type: none"> • Greywater Management in Low and Middle-Income Countries, Sandec (Water and Sanitation in Developing Countries) at Eawag (Swiss Federal Institute of Aquatic Science and Technology), 2006

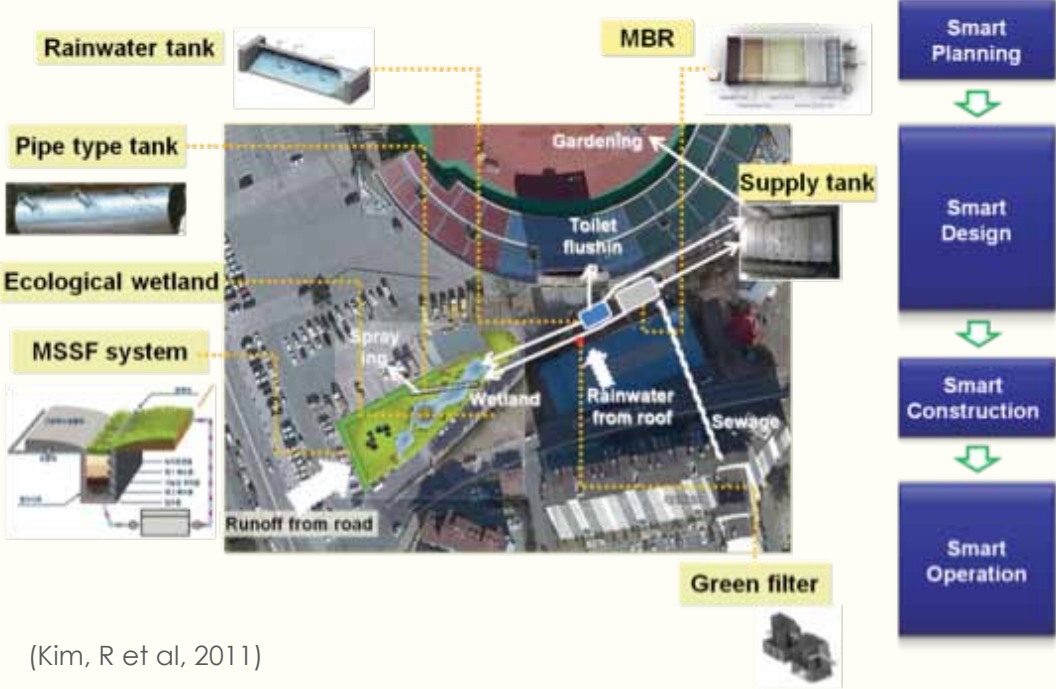
Classification	Contents
Background	<p>The city of Djenné with its approx. 20,000 inhabitants is situated in the inner delta of the Niger River (Sub-Saharan climate). The city, famous for its adobe buildings, is considered one of the most architecturally interesting cities of West Africa. Since 1988, UNESCO lists Djenné as a World Heritage Site. In the early 1990s, foreign development organizations built a drinking water supply system in the city of Djenné. Washing and bathing activities were thus shifted from the river shore to the household. No facilities were provided for greywater disposal. Despite the very low water consumption of 30 liters per person and day, a considerable daily greywater volume was discharged directly onto the streets. This type of disposal not only had a detrimental effect on public health, but also led to impassable roads and suspended street cleaning operations altogether.</p> <p>In 2000, a study was conducted to evaluate possible options to mitigate the greywater problem. Local greywater infiltration was piloted in 2002. Within the project framework, one hundred infiltration system were built throughout the city using local material and labor. By 2004, already 600 households were connected to a greywater infiltration system.</p>
What was done	<p>Greywater from kitchen, bath and laundry flows through a PVC pipe (Ø 110 mm, covered with local pottery so as to blend in with the adobe buildings) into a grease and grit trap (Figure 5-1). The trap, located at the bottom of the outer wall of the house, is easily accessible for maintenance. The pretreated greywater leaves the grease and grit trap through a small bore pipe (Ø 40 mm) entering the infiltration trench. The infiltration trench is 0.5 m wide and not more than 1.5 m deep to allow safe working conditions for the craftsmen.</p> <div data-bbox="557 1149 1260 1568"> </div> <div data-bbox="557 1583 1313 1968"> </div> <p>(Greywater Management in Low and Middle-Income Countries,2006)</p>


Results	<p>Success of the project strongly depends on local community involvement. The basic principle and impact of the infiltration system were demonstrated at two strategic locations: at the house of a person of rank and of the mayor. Based on the visible success of these two reference locations, acceptance and willingness of the community to cooperate increased significantly. Organization of instruction meetings with woman groups before, during and after construction of the infiltration system with special focus on maintenance of the grease and grit trap also contributed to successful implementation of the system. Much effort was put into training local craftsmen who were organized in teams of one mason and two laborers. After intensive training, the first team further disseminated its knowledge to other teams. Upon project evaluation in January 2003, the various teams trained could set up an infiltration system in two years. In September, 2004, over 600 houses were equipped with infiltration facilities whose number is further increasing.</p> <p>This case study is a good example for successful implementation of a simple but effective greywater treatment system. Involvement of local technical expertise and intensive training of users proved to be an important tool for implementing a sustainable solution. Future potential clogging of the infiltration trench should continue to be investigated with increasing water consumption and greywater production.</p>
References	<ul style="list-style-type: none"> • Greywater Management in Low and Middle-Income Countries, Sandec (Water and Sanitation in Developing Countries) at Eawag (Swiss Federal Institute of Aquatic Science and Technology), 2006

4.3 Decentralized wastewater treatment

Gangneung sports complex, Gangneung, South Korea

Classification	Contents
Key lessons	<ul style="list-style-type: none"> • Secure competitive technology for combination of grey water and rainwater hybrid system • Acquire smart operation & management of hybrid system to adapt climate change • Correct negative recognition against grey water and encourage water saving • Establish sustainable and low cost water supply measure • Enhance social awareness to sustainable water management • Improve national competitiveness of green city
Background	<p>In Gangneung city where located in middle-east part of Korea, a master plan for Low Carbon Green City was prepared in 2009 to develop test bed for realizing representative world-wide Low Carbon Green City. The basic concepts for this project are utilization, remobilization, preservation and management. The plan for land use is shown in the below figure.</p>  <p>(Kim, R et al, 2011)</p> <p>Particularly, water circulation and reuse such as restoration of eco stream, rainwater storage and infiltration, grey water and non-point source control is emphasized in the project. One of representative facilities, Rainwater harvesting and wastewater reuse hybrid system was completed at the sports on Oct. 2011.</p>

What was done	<ul style="list-style-type: none"> • Wastewater treatment and reuse system • Membrane Biological Reactor (MBR): 100 m³/day • Rainwater and stormwater harvestings system • Catchment area: roof - about 1,500m²/ road & parking lot: 2,400m² • Storage capacity: 60 m³ +20 m³ • Usage: Gardening, spraying, toilet flushing, wetland, fire fighting, etc
Results	 <p>(Kim, R et al, 2011)</p>
References	<ul style="list-style-type: none"> • Reeho Kim, Jungsoo Mun, Jung-hun Lee, Hana Kim and Yong hak Kim (2011) Rainwater Harvesting System connected with other water resources, 8th International Rainwater Forum, 22 March 2011, Changwon Exhibition Convention Center (CECO), Changwon, Korea.

Classification	Contents
Background	<p>Piperton, Tennessee, a rural city on the outskirts of Memphis, was in need of wastewater infrastructure to accommodate new development. In 2001, facing pressure from increasing growth in the Memphis area, the city evaluated three methods of providing wastewater infrastructure: (1) constructing a centralized wastewater treatment plant (WWTP); (2) tying into the adjacent town's WWTP; and (3) using a distributed network approach to accommodate development when and where it was needed. So, Overarching project objectives were to sustainably accommodate and serve new growth in Piperton when and where it was needed and to preserve open space. Distributed treatment gives the city independence with its own infrastructure, limits the burden on tax payers, lowers the energy costs associated with centralized collection and ultimately is better for public health and the environment than individual septic tanks or widespread sewerage. Perhaps the biggest benefit is the ability to build when and where needed, which eliminates the huge capital outlay and burden on taxpayers.</p>
What was done	<ul style="list-style-type: none"> •Collection: Septic tank effluent pumping (STEP) and septic tank effluent gravity (STEG) to low pressure sewer mains. •Treatment: Bioclere™ fixed-film system followed by UV disinfection. • Flow rate: Six cluster systems of 75 to 300 m³/d (20,000 to 80,000 gpd). • Total of 1,000 m³ /d (280,000 gpd) of sewer capacity is installed.  <p>(www.aquapoint.com/images/Piperton%20Case%20Study-FOR%20SPE%20ONLY.pdf)</p>
Results	<p>As of March, 2008, Piperton has installed four systems with two under construction. When these are all operational the Bioclere systems will be capable of treating wastewater from 750 homes. The systems range in size from 20,000 gpd to 80,000 gpd. Currently, the total distributed network can handle 280,000 gpd. But this is just the beginning. Piperton is in the initial stages of development and their decision to go with distributed wastewater treatment has already proven to be a smart choice.</p>
References	<ul style="list-style-type: none"> •www.aquapoint.com/images/Piperton%20Case%20Study-FOR%20SPE%20ONLY.pdf

4.4 Integrated water management

Project : Asan new city, South Korea

Classification	Contents
Background	<p>Tangeong area, Asan new city was constructed a decentralized rainwater management system with construction worth of USD 77 million (company share: USD 31 million). As a part of "Low Carbon, Green Growth" movement in Korea, Taeyoung E&C will install a management system - with a total size of 1,753,385 m² and schedule for completion by 2016 - in Buldang area, Cheonan-si, Chungcheongnam-do, that will collect and evaporate rainwater in order to prevent stream pollution.</p>
What was done	<ul style="list-style-type: none">• Application of decentralized stormwater and rainwater management in a whole city scale• Infiltration and storage of runoff: over 40 % out of total rainfall
Results	<ul style="list-style-type: none">• Proposition of new paradigm of rainwater management through development of localized rainwater management technologies• Enhancement of urban environmental quality by restoration of water cycle• Improvement of urban micro climate by mitigation of heat island phenomena• Non-point source by first-flush storage and infiltration• Security of alternative water resources by rainwater use• Reduction of water-related disasters by source control• Promotion of Green new technologies through introduction of innovative process
References	<ul style="list-style-type: none">• Choi, Hanna (2011) New city planning with decentralized rainwater management based on LID, Symposium on decentralized rainwater management

5. Summary and future perspectives

Present water management system is vulnerable to climate change and urbanization. Thus, future water management system should be considered water security, urban flood control, improvement of thermal environment, reduction of energy consumption and production of energy using potential and heat energy of water resources. The goal of Eco-Efficient Water management Infrastructure (EEWI), which is the future water management strategy, is to achieve the smart watery city which includes water, energy and ecology. It is important to promote the watery city to improve efficiency of water management system and adapt climate change. The first strategy to achieve the EEWI is the site development planning to encourage conservation of natural resources, functionalize green area and minimize impervious area and DCIA. And the second one is water management including separated sewer systems, on site rainwater and stormwater management, efficient use of rainwater and stormwater runoff and wastewater, decentralized wastewater management with Eco-San, improvement of flood control capacity with preparation of flood plain and pollution prevention. Finally, the third one is public involvement such as education program.

To further promote EEWI, however, more attention should be paid to policy making and technology development. Since there are many different aspects of EEWI, the policy to promote or regulate EEWI should consider water, energy and ecology. In addition, the detailed guidelines for design, installation, and maintenance of EEWI should be prepared together with the laws and ordinances. Successful implementation of demo projects will be also a great contribution for future application of EEWI technology. Since there are many different aspects of EEWI, the policy to promote or regulate EEWI should consider water, energy and ecology. In addition, the detailed guidelines for design, installation, and maintenance of EEWI should be prepared together with the laws and ordinances. Successful implementation of demo projects will be also a great contribution for future application of EEWI technology.

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