NATURE-BASED SOLUTIONS FOR BUILDING RESILIENCE IN TOWNS AND CITIES

Case Studies from the Greater Mekong Subregion

ASIAN DEVELOPMENT BANK

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Foreword

Climate-related disasters increasing around the world have led to a sense of alarm. These include extreme weather events such as floods and typhoons, and slow onset changes such as sea level rise. As a result, irreplaceable losses occur across all sectors of the economy. Affected communities face long-term socioeconomic impacts due to the diversion of scarce economic resources from required development to emergency responses. Nature-based solutions, or green infrastructure, can play a significant role by offsetting such losses to a certain degree. Green infrastructure approaches contribute to building resilience by rehabilitation and expansion of natural ecosystems within built areas.

This publication highlights the results of a successful partnership between the Asian Development Bank (ADB) and the International Centre for Environmental Management (ICEM) with cofinancing from the Nordic Development Fund (NDF). This was implemented through a technical assistance on climate resilience in cities in the Greater Mekong Subregion (GMS).[1] ICEM's demonstrated and widely tested expertise in climate adaptation and mitigation methodology provided the technical basis for the study. Cofinancing from the NDF provided the impetus for capacity building and knowledge sharing of international good practices. This was done through provincial and regional workshops in the three GMS towns specifically selected for the study due to their unique characteristics of riverine and coastal flood vulnerability. These included Battambang (Cambodia) with its large flood- and drought-prone watershed area and the Great Tonle Sap Lake; Kaysone Phomvihane (Lao People's Democratic Republic) which faces frequent extreme flooding along the Mekong River; and Dong Hoi (Viet Nam), the typhoon-prone coastline city threatened by sea level rise, storm surge, and flash flooding. Thus, learning covered a broad range of climate change-related issues such as the process of assessing climate change impacts and vulnerabilities, recording data, identifying and prioritizing adaptation measures, and preparing and implementing adaptation plans. Institutional mechanisms and technical measures for application and wider replication were identified from the experience gained from the three towns.

A core group of key players involved in climate change adaptation planning was established in each town. This comprised scientists, planners, government officials, nongovernment organizations and women's unions. A "train the trainers" approach was followed by the core groups to ensure systemic capacity building. This also fostered cross-sector collaboration and citizens' ownership, which is key to building resilience. The core groups helped to identify adaptation measures including application of alternative technology. These included green

[1] ADB. 2012. Greater Mekong Subregion: Climate Resilience in Cities. Manila. https://www.adb.org/projects/46252-001/main#project-pds

infrastructure measures to complement structural solutions and climate-proofing techniques for flood control and slope stabilization. As a result, comprehensive adaptation plans were prepared for socially inclusive urban climate resilience in each town.

This publication summarizes the rich seven-volume “Resource Kit on Building Resilience and Sustainability in Mekong Towns.”[2] It includes the principles of green infrastructure and measures for building resilience; nature-based solutions of special relevance to Mekong towns, grouped into four categories of water and flood management, slope stabilization, and pollution management; the urban planning and management framework required for mainstreaming of green infrastructure, in particular, the role of town master planning and zoning schemes; the process for conducting vulnerability assessment; and includes case studies in building urban resilience in the selected cities.

There is an opportunity for developing member countries to build on this learning and replicate institutional and technical measures within and outside the GMS. Progress in implementing national climate change mitigation and adaptation policies especially in urban areas is limited, largely due to awareness and institutional, technical, and financial limitations. A step forward is to advance the process of establishing an adaptation network between cities for city-to-city mentoring. This would also help scale up effective solutions through demonstration impact. Reforms in planning processes to systematically mainstream resilience in infrastructure development may range from the process of preparing and reviewing master plans and zoning schemes, to the design and management of urban infrastructure such as flood gates, drainage and sewerage, ports, markets, roads, and river training.

This publication highlights the need for integrating these principles into infrastructure policy, planning, and design. The value of the strong ownership and institutional commitment toward climate change adaptation and resilience built through the participatory and “hands-on process” has also been demonstrated. There is merit in maintaining this momentum by leveraging partnerships that optimize the competitive advantage of partners. These would extend to outreach in policy shifts, innovations in planning, design, and implementation together with continued training and capacity building.

Bambang Susantono
Vice-President for Knowledge Management and Sustainable Development
Asian Development Bank

[2] ICEM. Resource Kit for Building Resilience and Sustainability in Mekong Towns. http://icem.com.au/portfolio-items/resource-kit-for-building-resilience-and-sustainability-in-mekong-towns/

Message from the Nordic Development Fund

All over the world, urban populations are growing fast, projected to increase from 54% to 66% of the global population by 2050, with close to 90% of the increase concentrated in Asia and Africa.[3] That rapid and unplanned growth brings with it great challenges for environmental quality and sustainability—all made more serious by climate change. Cities and towns will need to play a crucial role in addressing those challenges, by mitigating the scale of climate change and reducing vulnerability to its negative effects. Cities are a growing source of greenhouse gas emissions. Low-carbon pathways are essential in reducing the contribution of urban areas to greenhouse gases. Equally important are urban adaptation plans and measures to build resilience to the changes. A foundation strategy for both those imperatives—mitigation and adaptation—is planning and managing urban areas according to ecosystem principles and by emphasizing green infrastructure solutions.

Vulnerability assessments and adaptation planning processes with close engagement of relevant stakeholders, including national and local governments, open the way to the promotion and development of green infrastructure. Vulnerability assessments document past extreme events and bring in climate change projections to determine potential impacts on infrastructure, communities, and areas. Adaptation planning defines appropriate responses to those impacts. When assessed and planned through a green infrastructure lens, the solutions explore options which bring greater local self-reliance through the use of local materials, labor, and capacities. Bioengineering, and local involvement in design, construction, management, monitoring, and repair are all key ingredients in resilience building, as a complement or alternative to conventional measures.

The financing partnership between the Asian Development Bank (ADB) and the Nordic Development Fund (NDF), together with the technical capabilities of ICEM–International Centre for Environmental Management, has applied that nature-based approach in identifying climate change vulnerabilities and development of relevant adaptation options in three towns of the Greater Mekong Subregion. Working closely with local government, nongovernment organizations, women's groups, and professional associations, adaptation measures were defined town-wide by overlaying climate change projections on town plans and zoning schemes, and for specific strategic infrastructure systems such as drainage corridors, river embankments, floodgates, and markets. The experience and lessons from this highly collaborative project are captured in this publication.

As a financing institution with a focused mandate on climate change and development, NDF is committed to promoting the adaptation and mitigation agendas of developing countries. Since the launch of the climate mandate, NDF has built a track record of adding value by investing in drivers of climate change mitigation and adaptation in over 20 countries, including the Greater Mekong

[3] United Nations. 2014. *World Urbanization Prospects: The 2014 Revision*. New York.

Subregion countries. Nordic countries score consistently high on global urban indices and a large repository exists of functioning Nordic urban solutions and knowledge for sharing through NDF-supported projects such as the one described here. The project provides multidisciplinary measures, tools, and lessons of value to similar towns and cities globally.

This publication rightfully emphasizes the importance of availability and reliability of climate data and of ensuring the availability of skilled human resources as the key aspects in achieving sustainable adaptation options in urban planning. Following the valuable lessons learned from the collaboration between ADB and NDF, a good platform now exists for further work. One relevant mechanism for taking forward such work is the Project Readiness Improvement Fund recently established at the initiative of ADB and NDF. This will help countries strengthen climate adaptation and mitigation components of investment projects, improve project design and procurement readiness, and accelerate implementation. The fund will also be an important enabling factor in achieving the Intended Nationally Determined Contributions of several countries in Asia, thus contributing to relevant, solid, country-owned adaptation and resilience actions. An increased focus on project preparation together with a deepened knowledge and innovation around functioning adaptation options, as well as an enhanced focus on education and long-term capacity building are the best ingredients for further work in addressing increasing urban resilience challenges in a systematic way.

Leena Klossner
Vice President and Deputy Managing Director
Nordic Development Fund

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This publication summarizes the rich seven-volume "Resource Kit for Building Resilience and Sustainability in Mekong Towns", prepared under TA 8186-REG: Greater Mekong Subregion: Climate Resilience in Cities, funded by the Asian Development Bank (ADB) and the Nordic Development Fund (NDF).

The technical assistance project was led by Sonia Chand Sandhu, senior advisor to the ADB Vice-President for Knowledge Management and Sustainable Development; and Aldrin Plaza, urban development specialist; supported by Tadeo Culla, associate social development officer and Jake Tio, environment impact assessment consultant.

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The Resource Kit was prepared by ICEM — International Centre for Environmental Management, led by Jeremy Carew-Reid, international climate change specialist. The multidisciplinary technical team comprised of Jeremy Sung, climate change specialist and project manager; Luke Taylor, ecosystem specialist and project manager; Penny Beames, communications specialist; Julia Winter, environmental engineer; and Ha Thi Hoang Lan, administration officer. The multidisciplinary country team specialists Virachith Douangchanh, climate change specialist –Lao PDR; Pho Duc Tung, climate change specialist–Viet Nam; Try Thuon, climate change specialist–Cambodia; Redmond Macnamar, urban planner (Hansen Partnership); Mai Ky Vinh, GIS specialist; and Luong Thi Quynh Mai, training/workshop coordinator.

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Climate Change Core Groups Involved in Preparing the Resource Kit

The city-specific Climate Change Core Groups, with multidisciplinary and cross-sector expertise, tested the vulnerability assessment methods that were applied to develop socially inclusive urban climate resilience adaptation plans in each town. Their contribution for building stakeholder ownership and diligence toward the effectiveness of the “train the trainers” approach is sincerely acknowledged.

Battambang, Cambodia
Vong Piseth, Sieng Eam Wounzy, Ear Kimchheng, Kem Sokuntheary, Khoeu Sophal, Nou Chharvivann, Chea Vong Narith, Mao Sok San, Nou Sean, Iv Ngorn, Ya Sophat, Kea Chhun, Yan Bophay, Seng Sorath, Phok Sinmary, Song Soeung, Sok Kina, Nou Chamroeun, Thuch Vannarath, Chheng Sivutha, Nhek In Rotha, Tuy Rong, Ty Kim Heng, Pich Leakhena, Kun Ratanak, Keo Putchenda, Chhoeung Vuthy, Soeung Bora, Yong Tonghan, Chin Vuthy, El Sales, Kim Chorng, Touch Monyroth, Kok Han, Horm Heng, Samrith Chhorn, Sourn Sokhen, Mao Siny, Lim Ymeng, and Carmen Kugele.

Dong Ha, Viet Nam
Hoàng Quân Chính, Nguyễn Quốc Tuấn, Nguyễn Thị Thu, Hoàng Văn Thiền, Hồ Sỹ Hiền, Trần Trọng Cường, Nguyễn Đức Phương, Trần Thị Phong Lan, Nguyễn Xuân Dương, Trần Hữu Thành, Trần Quang Khoa, Lê Thi Quỳnh Sa, Trần Văn Thanh, Khuất Ngọc Minh, Nguyễn Hồng Phong, Nguyễn Thanh Đồng, Lê Chí Hồng, Trần Quang Tĩnh, Nguyễn Thị Thuỳ Nga, Trương Văn Hưng, Trần Thị Thúy Hằng, Hoàng Ngọc Cảnh, Đoàn Thị Minh Hải, and Lê Thị Thúy Loan.

Kaysone Phomvihane, Lao People’s Democratic Republic
Sengthong Vangkeomany, Phavanh Bualuanglath, Phouthalom Saysanavongphet, Phomma Vongphachith, Daovanh Phetphansy, Souvanh Sengchamphone, Vanthong Xayphavong, Khamsy Boulom, Hongkham Xayakhom, Oukham Phounprakorn, Bounthalangsy Khammanivong, Sanchone Dysameu, Nuanlahong Inthilath, Ounkham Phiewphachanh, Thoune Saychandy, Lamphan Sangboutho, Vatthana Pongvilay, Lamkeo Souvannalat, Orathai Chansity, and Viengkham Sengsoulichanh.

Mekong Resource Kit Partner Organizations

Cambodia
Department of Public Works, Provincial Department of Environment (PDE), Provincial Department of Public Works and Transport (PDPWT), Provincial Department of Water Resources and Meteorology (PDOWRAM), Provincial Department of Urban Planning, Construction and Cadastral, Provincial Technical Unit of Water Supply, Provincial Department of Health, Provincial Red Cross Provincial Electricity Transmission Line (EDC), Battambang Governors Office, Battambang Municipality Office, Battambang Office of Drainage Systems and Water Pollution Treatment, PDPWT, Battambang Office of Legal Services and EIA, PDE, Battambang Office of Meteorology, PDOWRAM, Battambang Office of Agricultural Extension, Provincial Department of Agriculture, Battambang Office of Municipal Public Works, Battambang Office of Municipal Beauty and Waste Management, Battambang Office of Administration and Finance, Battambang Office of Planning and Commune/Sangkat Support, Battambang Office of Urban Development, Battambang Office of Tourism, Battambang Office of Urban Planning, Construction and Land Management, Battambang Office of Social Affairs and Rehabilitation, Aphivath Srey Commune Office, Sla Ket Commune Office, O Char Commune Office, Prek Preah Sdech Commune Office, Chamkar Samrong Commune Office, Ratanak Sangkat Commune Office, Toul Ta Ek Commune Office, Svay Por Commune Office, and Kdol Dountiev Commune Office.

Viet Nam
Agriculture Department–Quang Tri Peoples Committee, Planning and Financial Department–Quang Tri Department of Rural and Agriculture Development, Quang Tri Department of Flood and Storm Damage Prevention, Planning Department–Quang Tri Construction Department, Quang

Tri Department of Ocean, Islands and Hydrometeorology, Quang Tri Department of Environmental Protection, Dong Ha Department of Natural Resources and Environment, Dong Ha Urban Management Department, Dong Ha Peoples Committee, Trieu Phong Department of Finance and Planning, Quang Tri Transportation Consultancy Company, Department of PPMU of Investment and Construction, Dong Ha Urban Environmental Center, Dong Ha Department of Economics and Infrastructure, Trieu Phong Department of Natural Resources and Environment, Dong Ha Department of Planning and Finance, and Technical Appraisal Department–Quang Tri Department of Transportation.

Lao People's Democratic Republic
Urban Development Division–Department of Housing and Urban Planning–Ministry of Public Works and Transport, Savannakhet Provincial Department of Public Works and Transport (PDPWT), Housing Urban Planning and Environment Office–PDPWT, Road-Bridge Office–PDPWT, Kaysone Phomvihane Urban Development and Administration Office, Kaysone Phomvihane Cabinet Office, Kaysone Phomvihane Office of Public Works and Transport, Kaysone Phomvihane Natural Resources and Environment Office, Kaysone Phomvihane Women's Union, Meteorology and Hydrology Division–Savannakhet Natural Resources and Environment Department, and Kaysone Phomvihane Agriculture and Forestry Office.

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Introduction

I.1 Purpose of This Publication

This publication emphasizes the need to recognize rehabilitating natural systems with nature based solutions as key for building sustainability and resilience in urban areas.[4] It highlights the inextricable link of the two imperatives of resilience and sustainability in town development, as the solutions to one satisfy the needs of the other. This publication describes green infrastructure as nature based solutions for resilience to climate change adaptation for building better and more livable Mekong towns. It is a compendium of resources, ideas, and information sourced from around the world, referenced to allow users to follow through more deeply on topics of special interest. It summarizes in case studies the experience of three Greater Mekong Subregion (GMS) towns—Battambang, Dong Ha, and Kaysone Phomvihane.

The publication provides guidance for wide application of green infrastructure as an alternative and essential adjunct to conventional town infrastructure and development planning. This chapter distills some of the lessons learned by the three town climate change core groups involved in the project—from Battambang on the Northwest of Tonle Sap Lake in Cambodia, Dong Ha on the central coast of Viet Nam, and Kaysone Phomvihane lying on the Mekong River in Southern Lao People's Democratic Republic (Lao PDR). The three groups, representing towns facing the full range of climate change challenges found in the GMS, were the central force in conducting the demonstration vulnerability assessment and adaptation planning work of the project. They wished to share some of those experiences with their planning and engineering counterparts in other Mekong towns in the form of consolidated lessons. More detailed lessons learned are provided in each of the town story chapters.

This chapter introduces users to the GMS Climate Resilience in Cities technical assistance project of the Asian Development Bank (ADB). It describes in summary form the *Resource Kit for Building Resilience and Sustainability in Mekong Towns*, which is the main documented outcome of the project, and how it can guide town planning throughout the GMS.[5] It is directed mainly at small and medium-sized Mekong towns but has immediate relevance for any size urban area.

I.2 Trends and Regional Context for the Project

The need for Mekong towns to act now in building resilience and sustainability has never been more urgent. The region is experiencing rapid urbanization with cities expanding five times faster than those in member countries of the Organisation for Economic Co-operation and Development (OECD). In the next 50 years,

[4] Resilience is the capacity for a socioecological system to absorb stresses and maintain function in the face of external stresses imposed upon it by climate change and adapt, reorganize, and evolve in ways that improve the sustainability of the system.

[5] ADB. 2015. *Resource Kit for Building Resilience and Sustainability in Mekong Towns.* Prepared by International Centre for Environmental Management (ICEM) for the Asian Development Bank and Nordic Development Fund. Manila (TA 8186-REG).

urban growth in the GMS is expected primarily in small and medium-sized cities and peri-urban areas along existing and new growth corridors. The GMS, consisting of Cambodia, the Guangxi Zhuang Autonomous Region and Yunnan Province of the People's Republic of China (PRC), the Lao PDR, Myanmar, Thailand, and Viet Nam, had a population in 2010 of about 320 million, of which less than 25% were urban. By 2030, the GMS urban populations are expected to rise by about 60%, but the large cities in the region will only experience a modest increase of about 30%. The big population increases will be in the smaller cities and towns (Table 1).

The extensive coastline, riverine and low-lying wetland areas, and seasonal variability make the GMS countries especially vulnerable to storms and floods. Short and steep watersheds in the upland areas are also subject to frequent flash flooding and landslides. Despite being under the influence of two monsoon seasons—one from the west, the other from the east—some countries of the region also experience severe drought. Climate change is projected to bring more extreme conditions to the region, increasing the frequency and severity of climate and hydrological events. Sea level rise, storm surge, increased flood levels and duration, and more extensive and unpredictable droughts threaten populations and critical infrastructure across the GMS.[6]

In the GMS, urban development is largely driven by project-level design which fails to adequately consider its functioning in extreme events, area-wide effects and sustainability, and the maintenance of multiple uses of the affected sites. Climate change is rarely taken into account, a situation which is aggravated by the "language gap" between hydrometeorological agencies and infrastructure developers. The information on climate change that is made available is often of little practical use to design engineers and town planners. Even with

Table 1: Total and Urban Populations in the Greater Mekong Subregion, 2010–2030

Urban Population Assuming % Urban for 2020 and 2030

	2010 Population			2020 Population			2030 Population		
Country	Total (million)	Urban (%)	Urban (million)	Total (million)	Urban (%)	Urban (million)	Total (million)	Urban (%)	Urban (million)
Cambodia	14.14	21.41	3.03	15.89	27	4.21	17.36	34	5.87
PRC									
Guangxi	47.19	24.01	11.33	53.17	28	14.64	59.90	32	18.91
Yunnan	44.83	24.00	10.76	50.51	28	13.91	56.91	32	17.97
Lao PDR	6.20	34.45	2.14	7.05	48	3.38	7.75	61	4.70
Myanmar	47.96	35.42	16.99	51.69	44	22.57	54.33	53	28.55
Thailand	69.12	33.48	23.14	72.09	39	27.81	73.32	46	33.62
Viet Nam	87.85	30.79	27.05	99.36	37	36.27	101.48	42	42.59
Total	**317.29**		**94.43**	**349.75**		**122.79**	**371.07**		**152.21**

PRC = People's Republic of China, Guangxi = Guangxi Zhuang Autonomous Region, Lao PDR = Lao People's Democratic Republic, Yunnan = Yunnan Province.

Sources P. Rogers. 2012. *Water-Energy Nexus: Sustainable Urbanization in the Greater Mekong Subregion-Balancing Economic Growth and Environmental Sustainability*. Harvard University. http://southasiainstitute.harvard.edu/ website/wp-content/uploads/2014/03/Peter-Rogers-2012-2.pdf; United Nations Department of Economic and Social Affairs. 2011. *World Economic and Social Survey 2011.* New York: United Nations. http://www.un.org/en/development/desa/policy/wess/wess_current/2011wess.pdf; Yunnan and Guangxi projected from Asian Development Bank (ADB) and United Nations Environment Programme (UNEP). 2004. *Greater Mekong Subregion (GMS) Atlas of the Environment (First Edition).* Manila.

[6] ICEM. 2013. Mekong Adaptation and Resilience to Climate Change (ARCC). http://icem.com.au/portfolio-items/ mekong-arcc/?portfolioID=2631

appropriate spatial information on regular and extreme climate events, area-wide approaches to adaptation planning which assess urban infrastructure proposals as systems rather than individual assets are not normal practice in GMS urban planning.

Climate Resilience in Cities, a 1-year technical assistance project in the GMS supported by ADB, was designed to begin to address some of the constraints to building resilience in small and medium-sized towns. The project culminated in the preparation of this publication by assessing vulnerability of the three project towns and some of their key infrastructure systems and by involving multidisciplinary core groups to plan for climate change and help connect planning and infrastructure design to climatic and site realities.

Engineers and planners in Mekong towns recognize the importance of building sustainability and climate resilience in urban areas. They understand that to do so will require significant changes to current town planning and development decision-making processes and practice. What those changes should be and how to make them remains relatively unexplored in the GMS. This publication, shaped by more than 100 local town planners and engineers from the three towns, helps fill that gap in knowledge and practice.

I.3 The Greater Mekong Subregion Climate Resilience in Cities Project

I.3.1 Economic Corridor Towns

Over the course of a year between 2013 and 2014, ADB, with support from the Nordic Development Fund, commissioned the International Centre for Environmental Management (ICEM) to provide technical assistance to Battambang, Dong Ha, and Kaysone Phomvihane to strengthen their resilience to climate change.

The three towns were selected for this demonstration and capacity building project due to their distinctive climate change challenges, their rapidly growing populations and economies, and the large planned ADB infrastructure investment programs linked to corridor development. They are capitals in their respective provinces and important urban centers for national and regional socioeconomic development (Figure I.1).

Dong Ha and Kaysone Phomvihane are situated within the East–West Economic Corridor, while Battambang sits in the Southern Economic Corridor of the GMS.

The three towns are part of a wider body of work being undertaken by national governments with support from ADB, other development partners, and private sector investors aimed at consolidating the economic corridors as the principal focus of regional connectivity and economic prosperity:

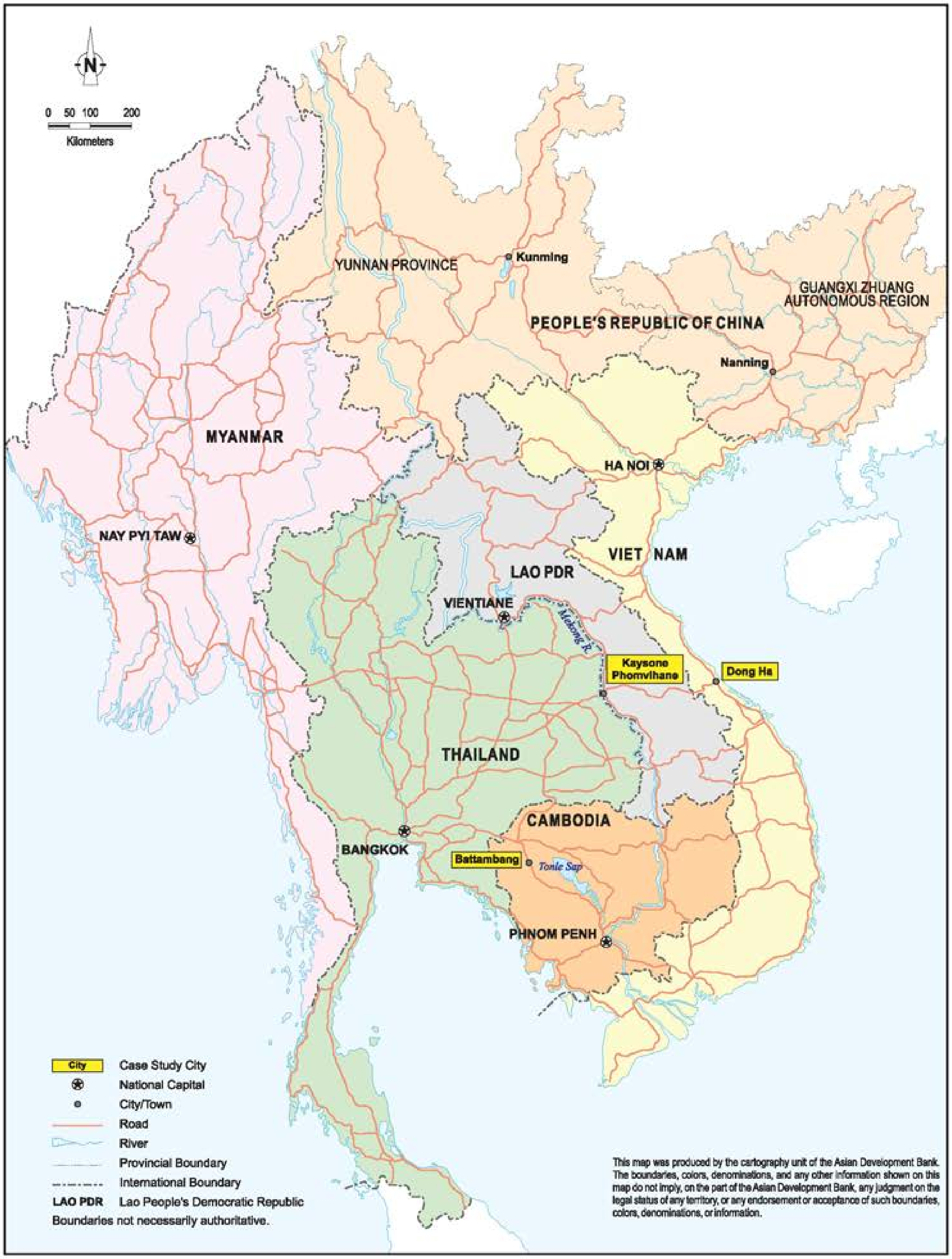
- **Battambang** is one of three towns in Cambodia targeted by ADB's Southern Economic Corridor Towns Development Project (SECTDP). Battambang has also been identified as a city where several climate resilience measures will be implemented under the Pilot Program for Climate Resilience (PPCR);[7]
- **Dong Ha** is one of three towns in Viet Nam targeted by ADB's GMS Corridor Towns Development Project (CTDP); and
- **Kaysone Phomvihane** is one of three towns in the Lao PDR participating in the GMS East–West Economic Corridor Towns Development Project (EWECTDP).

I.3.2 Town Climate Change Core Groups as the Engines for Innovation

As the main focus of capacity building and action, climate change core groups of 20–40 municipal and provincial representatives, technical experts, and nongovernment representatives were established in each of the target towns to undertake all work associated with the technical assistance project. Those core groups were involved in the use of tools to plan and build climate resilience, with the vision to make future town planning and infrastructure

[7] In 2008, the Pilot Program for Climate Resilience (PPCR) was initiated through the Strategic Climate Fund (SCF), under the Climate Investment Funds (CIF). This program builds upon national adaptation programmes of action (NAPAs) to fund technical assistance and investments to support countries' efforts to integrate climate risk and resilience into core development planning and implementation. Through the PPCR, a country-specific Strategic Program for Climate Resilience (SPCR) was developed for Cambodia and endorsed by the PPCR Subcommittee in June 2011. The SPCR sets out a road map for developing large-scale investment opportunities as well as capacity strengthening to improve the country's resilience.

Figure I.1: Location of Battambang, Dong Ha, and Kaysone Phomvihane along the Greater Mekong Subregion Economic Corridors



Lao PDR = Lao People's Democratic Republic.

Source: Asian Development Bank.

investments cost-effective and robust by considering climate change impacts.

Through the project, the core groups applied hands-on vulnerability assessment and adaptation planning tools to assess and rank the impacts of climate change on specific strategic infrastructure and areas and to formulate locally appropriate adaptation responses to those impacts. At the town-wide level, they reviewed spatial master plans and defined climate change hot spots and safeguards. This chapter distills and describes those core group experiences into a set of resources to share with planners from similar towns throughout the region.

The intended outcome of the project was an "enhanced understanding of climate change impacts and adaptation options by key stakeholders in GMS cities."[8] To achieve this outcome, the project was organized around two outputs (Figure I.2):

- Output 1: Knowledge-sharing workshops and policy dialogue
- Output 2: Resource Kit for Building Resilience and Sustainability in Mekong Towns

I.3.3 Output 1: Knowledge-Sharing Workshops and Policy Dialogue

Output 1 comprised three rounds of 3–4-day workshops. Each town conducted the first two workshops on baseline and impact assessment and on adaptation planning. The third workshop was a combined regional event involving the three town core groups sharing their experiences and working together in four languages simultaneously.

I.3.3.1 Baseline, Impact, and Adaptation Workshops

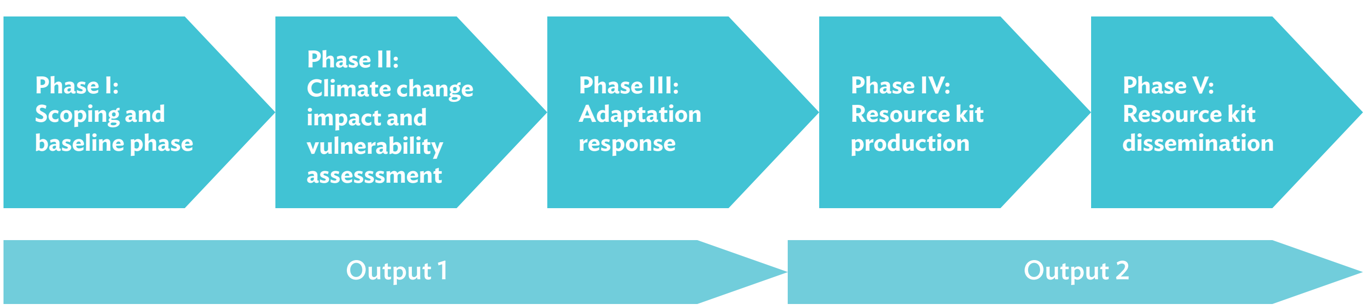
The 4-day baseline, impact, and adaptation workshops conducted during December 2013 and January 2014 were designed to engage municipal and provincial technical experts in an on-the-job process of assessing the vulnerability of strategic infrastructure and areas to climate change impacts and to identify preliminary adaptation measures to address the impacts.

The workshops focused on cross-sector collaborative and field-based exercises in applying and adjusting the climate change assessment and adaptation planning methodology to local conditions. The project team guided workshop participants in assessing the impacts of two or three sites and infrastructure systems in the towns and in defining relevant adaptation measures. There was an initial scoping phase in each town in which target sites and infrastructure were identified by local government officers against a set of priority setting criteria, including areas subject to past flooding, infrastructure of strategic importance to the town economy, and, if feasible, infrastructure which involved or is planned to involve ADB investments.

Over the course of this initial round of workshops, participants used field templates and workshop criteria and matrices in three steps in their assessment of the target sites:

(i) Scoping and baseline assessment
(ii) Impact and vulnerability assessment
(iii) Definition and assessment of adaptation options

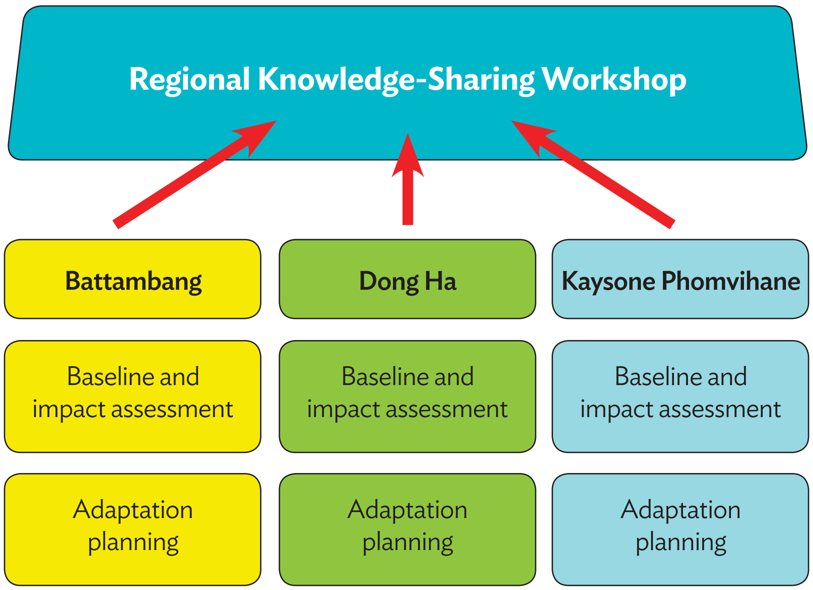
Figure I.2: Project Phases and Outputs



Source: ADB and ICEM.

[8] ADB. 2016. *Completion Report: Climate Resilience in Cities in the Greater Mekong Subregion.* Manila. p. 3.

Figure I.3: Project Workshops



Source: ADB and ICEM.

A guide to the methodology demonstrated by the core groups appears in Chapter 4.

I.3.3.2 Adaptation Policy Dialogue

The adaptation policy dialogue workshops took place in each town between February and April 2014 in which core groups

- prepared adaptation plans for the target infrastructure and areas identified in the baseline, impact, and vulnerability assessment phase;
- developed climate change hot spot maps and linked land use zone safeguards for the town and in more detail for each target site; and
- defined reforms to the town master plans and other policies and procedures at the local and national level to facilitate adaptation plan implementation.

The overall aim of the project was to support the three core groups in developing practical tools for integrating climate change into town planning. They focused on defining climate change hot spots and safeguards linked to spatial zones which can be built into the town master plans. They also prepared specific adaptation plans for high priority areas and identified a range of institutional and policy adjustments needed to facilitate their implementation. The main strategy for achieving sustainability and resilience in town development is to promote nature based adaptation. Volume 2 is a guide to the kinds of green infrastructure measures discussed by the core groups and Volume 3 provides best practice principles and cases from other countries of how green infrastructure is applied systematically within the overall urban planning framework.

I.3.3.3 Regional Knowledge-Sharing Workshop

The Regional Knowledge-Sharing Workshop was held in July 2014 in Kaysone Phomvihane. It brought together climate change core group members from Battambang, Dong Ha, and Kaysone Phomvihane to

- synthesize the activities from the core group discussions and the consultations from previous policy dialogue and technical workshops;
- share findings from climate change impact and vulnerability assessments and adaptation plans developed by the core groups;
- finalize adaptation options and lessons learned that apply to the Mekong region for inclusion in the resource kit;
- develop strategies for building on the work undertaken within the three towns, particularly potential adaptation implementation projects in each town;
- discuss how the outputs from the project (in particular the resource kit) can be effectively disseminated; and
- help to build a community or network of local government practitioners on urban climate change resilience in the GMS.

The workshop included selected representatives from donor agencies and international development organizations such as ADB, the Nordic Development Fund, the Swedish International Development Cooperation Agency, and the United States Agency for International Development (USAID).[9]

Thanks to simultaneous translation in all three national languages and English, workshop participants were able to share experiences and results from their vulnerability assessments and adaptation planning work. They were able to build on the demonstrations to explore new

[9] A separate report on the regional workshop is available at http://icem.com.au/portfolio-items/resilient-citiesregional-workshop-report/

ways of promoting green infrastructure as a foundation concept and approach in developing resilience in Mekong towns.

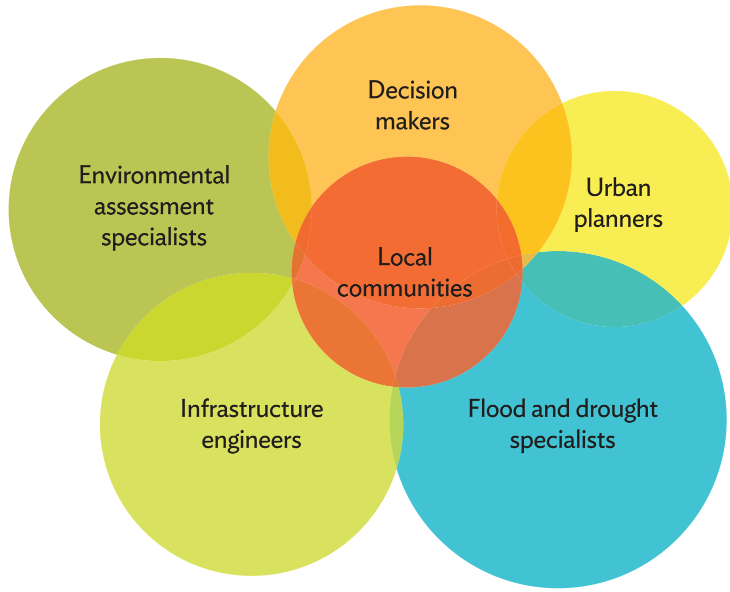
Continued capacity building in local line agencies and in town and infrastructure staff was highlighted as a primary need, given that incorporating green infrastructure and nature-based solutions necessitates retraining regional planners, engineers, and developers. Furthermore, while participants noted that many of the adaptations discussed could be implemented within established local and national budgets, external financial support would be required for some of the larger, more comprehensive adaptation strategies.

I.3.4 Output 2: Resource Kit

The resource kit synthesized and built on the work of the three core groups in Battambang, Dong Ha, and Kaysone Phomvihane. Its seven volumes form the basis of the chapters of this publication:

1. Nature-Based Solutions for Sustainable and Resilient Mekong Towns
2. Green Infrastructure for Resilient Mekong Towns
3. Urban Planning for Building Resilient Mekong Towns
4. Vulnerability Assessment and Adaptation Planning Guide for Building Resilient Mekong Towns
5. Case Study 1: Building Urban Resilience in Battambang, Cambodia
6. Case Study 2: Building Urban Resilience in Dong Ha, Viet Nam
7. Case Study 3: Building Urban Resilience in Kaysone Phomvihane, Lao PDR

Figure I.4: Who Will Find This Publication Useful?



Source: ADB and ICEM.

The purpose of the resource kit is to provide practical tools, advice, and lessons to improve urban and infrastructure planning in the GMS to cope with climate change. The kit helps town planners and infrastructure practitioners to do the following:

- Identify and incorporate green infrastructure strategies and measures into development.
- Undertake climate impact and vulnerability assessments as an essential foundation for town planning and infrastructure design.
- Regularly review and revise town master plans and their zoning and development control frameworks to build resilience.
- Prepare local area adaptation plans.

Chapter 1

Nature-Based Solutions for Sustainable and Resilient Mekong Towns

1.1 Principles for Applying Green Infrastructure to Build Resilience in Mekong Towns

Green infrastructure[10] refers to a strategically planned and managed network of green spaces and other environmental features and technologies necessary for the sustainability of any urban area.

Green infrastructure uses vegetation, soils, and natural processes to manage water, temperature, and air quality to create healthier, resilient, and beautiful urban environments. At the town scale, green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, clean air, clean water, food, and recreation. At the local level, green infrastructure includes stormwater and drainage management systems that mimic nature by soaking up and storing water and to improve its quality. For specific infrastructure systems, most importantly, it improves engineering by including natural components and bioengineering methods. At all scales, green infrastructure emphasizes nature-based solutions and uses of local resources and materials to build community self-reliance and resilience.

Examples of "green" infrastructure include green roofs and walls, hard and soft permeable surfaces, green streets, urban forestry, green open spaces such as parks, wetlands, and green drainage corridors. Green infrastructure also includes a wide range of green technologies for adapting and complementing buildings and infrastructure (such as roads, irrigation systems, floodgates, and canals) to be more efficient and to better cope with floods, storms, and heat. It covers natural water management systems, slope stabilization approaches, energy conservation measures, and many natural materials and techniques. Green infrastructure applies or mimics nature to improve the performance and resilience of conventional "gray" infrastructure and often can replace it entirely for much cheaper and stronger results that allow for local community monitoring, maintenance, and multiple uses.

Green infrastructure planning should be the first step in the town spatial planning and development process and should be closely coordinated with planning for gray infrastructure. Integrated planning and design connects the two—gray and green—in a more effective, economical, and sustainable network.

[10] This section adapts and draws from guidelines prepared by the United Kingdom Town and Country Planning Association, especially its September 2008 guide *The Essential Role of Green Infrastructure: Eco-towns Green Infrastructure Worksheet: Advice to Promoters and Planners*, available at http://www.tcpa.org.uk/data/files/etws_green_infrastructure.pdf. It also draws from *Green Infrastructure: Smart Conservation for the 21st Century*, the 2001 monograph by M. Benedict and E.T. McMahon of the Conservation Fund for the Sprawl Watch Clearinghouse, available at http://www.sprawlwatch.org/greeninfrastructure.pdf. Another good source of technical advice is the Landscape Institute's web page on Green Infrastructure at http://www.landscapeinstitute.org/policy/GreenInfrastructure.php

Green infrastructure can contribute significantly to the delivery of other forms of infrastructure and services and should be given the same emphasis in planning and budgeting.

Ideally, the green infrastructure strategy for a town and specific green measures should be defined and mapped out before gray infrastructure options are considered and planned. In many situations, green infrastructure provides the best solutions to town development, leaving hard engineering to complement or make up any shortfall. If gray infrastructure is put in place first, it often rules out green options and reduces urban sustainability and resilience. For Mekong towns to function and develop effectively, green infrastructure needs to be treated as an essential accompaniment or alternative to conventional or "gray" infrastructure.

In summary, green infrastructure should
- be a foundation for planning, developing, and maintaining Mekong towns;
- be shaped by existing or past natural systems in the town area including its local landscapes, drainage patterns, habitats, and biodiversity;
- be a strategically planned and interconnected network set out in town master plans;
- be multipurpose, seeking to serve many functions and uses as well as building resilience in town areas and structures;
- involve local communities in design, construction, management, maintenance, and use;
- involve all relevant local authority departments in a coordinated and cross-sector manner; and
- be established permanently with financial support for continued maintenance and adaptation.

These points can be expressed as a number of foundation principles which should drive the introduction of green infrastructure and nature-based solutions to build ecological sustainability and climate change resilience in Mekong towns.

1. Green infrastructure should be the foundation for town planning and development
Green infrastructure should be planned and implemented as a foundation for sustainable and resilient town development. Like town electric power, transport, and telecommunication systems, the green infrastructure systems need to be planned comprehensively to provide ecological, social, and economic benefits, functions, and values. Green infrastructure needs to be integrated with development at all spatial scales: site, neighborhood, local, and regional levels. Green infrastructure is most effective when it functions at multiple scales.

2. Green infrastructure should be supported by a green plan
All Mekong towns require a formally adopted green infrastructure plan supported by design standards and development controls. The strategic planning of green infrastructure requires a coordinated approach involving a multidisciplinary team from a broad range of government sectors. Local authorities, national agencies, and major landowners will need to work with developers to prepare the strategy and supporting regulations. It will be required of national government infrastructure sectors in particular to respect and uphold town green plans within their own development plans and projects.

3. Green infrastructure should be applied through town zones and environmental impact assessment
All tools and procedures for shaping and assessing development proposals should be reviewed and revised to include green infrastructure safeguards and screening tools. All town development should proceed in a way that applies green infrastructure approaches consistent with the overall town green plan. Each town zone needs to be reviewed and accompanied by a framework of sustainability and resilience safeguards and development controls that promote green infrastructure. The environmental impact assessment process, which operates at the project proposal level, needs to include specific tools for ensuring that proposals embrace green infrastructure.

4. Green infrastructure systems should form connected networks across the entire town area
Green infrastructure systems should be developed as a strong green fabric or network which binds a town together. It should achieve

physical and functional connectivity between sites at all levels and right across a town. Each item of green infrastructure needs to function as part of a larger network incorporating all the green spaces, features, and facilities of a town, both public and private. Green infrastructure systems help protect and restore naturally functioning ecosystems and provide a foundation for future development.

Connectivity may not always mean a direct physical connection between sites, although a physically joined-up network should be a priority—and may need to be established over time. Private land can also provide useful “stepping stones” in the green infrastructure network. Separate but closely colocated green spaces can still operate collectively in mitigating the effects of climate change and provide many ecosystem functions. The goal of all Mekong towns should be to eventually join up its green infrastructure network through a diverse arrangement of greening strategies.

The strategic connection of different system components—parks, preserves, riparian areas, wetlands, and other green spaces and technologies—is critical to maintaining ecological processes and services and to maintaining the health of the town’s residents and its biodiversity.

5. Green infrastructure should be implemented across different sectors and with communities

Green infrastructure requires close collaboration between developers, local planners, and affected communities. It should involve government, nongovernment organizations, and community groups representing interests as diverse as transport, water and waste management, biodiversity, food, health, and community development. All the local authorities within a town need to have a unified approach, to hold a common vision and be committed to implementing the same green strategy.

6. Green infrastructure should be multipurpose

Green infrastructure should provide outdoor spaces and facilities that are welcoming to local people and that meet a variety of human needs, including food, contact with nature, recreation and leisure, as well as safety. The green infrastructure network must provide a wide variety of spaces, habitats, and connections, supplying a broad range of fully integrated ecosystem services. It should support specific local priorities and strategies for environmental management—for example, energy efficiency, food production, and sustainable urban drainage. Multipurpose includes the provision of diverse products and services from agriculture, forestry and horticulture, renewable energy installations and fuel sources, climate change adaptation and mitigation, transportation routes, cycle paths and walkways, water management, recreational and sporting activity space, biodiversity, and aesthetics.

Multipurpose green infrastructure means taking an “ecosystem approach” to town development in which the management of land, water, and living resources is integrated to promote conservation and sustainable use. It also seeks equity among social groups and respect for cultural and socioeconomic diversity.

7. Green infrastructure should be financed a primary budgetary item for continued maintenance and adaptation.

Green infrastructure needs to be properly funded as part of a town’s core infrastructure, with provisions made for long-term maintenance and management. It should be funded up front with other essential services. That will require national and local governments to recognize green infrastructure and green plan implementation as a formal part of the regular budget allocation and priority setting.

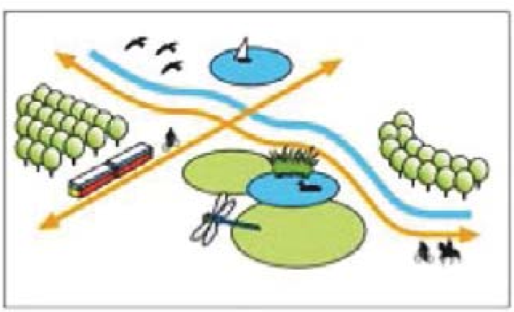
Well planned green infrastructure decreases the costs of gray infrastructure and public services, including the costs for stormwater management and water treatment systems. Investing in green infrastructure can often be more cost-effective than conventional public works projects.

The functions, values, and benefits of green infrastructure are available for all town residents and visitors. Recognizing the public benefits of green infrastructure is an important first step in providing adequate funding.

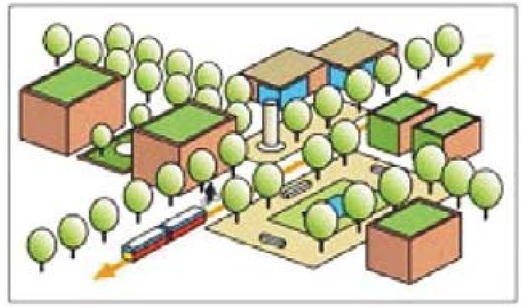
1.2 Ten Strategies for Green Infrastructure and Nature-Based Solutions to Town Development

Green infrastructure complements, strengthens, and can replace hard infrastructure measures in Mekong towns. It acts to manage and conserve water and energy; reduce heat, flooding, and the impacts of natural disasters; and bring nature back as the foundation for urban development and life. Green infrastructure needs to become an essential ingredient in all Mekong town spatial plans and infrastructure projects. The goal is to achieve ecological sustainability and climate change resilience along with community well-being and safety, environmental quality, and beauty by seeking natural solutions to development challenges.

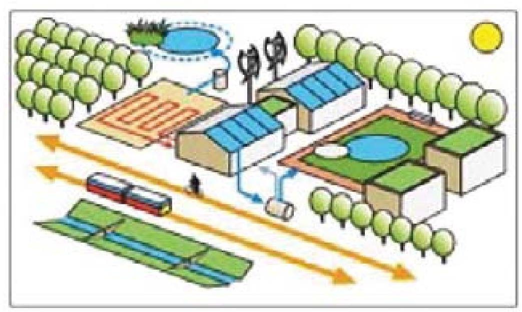
This section introduces 10 strategies for bringing nature back into Mekong towns as a core development goal. It requires the greening of town plans and modification of infrastructure design standards and controls to promote green infrastructure and nature-based solutions. It is both a town planning challenge and a challenge to the way infrastructure is currently planned, designed, and constructed in the Mekong region. The text and diagrams in this section are drawn from a web-based tool on urban planning prepared by the Royal Chartered Institute for Landscape Architects in the United Kingdom.[11]



1. **Creating a fabric of interconnected green corridors and spaces:** These should be the foundation for town development. Linking trees, parks, green areas, river valleys, wetlands, and drainage corridors with vegetated pedestrian walkways, cycle paths, and transport routes increases biodiversity and enables wildlife to flourish while building resilience to floods, drought, heat, and climate change.



2. **Greening of core urban areas:** Creating treed and vegetated streets and boulevards, green plazas, green roofs, and walls makes for attractive settings for shopping and leisure in the intensive use areas of towns and also improves the vibrancy of local economies. Street trees and green spaces provide cooling, shade, cleaner air, and noise reduction, making core urban areas more livable and bringing multiple economic benefits.

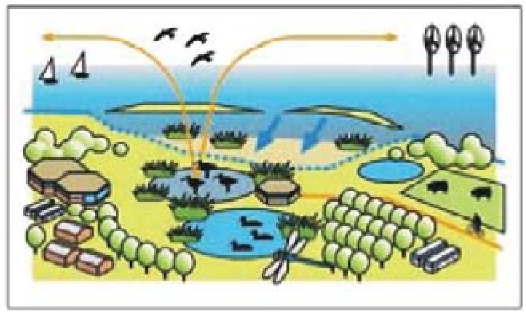


3. **Greening of industrial and business zones:** Attractive green settings encourage inward investment and establishment of new businesses. Industrial and business centers need to be carefully planned for sustainable and efficient transport, sustainable urban drainage, rainwater collection and wastewater cleansing, and reduced energy demands, all by applying green infrastructure and natural system solutions. This creates attractive and desirable workplaces and contributes to healthy local economies, reducing flood risk and climate change impacts and expanding the space for nature to thrive.

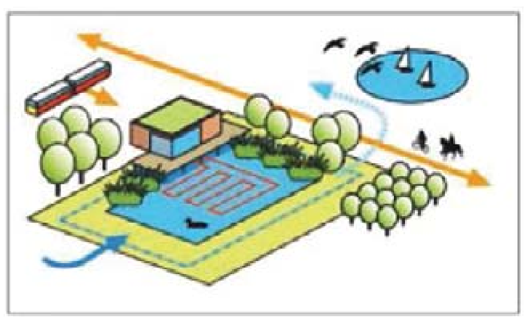
[11] Landscape Institute. 2014. *Local Green Infrastructure: Making the Most of Our Landscape*. http://www.landscapeinstitute.org/PDF/Contribute/LIGIDiagram1.pdf. The Landscape Institute is the Royal Chartered body for landscape architects in the United Kingdom.

4. **Beautiful, healthy, and green residential areas:** Green spaces for recreation and healthy living encourage social interaction, neighborhood events, and food growing. Interconnected green spaces build community cohesion and identity, making settlements more functional and livable. Green space networks improve property values and reduce the effects of climate change, through natural drainage, renewable energy use, green building design, and building spacing and orientation.

5. **Green community centers:** They are an important opportunity to demonstrate and pilot green infrastructure methods with local community support by acting as a neighborhood hub.[12] They can demonstrate sustainable building design with green roofs and walls, solar heating and shade, and passive design cooling systems and rainwater collection. Associated green spaces including wetlands and agroforests cater for healthy living activities including sports and opportunities for learning through connecting with nature and food growing, as well as employment in green space management. Wetlands can also provide demonstration spaces for natural wastewater purification.



6. **Greening of towns on rivers and coasts:** Riverine and coastal areas provide a unique opportunity for sustainable town development with nature. Green belts to shelter against storms and for recreation and as an amenity, extensive wetlands linked to inland drainage corridors as part of flood and storm protection and food security, and providing connected habitats for wildlife all need to be factored into river and coastal town plans. Natural systems and green infrastructure can be applied for wastewater treatment and renewable energy generation. Other economic benefits can be achieved by creating distinctive places for tourism, leisure, and learning.

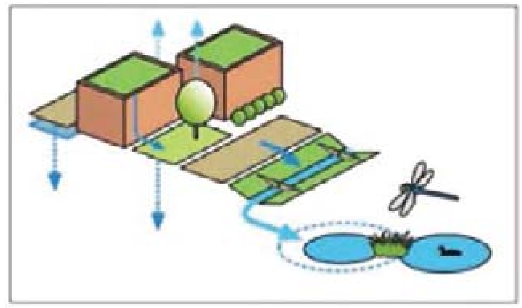


7. **Networks of connected urban parks:** Every Mekong town needs to set targets for green cover and for urban parkland. Networks of parks have an important contribution to

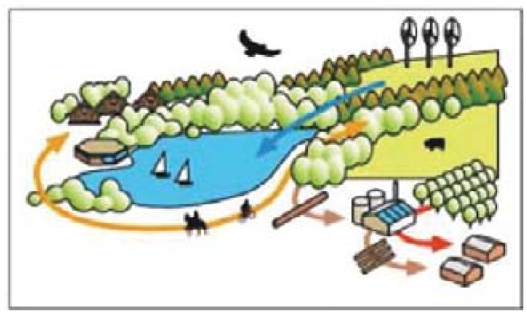
[12] Community centers are public locations where members of a community tend to gather for group educational, social, sporting, or cultural activities. They can provide community support, public information, and other services such as youth clubs. They may be open for the whole community or for particular groups within the greater community. Community centers play an increasingly important role in greening projects involving local action.

make to the quality of the environment and to the quality of life in urban areas. Such sites are valued by the community, provide important refuge for wildlife in otherwise impoverished areas, and are beneficial to public health and well-being. They create learning and employment opportunities via interpretation facilities, events, rangers and green space managers, and education outreach. Urban parks are an essential component in building resilience to climate change, drought, and flooding. They can be integrated with water supply, cooling, and waste treatment, and are important in air purification.

8. **Expanding allotments, smallholdings, and orchards:**[13] Town plans need to provide space to protect and restore locally sourced and distinctive food production and to connect urban populations with the rural economy. They enhance food security and provide opportunities to learn about and gain employment in gardening, vegetable and fruit growing, beekeeping, and horticulture, as well as providing for outdoor places and activities that help bring communities together, maintain culture and customs, and provide for active lifestyles.



9. **Creating sustainable drainage systems (SUDS):** Attenuation ponds, swales, and reed beds need to be established throughout the urban environment,[14] providing natural ways to reduce flood risks, provide temporary storage, and improve water quality. SUDS create wetland habitat for wildlife in an attractive aquatic setting with potential for recreation, education, and leisure facilities.



10. **Greening and rehabilitating urban catchments and uplands:** Forested and well maintained urban uplands and watersheds provide many benefits to towns: flood control, water supply, agricultural produce, pasture land, and timber production and products including biomass for local

[13] Allotments are small plots of land rented by an individual or community group for growing vegetables or flowers. Smallholdings are usually small farms supporting a single family or community group with a mixture of cash crops and subsistence farming.

[14] An attenuation pond is designed to slow the passage of water from surface runoff to the drainage system, e.g., stormwater sewers. It does this by storing the runoff during times of heavy rainfall and slowly releasing it at a controlled rate after the peak flow has passed. A swale is a low tract of land, especially one that is moist or marshy. The term can refer to a natural landscape feature or a human-created one. Artificial swales are often designed to manage water runoff, filter pollutants, and increase rainwater infiltration.

combined heat and power (CHP) plants and renewable power generation, all providing economic benefits and contributing to reduced climate change impacts.[15] Green urban catchments allow for recreation, relaxation, and activities that contribute to a healthy lifestyle for town residents. They protect vulnerable wildlife and retain the essential natural character of the urban landscape.

1.3 Lessons Learned by the Climate Change Core Groups in Battambang, Dong Ha, and Kaysone Phomvihane

As the three town core groups reviewed their master plan zoning scheme and conducted the area-specific vulnerability assessments and adaptation planning, they each identified various guiding lessons relating to opportunities for innovation and impediments to reform which need to be overcome. This section summarizes the main lessons to be shared with urban and infrastructure planners in other Mekong towns. The lessons provide directions for change and a guide to the interpretation and use of this publication.

If Mekong towns are to respond effectively and systematically to climate change in their urban planning and infrastructure development, significant reforms in the spatial planning and development control processes are needed. Those reforms range from the way master plans are prepared and reviewed, to local area adaptation planning, and to the way infrastructure is designed and managed.

1.3.1 Green Infrastructure

Green infrastructure approaches and an emphasis on rehabilitating and expanding natural systems in towns are an essential foundation for building urban resilience in the GMS. Green infrastructure is a way of designing and implementing infrastructure assets such as roads, bridges, river embankments, canals, markets, and ports in a way which improves their durability and performance as well as the beauty, amenity, and multiple functions of the areas where they are located.

There are highly vulnerable infrastructure systems in each town that, if properly addressed through careful adaptation planning and design of green infrastructure, could greatly improve the climate change resilience of each town and act as GMS demonstration sites for replication within the towns and more widely.

Multidisciplinary teams including engineers trained in bioengineering, landscapers, horticulturalists, and other specialists will be required to successfully design, implement, and demonstrate green infrastructure solutions.

1.3.2 Town Planning

Current Mekong urban planning inhibits nature-based solutions and innovations: There is growing recognition by government agencies and other stakeholders in the GMS that the existing, largely engineering-led approach to dealing with urban growth and development issues such as flooding and drought is failing to deliver outcomes which build resilience over time—and in some cases directly competes with them. All too often, master plans encourage growth in areas subject to serious flooding (e.g., Dong Ha) even when past extreme events are considered which are projected to become more frequent and severe.

Equally, there are many cases where infrastructure investments have made the urban conditions worse even though national and sometimes international development safeguards and procurement procedures were followed.

Gains in resilience can only be achieved through significant reforms to existing systems of urban planning and development control: In view of existing deficiencies, a critical rethinking is needed on how infrastructure and other development projects are conceived, designed, and delivered within Mekong towns, so that they might better respond to climate change and sustainability. The role of town master planning, town zones, and development controls systems, as well as environmental impact assessment is fundamental in this process. Climate change vulnerability

[15] CHP plants can utilize waste gas as fuel for electricity and heat generation. Waste gases can be gas from animal waste, landfill gas, gas from coal mines, sewage gas, and combustible industrial waste gas.

assessment and adaptation planning need to be well integrated with those processes and tools.

Town master planning should be formally adopted as a cyclical process with review and revision at least every 3–5 years and a tight statutory period within which the provincial and national governments must approve the plan. In situations of scarce resources, it is not possible to do everything at once; priorities must be set as the focus of attention. In a cyclical planning system, this means that the most important or vulnerable areas receive attention while others can be addressed in future cycles. At this stage, town spatial plans or master plans in the region are often treated as a one-off event rather than a cyclical process. Adaptation planning needs to be an integral part of a cyclical master planning process so that systems of zoning and development controls can be progressively built up and improved with each planning cycle.

Climate change threat and impact assessment needs to be an integral part of town planning: Town master planning and spatial zoning should include documentation of past extremes, such as floods, combined with projected climate change to define hot spots such as flood- and drought-prone areas. Those hot spots should be overlaid on existing zoning schemes to adjust boundary definitions and designations and to guide development and design of suitable town-wide and zoning safeguards to promote resilient land uses and structures. Participatory mapping approaches involving local officials and communities are adequate for hot spot definition.

Consultation across sectors and with local communities is key to adaptation success: Town-wide and site-specific climate change vulnerability assessment and adaptation planning is a process that needs to involve local, provincial, and national governments; the private sector; and local communities. All levels of government, local communities, and the private sector will have an essential role in plan definition and implementation.

Local adaptation plans are needed for particularly vulnerable areas: Each year, detailed climate change impact assessments and adaptation planning can be conducted for a few key areas within a town, leading to local area adaptation plans. Over time, the number of areas covered by adaptation plans will grow and the system of development controls will be improved feeding into the regular review of the overall town master plan.

Area-wide approaches to adaptation of specific infrastructure assets: Gray infrastructure tends to be designed in isolation from the surrounding context which can lead to negative impacts, poor performance, and eventual breakdown in functions. This approach, sharply focused on the specific structure, is not suited to dealing with extreme conditions, especially those projected with climate change. Area-wide or ecosystem approaches that consider how all components of the affected system work together to reinforce and strengthen an infrastructure asset are needed. The town stories in this publication (Chapters 5–7) illustrate the importance of area-wide approaches to building resilience—whether a floodgate, river embankment, or town market.

Climate change core groups bring cross-sector collaboration in resilience building: The core group approach to town planning demonstrated in Battambang, Dong Ha, and Kaysone Phomvihane are important multisector technical structures for mainstreaming climate change in urban development. They act as technical advisory groups on climate change providing review and evaluation functions in assessing proposed infrastructure development projects and providing advice on zoning and development controls in the town master planning process. To function effectively, core groups need to be formally recognized with a clear mandate and a secretariat as well as financial and political support.

Siting of strategic infrastructure away from severe flood-prone areas: The vulnerable areas within each town need to be mapped based on an understanding of past experience with extreme events and projections of additional climate change influences. For example, areas prone to flooding, landslides, and river bank collapse, subsidence and drought should be mapped and overlaid on the town plan so that adjustments can be made to zone boundaries and controls to ensure that development projects are appropriately sited and designed. Strategic infrastructure and other buildings should not be located in areas prone to severe flooding. Planning of land allotments prone to any form of flooding and the design of any structures on them needs to be guided by mandatory standards and controls which ensure resilience.

Technology can improve information, public consultation, and consensus in adaptation planning: Computers, the internet, mobile phones, and social media are all powerful tools that could be used to gain consensus and increase public participation in town planning and development approval processes. For example, shared information networks between town planning and development agencies, electronic surveys and feedback systems via the internet or mobile phone, or online public notification and response portals for development applications are all valuable tools for improving information and consensus for adaptation planning and green infrastructure design.

Participatory mapping is an essential process for towns to document past extreme events and projected changes: In the context of vulnerability assessment and adaptation planning, it is a process in which core stakeholder groups define areas prone to regular and extreme climate and hydrological events so that development location and design can be adjusted to minimize negative impacts and build resilience. In situations of limited modeling and geographic information system (GIS) mapping, participatory mapping is an appropriate way of accurately identifying hot spots. It begins with drawing areas affected by past extreme events. Then through discussion and consensus, the additional effects of climate change can be added drawing on whatever information is available on projected conditions. Participatory mapping involves delineating hot spots and then adjusting land use zoning schemes and development controls as part of town master planning.[16]

Participatory mapping builds capacity and working relationships in cross-sector core groups. It promotes sharing of information and experiences and strengthens understanding of practical urban planning responses to climate change.

Zoning schemes and development controls provide the framework for building urban resilience: Most small and medium-sized towns in the GMS do not have spatial master plans with zoning schemes and linked development controls. In cases where towns have master plans, zoning schemes are often rudimentarily defined without consideration of potential flooding or other threats to development. The rationale for zone boundaries and location are not clear. Few include town-wide or zone-specific development controls. For example, the comprehensive Dong Ha master plan has urban and infrastructure expansion zones in areas prone to severe flooding and in areas where maintenance of natural drainage corridors is essential to town resilience. The zones do not consider this vulnerability and are not accompanied by appropriate development guidance. In many cases, town zoning plans are long out of date and no longer reflect the way the town has developed. High priority should be given to preparing and regularly reviewing and revising town zoning schemes and associated development controls in ways that account for climate and hydrological vulnerabilities.

Comprehensive asset management and good operation and maintenance procedures are needed for increasing resilience: Good asset management, including regularly updated asset inventories and operation and maintenance plans, is essential for ensuring that town infrastructure assets are well maintained and perform as intended. All Mekong towns should have a town asset inventory and an asset operation and maintenance plan covering all major pieces of infrastructure including green infrastructure. While maintenance plans and strategies vary by project type, proper maintenance is essential to maximizing the environmental, social, and economic benefits of green infrastructure, as well as ensuring that projects continue to perform in the face of climate change.

Simple and practical vulnerability assessment and adaptation planning methods are needed as part of town planning and project review: The aim is to make vulnerability assessment part of normal urban planning and

[16] When conducting participatory mapping, it is useful to separate mapping of historical flooding caused by pooling and flooding due to river overtopping. They have very different flood characteristics in terms of depth, duration, and impact, and need different responses.

environmental impact assessment. It is a two-way relationship—a climate threat will impact the area or asset—and new infrastructure and uses in the area will affect how serious the threat becomes. Vulnerability assessment is applied in town master planning as part of zone and development control definitions and as a tool in assessing specific infrastructure proposals in the development control process. The most important step is in listing the potential impacts of the climate and hydrological threats facing an area or proposed infrastructure asset. Adaptation measures are defined to address those impacts.

1.4 Conclusion

Concerted reforms are needed in national legislation, policies, and procedures and in local government regulations and decisions before it will be possible to build resilient and sustainable towns in the GMS in a systematic and visionary way. Widespread piloting and demonstrations accompanied by capacity building in skills, tools, and supporting technologies are needed as a first phase to build momentum and commitment to that reform.

Gray infrastructure is the driving force for development shaping Mekong towns. It is often designed in isolation of the wider environmental and social effects and usually without adequate understanding of past extremes affecting the target area and of projected climate changes. Major projects are proceeding on a project-by-project basis and following assessments limited to site-specific concerns. Detailed safeguard and development controls measures are not well integrated in town master plans nor matched with the particular characteristics and vulnerabilities of each town zone.

At the project level, environmental impact assessment processes are capturing only a very small percentage of development proposals and are conducted without the benefits of information on climate change. Most often, local governments and communities are not engaged in the assessment and planning that does take place for major infrastructure. The cumulative impact across the urban landscape of many poorly assessed and planned projects is making towns more vulnerable and committing them in the long term to expensive maintenance and reconstruction.

Outmoded infrastructure design standards inhibit the use of appropriate measures and materials and promote hard engineering no matter what the cost. There are many impediments to the use of green infrastructure and nature-based solutions which require more flexible and innovative standards and supporting directives. Even when arising through development aid and involving the application of externally driven planning and review processes, gray infrastructure is failing to perform well in increasingly severe climatic and flood conditions. Some major infrastructure projects reviewed as part of this technical assistance have made local environmental and social conditions worse—and reduced town resilience and sustainability.

High-level commitment in the GMS to climate change adaptation creates a unique opportunity to commence the reform process and refocus town development on the linked goals of resilience and sustainability. This project has begun that process in three towns, and this publication stemming from their work is a tool to support and guide the reform process. An immediate step is to create a network of adaptation demonstration sites across the GMS based on green infrastructure approaches. There is an opportunity to build on the formation of the three core groups to create a GMS network of towns seeking to address climate change. That would involve continuing support in bringing together towns on a regular basis to motivate, share, and train. It would involve establishing demonstration sites in each town where green infrastructure approaches to resilience building are being tested and showcased. It would also involve setting up core groups in other towns as part of an expert network of local planners and adaptation practitioners in the GMS. Those groups could be the focus of intensive capacity building with specialist input and funding support to help drive and add creative energy to the reform process.

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Green Infrastructure for Resilient Mekong Towns

2.1 Introduction

The methods presented in this chapter have been chosen from a variety of green infrastructure solutions because they relate specifically to Greater Mekong Subregion development needs. The integration of green infrastructure solutions in the early stages of the decision-making process of urban planners should be in every way facilitated. Green infrastructure should be included in design standards and safeguards to be recognized as a complement and alternative to traditional infrastructure development.

Design engineers wishing to explore different approaches to conventional infrastructure should ask themselves the following questions:

1. Can you meet the requirements with a completely natural approach?
2. If not, how can you use natural elements to strengthen the conventional infrastructure?
3. If you cannot act directly on site, how can you reinforce the life and effectiveness of the conventional infrastructure by acting on the surroundings?

2.2 Infrastructure Matrix

Green infrastructure technologies often work best when combined. To help practitioners begin implementing green infrastructure options, we have provided a matrix to illustrate how different technologies may pair and interact with other complementary techniques (Table 2.1).

The columns represent the development needs that may be encountered in an urban context. For each, the green infrastructure elements that could bring benefit are highlighted. All the development needs listed are covered by one or more case studies.

Table 2.1: Green Infrastructure Techniques and Development Needs Matrix

	Bridges	Buildings	Canals	Commercial area redevelopment	Culverts and drains	Dykes	Drainage	Flood gates	Industrial areas	Markets	Parking areas	Port redevelopment	Residential areas	River embankments	Road embankments	Roads and footpaths	Stormwater outfall	Wastewater treatment plants	DEVELOPMENT NEEDS
Bioretention pond		■		■			■		■	■	■	■	■			■	■	■	
Bioswales		■		■			■		■	■	■	■	■			■	■	■	
Brush mattress	■		■		■	■		■						■	■		■		
Constructed wetlands				■			■		■	■			■				■	■	
Drainage corridors			■				■										■		
Greywater recycling		■		■					■	■		■	■					■	
Green roofs and walls		■		■			■		■	■		■	■					■	
Live crib wall	■		■			■	■		■						■	■		■	
Live fascines	■		■			■	■		■						■	■		■	
Live fencing	■		■			■	■		■						■	■		■	
Live staking	■		■			■	■		■						■	■		■	
Log terracing	■		■			■	■		■						■	■		■	
Palisades	■		■			■	■		■						■	■		■	
Permeable paving				■			■		■	■	■	■	■			■			
Rain gardens		■		■			■		■	■	■		■				■		
Solid waste management		■		■			■		■	■		■							
Stormwater tree pits		■		■			■		■	■	■		■			■			
Urban river terracing			■	■											■		■		
Urban tree canopy cover		■		■					■	■	■	■				■			
Vegetated gabions			■		■	■		■						■	■		■		
Vegetated eotextiles	■		■	■	■	■		■	■	■	■	■	■	■	■	■	■		
Vegetated revetment			■		■	■		■						■			■		
Vegetated riprap			■		■	■		■						■			■		
Vetiver grass	■		■		■		■	■	■			■	■	■	■		■		
GREEN INFRASTRUCTURE																			

Source: ADB and ICEM.

2.3 Water and Flood Management

2.3.1 Constructed Wetlands

Category: Water and flood management; pollution management; energy, heat, and greenhouse gas management
Application: Town-wide planning

Description and Application

A constructed wetland is an artificial wetland created as a new or restored habitat for native and migratory wildlife, for discharge such as wastewater, stormwater runoff, or sewage treatment and for land reclamation in natural areas impacted by development. They are generally built on seriously degraded wetlands or new areas where there are problems with drainage and water quality. They can substitute for conventional stormwater and graywater treatment plants. Wetlands are frequently constructed by excavating, backfilling, grading, diking, and installing water control structures to establish desired hydraulic flow patterns. They consist of shallow (usually less than 1-meter-deep) ponds or channels which have been planted with aquatic plants.

Facts

- Wetlands act as a biofilter, removing sediments and pollutants such as heavy metals from the water, and constructed wetlands can be designed to emulate these features.
- Wetlands trap suspended solids while other pollutants are transformed and taken up by plants or rendered inactive.

Benefits

- Provides food and habitat for wildlife.
- Improves water quality.
- Provides flood protection, drought relief, and opportunities for recreation.

Caution

While constructed wetlands seem simple, they are complex to design and require ongoing management.

Sources
United States Environmental Protection Agency (EPA). 2004. *Constructed Treatment Wetlands.* https://nepis.epa.gov/Exe/ZyPDF.cgi/30005UPS.PDF?Dockey=30005UPS.PDF
EPA. 1999. *Manual: Constructed Wetlands Treatment of Municipal Wastewaters.* Cincinnati, OH. https://nepis.epa.gov/Exe/ZyPDF.cgi/30004TBD.PDF?Dockey=30004TBD.PDF
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Constructed wetland

Source: Youth Landscape Architecture. www.youthla.org

2.3.2 Drainage Corridors

Category: Water and flood management
Application: Town-wide planning

Description and Application

Creating natural drainage corridors normally involves converting a ditch or storm drain into a natural creek flowing within a multipurpose corridor. They can also be created by rehabilitating and enhancing natural creeks and streams. They greatly reduce the number of drain pipes and other costly technologies required to manage stormwater runoff, and they reduce flood management costs overall. Stormwater is collected in a traditional pit and pipe network within the road reserves. The pit and pipe network conveys flows to the drainage corridor where wetland conditions treat runoff before discharging to the natural watercourse.

Drainage corridors

Sources: Hazen and Sawyer. www.hazenandsawyer.com, and Pace. 30zz0j1ewgra3qf6cz317ytj.wpengine.netdna-cdn.com

Facts

- Natural drainage corridors require sufficient land allocation, and must be recognized as a legitimate land use that needs to be appropriately considered during the planning of new urban developments and the redevelopment of existing urban areas.
- Natural drainage corridors help direct stormwater flows, thus reducing flooding in built and residential areas.

Benefits

- Improved drainage during minor and major storms.
- Reduced flooding.
- Natural stormwater and pollution filtration.
- Increased habitat for native plant and animal species.
- Improved flow, which reduces stagnant water and associated odor and disease vectors.

Caution

Natural drainage corridors are often multiuse and therefore require sufficient space to be effective.

Sources

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Northrop Engineers. 2008. *Wagga Wagga Planning Study: Lloyd Study Area—Environmental Study – Stormwater*. Sydney, Australia. http://www.wagga.nsw.gov.au/__data/assets/pdf_file/0018/4635/Lloyd_Study_Area2.pdf

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State of Queensland (Department of Energy and Water Supply). 2013. *Queensland Urban Drainage Manual*. Third edition 2013—provisional. City East, Queensland, Australia. http://www.dews.qld.gov.au/__data/assets/pdf_file/0008/78128/qudm2013-provisional.pdf

2.3.3 Permeable Paving

Category: Water and flood management, pollution management
Application: Town-wide planning

Description and Application

Permeable pavements are paved surfaces that infiltrate, treat, and/or store rainwater where it falls. They may be constructed from pervious concrete, porous asphalt, permeable interlocking pavers, and several other materials. They function similarly to sand filters in that they filter the water by forcing it to pass through different aggregate sizes and filter fabric (Figure 2.1).

Facts

- Long-term research on permeable pavers shows they effectively remove pollutants such as total suspended solids, total phosphorous, total nitrogen, zinc, motor oil, and copper.
- In the void spaces, naturally occurring microorganisms break down hydrocarbons and metals.

Benefits

- Reduces flooding during storm events.
- Stormwater pollutants are broken down in the soil instead of being carried to surface waters.
- Allows water seepage to groundwater recharge.
- Helps prevent stream erosion problems.
- Takes pressure off existing drainage and stormwater management systems.

Caution

Permeable paving is only suitable in areas that experience light vehicle traffic, for example, parking lots, road shoulders, sidewalks, and driveways.

Sources

United States Environmental Protection Agency. What Is Green Infrastructure? https://www.epa.gov/green-infrastructure/what-green-infrastructure#permeablepavements

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2.3.4 Rainwater Harvesting

Category: Water and flood management
Applications: Town-wide planning, individual owners

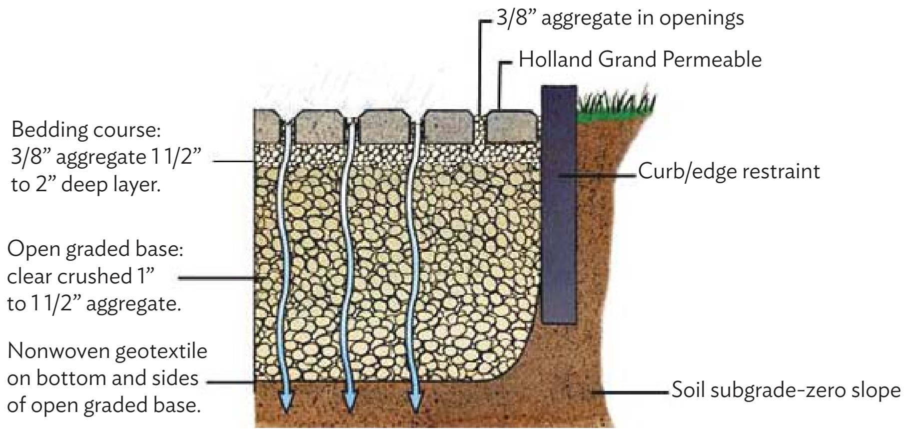
Description and Application

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface, or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams. The harvested water can be used as drinking water, for domestic needs, and for irrigation (Figure 2.2).

Facts

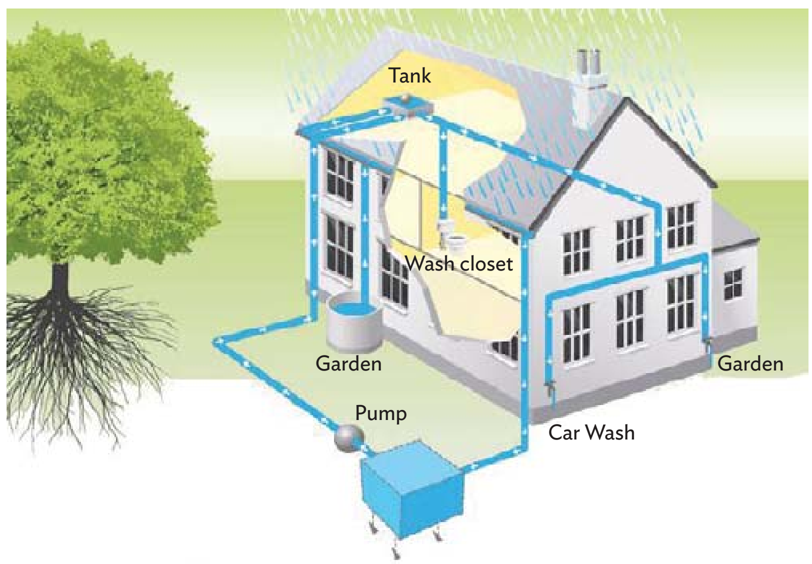
- The history of rainwater harvesting in Southeast Asia can be traced back to the 9th or 10th century—the small-scale collection of rainwater from roofs and simple brush dam constructions.
- Can improve the engineering of building foundations when cisterns are built as part of the substructure.

Figure 2.1: Cross-Section of Components of Permeable Paving



Source: RJ Wolfe and Sons. rjwolfeandsons.com

Figure 2.2: Illustration of a Sophisticated Rainwater Harvesting System and Its Uses



Source: Hinren Technologies. www.hinren.com

Benefits

- Reduces domestic and municipal water demand and expenses.
- Is an accessible replacement for groundwater.
- Reduces pollutants and flow into surrounding surface waters.
- Serves as a backup water supply during emergencies and natural disasters.
- Reduces size of traditional stormwater management practices.
- Lowers strain on municipal water supply system.

Caution

Rooftops should be constructed of chemically inert materials such as wood, tiles, tin, aluminum, or fiberglass, and cleaned regularly to avoid adverse effects on water quality.

Sources

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2.3.5 Stormwater Tree Pits

Category: Water and flood management, pollution management

Application: Town-wide planning

Description and Application

Stormwater tree pits consist of an underground structure and aboveground plantings which collect and treat stormwater using bioretention. Treated stormwater is then infiltrated into the ground or, if infiltration is not appropriate, discharged into a traditional stormwater drainage system (Figure 2.3).

Facts

- Numerous prefabricated tree pit structures are commercially available. These typically include a ready-made concrete box containing an appropriate soil mixture and may also include plantings, usually one tree or a few small shrubs.
- Ideally, stormwater tree pits are employed in conjunction with other stormwater best management practices. Their usefulness is enhanced with greater soil volume and by connecting individual pits with trenches.

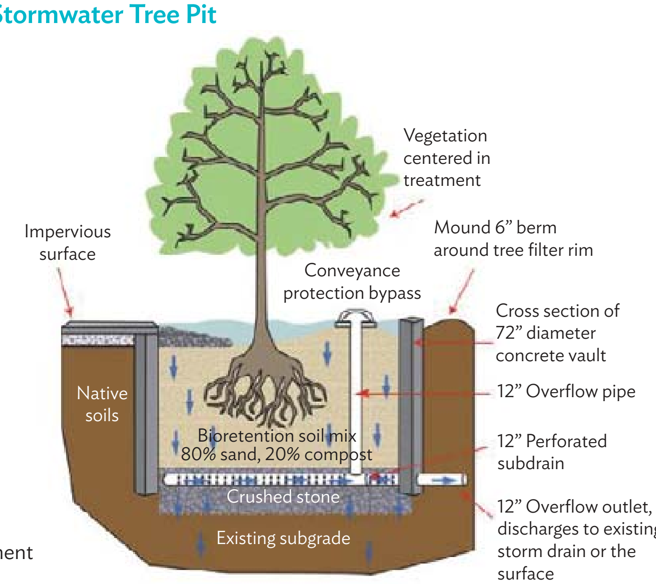
Benefits

- Reduce stormwater runoff volume, flow rate, and temperature.
- Increase groundwater infiltration and recharge.
- Treat stormwater runoff.
- Improve quality of local surface waterways.
- Improve aesthetic appeal of streets and neighborhoods.
- Provide wildlife habitat.
- Require limited space.
- Are simple to install.

Caution

Stormwater tree pits generally capture and treat stormwater runoff from small, frequently occurring storms but are not designed to capture all runoff from large storms or extended periods of rainfall.

Figure 2.3: Cross-Section Illustration of the Components of a Stormwater Tree Pit



Sources: NYC Parks. www.nyc.gov, and Rutgers New Jersey Agricultural Experiment Station. njaes.rutgers.edu

Sources
Arbor Day Foundation. How Trees Can Retain Stormwater Runoff. *Tree City USA Bulletin* No. 55. http://www.fs.fed.us/psw/topics/urban_forestry/products/11/800TreeCityUSABulletin_55.pdf

Auckland Council. n.d. *Tree Pits: Construction Guide*. Stormwater Device Information Series. http://www.aucklandcouncil.govt.nz/EN/environmentwaste/stormwater/Documents/treepitsconstructionguide.pdf

Charles River Watershed Association. 2008. *Stormwater Tree Pit*. http://www.crwa.org/hs-fs/hub/311892/file-640261436-pdf/Our_Work_/Blue_Cities_Initiative/Resources/Stormwater_BMPs/CRWA_Tree_Pit.pdf

Philadelphia Water. Stormwater Tree Trench. http://www.phillywatersheds.org/what_were_doing/green_infrastructure/tools/stormwater_tree_trench

2.3.6 Urban River Terracing

Category: Water and flood management
Application: Town-wide planning

Description and Application

Urban river terracing has as its main objectives flood protection, master landscaping, and the improvement of overall environmental conditions. The philosophy is to move from flood resistance to flood accommodation. In a stream area, the floodplain is widened and deepened, allowing it to fill during rain events and preventing stormwater from flooding urban areas.

Secondary channels are built parallel to the main stream to allow for more drainage during heavy rainfall.

Facts

- Between heavy rain events, the floodplain is made available as a park and green space for local residents.
- Dikes, streambed stabilization, and other technologies used to guide the stream are built using natural materials to maximize water filtration and rehabilitation benefits.

Benefits

- Reduces flood risk in inhabited areas.
- Increases ecological functions such as water filtration.
- Provides fish, bird, and wildlife habitat.
- Creates opportunities for recreation and tourism.

Urban river terracing

Sources: Community Conservation Solutions. www.conservationsolutions.org, and Landezine: Landscape Architecture Works. www.landezine.com

Caution

Urban river terracing can require large investments to dredge and stabilize the area.

Sources
European Centre for River Restoration. http://www.ecrr.org/

D. Higgitt and G. Brierley. 2012. New Approaches to Flood Hazard in Asian Cities. *Innovation*. Volume 10, No. 2. http://www.innovationmagazine.com/volumes/v10n2/coverstory3.html

R. Jones-Bos and D. Morris. 2011. Room for the River: From Flood Resistance to Flood Accommodation. Presentation slides. http://www.slideshare.net/DutchEmbassyDC/room-for-the-river-presentation-2011

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2.4 Slope Stabilization

As with green infrastructure on the whole, slope stabilization options are often most effective when combined with complementary techniques.

Table 2.2: Slope Stabilization Combination Matrix

	Brush mattress	Live cribwall	Live fascines	LIve fencing	Live staking	Log terracing	Palisades	Vegetated gabions	Vegetated geotextiles	Vegetated revetments	Vegetated riprap	Vetiver grass
Brush mattress												
Live cribwall												
Live fascines												
Live fencing												
Live staking												
Log terracing												
Palisades												
Vegetated gabions												
Vegetated geotextiles												
Vegetated revetments												
Vegetated riprap												
Vetiver grass												

Source: ADB and ICEM.

Brush mattress

Source: Natural Resources Conservation Service New York. www.nrcs.usda.gov

This matrix (Table 2.2) outlines how the slope stabilization techniques explained in this guide fit together and work to improve each other.

Both columns and rows present all the slope stabilization techniques introduced in the volume. A green correspondence between rows and columns indicates the suitability of pairing the two techniques to maximize the effectiveness of the project.

2.4.1 Brush Mattress

Category: Slope stabilization
Applications: Town-wide planning, large infrastructure

Description and Application
Also known as live brush mats or brush matting, a brush mattress is a combination of live stakes, live fascines, and branch cuttings installed to cover and stabilize streambanks. Brush mattresses are used to form an immediate, protective cover over the streambank. A thick mat of dormant cuttings is placed on the bank and held down with stakes. The goal of a brush mattress is to create structural streambank protection that will eventually root and provide vegetative stabilization.

Facts
- Layers of living branches are laid in a crisscross pattern on a streambank to protect the bank surface until the branches root.
- A properly staked brush mattress can withstand considerable stream velocities, but must have a secure toe.
- Cuttings root along the entire length of the structure, providing long-term protection.

Benefits
- Works well on steep, fast-flowing streams.
- Restores riparian vegetation and streamside habitat rapidly.
- Forms an immediate protective cover over the streambank.
- Captures sediment during flood conditions.
- Enhances conditions for colonization of native vegetation.
- Serves as habitat for birds, small animals, and insects.

Caution
Brush mattresses are not recommended for streambanks steeper than 2.5:1, nor should they be used on streambanks where mass wasting occurs.

Sources
H. H. Allen and C. Fischenich. 2000. Brush Mattresses for Streambank Erosion Control. EMRRP Technical Notes Collection (TN EMRRP-SR-23). Vicksburg, MS: United States Army Engineer Research and Development Center. http://acwc.sdp.sirsi.net/client/en_US/search/asset/1004293

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Iowa Department of Natural Resources. 2006. *How to Control Streambank Erosion*. Des Moines, IA. http://www.ctre.iastate.edu/erosion/manuals/streambank_erosion.pdf

2.4.2 Live Cribwalls

Category: Slope stabilization
Applications: Town-wide planning, large infrastructure

Description and Application

A live cribwall is a structure made of live materials to reconstruct the streambank where extreme erosion has occurred. Once completed, this structure acts as a retaining wall. The timbers provide immediate protection and stability for the structure. Over time, their importance gradually decreases as they decompose. Meanwhile, the live cuttings grow, and the resulting root mass binds together the internal fill and the adjacent undisturbed soil.

Facts

- A live cribwall is best used on the outside bend of a stream because the strongest currents act on this side of the stream.
- They can be used instead of gabions or concrete blocks where natural appearance and habitat features are important.
- Live cribwalls help reduce the grade of a slope by stabilizing the toe and protecting it against undercutting.

Benefits

- Require minimal space.
- Provide stability above and below the water level.
- Stabilize the toe of the slope.

Live cribwall

Source: Calgary City News Blog. www.calgarycitynews.com

- Provide a natural habitat for wildlife.
- Provide immediate slope protection.

Caution

The height of a cribwall should not exceed 2 meters.

The width of a cribwall should not exceed 6 meters.

Sources
City of Knoxville. 2003. Activity: Bank Stabilization and Soil Bioengineering. Knoxville BMP Manual Erosion and Sediment, ES-20. http://www.knoxvilletn.gov/UserFiles/Servers/Server_109478/File/Engineering/BMPManual/ES-20.pdf

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2.4.3 Live Fascines

Category: Slope stabilization
Applications: Individual owner, town-wide planning

Description and Application

Live fascines are bundles of dormant, live cuttings bound together into a long, cylindrical form. They are used to protect banks from washout and seepage, particularly at the edge of a stream where water levels fluctuate moderately. Live fascines are used from the baseflow elevation and up along the face of an eroded streambank, acting principally to protect the bank toe and bank face. They are also useful over the crown to improve erosion control, infiltration, and other riparian zone functions.

Facts

- Fascines should be placed in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow sliding. They are best suited for moist soil conditions.
- Live fascines are most effective when combined with live staking and riprap, and can also be used in conjunction with many other soil bioengineering techniques.

Benefits

- Immediately reduce surface erosion or rilling.
- Are suited to steep, rocky slopes where digging is difficult.
- Are capable of trapping and holding soil on the slope face, thus reducing a long slope into a series of shorter steps.
- Can manage mild gully erosion and can serve as slope drains when bundles are slightly angled.

Caution

Live fascines are only appropriate on slopes not undergoing mass movement and above bank-full discharge levels.

Live fascines

Source: Bender: Revegetation Bioengineering. www.bender-rekultivierungen.de

Sources

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2.4.4 Live Fencing

Category: Slope stabilization

Applications: Town-wide planning, large infrastructure

Description and Application

Live fencing is a retaining structure installed along the contour of the slope. It comprises flexible boards or wattle interwoven between living or dead posts to form a series of narrow terraces across the slope. When placed in shallow trenches across the slope of a bank, these structures provide protection from erosion and create a sediment trap. They can be used to support failing slopes or to reduce slope angles and allow other vegetation to be established.

Live fencing

Source: Kennebecasis Watershed Restoration Committee. www.kennebecasisriver.ca

Facts

- Live fences are most effective on lower-angle slopes and on sites with thin soils where excavation would be difficult.
- They are used where site moisture conditions will allow the living cuttings to sprout and grow.
- They can also be used to protect the slope toe.

Benefits

- Is used with living cuttings to make the walls sprout and grow, further strengthening the structure.
- Rooted fences retain and stop moving soil to establish terraces that slow runoff velocity and reduce erosion.
- Enhances conditions for native vegetation growth.
- Is easily combined with other methods.

Caution

Live fencing is easily damaged and is therefore not sufficient for persistent rockfall.

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Redwood, Design a Fence. n.d. *Redwood Fences for All Reasons*. http://www.big-creek.com/files/5513/3830/9801/redwood-fences-how-to.pdf

Live staking
Source: Wendy DesCamp, University of Washington. depts.washington.edu

2.4.5 Live Staking

Category: Slope stabilization
Applications: Individual owner, town-wide planning

Description and Application

Live staking and joint planting involves the insertion of woody shrub cuttings into the ground in a manner that allows the cutting (stake) to take root and grow. Live stake cuttings can be used to repair small earth slips and slumps. The stakes can help buttress the soil and arching.

Facts

- Live stakes can be used to anchor and enhance the effectiveness of willow wattles, straw rolls, coir rolls, turf reinforcement mats, coir mats, continuous berms, and other erosion control materials.
- Live stakes also work very well as a means of introducing a particular plant species to a site.

Benefits

- Can improve aesthetics and provide wildlife habitat.
- Slows the flow of water in high water stages.
- Staking a streambank helps dry out a wet, unstable bank and allows it to become more stable.
- Is most useful in conjunction with other more complex erosion control methods.

Caution
Live staking must be carried out when plants are dormant. Live stakes provide very little initial site protection during the establishment period.

Sources
Ernst Conservation Seeds. Live Stakes and Whips. http://www.ernstseed.com/products/bioengineering/live-stakes-and-whips/
C. E. Eubanks and D. Meadows. 2002. *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization*. San Dimas, CA: United States Department of Agriculture Forest Service. http://www.fs.fed.us/t-d/pubs/pdf/fs683/cover.pdf
Iowa Department of Natural Resources. 2006. *How to Control Streambank Erosion*. Des Moines, IA. http://www.ctre.iastate.edu/erosion/manuals/streambank_erosion.pdf
Massachusetts Nonpoint Source Pollution Management. n.d. *Live Stakes/Pole Plantings*. http://projects.geosyntec.com/NPSManual/Fact%20Sheets/Live%20Stakes.pdf
Ontario Streams. n.d. *Live Staking*. http://www.ontariostreams.on.ca/PDF/OSRM/Tech8.pdf

Log terracing
Sources: (from top) Coco Agri. www.cocoagri.com, and River Restoration in Northern Michigan. www.northernmichiganstreams.org

2.4.6 Log Terracing

Category: Slope stabilization
Applications: Town-wide planning, large infrastructure

Description and Application
Log terracing is a way to intercept water running down a slope and comprises bedding logs or coir logs in shallow trenches along the corridor. Log terracing is used on burned slopes that have less than 30% of the original ground cover remaining and are at risk of increased erosion, and where there are enough logs of adequate size to construct a semicontinuous line at the desired horizontal spacing. It is better to use coir logs made locally than to fell trees. Log terracing shortens the slope length and the gradient between each structure, providing stable planting areas throughout most of the slope face. Logs must be installed in trenches and staked into place.

Facts
- Contour logs reduce water velocity, break up concentrated flows, and introduce hydraulic roughness to burned watersheds.
- Log terracing should be effective for a period of 1–3 years, providing short-term protection on slopes where permanent vegetation that provides long-term erosion control will be established.

Benefits
- Reduces length and steepness of the slope.
- Provides stable areas for establishment of other vegetation such as trees and shrubs.
- Provides immediate slope stabilization and helps to store sediment.

Caution
Implementing log terracing is labor-intensive and can pose possible safety hazards because of the use of logs on a slope.

Sources
Tahoe Regional Planning Agency. 2014. Chapter 4: BMP Toolkit, 4.2-e Terracing. In *TRPA BMP Handbook*. http://www.tahoebmp.org/Documents/BMPHandbook/Chapter%204/4.2/e_Terrac.pdf
United States Department of Agriculture, Natural Resources Conservation Service, Wyoming. Log Terracing Fact Sheet. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wy/technical/engineering/?cid=nrcs142p2_027265

Pallsades
Source: New South Wales Department of Primary Industries. www.water.nsw.gov.au

Washington State Department of Transportation. 2003. Chapter 740: Soil Bioengineering. In *Roadside Manual*. http://www.wsdot.wa.gov/publications/manuals/fulltext/M25-30/740.pdf

2.4.7 Palisades

Category: Slope stabilization
Applications: Individual owner, town-wide planning

Description and Application

A palisade, sometimes called a stakewall, is typically a fence or wall made from wooden stakes or tree trunks and used as a defensive structure. It is a wall consisting of living uniform stakes of live material driven into the ground (a third of their length), close to each other to form a palisade. The top ends are cut plane and may be tied to a horizontal (living or dead) pole that ties in the ground at both sides of a gully.

Facts

- Palisades are used to promote deposition in rills and V-shaped gullies and rehabilitation in fine soils (clay, sand, loess, or loam).
- After sprouting, the resulting vegetation becomes the major structural component.
- They help to dry wet soils through transpiration.

Benefits

- Are quickly and easily built.
- Provide immediate slope stabilization.
- Form a strong barrier to reinforce the slope, especially once cuttings have taken root.
- Are inexpensive where materials are available.
- Have a positive filter effect.

Caution

Palisades are only effective up to 6 meters in width and 2–4 meters in length.

Sources

Capital Regional District, Canada. Erosion. https://www.crd.bc.ca/education/our-environment/concerns/erosion

Cesvi. 2013. Natural Resource Management Hand Book: Soil Bio-engineering Techniques for Slope Protection and Stabilization. Dushanbe. http://www.cesvi.org/aaa-root/o/Erosion%20control_Tajikistan2013.pdf

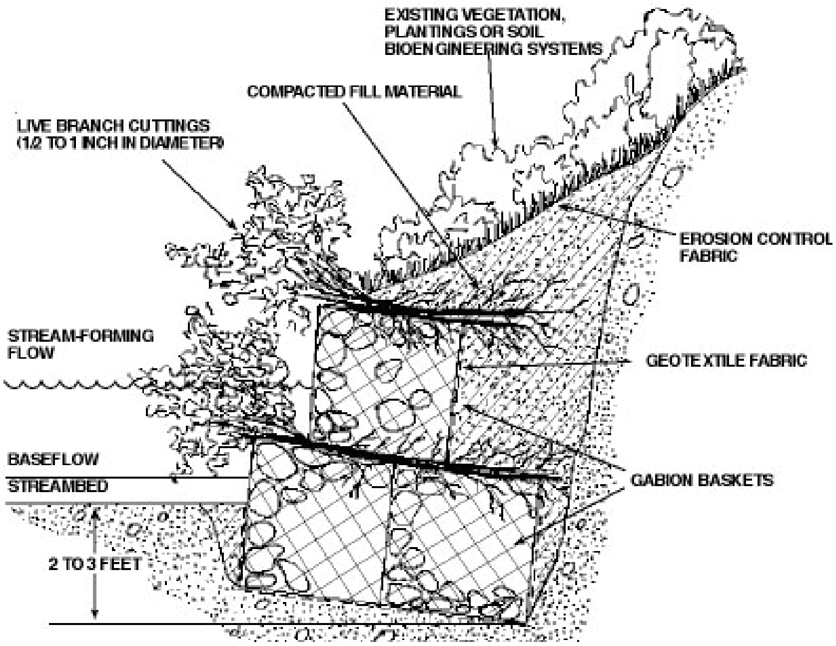
2.4.8 Vegetated Gabions

Category: Slope stabilization
Applications: Town-wide planning, large infrastructure

Description and Application

A gabion is a rectangular basket made of heavily galvanized wire mesh filled with small to medium-sized rock. The gabion is a geotextile, either natural (jute) or synthetic (wire), which

Figure 2.4: Cross-Section Illustration of Components Involved in the Use of Vegetated Gabions



Sources: Temperate Climate Permaculture. tcpermaculture.com, and Victor M Ponce San Diego State University. ponce.sdsu.edu

serves to hold soil and or rocky backfill in place until roots from live cuttings can grow. The gabions are laced together and installed at the base of a bank to form a structural toe or sidewall. Gabions are used to stop undercutting and/or scouring at the base of steep slopes. Live cuttings are placed on each gabion layer (Figure 2.4).

Facts

- This technique stabilizes steep slopes where live fascines and brushlayers are inadequate.
- Gabions can be used to reduce wave run-up and overtopping.
- Gabions help protect areas experiencing erosion due to waves, currents, or groundwater flows.

Benefits

- Are useful on steep slopes where grading is not possible.
- Can withstand higher shear stress.
- Can be installed without special equipment.
- Adjust to stresses and soil settlements.
- Simple field maintenance is feasible without the use of heavy equipment.

Caution

When the baskets are not completely filled, flexing occurs, which leads to wire fatigue and eventual failure.

Sources

Lake County Stormwater Management Commission, Lake County Planning, Building and Development Department, and United States Department of Agriculture Natural Resources Conservation Service. 2002. Streambank and Shoreline Protection Manual. http://www.lrc.usace.army.mil/Portals/36/docs/regulatory/pdf/StrmManual.pdf

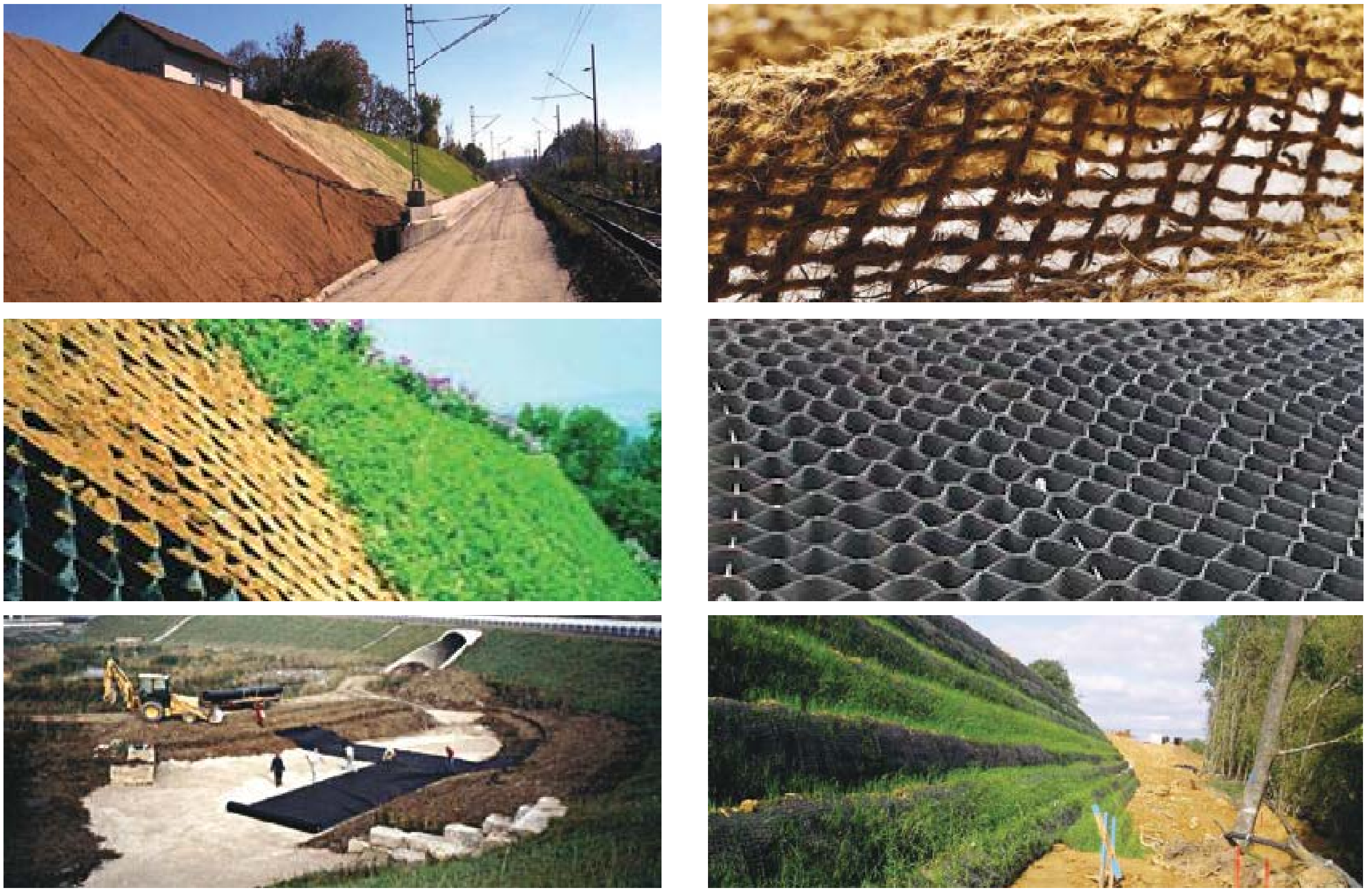
Riparian Habitat Restoration. Live Sot Gabion. http://riparianhabitatrestoration.ca/575/livesoftgabion.htm

2.4.9 Vegetated Geotextiles

Category: Slope stabilization
Application: Large infrastructure

Description and Application

A geotextile is a permeable textile material made of natural or synthetic fibers that is used with foundation, soil, rock, and earth to increase stability and decrease wind and water erosion.



Examples of Natural and Synthetic Geotextiles at Varying Stages of Installation and Growth

Sources: (starting with column 1, from top) Agro Juta. www.agrojuta.com.br, Presto Geosystems. www.prestogeo.com, Layfield Construction Products. www.layfieldgroup.com, Tencate Geosynthetics. www.tencate.com, Typar. www.typargeosynthetics.com, and Tencate Geosynthetics. www.tencategeosynthetics.uk.com

Geotextiles are designed to be permeable to allow the flow of fluids through or within them. Live cuttings can be placed between geogrids, and a root structure is established to bind the soil within and behind the geogrids. The toe of the bank is stabilized by placing layers of rock on top of the same geotextile fabric.

Facts

- Natural fiber geotextiles are more environmentally friendly, but they degrade faster and have a shorter shelf life.
- Vegetated geogrids can be used where the bank cannot be pulled back to a gentle slope.
- Woven geotextiles are generally preferred where high strength properties are needed, but where filtration requirements are less critical and planar flow is not a consideration.

Benefits

- Live cuttings provide rapid vegetation growth, which slows water during high water stages.
- Slows rill and gully erosion and stabilizes fill banks.
- Quick and effective protection against erosion.
- A wide variety of geotextile products are available to match specific needs.

Caution

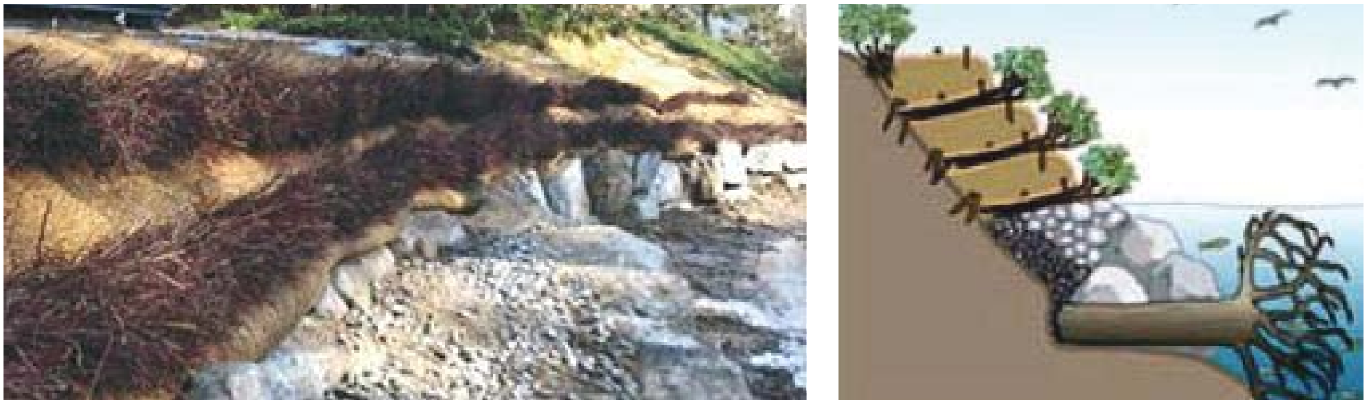
When placing live cuttings in the geogrid, plants must be installed during their dormant season for them to properly take root.

Sources

Idaho Department of Environmental Quality. 2005. *IDEQ Storm Water Best Management Practices Catalog*. http://www.deq.idaho.gov/media/616538-17.pdf

Iowa Department of Natural Resources. 2006. *How to Control Streambank Erosion*. Des Moines, IA. http://www.ctre.iastate.edu/erosion/manuals/streambank_erosion.pdf Washington State Department of Transportation. 2003. Chapter 740: Soil Bioengineering. In *Roadside Manual*. http://www.wsdot.wa.gov/publications/manuals/fulltext/M25-30/740.pdf

Figure 2.5: Cross-Section Illustration of Vegetated Revetments, Including Components Installed Below and Above the Water Line



Sources: F. X. Browne. 2012. www.fxbrowne.com, and Seattle Public Utilities. www.seattle.gov

2.4.10 Vegetated Revetments

Category: Slope stabilization
Applications: Town-wide planning, large infrastructure

Description and Application

Revetments are sloping structures placed on banks or cliffs to absorb the energy of incoming water. The lower portion of an eroding streambank is stabilized by burying or securing nonerosive materials below and slightly above the water line. Natural stabilization materials include logs, trees, root wads, and boulders. Footer boulders or logs are installed at the base parallel to the streambank. Boulders can be used to anchor the footer log. Trenches excavated into the streambank allow root wads to face slightly toward the direction of the flow so that brace roots can be flush with the streambank (Figure 2.5).

Facts

The streambank can be gradually sloped from the hard toe/revetment to promote faster establishment of vegetation.

Benefits

- Reduce erosion and shear stress along banks.
- Established root systems help strengthen soil behind the bank.
- Lower stream temperatures.
- Decrease stream velocity.
- Increase habitat for aquatic and other wildlife.

Caution

Vegetation incorporated into the revetment must be planted at medium density to avoid excessive sediment deposition and projection into the stream.

Source
WatershedBMPs.com

2.4.11 Vegetated Riprap

Category: Slope stabilization
Applications: Town-wide planning, large infrastructure

Description and Application

Vegetated riprap comprises a combination of rock and native vegetation in the form of live cuttings. Biological and technical bank protection techniques are combined to give excellent waterside erosion protection together with natural scenic beauty. For example, long and living willow or cottonwood posts can be planted in conjunction with the placement of rock used to armor the banks of watercourses or redirect flows.

Facts

Five methods for constructing vegetated riprap that have proven effectiveness:

- Vegetated riprap with willow bundles.
- Vegetated riprap with bent poles.
- Vegetated riprap with brush layering and pole planting.
- Vegetated riprap with soil cover, grass and ground cover, and joint or live stake planted riprap.

Benefits

- Resists hydraulic forces, increases geotechnical stability, and prevents soil loss.

Vegetated riprap
Source: Midwest Construction Products, midwestconstruct.com

Vetiver grass
Source: Chhajed Garden. www.chhajedgarden.com

- Creates habitat for both aquatic and terrestrial wildlife.
- Provides shade and improves aesthetic and recreation.
- Roots, stems, and shoots will help anchor the rocks and resist "plucking" and gouging by debris.

Caution

Installing plants that can survive at various submersions during the normal cycle of low, medium, and high stream flows is critical to the success of vegetative riprap.

Sources

P. Raymond. 2012. Soil Bioengineering Applications for Stream Bank Erosion Protection, Fish and Wildlife Habitat Creation. Presentation slides, Terra Erosion Control Ltd. http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2013/01/Pierre_Raymond_Vegetated-Riprap-Installation-Techniques-Mar-28-2012.pdf

Terra Erosion Control. 2010. Vegetated and Complex Riprap Application. http://www.terraerosion.com/VegetatedRiprap.htm

United States Department of Transportation, Federal Highway Administration. 2009. *Bridge Scour and Stream Instability Countermeasures Experience, Selection, and Design Guidance Third Edition, Volume 1.* http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=23&id=142

Wisconsin Department of Natural Resources. 2013. Waterway Protection. http://dnr.wi.gov/topic/Waterways/shoreline/erosioncontrol-vegetated.html (last revised 31 October 2013).

2.4.12 Vetiver Grass

Category: Slope stabilization, pollution management
Applications: Town-wide planning, large infrastructure

Description and Application

Vetiver is planted as a hedgerow across a slope to form a very dense vegetative barrier that slows down and spreads runoff. Combined with a deep and strong root system, a wide range of pH tolerance, resistance to both drought and immersion, a high tolerance to most heavy metals, and an ability to remove nitrates, phosphates, and farm chemicals from soil and water, the vetiver plant can be used for soil and water conservation, engineered construction site stabilization, pollution control (constructed wetlands), and other uses where soil and water come together.

Facts

- A vetiver hedge traps particles which can lead to a buildup of natural terraces behind it.
- It is ideal for road side slopes, coastal slopes, dams, bridge abutments, river and stream sidings, exposed earth worked areas, agricultural erosion control, and landslide control.

Benefits

- Will not turn into an invasive species or weed.
- Detoxifying capacity helps clean toxic areas like industrial sites and landfills.

Bioretention pond

Source: Hanover Land Services. www.hanoverlandservices.com

- Drought and frost tolerant; can withstand brief periods of submergence.
- Requires little maintenance once the hedge is established.

Caution

- Vetiver is intolerant to shading, especially in its establishment phase.
- Vetiver must be grown in full sun to succeed.

Sources

The Vetiver Network International. http://www.vetiver.org

Vetiver Systems NZ. http://www.vetiversystems.co.nz/

2.5 Pollution Management

2.5.1 Bioretention Ponds

Category: Pollution management, water and flood management

Application: Town-wide planning

Description and Application

A bioretention pond is a shallow planted depression designed to retain or detain stormwater before it is infiltrated or discharged downstream. Bioretention basins retain, filter, and treat stormwater runoff using a shallow depression of conditioned soil topped with a layer of mulch or high carbon soil layer and vegetation tolerant of short-term flooding. Depending on the design, they can provide retention or detention of runoff water, will trap and remove suspended solids, and filter or absorb pollutants to soil and plant material.

Benefits

- Provide a variety of pollutant removal mechanisms, including filtration, adsorption to soil particles, and biological uptake by plants.
- Provide stormwater peak flow and volume control as well as water quality control where stormwater infiltration is used.
- Reduce temperature impacts of runoff.
- Bioretention ponds can be included in the designs for gardens, commercial developments, parking lot islands, and roadways.
- Water is ponded to a depth of 15 centimeters and gradually infiltrates the bioretention area or is evapotranspired.

Caution

Bioretention areas should usually be used on small sites (i.e., 2 hectares or less). Larger ponds tend to clog.

Sources

F.X. Browne, Watershed Management Consultants. n.d. *Bioretention Systems for Stormwater Management: Ten Towns Great Swamp Watershed Management Committee*. http://www.fxbrowne.com/html/gs-facts/gs-factsheet05v9.pdf

Office of Lakes and Watersheds, Dane County, Wisconsin. 2007. Dane County Erosion Control and Stormwater Management Manual, Appendix I – Bioretention Basin. http://danewaters.com/pdf/manual/Appendix_1/BioretentionBasin.pdf

Prince George's County, Maryland. Bioretention Design Specifications and Criteria. http://www.leesburgva.gov/home/showdocument?id=5057

Stormwater Manager's Resource Center. Stormwater Management Fact Sheet: Bioretention. http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Filtering%20Practice/Bioretention.htm

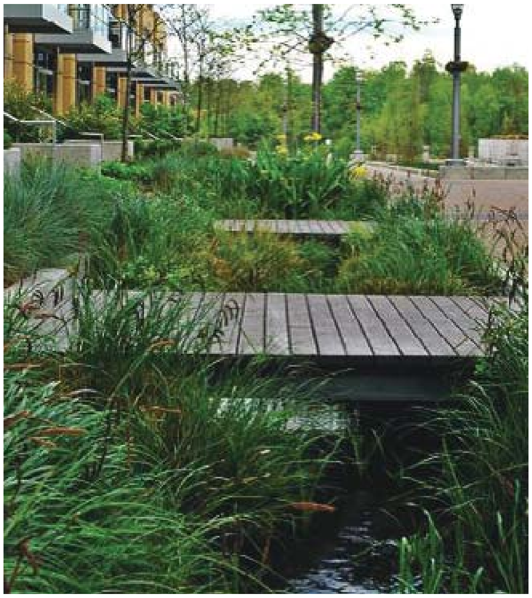
2.5.2 Bioswales

Category: Pollution management, water and flood management

Application: Town-wide planning

Description and Application

Bioswales are vegetated channels designed to remove silt and pollution from surface runoff. The water's flow path, along with the wide and shallow ditch, is designed to maximize



Bioswales

Source: St George Rainway Project. www.rainway.ca

How these interact with the street and other vegetation; graywater recycling

Source: Novel Remodelling. novelremodeling.files.wordpress.com

the time water spends in the swale, which aids the trapping of pollutants and silt. A common application is around parking lots, where substantial automotive pollution is collected by the pavement and then flushed by rain. The bioswale wraps around the parking lot and treats the runoff before releasing it to the watershed or storm sewer.

Facts

- Bioswales may be designed to contain check dams that facilitate pond formation, further increasing infiltration and decreasing stormwater flows.
- Depending upon the land available, a bioswale may have a meandering or almost straight channel.

Benefits

- Trap and break down common pollutants.
- Improve water quality in surrounding water bodies.
- Reduce stormwater runoff rates and flood prevention.
- Increase green space and aesthetic appeal.
- Recharge surrounding groundwater.
- Provide habitat for aquatic and other wildlife.

Caution

A bioswale is primarily a conveyance system and must be designed to transport water of a specific storm severity without flooding.

Sources
SUNY College of Environmental Science and Forestry, Department of Environmental Resource Engineering. Bioswales. http://www.esf.edu/ere/endreny/gicalculator/BioswaleIntro.html
United States Environmental Protection Agency. https://www.epa.gov/green-infrastructure/what-green-infrastructure#bioswales
University of Florida, IFAS Extension. 2008. *Bioswales/Vegetated Swales*. Florida Field Guide to Low Impact Development. .http://buildgreen.ufl.edu/Fact_sheet_Bioswales_Vegetated_Swales.pdf

2.5.3 Graywater Recycling

Category: Pollution management, water and flood management
Applications: Individual owners, town-wide planning

Description and Application

Graywater recycling systems collect the water from sinks, showers, and baths. Using state-of-the-art filtration, the system cleans the water and plumbs it back into toilets, washing machines, and outside taps. The easiest way to use graywater is to pipe it directly outside and use it to water decorative plants or fruit trees, or to clean pavements, cars, and dust.

Facts

- Graywater recycling systems have been successfully adapted to suit large commercial

A rain garden

Source: United States Environmental Protection Agency. www3.epa.gov

buildings like hotels and even industrial plants.
- Unlike a rainwater harvesting system, which relies on rainfall, graywater is replenished daily.

Benefits

- Keeps dirty water from polluting sensitive ecosystems.
- Graywater can be used to enhance nearby wetlands.
- Reduces demand on municipally supplied fresh water.
- Reduces strain on water treatment plants.
- Provides water for groundwater recharge.
- Reduces cost and energy required to pump municipal water.

Caution

Graywater recycling produces water for nonpotable uses. Graywater can be used for irrigation, but it should not touch edible plants.

Sources

D. Ferguson. 2014. Greywater Systems: Can They Really Reduce Your Bills? *The Guardian*. 21 July. http://www.theguardian.com/lifeandstyle/2014/jul/21/greywater-systems-can-they-really-reduce-your-bills?CMP=twt_gu

Graywater. http://www.graywater.net/

United States Environmental Protection Agency. Water Recycling and Reuse: The Environmental Benefits. http://www.epa.gov/region9/water/recycling/

Wholly H2O – Mainstreaming Efficient Water (re(Use). Uses and Benefits of Graywater. http://www.whollyh2o.org/graywater/item/348-uses-and-benefits-of-graywater.html

2.5.4 Rain Gardens

Category: Pollution management, water and flood management

Applications: Individual owners, town-wide planning

Description and Application

A rain garden detains rainfall and stormwater runoff to slow flow, reduce pollution, and increase infiltration. Usually, it is a small garden designed to withstand the extremes of moisture and concentrations of nutrients, particularly nitrogen and phosphorus, that are found in stormwater runoff. Rain gardens are ideally sited close to the source of the runoff and serve to slow the stormwater as it travels downhill, giving it more time to infiltrate and less opportunity to gain momentum and erosive power.

Facts

- Soils must be engineered with proper ratios of clay and sand, and a pH level appropriate to the region. Plants should be native and capable of withstanding periods of submergence.
- Nitrogen and phosphorus levels and overall sediment loads in the stormwater are reduced by the action of the plants and soils.

Benefits

- Clean and break down pollutants like oil, fertilizer, pesticides, pet waste, transportation chemicals, and sediment, and prevent them from reentering the water system.
- Reduce localized flooding and strain on stormwater systems.
- Provide wildlife habitat.
- Contribute to groundwater recharge.

Caution

Water should only pool for a maximum of a few hours to protect plants and reduce mosquito breeding concerns.

Sources

Rain Garden Network. 2015. Benefits of Planting Rain Gardens. 26 April. http://www.raingardennetwork.com/whyplantraingarden.htm

The University of Rhode Island. Rain Gardens. http://web.uri.edu/riss/take-action/simple-steps-at-home/rain-gardens/

United States Environmental Protection Agency. What Is Green Infrastructure? https://www.epa.gov/green-infrastructure/what-green-infrastructure#raingardens

2.6 Energy, Heat, and Greenhouse Gas Management

2.6.1 Green Roofs and Walls

Category: Energy, heat, and greenhouse gas management; water and flood management; pollution management
Applications: Individual owner, town-wide planning

Description and Application

A green roof system is an extension of the existing roof which involves a high-quality water-proofing and root-repellant system, a drainage system, filter cloth, a lightweight growing medium and plants. Green roofs are particularly cost-effective in dense urban areas where land values are high and on large industrial or office buildings where stormwater management costs may be high. They can be as simple as a 5-centimeter covering of hardy groundcover or as complex as a fully accessible park complete with trees.

Facts

- Through the dew and evaporation cycle, plants are able to cool cities and reduce the urban heat island effect. The light absorbed by vegetation would otherwise be converted into heat energy.
- On hot days, the surface of a green roof can be cooler than the air temperature, while the surface of a conventional rooftop can be up to 50°C warmer.

Benefits

- Retain rainwater, moderate water temperature, and act as natural filters.
- Reduce and delay stormwater runoff.
- Capture airborne pollutants and filter noxious gases.
- Increase green space.

A green roof
Source: Herbidacious. herbidacious.wordpress.com

- Insulate buildings and moderate building temperature.
- Provide wildlife habitat.

Caution

The additional mass of the soil substrate and retained water places a large strain on the structural support of a building.

Sources
Green Roofs for Healthy Cities. About Green Roofs. http://www.greenroofs.org/index.php/about/aboutgreenroofs

United States Environmental Protection Agency. Using Green Roofs to Reduce Heat Islands. https://www.epa.gov/heat-islands/using-green-roofs-reduce-heat-islands

United States Environmental Protection Agency. What Is Green Infrastructure? https://www.epa.gov/green-infrastructure/what-green-infrastructure#Greenroofs

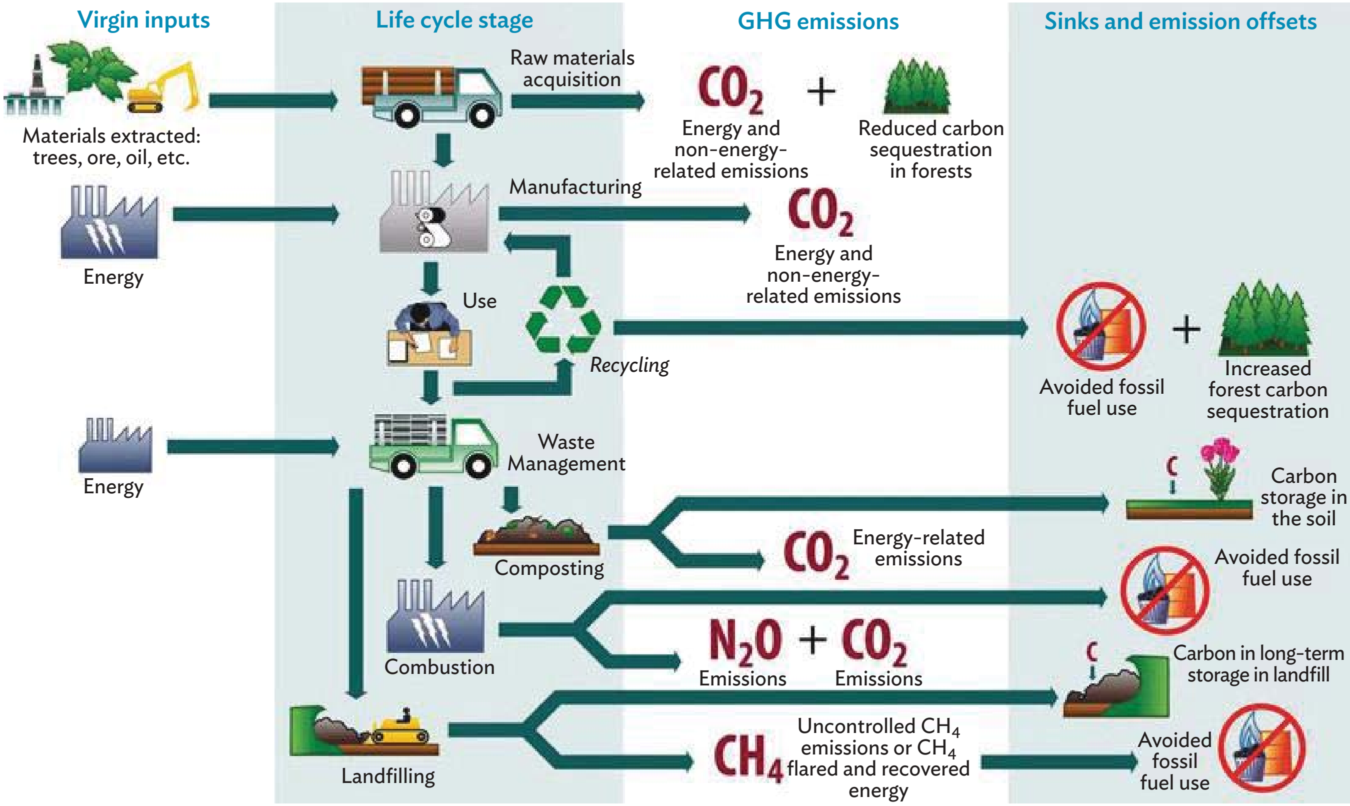
2.6.2 Solid Waste Management

Category: Energy, heat, and greenhouse gas management; pollution management
Applications: Town-wide planning

Description and Application

Municipal solid waste management (MSWM) refers to the collection, transfer, treatment, recycling, resource recovery, and disposal of solid waste generated in urban areas (Table 2.3). MSWM is a major responsibility of local government and a complex service involving appropriate organizational, technical, and managerial capacity and cooperation between numerous stakeholders in both the private and public sectors (Figure 2.6).

Figure 2.6: Stages of Solid Waste from Extraction through to Emissions and Their Offsets



Source: United States Environmental Protection Agency. www3.epa.gov

Table 2.3: Solid Waste Management Techniques

Source reduction	Also known as waste prevention, means reducing waste at the source.
Recycling and composting	Involves collecting used, reused, or unused items that are considered waste; sorting and processing recyclable products into raw materials; and turning recycled materials into new products.
Energy recovery	Conversion of nonrecyclable waste into usable heat, electricity, or fuel through combustion, gasification, pyrolization, anaerobic digestion, and landfill gas recovery.
Treatment and disposal	Landfills are the most common form of waste disposal and are an important component of an integrated waste management system.

Source: ADB and ICEM.

Benefits

- Source reduction, also known as "lightweighting," reduces resource use and greenhouse gas emissions. Source-reducing paper products reduce tree harvesting, and larger forests store more carbon.
- Recycling avoids greenhouse gas emissions from using virgin materials, and manufacturing a product from recycled materials uses less energy.
- Adding compost to soils stores carbon and releases small amounts of methane and nitrous oxide that can be burned.
- When landfill waste breaks down, it releases methane. Capturing and burning this methane can reduce atmospheric pollution.
- Burning waste is an alternative energy source.

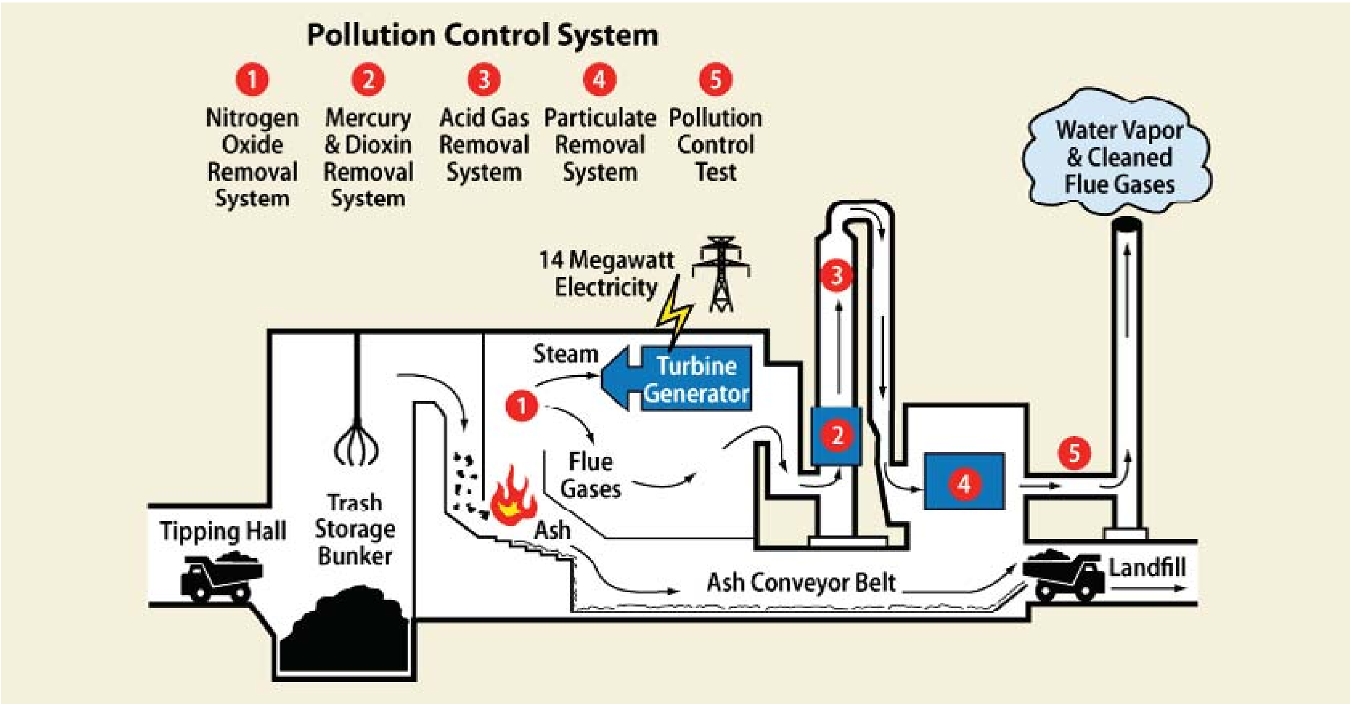
2.6.2.1 Solid Waste Management: Energy Production

Category: Energy, heat, and greenhouse gas management; pollution management
Application: Town-wide planning

Description and Application

Energy recovery from waste is the conversion of nonrecyclable waste materials into usable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion, and landfill gas recovery. This process is often called waste-to-energy. Most waste-to-energy processes produce electricity and/or heat through combustion, or by producing methane, methanol, ethanol, or synthetic fuels (Figure 2.7).

Figure 2.7: Stages in the Conversion of Solid Waste to Energy



Source: Fides Global. fidesglobal.co.uk

Facts

- At a municipal solid waste combustion facility, solid waste is burned in a combustion chamber.
- The heat released from burning is used to convert water to steam which turns a turbine generator to produce electricity.
- The ash is treated and kept in a landfill designed to prevent groundwater contamination.

Benefits

- Reduces waste kept in regular landfills, and existing landfills can even be a source of material.
- Cheap, reliable source of fuel.
- Burning waste reduces fossil use and reduces greenhouse gas emissions.
- Helps recover metals that may have been missed in initial recycling efforts.

Caution

Waste-to-energy facilities can be expensive to construct and can release toxins if not constructed properly. Residual ash must be treated properly.

Sources

Brightside. Waste-to-Energy Pros and Cons. http://www.brightknowledge.org/knowledge-bank/geography-and-environment/features-and-resources/waste-to-energy-pros-and-cons

SUEZ Isle of Man. Benefits of Energy-from-Waste. http://www.sita.co.im/energy-recovery/benefits-of-energy-from-waste

United States Environmental Protection Agency. Energy Recovery from the Combustion of Municipal Solid Waste (MSW). https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw

2.6.2.2 Solid Waste Management: Recycling

Category: Energy, heat, and greenhouse gas management; pollution management
Application: Town-wide planning

Description and Application

Recycling involves collecting used, reused, or unused items that would otherwise be considered waste; sorting and processing the recyclable products into raw materials; and turning recycled materials into new products. Recycling prevents the waste of useful

Recyclable materials are collected and sorted for processing into new products

Sources: University of Minnesota. zeropluscampus.umn.edu, and Going Slowly. journal.goingslowly.com

materials, reduces consumption of fresh raw materials, reduces energy usage, reduces air and water pollution by reducing the need for "conventional" waste disposal, and lowers greenhouse gas emissions.

Facts

- Recycling is a key component of modern waste reduction and is the third component of the "Reduce, Reuse and Recycle" waste hierarchy.
- Recyclable materials include many kinds of glass, paper, metal, plastic, textiles, and electronics. Materials to be recycled are collected, sorted, cleaned, and reprocessed into new materials bound for manufacturing.

Benefits

- Reduces the amount of waste sent to landfills and incinerators.
- Conserves natural resources such as timber, water, and minerals.
- Prevents pollution by reducing the need to collect new raw materials.
- Saves energy.
- Reduces greenhouse gas emissions that contribute to global climate change.

Caution

It is important that materials are properly sorted in the recycling process. Contamination can lower the quality of recycled content.

Sources

United States Environmental Protection Agency. Recycling Basics. http://www2.epa.gov/recycle/recycling-basics

United States Environmental Protection Agency. Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy. https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy

2.6.2.2 Solid Waste Management: Mulching

Category: Energy, heat, and greenhouse gas management; pollution management

Application: Town-wide planning

Description and Application

A mulch is a layer of material applied to the surface of an area of soil. Its purposes can be to conserve moisture, to improve the fertility and health of the soil, to reduce weed growth, and to enhance the visual appeal of the area (Figure 2.8). A mulch can be organic, recycled plastic, rubber, rock, gravel, cardboard, and/or paper. It may be permanent or temporary. Mulches of manure or compost will be incorporated naturally into the soil.

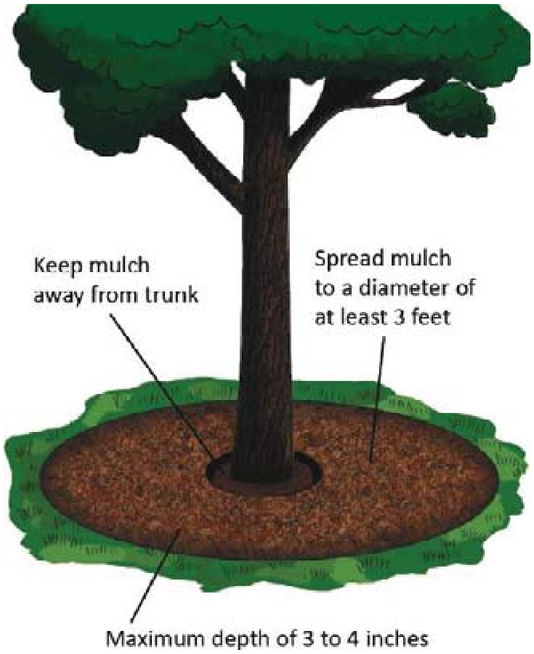
Facts

- Mulching is crucial for the maintenance of an urban tree canopy.
- Most mulching can be done anytime during the growing season, but generally the earlier the better.
- Regularly refresh and form mulch to ensure water can penetrate.

Benefits

- Recycles material which would have ended up in landfills.
- Reduces evaporation from soil surface, cutting water use by 25%–50%.

Figure 2.8: Illustration of Mulch Around the Base of a Tree



Source: Lauren Lanphear. forestcitytree.files.wordpress.com

- Stabilizes soil moisture and soil temperature.
- Prevents soil compaction.
- Reduces erosion.
- Controls weeds, which rob soil moisture.
- Adds an aesthetic finish to the urban landscape.

Caution

Do not make "mulch volcanoes" around tree trunks by applying chips up against a tree's trunk. Keep the mulch back at least 150 millimeters from the trunk.

Sources

Horticare, Inc. n.d. The Facts about Mulch. https://www.asawmill.com/uploads/Mulch_Facts.pdf

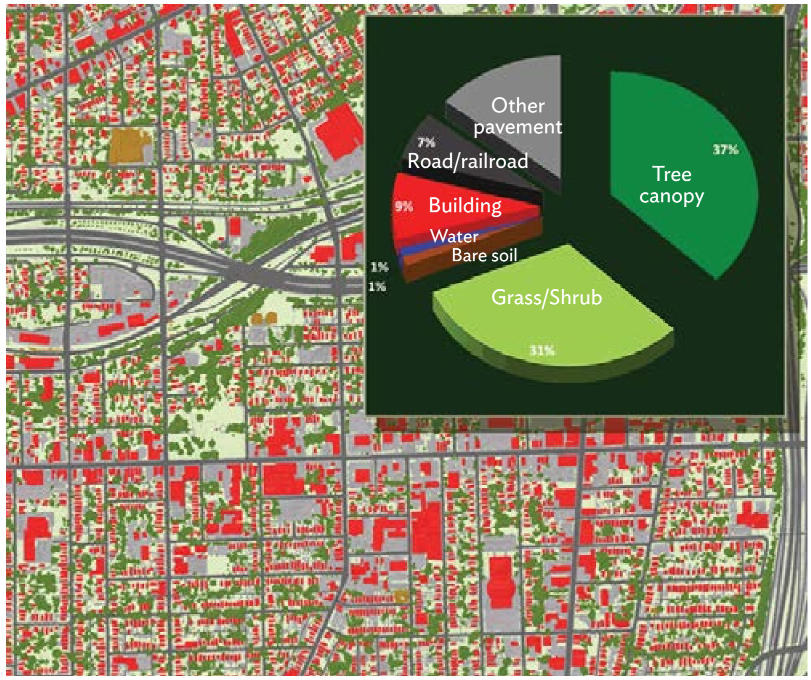
M. Shinn. 2011. Organic vs. Non-organic Mulch. *Horticulture*, 6 September. http://www.hortmag.com/weekly-tips/tools-materials/organic-vs-non-organic-mulch

M. D. Whalen. 2010. Mulching. Colorado State University, Denver County Extension Master Gardener. http://www.colostate.edu/Dept/CoopExt/4dmg/Garden/mulching.htm

2.6.3 Urban Tree Canopy

Category: Energy, heat, and greenhouse gas management; pollution management
Application: Town-wide planning

Figure 2.9: Map and Graph Illustrating Urban Tree Canopy in Cuyahoga, Ohio, United States



Source: Cuyahoga County Planning Commission. countyplanning.us

Description and Application

The urban tree canopy is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above. Tree cover can mitigate climate change by reducing the levels of greenhouse gases in the atmosphere and can help to reduce the urban heat island effect. A tree is a natural air conditioner. The evaporation from a single tree can produce the cooling effect of 10 room-size, residential air conditioners operating 20 hours a day (Figure 2.9).

Facts

- Canopy cover and trends are measured by classifying remotely sensed data, ground sampling, and aerial photos.
- Evaluating baseline and potential tree canopy aids in establishing realistic targets.
- Canopy targets by zone are recommended due to fundamental differences in land-use characteristics.

Benefits

- Reduces greenhouse gases and improves air quality.
- Lowers temperatures in streets and in buildings under shade by reducing solar radiation reaching the ground.
- Reduces cooling costs in residential and commercial buildings.

Slope stabilization methods were used for the Balephi landslide
Source: Nepal District Road Support Program. www.flickr.com

- Filters particles and pollution from the air and prevents pollutants from entering water supply during rain events.
- Provides wildlife habitat.
- Creates green public spaces for locals and tourists.

Caution
Trees and shrubs require maintenance. Failing to maintain trees can lead to interference with other infrastructure like electricity lines and building foundations.

Sources
Center for Watershed Protection and United States Forest Service (Northeastern Area State and Private Forestry). Watershed Forestry Resource Guide – Urban Tree Canopy. http://www.forestsforwatersheds.org/urban-tree-canopy/

Portland Parks and Recreation. 2012. *Tree Canopy Monitoring: Protocol and Monitoring from 2000–2010*. Portland, OR. https://www.portlandoregon.gov/parks/article/403426

United States Environmental Protection Agency. 2008. *Reducing Urban Heat Islands: Compendium of Strategies, Urban Heat Island Basics*. Washington, DC. https://www.epa.gov/heat-islands/heat-island-compendium

United States Environmental Protection Agency. What Is Green Infrastructure? https://www.epa.gov/green-infrastructure/what-green-infrastructure#Urbantreecanopy

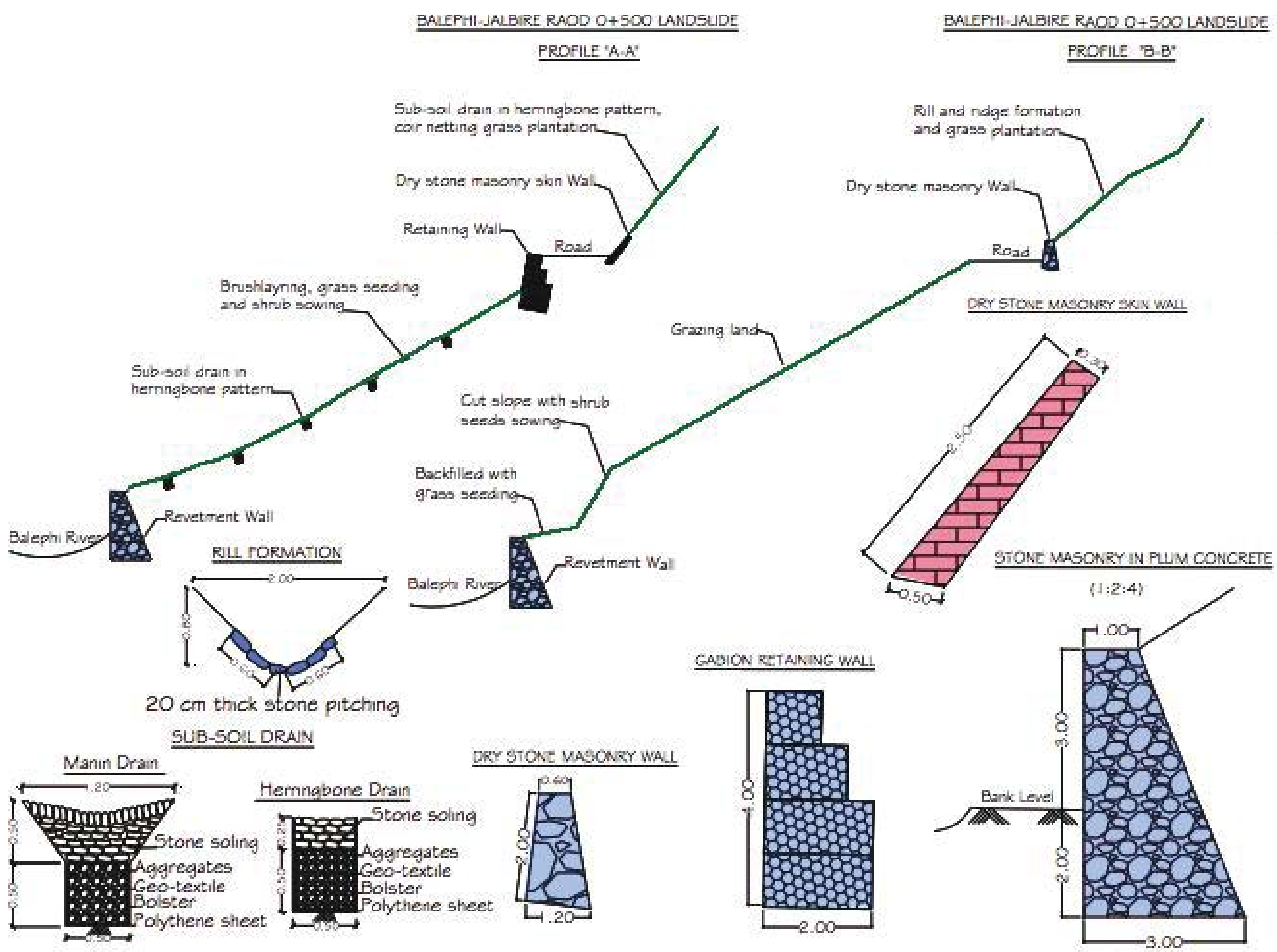
2.7 Case Studies

2.7.1 Balephi, Nepal

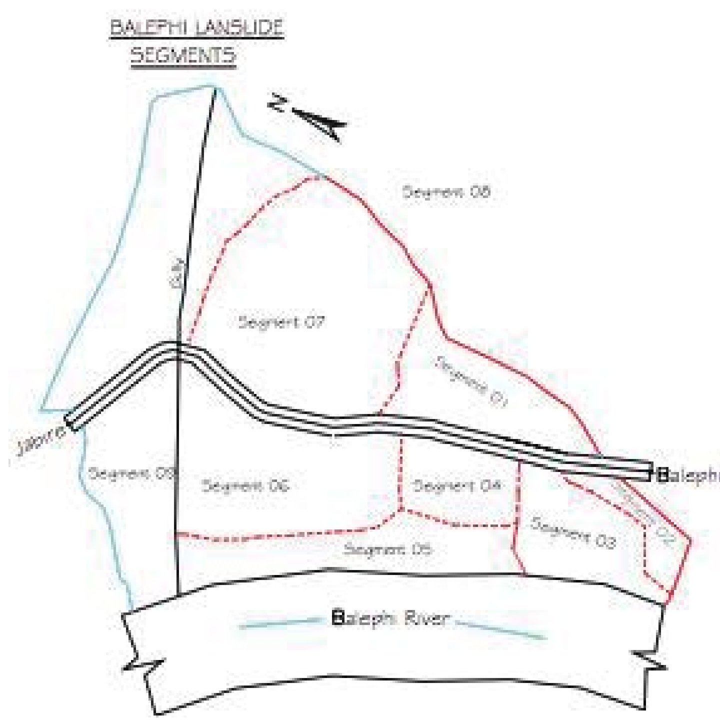
Balephi Landslide Slope Stabilization
Category: slope stabilization, water and flood management
Applications: town-wide planning, large infrastructure
Development Needs: road embankments
Green Infrastructure: branch packing, brush mattress, gabions, live cribwall, live fascines, live staking

Roads construction and maintenance in the mountainous region of Nepal is challenging because of its steep slopes, weak rock mass, thick soil profile, and high rainfall during the monsoon period. Landslides, debris flows, slumping, and erosion on slopes are common during and after road construction and can be the most destructive disaster for roads.

Figure 2.10: Illustration of Bioengineering Components Involved in the Restabilization of the Balephi Landslide Site



Source: District Roads Support Programme



The Balephi Landslide occurred at Ch. No. 0+500 of Balephi–Jalbire Road in Sindhuplachowk during the 2002 monsoon. The Balephi to Jalbhire road is an important access road for people living in the areas around and beyond Jalbhire and provides a route for agricultural products on their way to major markets in Dhulikhel, Kavre, and Kathmandu.

The landslide completely washed away a 120-meter section of the road and disconnected the traffic flow for days.

The District Development Committee, the local community, and the bus operators' organization temporarily opened the road by installing a basic gabion wall and backfilling, but the slide was still active and would have undoubtedly caused more problems during the coming monsoons.

Analysis showed that the cost of conventional engineering alone would have been 48% higher than the combination of conventional and bioengineering.

Source: WWF Nepal. www.wwfnepal.org

The bioengineering aspects of the project provided several days' employment for local people.

The Balephi Landslide was independently assessed, and designs were drawn up by a geotechnical and structural engineer using conventional engineering methods. The engineer prepared a detailed assessment report and proposed a revetment and/or retaining toe wall of stone masonry in mass concrete along the river. Four retaining walls at different levels were also proposed to retain the road bench and a cutoff drain on the slope above to carry surface water from the slide and from surrounding agricultural land. A bioengineering specialist was also called in to incorporate suitable bioengineering techniques to enhance the performance of the proposed structure and to create a more sustainable long-term solution.

Methods Used

The landslide was split into nine segments according to the nature of the materials, water movement behavior on the slope, and the failure mechanisms. Each segment was handled according to its needs, which included debris removal, slope trimming, drainage, stabilization, and erosion control. Standard engineering technologies such as stone and concrete revetments acted as the base of the stabilization. However, native grasses, shrubs, and wood cuttings were added to increase stability and provide natural water management. Brush layering increased slope stability and created more habitat for plant and wildlife species.

Benefits

- Improved road reliability and quality.
- Restored access to markets in Dhulikhel and Kathmandu.
- Road and slope strengthened against erosion and impacts of monsoon rain.
- Local people economically benefit from new broom and fodder plants and timber from the slope.
- Primary school located about 10 meters above the scar now protected from further slides.

The Balephi Landslide project demonstrates that bioengineering techniques can produce better economic and environmental results for slope stabilization when compared to conventional engineering solutions, and they can be implemented at a lower cost.

Bioengineering brings other benefits, as well, including improved water quality, increased wildlife habitat, and improved aesthetics.

Local and natural materials are utilized to reduce cost and carbon footprint. The external walls are made of in situ concrete with a bamboo formwork, while locally-sourced bricks are exposed on the internal walls as finishing

Source: Inhabitat. http://inhabitat.com/a-five-towered-home-topped-with-lush-banyan-trees-pops-up-in-viet-nam/

2.7.2 Ho Chi Minh City, Viet Nam

Green Buildings
Category: slope stabilization, water and flood management, pollution management
Applications: individual owner, town-wide planning
Development Needs: buildings
Green Infrastructure: green roofs and walls, permeable paving

Ho Chi Minh City lies on the Saigon–Dong Nai River estuary and is among the world's most threatened cities from global climate change. It faces risks from sea-level rise, storms, and flooding. With over 8 million people, the city is experiencing increasing densification and overcrowding of the inner city districts, together with expansion into surrounding areas, often by reclaiming land from the flooded forests and swamps that characterize the region. Now only 0.25% of the city is covered by greenery. Natural drainage channels have been filled, encroached, and blocked by waste. Water pollution and air pollution are serious health problems, especially as upstream developments cut off water supply and flow during dry periods.

Yet, there are the beginnings of a trend to promote green buildings—buildings that are resilient, sustainable, and lead to improved environmental and living conditions—in response to the degrading urban environment

President Place
Source: Refico Real Estate Group. www.refico.com.vn

The green houses are built on vacant land hemmed in by buildings on all sides in one of the most densely populated areas of Ho Chi Minh City. The aim of the project is to return green spaces to the city, accommodating high-density dwelling with tropical trees. The houses comprise concrete boxes designed as "pots" to contain tress and roof gardens.

Banyan trees were chosen for the roofs because they have an aerial root system and fewer underground roots.

Stacking Green in Tube Houses

Source: Archdaily. www.archdaily.com/199755/stacking-green-vo-trong-nghia

Green Walls

Source: Inhabitat. assets.inhabitat.com

The roofs are also designed to retain stormwater to prevent flooding, with soil more than 1.5 meters deep, which required significant structural support underneath. With this thick soil layer, the "pots" function as stormwater basins for detention and retention. In addition to the green rooftops, the ground is built with permeable bricks which increase infiltration during the rainy season.

Methods Used
Green Office and Commercial Buildings

President Place, located at 93 Nguyen Du in District 1, is the greenest building in the city. It has received Leadership in Energy and Environmental Design (LEED) Gold certification, the first building in Ho Chi Minh City to receive this status. LEED is a system designed by the United States Green Building Council to determine how environmentally friendly buildings are based on the following:

- Sustainable use of construction materials.
- Sources building material locally.
- Avoids sending waste to a landfill.
- Trains construction workers how to do things up to LEED standards.
- Avoids dumping paint and waste materials into drains.
- External cladding louvered-wrapped and screens for shade.
- Coolness of the interior reduces need for air conditioning.
- Building uses 50% less water than a non-LEED structure.
- Air quality inside 30% better than in other buildings.
- Trees and gardens on the 9th and 13th floors.
- Trees and permeable paving at ground level.

Benefits
Other Green Residential Buildings in Ho Chi Minh City

Environmental Benefits
- Improve air and water quality.
- Use local materials and conserve natural resources.
- Reduce temperature and heat island effect.
- Enhance and protect biodiversity.
- Reduce flooding and strain on local drainage infrastructure.
- Create opportunities for water collection and storage.

Economic Benefits
- Reduce operating costs.
- Create, expand, and shape markets for green product and services.
- Improve occupant productivity.
- Optimize building life-cycle performance.

Social Benefits
- Enhance occupant comfort and health.
- Heighten aesthetic qualities.
- Improve overall quality of life of residents and users.

2.7.3 Pasig River, Philippines

Pasig River Cleanup and Restoration

Category: slope stabilization, water and flood management, solid waste management
Applications: town-wide planning, large infrastructure

Development Needs: canals, culverts and drains, drainage, port redevelopment, residential areas, river embankment, stormwater outfall

Green Infrastructure: bioswales, urban river terracing, solid waste management, vegetated revetment, vegetated riprap

The Pasig River is a 27-kilometer body of water that traverses Metro Manila from Manila Bay. Once a major transport route, source of water, and thriving ecosystem, the river is intimately connected to the country's history. It has become one of the most polluted and toxic river systems in the Philippines, and was declared biologically dead in the 1990s. It is considered the "toilet bowl" of Manila and is a dumping ground for domestic and industrial waste.

Rehabilitation efforts are overseen by the Pasig River Rehabilitation Commission whose mission is "[t]o restore the Pasig River to its historically pristine condition by applying bio-eco engineering and to attain sustainable socio-economic development."[17]

The Pasig River before and after the cleanup and restoration efforts
Sources: Rappler. static.rappler.com, and I Am Travelling Light. iamtravelinglight.files.wordpress.com

[17] Taken from presentation to Water Environment Partnership in Asia, Pasig River Rehabilitation Commission. http://www.wepa-db.net/pdf/0710philippines/10_PRRC.pdf

A floating billboard made of vetiver cleans polluted wastewater, mining wastes, and contaminated land.

Source: GMA News Network. images.gmanews.tv

Source: Pilipinas Coco Fibre. pilipinasecofiber.files.wordpress.com

Some rehabilitation efforts focused on the Estero de Paco, a tributary of the Pasig. Estero de Paco was home to the Paco Market, and for decades it absorbed waste from the market and the almost 10,000 informal residents who inhabited the banks. After a massive initial cleanup effort, community-based solid waste management programs took effect to help keep waste from reentering the river.

Materials recovery facilities have been set up around the Metro Manila area, including near Paco Market, to collect solid waste for treatment and recycling. These facilities are now run by local community organizations.

Methods Used

It was estimated that upward of 65% of waste entering the Pasig was domestic waste coming from illegal settlements along the riverbanks. Inhabitants in these settlements regularly dealt with waterborne diseases, river accidents, and flooding. One of the planks of the restoration project was the fair and equitable relocation of thousands of informal settlers.

Initial cleanup efforts involved dredging and the use of heavy machinery to remove accumulated trash from the river. Teams of "river warriors" trained in maintenance and in education raise awareness among local inhabitants of the importance of environmental protection and proper waste handling.

Some of the river's banks have been stabilized using geotextiles made of coconut fiber from local materials. Coco fiber provides the added benefit of filtering and cleaning water on its way through the river.

Benefits

Benefits noted by inhabitants after rehabilitation efforts include:

- reduced pollution,
- increased vegetation,
- increased wildlife,
- lower incidence of illness, and
- fewer unpleasant odors.

Future plans envision a human-made wetland constructed at the mouth of the Pasig to act as a natural filtration system to clean pollutants and grow mangrove seedlings to be planted along the river.

Source: Malaysian Tourism. malaysiantourism.net

2.7.4 Putrajaya, Malaysia

Putrajaya Constructed Wetland

Category: heat, energy, and greenhouse gas management, water and flood management
Application: town-wide planning
Development Needs: commercial area redevelopment, dikes, industrial areas, markets, parking areas, residential areas, wastewater treatment plants
Green Infrastructure: commercial area redevelopment, dikes, industrial areas, markets, parking areas, residential areas, wastewater treatment plants

Putrajaya, the administrative capital of Malaysia, is the country's largest urban development project on a greenfield site, and it has been designed to be a model city of sustainable development.

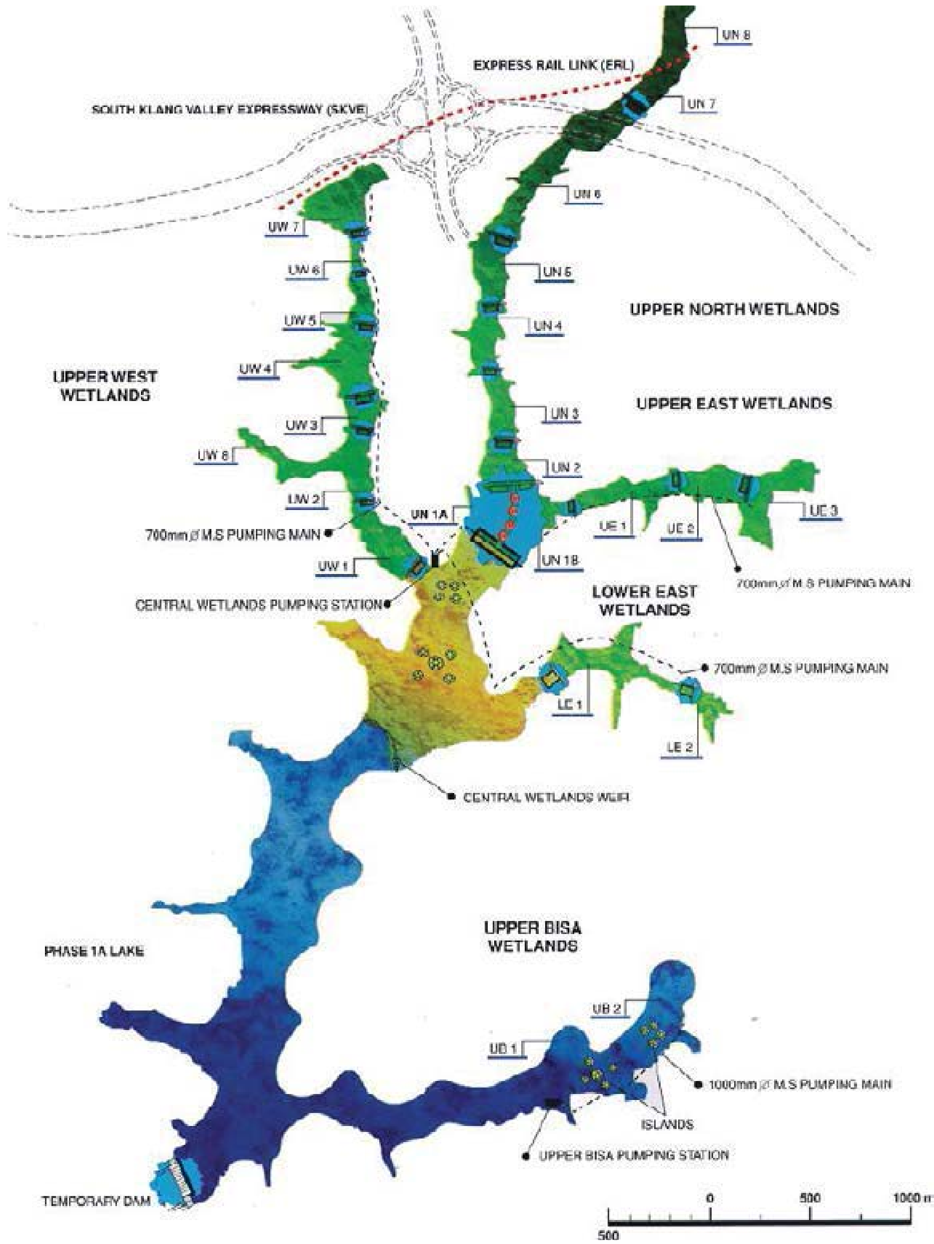
Putrajaya Wetland is located in the northern part of Putrajaya in the valley of the Chuau and Bisa rivers. A part of the Putrajaya Lake system, it covers approximately 200 hectares of lands and water. Putrajaya Wetland is a constructed wetland and is considered to be the largest constructed freshwater wetland in Southeast Asia. Construction began in 1997 and was completed in 2002. Its key environmental function is to treat catchment water before it enters Putrajaya Lake, thus ensuring that water in the lake remains clean and unpolluted.

Source: Putrajaya Lakes and Wetlands. portal.ppj.gov.my

Since the completion of the Putrajaya Constructed Wetland, the number of bird species in the area has increased more than 400% from 10 to 167.

Source: Wisata Malaysia. malaysia.panduanwisata.com

Figure 2.11: Illustration of the Regions And Components Involved in the Construction and Function of the Putrajaya Wetlands



Source: PLWMOS. plwmos.ppj.gov.my

The Putrajaya Wetlands project illustrates the benefits of incorporating wetlands into urban development. It demonstrates how a town can draw inspiration from nature to solve an urban problem that is of local and global significance.

Wetlands, whether natural or human-made, can be planned as an integral part of a city's green infrastructure to improve water quality and urban aesthetics with a wider role for tourism, education, and research (Figure 2.11).

Methods Used

The Putrajaya wetland system features a multicell multistage system with flood retention capability. The system consists of 24 cells divided into six arms. All arms except one discharge to the Central Wetland, the 24th cell, before flowing into Putrajaya Lake. These arms straddle Sungai Chuau, Sungai Bisa, and three tributaries.


Altogether, more than 70 species of wetland plants have been planted in Putrajaya Wetland.
Source: afadruskee. 3.bp.blogspot.com, and Malaysia Wetlands. archive.wetlands.org

Putrajaya ecohydrology management won gold in the 2012 International Awards for Liveable Communities.
Source: Weather Forecast. www.weather-forecast.com

A series of rockfilled weirs was constructed along the six arms of the wetland to divide the 24 cells. Although all the six arms are connected, they differ in size, depth, plant communities, and pollutant load capacity. Each wetland cell is planted with wetland plants native to Malaysia. The water that flows into all these 24 wetlands cells is cleansed multiples times by biochemical processes ensuring that only clean water enters Putrajaya Lake.

Putrajaya Lake is at the southern part of the wetland. About 60% of the lake's water flows from the wetland while the remaining 40% is direct discharge from the bordering promenade. The 20-meter-wide promenade is the buffer feature along the lake shorelines. The area of the whole lake is about 400 hectares. The lake's total volume is about 23.5 million cubic meters with a depth in the range of 3–14 meters.

Benefits

- Natural stormwater and flood management system for Putrajaya.
- Increased wildlife habitat and conservation zones.
- Nature education and research area.
- Increased outdoor tourism for Malaysians and international travelers.
- Filtration properties of the wetland trap, break down, and digest pollutants in water before it enters the lake.
- Nutrient removal performance along six cells in 2004 was
  - 82.11% for total nitrogen,
  - 70.73% for nitrate–nitrogen, and
  - 84.32% for phosphate.

Source: Inhabitat. http://inhabitat.com/how-the-cheonggyecheon-river-urban-design-restored-the-green-heart-of-seoul/

2.7.5 Seoul, Republic of Korea

Cheonggyecheon River

Category: slope stabilization; water and flood management; energy, heat, and greenhouse gas management

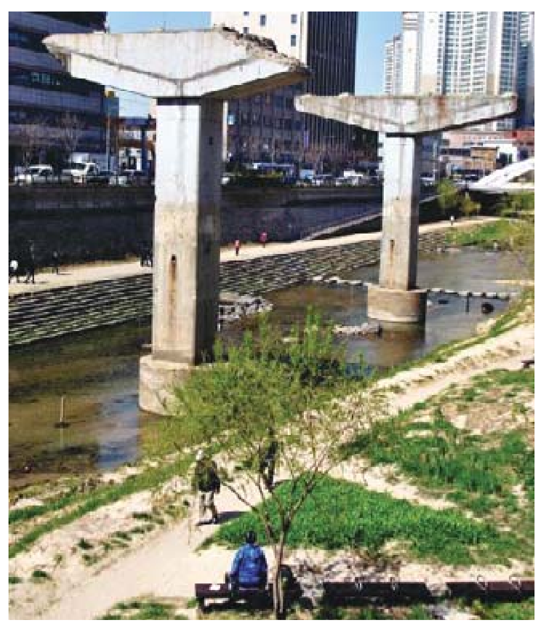
Applications: town-wide planning, large infrastructure

Development Needs: canals, culverts and drains, drainage, river embankment, roads and footpaths, stormwater outfall

Green Infrastructure: bioswales, dikes, drainage corridors, urban river terracing, vegetated revetment, vegetated riprap

Over the past decade, the Republic Korea—particularly the capital city, Seoul—has taken drastic steps to try to reduce the amount of pollution it creates and to curb its reliance on fossil fuels.

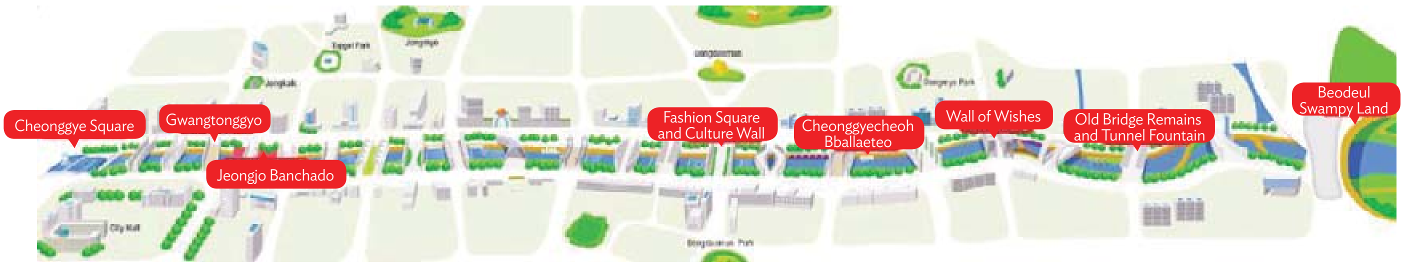
Perhaps the biggest change has been the restoration of the old Cheonggyecheon stream, which cuts east to west across the



Before restoration, residents of the area were more than twice as likely to suffer from respiratory disease than those in other parts of the city.

Source: Urban Planet. urbanplanet.info

Figure 2.12: Illustration of the Cheonggyecheon River Restoration Plan



Source: K. Johnson. Land of Morning Calm. 3.bp.blogspot.com

In the first 3 months following its restoration, a quarter of all Koreans (about 10 million people) visited the river.

Source: Urban Planet. urbanplanet.info

city. Neglected and highly polluted, it was covered over in 1958 to remove an eyesore and the stench emitting from its dirty waters. In the 1970s, a raised four-lane highway was completed on top of the stream, which had already been completely covered by concrete. Used by more than 120,000 cars a day and often gridlocked, the highway was a major contributor to air pollution.

When the ambitious project to uncover and rejuvenate the Cheonggyecheon was announced in 2003 by then-mayor Lee Myung-bak, it was met with huge opposition from citizens and businesses. After a period of negotiation with local inhabitants and business owners, work began and the stream was opened to the public in 2005, complete with plants and fish that have since flourished.

The City of Seoul is in the process of an important paradigm shift, changing from an auto-centric, development-oriented urban landscape to one that values the quality of life of its people and the importance of functioning ecosystems. By demolishing an elevated freeway and uncovering a section of the historic Cheonggyecheon Stream, the Cheonggyecheon Restoration Project created both ecological and recreational opportunities along a 5.8-kilometer corridor in the center of Seoul. The project has proven catalytic, spurring economic growth and development in an area of Seoul that had languished over the last several decades.

Methods Used

The design incorporated the original width of the stream, but the bed was lowered to allow for future floods. The outer parts of the previous road deck were also retained to carry a new two-lane side road and to allow space for floods to flow underneath. A new sloping embankment wall was then built alongside. The final river cross-section varies from 9 meters in width

Temperatures along the stream are 3.3°C–5.9°C cooler than on a parallel road 4–7 blocks away.
Source: Kimchi Bytes. i0.wp.com

upstream to 115 meters downstream, while low-level terraces on both sides of the river provide people and wildlife easy access to the water.

The river is allotted a daily supply of 1,006,370 barrels, which maintains an average depth of 40 centimeters and average current velocity of 0.25 meters per second. The design also takes into account the area's combined sewage system, which could release wastewater and rainwater runoff into the river during storms. Large sewers were built alongside the river to provide additional retention for stormwater and to protect its newly established ecological system.

Benefits

- Increases open space and recreational opportunities in the civic center area.
- Provides flood protection for up to a 200-year flood event and can sustain flow rate of 118 millimeters per hour.
- Increased overall biodiversity by 639% between the prerestoration work in 2003 and the end of 2008 (Table 2.4).

Table 2.4: Overall Biodiversity, 2003 (Prerestoration) vs 2008

Species	2003	2008
Plants	62	308
Fish	4	25
Birds	6	36
Aquatic animals	5	53
Insects	15	192
Mammals	2	4
Amphibians	4	8

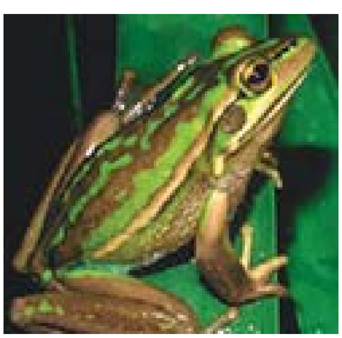
- Reduces the urban heat island effect: the cooling effect of the stream, increased vegetation, reduction in auto trips, and 2.2%–7.8% increase in wind speeds through the corridor.
- Reduced small-particle air pollution by 35% from 74 to 48 micrograms per cubic meter.
- Enhances pedestrian experience.
- Enhances tourism in the central business district.

2.7.6 Sydney, Australia

Homebush Bay Wetlands Renewal
Category: water and flood management, pollution management
Applications: town-wide planning, large infrastructure
Development Needs: commercial area redevelopment, industrial areas, parking areas, river embankments, stormwater outfalls, wastewater treatment plants
Green Infrastructure: bioretention pond, bioswales, constructed wetlands, drainage corridor, permeable paving, rain gardens, solid waste management, urban river terracing, vegetated revetment, vegetated riprap

Sydney Olympic Park's once-degraded wetland and terrestrial ecosystems underwent extensive restoration works during the late 1990s in what was the largest land remediation exercise ever undertaken in Australia. Located along the south bank of the Parramatta River in the inner west of Sydney, the region was contaminated with dioxin and other chemicals by landfilling and intensive industries that closed in the 1980s.




The Brick Pit, a former quarry, became an environmental feature of the Sydney Olympic Park and a critical component in the revival of the endangered green and golden frog

Sources: (starting from top) Wikipedia. upload.wikimedia.org, Sydney Olympic Park Authority. www.sopa.nsw.gov.au, Strata Live. www.stratalive.com.au, Australian Museum. australianmuseum.net.au, and Past/Lives of the Near Future. pastlivesofthenearfuture.files.wordpress.com

After winning the bid for the 2000 Summer Olympics, Sydney set out to renew 760 hectares of land in an effort to run the greenest games ever. The bid for the Olympic Games had included a set of environmental guidelines based on sustainability principles adopted at the 1992 United Nations Earth Summit. They included commitments to the preservation and protection of natural ecosystems and endangered species, as well as energy and water conservation, waste minimization, resource conservation, and prevention of pollution.

Figure 2.13: Illustration of Plans to Construct the Homebush Bay Wetlands

Source: Architecture AU. architectureau.com

The restoration works have won several major environmental awards:

- The United Nations Environment Programme's Global 500 Award for Environmental Excellence (2001)
- Gold Banksia Award (2000)
- Banksia Award – Conservation of Flora and Fauna (2000)
- Rivercare 2000 Gold Award (2000)
- Energy Australia–National Trust Heritage Award – landscape conservation commendation – saltmarsh (2005)
- Energy Australia–National Trust Heritage Award – landscape conservation – Brickpit Ringwalk (2006)

Methods Used

Stormwater and pollution control measures included (Figure 2.13):

- gross pollutant traps (GPTs), continuous deflective separation units (CDS units), and water quality control ponds installed throughout the park to capture locally generated pollutants and protect local waterways;
- three on-site water quality control ponds to collect stormwater runoff from the pavements, roads, and rooftops; and
- stormwater runoff from the 14-hectare parking lot and from much of the suburb of Newington is collected into irrigation storage ponds in Narawang Wetland.

The restoration involved:

- remediation of 160 hectares of contaminated land and the recovery and consolidation of 9 million cubic meters of excavated waste;
- restoration works to 100 hectares of remnant wetlands and 20 hectares of remnant forest;
- dechannelization of 2 kilometers of creekline, converting it from a concrete stormwater drainage channel into a naturalistic tidal waterway edged by vegetated terraces;
- restoration of tidal flushing 35 hectares of landlocked estuarine wetland;
- construction of new wetland, grassland, woodland, and saltmarsh landscapes on remediated lands; and
- design, construction, and establishment of new habitats for target flora and fauna communities.

The parklands attract millions of visitors a year

Source: River Canoe Club of New South Wales. www.rivercanoeclub.org

The stormwater diversion rate is 500 L/s which helps to replenish the water lost from Sydney Park due to evaporation.

Source: Games Bids.com/Bookmarc. www.bookmarc.com.au

Benefits

- Increased wildlife habitat:
  - 3 endangered ecological communities
  - protected marine vegetation
  - over 180 species of birds
  - 7 species of frogs
  - 10 species of bats
  - 10 species of reptiles
  - many species of native fish
  - thousands of invertebrates
- Natural stormwater collection and treatment.
- Restored estuarine ecosystem health.
- Fishways between estuarine and freshwater creek systems to enable fish passage from the Parramatta River estuary to upstream habitats that were previously inaccessible.
- Increased vegetative biodiversity.
- Educational and awareness-raising opportunities for the benefits of biodiversity and green infrastructure.
- Increased green space for locals and tourists.

Source: ML Ingenieria. www.mlingenieria.com

The bridge demonstrates that natural elements can be integrated with traditional engineering without sacrificing the quality or functionality of the project or compromising its economical feasibility.

2.7.7 Veracruz, Mexico

Geotextile Bridge Abutments
Category: slope stabilization, water and flood management
Applications: town-wide planning, large infrastructure
Development Needs: bridge
Green Infrastructure: vegetated geotextiles

The bridge connects a new residential area, Nuevo Veracruz, with the existing Xalapa–Veracruz Highway. Nuevo Veracruz is approximately 7 kilometers away from Veracruz, a port city and economic hub. The bridge allows residents and commercial traffic to cross railroad tracks that link cargo trains to the rest of the country.

Geotextile bridge abutments are not only safe, but also capable of using elements that integrate harmoniously with the surrounding landscape. The goal was to build a robust bridge while encouraging future builders to use sustainable materials in their urban designs.

The design engineering had to first account for the low capacity of the soil and the short time line for completion. The use of geotextiles included time-saving construction without affecting safety or quality, and ensured that installation of the reinforcement could proceed without interrupting train traffic near the work site.

Geotextile materials also brought a flexible structural element. For stability and protection against erosion, geocells were placed on embankment surfaces for further vegetation using regional plants. The covering vegetation also provided valuable aesthetic properties.

2.7.8 Case Study Sources

The case studies presented in this chapter provide a snapshot of green infrastructure methods used in different cities to build resilience and use nature-based solutions to solve urban problems.

For more detailed information and descriptions on how each project was implemented, please visit the following websites.

Ho Chi Minh City, Viet Nam
Trees Grow on Rooftops
http://www.dezeen.com/2014/06/19/house-for-trees-vietnam-vo-trong-nghia-architects/

Pasig River, Philippines
Pasig River Rehabilitation Commission
http://www.prrc.gov.ph/

Putrayaja, Malaysia
PLWMOS Putrajaya Lake and Wetland Management and Operational System http://plwmos.ppj.gov.my/

Seoul, Republic of Korea
Cheonggyecheon Stream Restoration Project http://lafoundation.org/research/landscape-performance-series/case-studies/case-study/382

Sydney, Australia
Sydney Olympic Park Authority. Environment. http://www.sopa.nsw.gov.au/our_park/environment

Veracruz, Mexico
Geosynthetics. 2011. New Bridge Abutments with a Vegetated Finish. 1 February. http://geosyntheticsmagazine.com/2011/02/01/new-bridge-abutments-with-a-vegetated-finish/

2.8 Additional Reading

Readers may also find the following materials useful in their application of nature-based solutions in Mekong towns.

M. Bertule et al. 2014. *Green Infrastructure Guide for Water Management: Ecosystem-Based Management Approaches for Water-Related Infrastructure Projects*. United Nations Environment Programme (UNEP), UNEP-DHI Partnership – Centre on Water and Environment, International Union for Conservation of Nature, and The Nature Conservancy. http://www.unepdhi.org/-/media/microsite_unepdhi/publications/documents/unep/web-unep-dhigroup-green-infrastructure-guide-en-20140814.pdf

Center for Neighborhood Technology and American Rivers. 2010. *The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits*. Chicago, IL and Washington, DC: Center for Neighborhood Technology and American Rivers.http://www.cnt.org/repository/gi-values-guide.pdf

City of Melbourne. 2009. City of Melbourne WSUD *Guidelines: Applying the Model WSUD Guidelines. Inner Melbourne Action Plan*. https://www.melbourne.vic.gov.au/SiteCollectionDocuments/wsud-full-guidelines.pdf

K. Fritzsche et al. 2014. *The Vulnerability Sourcebook: Concept and Guidelines for Standardised Vulnerability Assessments*. Bonn and Eschborn, Germany: GIZ. http://www.preventionweb.net/files/38849_38849vulnerabilitysourcebookguideli.pdf

Institute for Social and Environmental Transition-International, Thailand Environment Institute, and Vietnam National Institute for Science and Technology Policy and Strategy Studies. 2014. *Urban Vulnerability in Southeast Asia: Summary of Vulnerability Assessments in Mekong-Building Climate Resilience in Asian Cities (M-BRACE)*. Bangkok: Institute for Social and Environmental Transition-International. http://i-s-e-t.org/projects/m-brace.html

M. Kramer. 2014. Enhancing Sustainable Communities with Green Infrastructure: A Guide To Help Communities Better Manage Stormwater While Achieving Other Environmental, Public Health, Social, And Economic Benefits. Office of Sustainable Communities Smart Growth Program. https://www.epa.gov/sites/production/files/2016-08/documents/green-infrastructure.pdf

United States Environmental Protection Agency. 2013. The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure: A Review of Green Infrastructure O&M Practices in ARRA Clean Water State Revolving Fund Projects. Office of Water. https://www.epa.gov/sites/production/files/2015-04/documents/green_infrastructure-om_report.pdf

P. Winters, C. Piasecki, and R. Pirani. 2012. *9 Ways to Make Green Infrastructure Work for Towns and Cities*. Regional Plan Association. http://www.rpa.org/library/pdf/RPA-9-Ways-to-Make-Green-Infrastructure-Work.pdf

Chapter 3

Urban Planning for Building Resilient Mekong Towns

3.1 Building Resilience through Urban Planning

Urban planning refers to the technical and decision-making processes concerned with the use of land and the design of the urban environment. It involves consideration of a range of different issues—environmental, social, economic, and aesthetic in nature. Urban planning determines how towns develop and who is involved in the process. Integrated urban development is centered on improving the quality of life or "livability" for residents by incorporating environmental, social, and climate change concerns into planning. Rapid urbanization and escalating demand for urban services have increased pressures on natural systems and resources within towns, reducing their livability. As more people fill towns in search of a better quality of life, the need for service infrastructure will intensify. The challenge for town managers is to maintain the natural system foundation of urban areas and natural resource availability while implementing sustainable solutions to urban service provision.[18]

The previous chapter introduced a range of green infrastructure methods which need to be systematically applied in Mekong towns to build sustainability and resilience. This chapter describes the urban planning and management framework which facilitates and guides the uptake of green infrastructure. It gives special attention to the role of town master planning and the use of zoning schemes and associated safeguards in promoting development that embraces nature-based approaches. An important section deals with development controls and safeguards. The term "safeguards," which is used by the Asian Development Bank (ADB), the World Bank, and other development assistance agencies, is not widely used in town planning in the Mekong region. Other terms such as development or planning controls, codes, and standards are more common in town plans.

3.1.1 Why Urban Planning?

There are a number of factors that contribute to making urban planning a suitable "vehicle" for driving green development and building resilience in towns across the Greater Mekong Subregion (GMS), with resilience meaning the capacity for a socioecological system to (i) absorb stresses and maintain function in the face of external stresses imposed upon it; and (ii) adapt, reorganize, and evolve in ways that improve the sustainability of the system, leaving it better prepared for future impacts (Table 3.1).

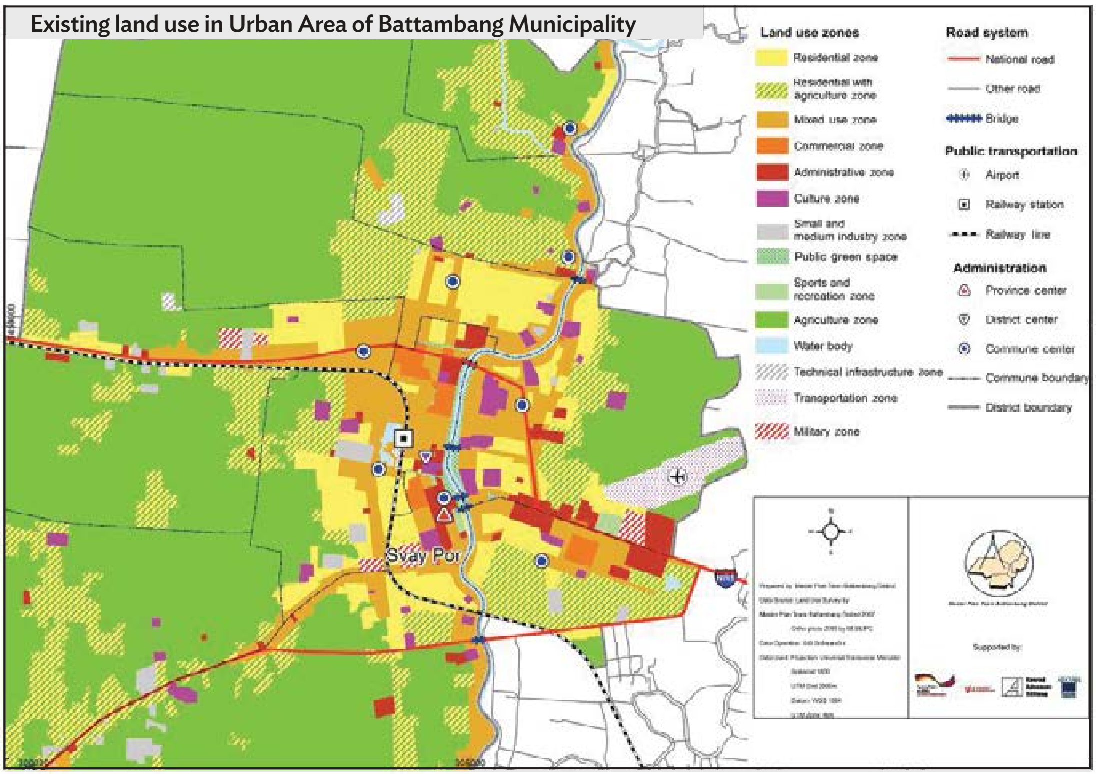
Of these factors, perhaps key is that urban planning, typically in the form of a land use

[18] ADB. 2014. Enabling GrEEEn Cities: An Operational Framework for Integrated Urban Development in Southeast Asia. *ADB Southeast Asia Working Papers Series*, No. 9, November 2014. Manila.

Table 3.1: Why Urban Planning and Management is a Good Framework for Promoting Green Infrastructure

Urban planning	Is integrated encompassing social, economic, and environmental considerations
	Is a process familiar to the Greater Mekong Subregion, typically in the form of urban master plans and spatial land-use plans (e.g., a zoning plan)
	Provides a process and tools for mainstreaming climate change into town development
	Represents the starting point for considering the direction of future town growth
	Operates at both a town-wide scale as well as a site-specific level
	Has potential to incorporate legal and economic incentives for green development
	Can be a vehicle for inclusive and participatory planning and management of urban development

Figure 3.1: Town Master Plan and Zoning System in Battambang, Cambodia



or zoning plan, is already a common feature in many towns across the GMS (Figure 3.1). Though in most cases, the regular review, revision, and endorsement of master plans is not systematic. Market and political forces also often override plan provisions. Even so, town plans are of growing importance and have a vital role in influencing future growth and development. To date, town master plans in the region and their zoning systems have not considered the impacts of climate change.

3.1.2 Problems with Current Mekong Urban Planning

There is growing recognition by government agencies and other stakeholders in the GMS that the existing, largely engineering-led approach to dealing with urban growth and development issues such as flooding and drought is failing to deliver outcomes which build resilience over time—and, in some cases, directly competes with them. All too often, master plans encourage growth in areas subject to serious flooding (e.g., in Dong Ha) even when past extreme events are considered and are projected to become more frequent and severe. Equally, there are many cases where infrastructure investments have made the urban conditions worse even though they follow national and sometimes international development safeguards and procurement procedures.

The reasons for this poor performance in urban planning and development control include the following:

- Plan zoning schemes do not have associated safeguards and fail to take into account climate change and environmental and social conditions.
- Engineering initiatives tend to be project based and site specific (i.e., they do not consider potential implications for broader environmental and social systems).
- Infrastructure projects are often conceived and delivered in isolation of wider town development considerations.
- Projects typically deteriorate over time (i.e., require expensive ongoing maintenance and renewal).
- Construction frequently is based on design standards which are not adjusted to factor in climate change and sustainability and are often decades old.
- Rehabilitating systems impacted by poorly conceived projects is difficult and expensive.
- Procurement and contracting processes inhibit rather than facilitate community involvement and management.
- Projects are not built for multiple uses but for a single purpose.
- Projects are inflexible and do not allow towns to shift and evolve over time.
- Projects occurring at a rapid pace and scale allow little opportunity for reflection and lessons learned.

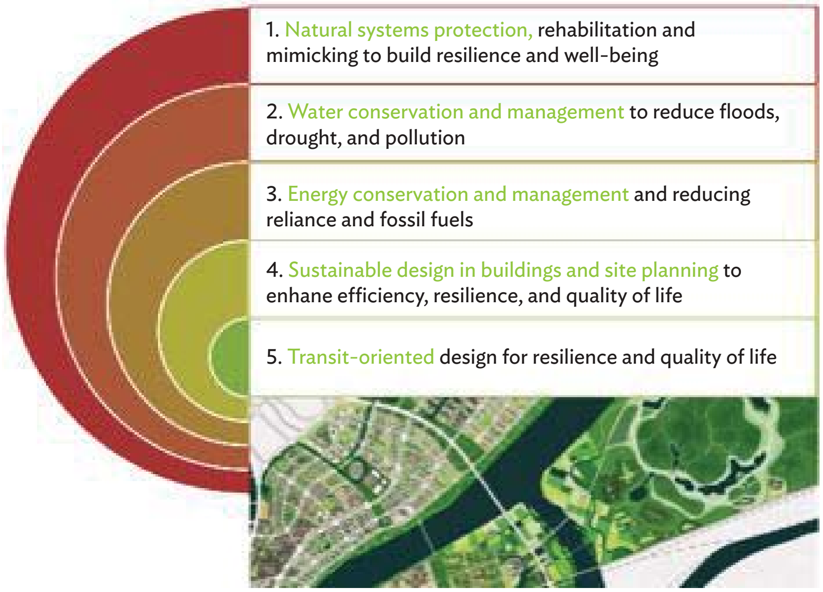
In view of these deficiencies, a critical rethinking is needed on how infrastructure and other development projects are conceived, designed, and delivered within the GMS, so they might better respond to climate change and sustainability. The role of urban planning and management is fundamental in this process.

3.1.3 Objectives of This Chapter

The key objectives of this chapter are to

- introduce guiding principles which can help shape town zoning plans to build resilience and sustainability through green infrastructure and development controls;

Figure 3.2: Principles for Building Urban Resilience through Green Infrastructure



Source: ADB and ICEM.

- describe how additional layers can be added to an urban planning framework to help inform and support a zoning plan—and how these layers can be tailored to address climate change and sustainability concerns; and
- equip local urban planners with an understanding of the opportunities for mainstreaming climate change and sustainability into the urban planning process.

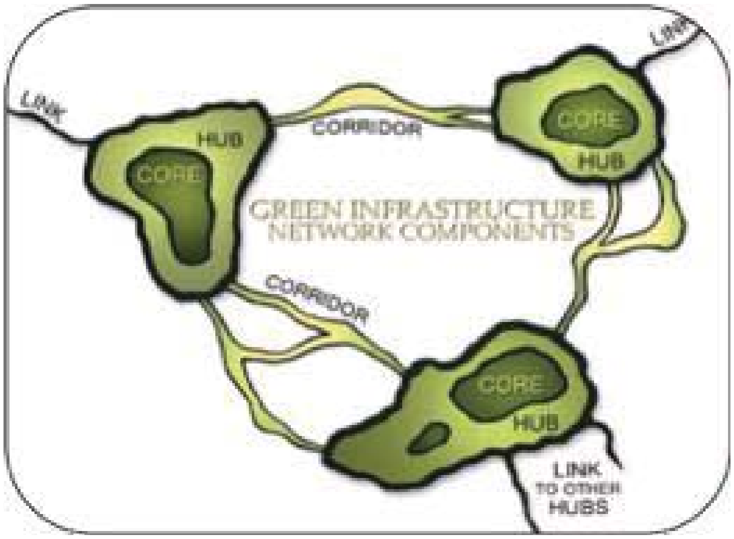
Examples of the approach taken by other urban planning frameworks internationally are referred to throughout the chapter.

3.2 Urban Planning for Resilience: Five Guiding Principles

The following section introduces guiding principles for incorporating resilience into an urban planning framework. The guiding principles are a snapshot of the concepts and approaches emerging in contemporary urban planning practice which have relevance to the challenges presented by climate change and ecological sustainability.

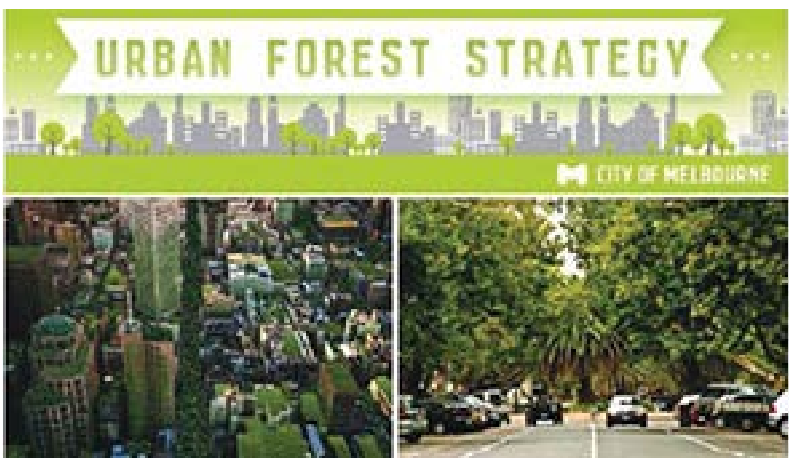
Their purpose is to stimulate thinking on how towns and cities within the GMS can use urban planning to build resilience. The principles, which all promote green infrastructure and nature-based solutions, are represented in Figure 3.2.

Figure 3.3: The Green Network Concept



Source: Chicago Metropolitan Agency for Planning. 2012. *Refinement of the Chicago Wilderness Green Infrastructure Vision: Final Report.* Chicago, IL.

Figure 3.4: Urban Forest Strategy of Melbourne, Australia



Source: City of Melbourne.

3.2.1 Guiding Principle 1: Protecting, Rehabilitating, and Mimicking Natural Systems

Protecting and expanding natural assets is a key function of an urban land-use planning system. Natural systems are a foundation of sustainable Mekong towns—and the foundation for their resilience. Towns need to develop in ways which protect, rehabilitate, and mimic natural systems so that the urban landscape maintains a network of natural corridors and connected green spaces. That network needs to be carefully planned and maintained. It is the single most important strategy that all Mekong towns need to adopt in response to climate change. It brings multiple benefits along with enhanced resilience including greater equity in living standards and community well-being. The concept of green urban networks involves large green spaces linked in a network through green corridors in ways which facilitate the flow of people, water, wildlife, and other resources (Figure 3.3). Application of this approach is illustrated through the following brief case studies.

Case Study 1: Melbourne, Australia

The city has adopted an urban forest strategy which would create such a green network and expand the city canopy cover to 40% (Figure 3.4).[19] The strategy aims to

- adapt the city to climate change;
- mitigate the urban heat island effect by bringing down inner-city temperatures;
- create healthier urban ecosystems;
- manage and conserve water; and
- engage and involve the community in city development.

The main approaches and targets for strategy implementation are

- increasing canopy cover from 22% to 40% by 2040;
- increasing forest diversity with no more than 5% of one tree species, no more than 10% of one genus, and no more than 20% of any one family; and
- improving vegetation health.

Case Study 2: Hamburg, Germany

The city has announced a similar green network plan over 40% of the city which seeks to eliminate cars from many areas and create bicycle ways and footpaths (Figure 3.5).[20]

The plan creates and links 70 square kilometers of new and existing green space throughout the city. The result will be a city that puts nature within easier reach of every resident, becomes more resilient to flooding caused by global warming, and provides enough connectivity for walking and bicycling to become car-optional

[19] See City of Melbourne. An Eco-City. http://www.melbourne.vic.gov.au/Sustainability/UrbanForest/Pages/About.aspx

[20] Inhabitat. 2014. Hamburg Announces Plans to Become a Car-Free City within 20 Years. http://inhabitat.com/hamburg-announces-plans-to-become-a-car-free-city-within-20-years/

Figure 3.5: Citywide Green Network Plan in Hamburg, Germany

Sources: Inhabitat. 2014. Hamburg Announces Plans to Become a Car-Free City within 20 Years. http://inhabitat.com/hamburg-announces-plans-to-become-a-car-free-city-within-20-years/ (map); Inhabitat. 2011. Hamburg Is Building a Giant Green Roof Cover Over Sections of the A7 Motorway. November. http://inhabitat.com/hamburg-is-building-a-giant-green-roof-cover-over-sections-of-the-a7-motorway/ (photos).

Terracing of River Banks for Multiple Uses, Flood Protection, and Recreation as Part of a Citywide Green Network

Source: Sasaki Associates. n.d. Cedar Rapids Riverfront. www.sasaki.com/project/133/cedar-rapids-riverfront

citywide in 20 years. The plan will connect parks, recreational areas, playgrounds, gardens, and cemeteries through green trails and waterways.

One exceptional component will be building a cover for the A7 expressway, one of the largest in Germany. The plan calls for installing a canopy cover 34 meters (m) wide and 2–3 m thick over the A7 in three sections, covering a total of 3.5 kilometers (km) to reconnect neighborhoods that have been disconnected for the 30 years since the expressway was built. The canopy would be covered with wooded parkland, meadows, pathways, and garden allotments for Hamburg residents (Figure 3.5).[21]

To establish and maintain such green networks, development needs to be controlled so that only projects consistent with the green network objectives are permitted and those which might have degrading impacts are avoided. The urban planning process, particularly land-use zoning and safeguards, has significant scope to provide that enabling environment for the establishment of green networks and the control of development within it. Care is needed to ensure the wider natural systems are taken into account. For example, a drainage channel renewal plan needs to consider the condition and management of upstream and downstream natural features—and even broader watershed management priorities. This could involve both natural and constructed elements, for example, the construction of wetlands, green street development, and the terracing and vegetating of riverbank stabilization works to allow for multiple uses.

[21] Inhabitat. 2011. Hamburg Is Building a Giant Green Roof Cover over Sections of the A7 Motorway. http://inhabitat.com/hamburg-is-building-a-giant-green-roof-cover-over-sections-of-the-a7-motorway/

River Bank Terracing and Vegetation as Part of a Green Infrastructure Network in Guadalupe River Park in San Jose, California, United States

Source: R. Horii. 2011. Guadalupe River Park and Gardens—Part 2 South: Santa Clara Street to I-280. www.oocities.org/rhorii/GRPG/GRPG2.html

The goal of bringing nature back into Mekong towns encourages the application of many green infrastructure methods and new infrastructure which replicates the functioning of natural systems and services wherever possible. For some practitioners, that is the primary function of green infrastructure. For them, "[g]reen infrastructure refers to natural, seminatural and engineered green assets that are connected across a landscape. Green assets include parklands, waterways and wetlands, large and small tracts of natural and re-established ecosystems, ecological corridors, grassy fields, street and habitat trees, community gardens, drainage swales, and innovative technologies such as vegetated roofs, bio-retention basins, wildlife crossing and nesting infrastructure."[22]

Establishing Natural Corridors across the Urban Landscape in Moreton Bay, Australia

Source: Moreton Bay Regional Council. 2013. *Draft Green Infrastructure Strategy 2013–2031*. www.moretonbay.qld.gov.au/uploadedFiles/moretonbay/development/planning/Draft-Green-Infrastructure-Strategy.pdf

Case Study 3: Moreton Bay Regional Council in Queensland, Australia

The council adopted the following vision in its Green Infrastructure Strategy:

A healthy and productive network of natural, seminatural and engineered green spaces and assets valued for what they are, the ecosystem services they provide, and their contribution to regional biodiversity and environmental resilience.

To realize its vision, the council identified the following underlying management approaches: The network should

- promote linkages between green infrastructure components,
- be multifunctioning,
- be integrated with all other infrastructure types,
- be flexible so that environmental values are strengthened while supporting development and other associated infrastructure networks, and
- promote diversity in biodiversity and ecosystem services.

The strategy should also be evidence-based so that its green infrastructure components are selected using scientific data validated through remote sensing, field monitoring, and ground-truthing against predetermined criteria such as ecological value and consideration of future land use intent.

[22] Moreton Bay Regional Council. 2013. *Draft Green Infrastructure Strategy 2013–2031*. p. 5. https://www.moretonbay.qld.gov.au/uploadedFiles/moretonbay/development/planning/Draft-Green-Infrastructure-Strategy.pdf

Wetlands in Suncheon, Republic of Korea

Source: Korea JoongAng Daily. 2012. Rare Birds, Sunset Lovers Flock to Suncheon Bay. 11 December. http://koreajoongangdaily.joins.com/news/article/Article.aspx?aid=2963720

Doi Saken Forest in Chiang Rai, Thailand

Sources Lanna Touring. n.d. Rai Doi Tung Flower Garden. www.lannatouring.com/TourPro/CHR01/CHR01.html (in Thai) (left); My Chiang Mai Tour. n.d. Attractions in Mae Fa Luang – Chiang Rai District. http://mychiangmaitour.com/maefaluang/

Case Study 4: Suncheon, Republic of Korea
The medium-sized city with approximately 270,000 residents is located on the south coast in South Jeolla Province, which contains 40% of the country's coastal wetlands. In the past decade, Suncheon has transformed itself into an eco-city committed to the conservation of its estuarine and other natural ecosystems as a foundation of its city development strategy. Suncheon Bay includes a long stream of 3.5 km, tideland 2,221 hectares (ha) wide, and a field of reeds 230 ha wide. In 2003, Suncheon Bay was designated as one of the first coastal wetland protection areas after the city council successfully blocked a private proposal to reclaim part of the bay for urban development. Three years later, the bay was listed as the Republic of Korea's first coastal Ramsar Wetland of International Importance. It is also to be protected as a "heritage landscape" under the Cultural Heritage Protection Act, and the local government is seeking to add it to the UNESCO World Heritage List.

Now, Suncheon Bay's wide tideland, field of reeds, and salt swamp are maintained as an essential part of the urban landscape functioning as a water and air pollution purification system, for city drainage, for storm and flood protection, and as a multipurpose recreational facility for the city's residents.

Case Study 5: Chiang Rai, Thailand
The municipality is located in Chiang Rai province, the northernmost province of Thailand in the Kok River Basin with a population of 70,000. The urban center serves as the main business area and is the location of government agency buildings. The suburbs are mostly agricultural and residential. The sensitive ecosystems in and around Chiang Rai are under severe pressure from rapid urban development and the growth in tourism.

In 2008, the local government initiated the Enhancing Urban Ecosystems and Biodiversity in Chiang Rai City project. It aims to restore and conserve the diverse ecosystems in the city area to maintain a natural economic, social, and environmental balance in urban development. Its objectives include biodiversity conservation as a carbon sink and food supply for city residents. In 2011, Chiang Rai received a UN-Habitat award for "good practice" in urban biodiversity conservation.

Several development strategies are being implemented to attain this vision. They include an integrated approach to climate change mitigation and adaptation involving all government agencies, the private sector, and community groups in linking biodiversity conservation with local economic development and disaster preparedness. The initiative has resulted in the demarcation of forests, lakes, and rivers as conservation zones in the town master plan; and in improved and expanded green spaces within the city, for example, a forested and wetland track called Doi Saken. These actions have boosted tourism and tourism revenue, spawned new educational programs for school children and youth, and strengthened community relationships reducing conflicts and social tensions.

Obstacles to the initiative which the municipality has had to address include

- residential and developer encroachment into the conservation zones designated by the municipality,
- a lack of biodiversity expertise to survey and identify priorities and define effective and realistic management plans, and
- limited local community capacity and awareness concerning biodiversity values and requirements.

3.2.2 Guiding Principle 2: Water Conservation and Wise Management

The principle of water conservation and wise management can take differing forms when applied to urban planning. With respect to drainage infrastructure, a frequent challenge in Mekong towns, minimizing the burden of new development on existing stormwater infrastructure would be a priority. It might take the form of a requirement that new development must not lead to a net increase in the quantity or decrease in the quality of stormwater discharged from the project site compared with pre-development levels. Measures promoted to achieve such a requirement might include rainwater tanks, rain gardens, retentions ponds, and bioswales.

Such water conservation and management measures could apply to an urban development of any scale whether an industrial site, market, government building complex, or dwelling. They are consistent with the emerging approach of water sensitive urban design, which is defined as "a land planning and engineering design approach which integrates the urban water cycle, including stormwater, groundwater and wastewater management and water supply, into urban design, to minimize environmental degradation and improve aesthetic and recreational appeal."[23]

There is scope for significant improvements to stormwater management practices in Mekong town which have potential to greatly reduce the impacts of pluvial flooding. An example of the situation in which these measures might be employed is provided in the following case study of a residential area in Melbourne, Australia.

Case Study 6: Green Streets in Heidelberg West, Melbourne, Australia

The city is an example of how new infrastructure can be designed and implemented in a way which helps build climate resilience. The residential area of Heidelberg was originally constructed as housing for athletes for the 1956 Olympic Games. It adjoins Darebin Creek. The creek is degrading due to an increase in rainwater runoff, increasing erosion and sedimentation, and decreasing water quality.

The impacts are due to stormwater from surrounding residential development which is piped directly to a series of outfalls to the creek without any form of flow management or treatment. No pollutant traps or wetlands exist to moderate quality and runoff to the creek (Figure 3.6). The planned response is to

[23] BMT WBM. 2009. *Evaluating Options for Water-Sensitive Urban Design: A National Guide.* Prepared by the Joint Steering Committee for Water Sensitive Cities in Delivering Clause 92(ii) of the National Water Initiative. Canberra: Joint Steering Committee for Water Sensitive Cities.

Figure 3.6: Residential Area before Green Street Redevelopment in Heidelberg, Melbourne, Australia

Clockwise from top left: typical streetscape in study area, aerial photograph of area at time of construction, impacts to quality of creek as a result of stormwater runoff, location plan of area and creek alignment.

Sources: City of Melbourne Urban Forest Strategy and Precinct Plans by City of Melbourne. Image: Anton Malishev. http://architectureau.com/articles/2014-victorian-landscape-architecture-awards/; City of Port Phillip. http://www.portphillip.vic.gov.au/content-images/Urban_Forest(1).jpg

introduce new street sections (green streets) with two elements:

- A large single sided bioretention swale incorporated at the low side of the road, with a single direction camber for the new road surface to direct all stormwater into this zone
- Self-irrigating tree planter pits integrated into the uphill side of the street within an area of permeable paving. At the edges of the main roadway, and partially encroaching into the parallel onroad parking area, a rumble strip of permeable paving or grasscrete to reduce the total hard surface area of the roadway without losing the ability for two-way passing traffic.

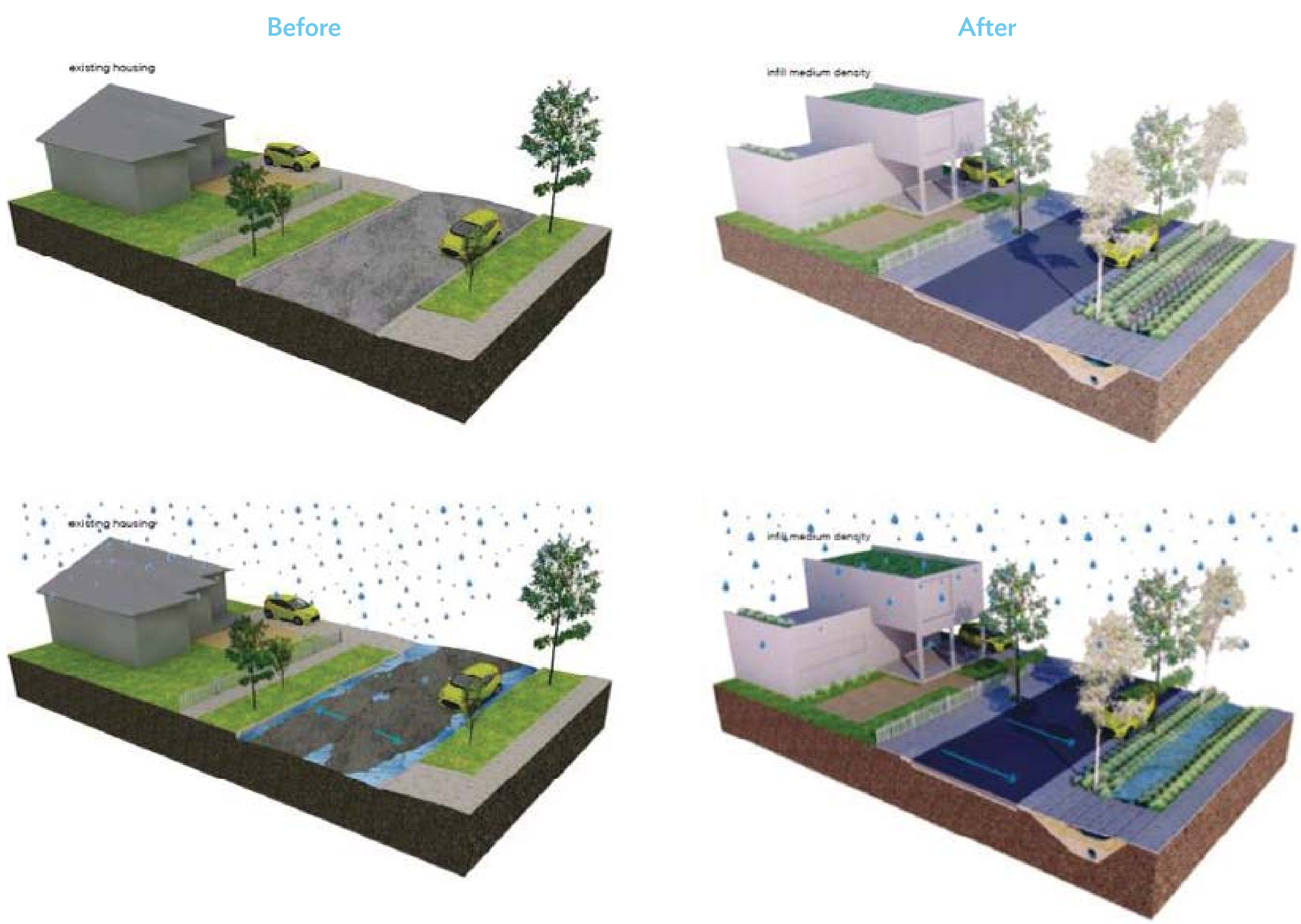
The outcome of the improvement works is improved quality of water entering the creek, reduced rate of flow, and reduced overall volume of surface water through increased infiltration (Figure 3.7).[24]

[24] This green streets approach has been implemented extensively in Portland, Oregon (United States). See https://www.portlandoregon.gov/bes/article/414873

Green Street Design Approaches for Heidelberg, Melbourne, Australia

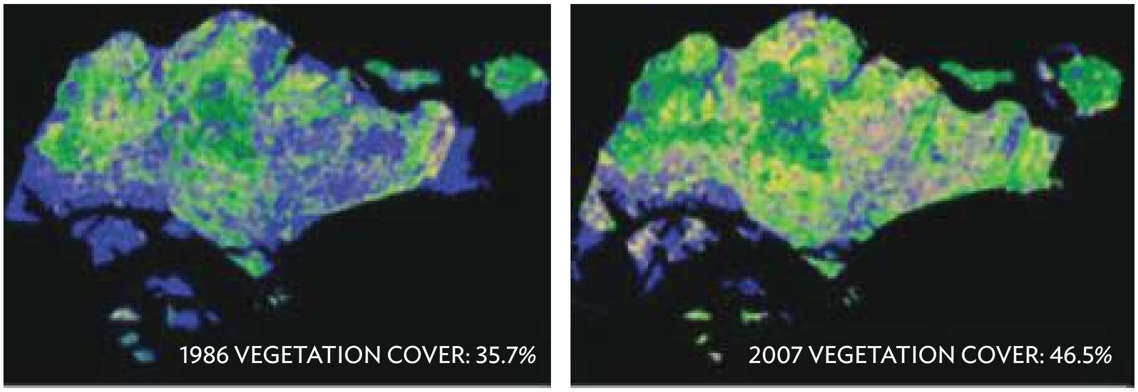
Sources: Landscape and Urbanism. 1.bp.blogspot.com, Green Infrastructure Digest. hpigreen.files.wordpress.com, and Chesapeake Stormwater Network. chesapeakestormwater.net

Figure 3.7: Schematic Illustration of Situation in Heidelberg, Melbourne, Australia



Existing situation (left) and proposed situation (right) showing how stormwater will be collected in a biogengineering swale, filtered for nutrients and sediments before passing slowly to Darebin Creek.

Figure 3.8: Vegetation Cover Increase from 1986 to 2007 in Singapore



Note: Dark green areas: tree canopy cover; light green areas: shrub cover or grasslands.

Source: Civil Service College Singapore. www.cscollege.gov.sg/Knowledge/Ethos/World%20Cities%20Summit/PublishingImag

Case Study 7: Combined Green Plan and Water Conservation Strategy of Singapore

The strategy enabled green cover in the city to grow from 35.7% to 46.5% between 1986 and 2007, despite the population growing by 68% from 2.7 million to 4.6 million (Figure 3.8).

The importance of greenery and water management for multiple uses for a quality living environment is emphasized in Singapore's Master Plan 2003, which has adopted the theme "A City in a Garden." The master plan, drawn up by the Urban Redevelopment Authority to steer Singapore's urban development to 2017, incorporates a new Parks and Water Bodies Plan with the following guiding principles:[25]

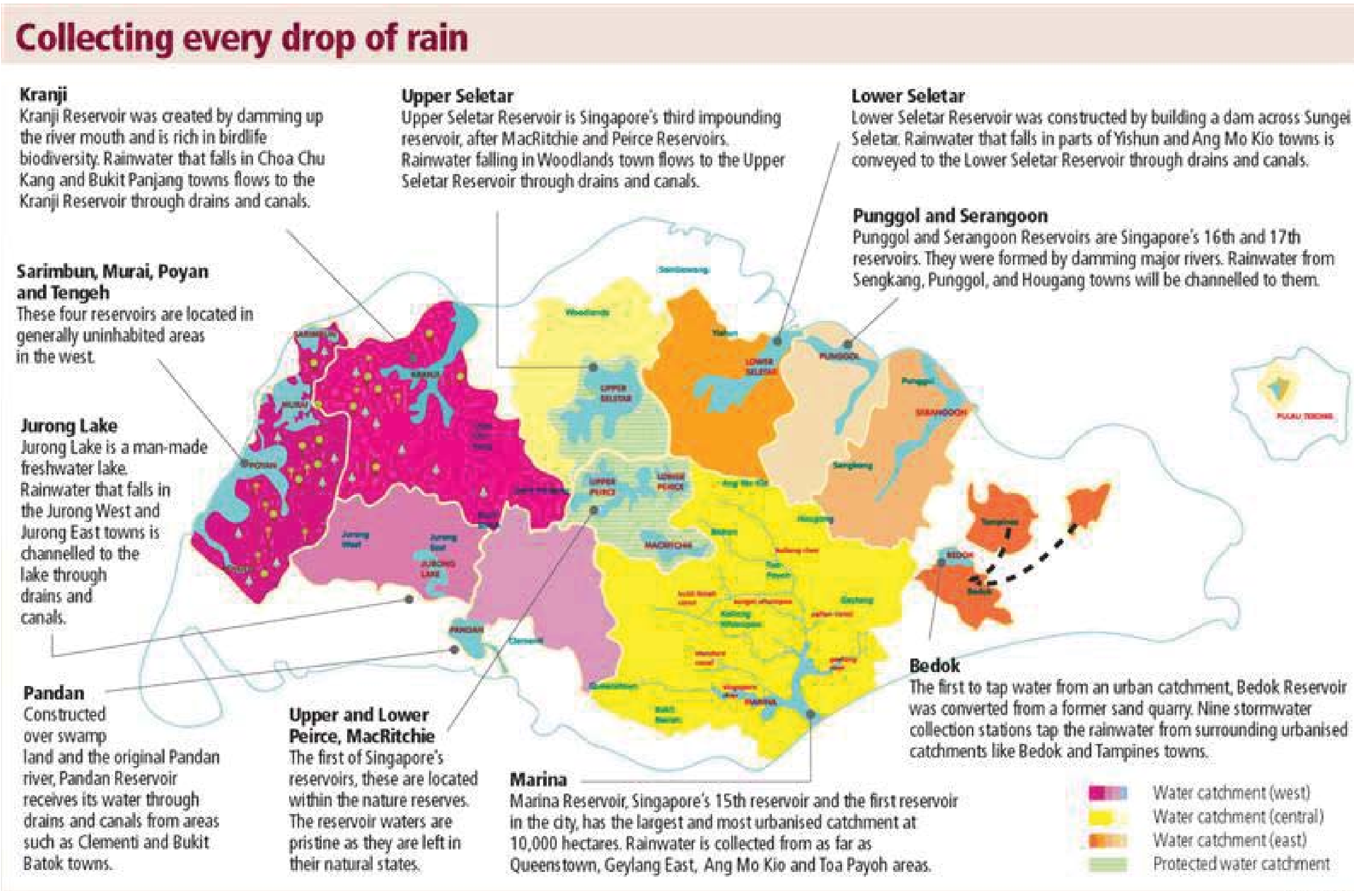
- Plan for a hierarchy of parks distributed throughout the island, from larger parks with more facilities to smaller parks near homes, with a guideline provision of 0.8 hectares per 1,000 population.
- Cluster groups of parks with complementary ecosystems and activities, such as wetlands, hill parks, and tropical rainforests, and connect them, where possible, to give a more holistic experience.
- Bring people closer to nature and, where possible, integrate nature areas within parks.
- Plan for an island-wide network of green links to connect parks and water bodies with residential areas.

As part of the implementation of the master plan, the Public Utilities Board has opened up and developed its water bodies for conservation and recreational activities. The Active, Beautiful and Clean (ABC) Waters Programme is one such initiative, where the objective is to rehabilitate water canals and landscape them for better integration with surrounding parks and green spaces.

Since 2011, the water catchment area has been increased from half to two-thirds of Singapore's land surface. Rainwater is collected through a comprehensive network of drains, canals, rivers, stormwater collection ponds, and reservoirs before it is treated for the drinking water supply. That strategy is accompanied by a comprehensive rehabilitation and greening of the city's watersheds and of water infrastructure using bioengineering methods and community involvement. This meets 30% of the city's water needs; a target that will be increased to 50% of future needs by 2060. This makes Singapore one of the few countries in the world to harvest urban stormwater on a large scale for its water supply (Figure 3.9).

[25] Extract from N. Lang. 2008. A City in a Garden. https://www.cscollege.gov.sg/knowledge/ethos/world%20cities%20summit/pages/08a%20city%20in%20a%20garden.aspx

Figure 3.9: Watersheds for Rainwater Collection in Singapore



Source: Singapore Water Constraint. http://4.bp.blogspot.com/-f6dioT6ghS8/UVl_ANMNSKI/AAAAAAAAAAw/DKmLYA8T47o/s1600/1.jpg

3.2.3 Guiding Principle 3: Energy Conservation and Wise Management to Reduce Reliance on Fossil Fuels

Urban planning and management needs to apply the energy conservation principle in a variety of ways—from emphasizing public transport use and reducing car dependence, incorporating sustainable building design and renewable energy in new development, through to protecting viable agricultural lands and green spaces within the urban landscape.[26] Each of the other urban planning green infrastructure principles has a role to play in promoting energy conservation and wise management. For example, energy conservation and management is a key principle applied through effective application of sustainable design in buildings and transport systems (principles 4 and 5).

It may take the form of applying a "green belt" around an urban area or green networks throughout to confine urban expansion or to incentivizing the inclusion of renewable energy in new proposals by allowing more intensive development than would otherwise be considered. For example, a proposed high-rise building which incorporates solar-powered recharge stations for electric vehicles may be permitted to exceed the prescribed height limit otherwise applicable to an area. Town planning can promote green infrastructure methods which reduce energy consumption such as "green" and "blue" roofs (i.e., roofs designed to store water), green walls, and various green street, urban canopy, and water management options that reduce the heat island effect.

[26] United Nations Human Settlements Programme (UN HABITAT). 2012. *Sustainable Urban Energy: A Sourcebook for Asia*. Nairobi, Kenya.

From an adaptation perspective, a further advantage of promoting decentralized and renewable energy is that at times of network failure, for example, during a storm or flood event, such forms of energy are likely to be more resilient than centralized technologies.

Case Study 8: City of Sydney, Australia
The city has adopted its Decentralised Energy Master Plan 2012–2030 emphasizing renewable energy and which is to be delivered through Green Infrastructure Master Plans for decentralized energy (trigeneration and renewable energy), decentralized water, energy efficiency, and advanced waste collection and treatment technologies.[27] The city plans to produce 70% of its energy needs locally from trigeneration systems. These small local generators are nearly three times more energy efficient than coal-fired power plants because they use waste heat to both heat and cool buildings. Other emissions cuts will come from energy efficiency and renewable energy. Thirty renewable energy technologies were screened for the master plan. The short list of 14 technologies is based on technologies that are commercially available today or will become commercially available by 2030. They include solar photovoltaic and solar water heating technologies, integrated wind turbines (Figure 3.10), and renewable gas from waste and biomass.

The Decentralised Energy Master Plan sets out the size and availability of renewable energy resources needed to meet Sydney's energy and climate change targets and the potential investment required. The first objective was to determine how much of the city's 30% renewable electricity target could come from within the local government area and, where there is a shortfall, to determine the amount of renewable electricity to be sourced from beyond but within proximity of the city to meet the target.

Figure 3.10: Buildings with Potential for Small Wind Turbines in Central Sydney, Australia

Source: City of Sydney. 2013. *City of Sydney Decentralised Energy Master Plan – Renewable Energy 2012–2030*. Sydney. http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0003/153282/Renewable-Energy-Master-Plan.pdf

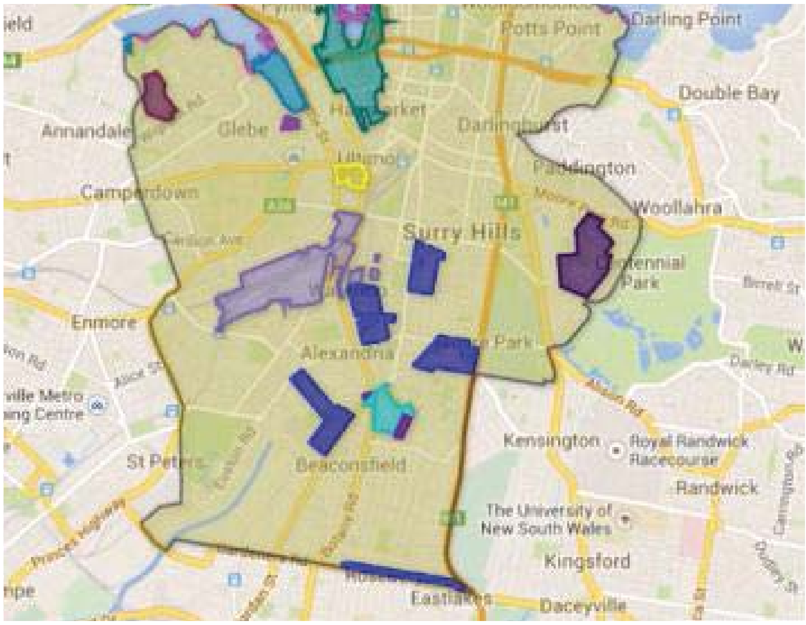
The overarching Sustainable Sydney 2030 Plan aims to turn the city into a low-carbon city using locally produced electricity instead of coal-fired power. The target is for Sydney to become virtually energy-independent and reduce its carbon emissions by 70% from 2006 levels by 2030.

The town urban master plan, referred to as the *Sydney Local Environmental Plan 2012*, provides the spatial planning and development control framework for realizing the city's energy and other green infrastructure targets.[28] The plan divides the city into zones and specifies the

[27] City of Sydney. 2013. *City of Sydney Decentralised Energy Master Plan – Renewable Energy 2012–2030*. Sydney. http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0003/153282/Renewable-Energy-Master-Plan.pdf

[28] City of Sydney. Local Environmental Plans. http://www.cityofsydney.nsw.gov.au/development/planning-controls/local-environmental-plans (last updated 8 October 2013).

Figure 3.11: Local Environment Plan and Zoning System in Sydney, Australia



Source: The Urban Developer. 2014. Proposed Zoning Changes for City of Sydney. July. www.theurbandeveloper.com/proposed-zoning-changes-for-city-of-sydney/

planning controls that must be followed within each zone and the "consent authorities" that must approve development applications (Figure 3.11). The plan is supported by a development control plan with more detailed planning and design guidelines.[29] For example, the plan's environmental management provisions are intended to ensure that principles of ecologically sustainable development are integrated into the design and construction of development, particularly in relation to reduced energy usage. They are also intended to lead to improved sun access to publicly accessible spaces and to lower overall levels of wind, noise, and reflectivity. Similar controls on water management promote green infrastructure approaches.

3.2.4 Guiding Principle 4: Sustainable Design in Buildings and Sites

Sustainable design relates to a process of ensuring buildings are environmentally responsible and resource efficient throughout their life cycle. It can be applied to virtually all aspects of a building including siting, orientation, materials, ventilation, water use, energy efficiency, and waste management. Figure 3.12 is an example of sustainable building best practice in Berkeley, California. It is a key to effective climate change mainstreaming. In addition to having positive environmental and resilience benefits, sustainable building design delivers health and well-being advantages to occupants and the wider urban community. Increasing the proportion of sustainable buildings within urban environments should be promoted through the urban planning framework of towns within the GMS.

Case Study 9: City of Yarra in Melbourne, Australia

An increasing number of countries are requiring new buildings to achieve a sustainability rating as part of the approval process. For example, the City of Yarra in Melbourne (Australia) requires developers to submit a sustainability design assessment (SDA) and sustainability management plan (SMP) with their development proposal application. The SDA is a simple sustainability assessment of a proposed design at the planning stage in support of the planning application by showing how the developer intends to address the 10 Key Sustainable Building Categories (Figure 3.13). The Yarra Council's Planning Scheme outlines general sustainable design guidance, but the SDA process encourages developers to strive for best practice, creativity, and innovation. An SMP is required for all larger developments of 10 or more residential dwellings or more than 1,000 square meters of nonresidential gross floor area. It addresses the 10 Key Sustainable Building Categories and demonstrates that a comprehensive sustainable design assessment has been undertaken during a project's early design stage. In relation to these categories, an SMP must identify relevant sustainability targets or performance standards and document the means by which the appropriate target or performance will be achieved.

Energy efficiency is one of Yarra's 10 sustainable building categories. The planning guidance points out that passive design principles including thermal mass, external shading, building orientation, cross-ventilation, and

[29] City of Sydney. Development Control Plans. http://www.cityofsydney.nsw.gov.au/development/planning-controls/development-control-plans (last updated 6 May 2016).

better insulation in buildings lead to less reliance on energy-hungry air conditioning systems to maintain comfortable internal temperatures: "Using renewable energy further reduces a building's environmental impact. Good building design decreases power consumption, saves money and reduces the effects of climate change. On the other hand, poor building design is uneconomical and contributes to greenhouse gas emissions."[30]

The Yarra Council has two levels of compliance when it comes to environmental sustainable design principles: mandatory and best practice. Mandatory requirements are that the building must meet the National Building Code Energy Efficiency standards. These requirements are the minimum standards but are not necessarily best practice. In addition, the Yarra Council requires developers to meet its best practice standards. For example, to achieve best practice energy efficiency building standards, as many as possible of the following environmental sustainable design principles must be incorporated into a new building or building extension design:

- Install appropriate external shading devices responding to different facade orientations.
- Demonstrate energy efficiencies beyond minimum national compliance benchmarks (e.g., +10%).
- For office buildings, include a NABERS Energy Commitment Agreement.[31]
- Ensure habitable rooms do not rely on artificial lighting throughout the day.
- Install energy-efficient artificial lighting, including sensible lighting controls.
- Provide external clothes-drying facilities.
- Consider renewable energy production for a proportion of water heating, space heating, and electricity demands.
- Specify energy-efficient (high star rating) heating and cooling systems.
- Install energy-efficient (high star rating) hot water systems.

Source: Walking Melbourne. www.thecollectormm.com.au

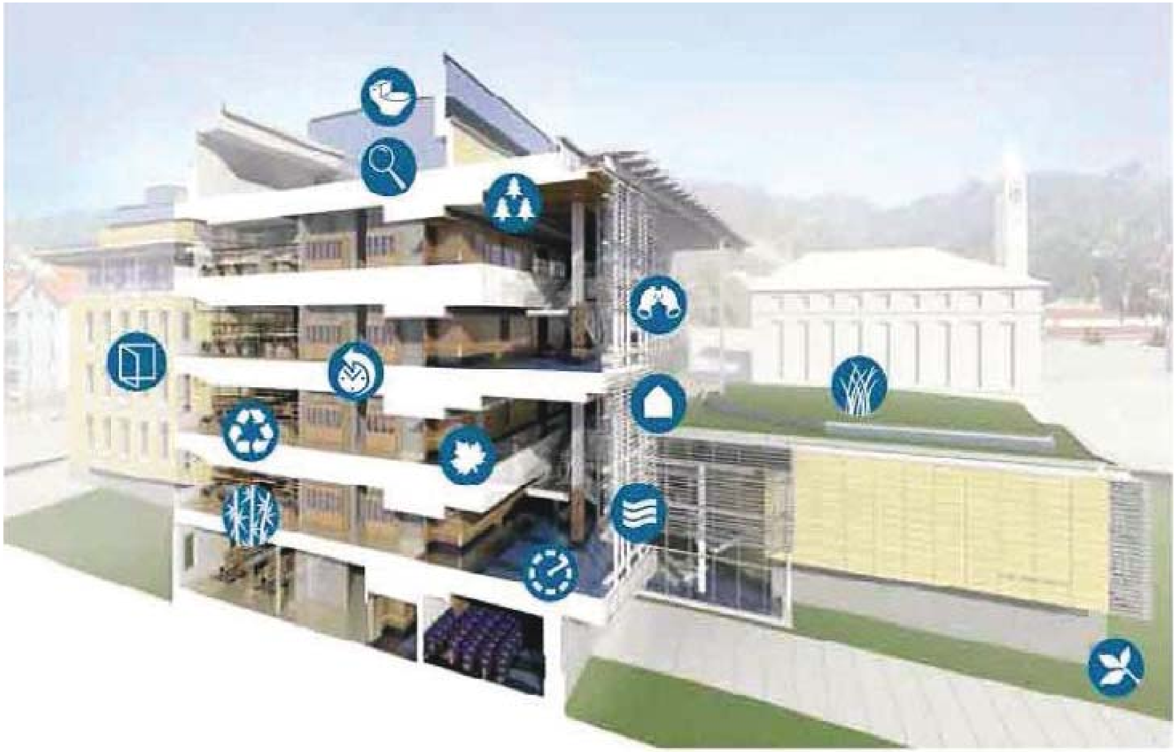
Developments that seek to vary from these best practice standards must demonstrate how energy efficiency can be satisfactorily achieved.

The Yarra Council's best practice standards also promote improved urban ecology. Urbanization has altered natural systems and processes such as soil filtration and drainage, overland and waterway flows, light availability, wildlife habitat, and other ecosystem services. For example, replacing areas of vegetation with hard surfaces including roads, driveways, and paving increases stormwater runoff and contributes to flash flooding, pollution, and infrastructure breakdown. The council has introduced environmental sustainable design principles aimed at decreasing the areas of hard or impervious surfaces and increasing vegetation and landscaping. It found that landscaping in urban areas can reduce air conditioning costs by up to 50%, for example, by shading windows and walls of a building. The cooling effect of one healthy tree can be the equivalent of 10 room-size air conditioners operating 20 hours a day. The council also recognized the growing body of research showing that communities are happier and healthier and have a greater sense of well-being in well vegetated and green urban streetscapes and spaces.

[30] City of Whittlesea. 2012. *Energy Efficiency: Building Design for a Sustainable Future.* Sustainable Design Assessment in the Planning Process (SDAPP), 10 Key Sustainable Building Categories. p. 1. https://www.whittlesea.vic.gov.au/building-planning-and-transport/planningdev/planning-permits/~/media/Files/Building%20Planning%20and%20Transport/PlanningDev/SDAPP%20-%20Energy%20Efficiency.pdf

[31] The Government of New South Wales' NABERS Energy Commitment Agreement allows developers and building owners to promote and market excellent greenhouse performance of new and refurbished commercial office buildings from the outset. The commitment agreement outlines the developer's commitment to design, build, and commission the building to a high star rating level. See http://www.nabers.gov.au/public/WebPages/ContentStandard.aspx?module=21&template=3&include=CA.htm&side=CommitmentAgrTertiary.htm

Figure 3.12: Sustainable Building Design Best Practice in Berkeley, California, United States



HIGH-PERFORMANCE BUILDING ENVELOPE
- Low-emitting glass with integrated sunscreens
- Terra cotta rain screen
- Thick board-formed concrete walls
- Stainless-steel shingles

NATURAL DAYLIGHTING AND VIEWS
- Expansive glazing and filtered daylight in 90% of spaces

NATURAL VENTILATION
- Operable windows provide fresh air, cooling, and a connection to the Bay Area climate

OPERABLE USER-CONTROLLED EXTERIOR SUNSCREEN SHUTTERS
- Preserve views to the bay while reducing solar heat gain and glare on the west-facing office windows
- Provide southwest sun protection in the open position

RECLAIMED WOOD THROUGHOUT
- Wood paneling harvested from a local demolished warehouse

FOREST STEWARDSHIP COUNCIL CERTIFIED WOOD

REGIONAL MATERIALS
- Local aggregates in terrazzo
- All California clay used in locally produced ceramic tiles

WATER USE REDUCTION
- 30% reduction

RAPIDLY RENEWABLE MATERIALS
- Bamboo laboratory casework

GREEN ROOFS
- Adaptive native plantings provide habitat for bees, insects and birds
- Stormwater mitigation
- Insulating heat-island/cooling effect

BUILDING MONITORING SYSTEM
- Real-time display in public areas of building energy and water usage
- Integrated color display continuously signals the most favorable time to open or close windows, based on outside temperature conditions

OCCUPANCY SENSORS
- Sensors control light throughout based on outdoor light levels
- Task lighting integrated into lab benches

OPTIMIZED ENERGY-USE PERFORMANCE
- Reduced lab air-change rate
- Night flushing
- Mechanical separation of lab zone and office/conference/public zone
- Low pressure drop

NATIVE LOW-WATER LANDSCAPING
- Palette of local plant species minimizes the need for maintenance and irrigation

RECYCLED CONTENTS
- Low emitting rubber floors in laboratory and carpet in offices
- Recycled aggregates in terrazzo
- Recycling of concrete board-forming wood

Source: Zimmer Gunsul Frasca Architects. 2011. *Li Ka Shing Center for Biomedical and Health Sciences, University of California, Berkeley*. Portland, OR. https://issuu.com/zgfarchitectsllp/docs/li-ka-shing-center?e=5145747/2590067

Figure 3.13: Sustainable Design Categories and Guidance by Yarra City Council, Melbourne, Australia

CITY OF YaRRA

The 10 Key Sustainable Building Categories

1.0 Indoor Environment Quality

Objective: to achieve a healthy indoor environment quality for the wellbeing of building occupants.

Examples of design decisions:

- daylight
- thermal comfort
- natural ventilation.

2.0 Energy Efficiency

Objective: to ensure the efficient use of energy, to reduce total operating greenhouse emissions and to reduce energy peak demand.

Examples of design decisions:

- effective shading
- building fabric enhanced above the minimum Building Code of Australia (BCA) requirements
- efficient heating and cooling services.

3.0 Water Efficiency

Objective: to ensure the efficient use of water, to reduce total operating potable water use and to encourage the appropriate use of alternative water sources.

Examples of design decisions:

- use efficient fixtures and fittings
- avoid the use of mains water for landscape irrigation
- re-use water (e.g. greywater).

4.0 Stormwater Management

Objective: to reduce the impact of stormwater run-off, to improve the water quality of stormwater run-off, to achieve best practice stormwater quality outcomes and to incorporate the use of water sensitive urban design, including rainwater re-use.

Examples of design decisions:

- minimise watercourse pollution
- maximise stormwater capture
- maximise onsite rainwater re-use (e.g. for flushing toilets and irrigation).

5.0 Building Materials

Objective: to minimise the environmental impacts of materials used by encouraging the use of materials with a favourable lifecycle assessment.

Examples of design decisions

- embodied energy of materials
- use of materials with recycled content
- future recyclability of materials.

6.0 Transport

Objective: to minimise car dependency and to ensure that the built environment is designed to promote the use of public transport, walking and cycling.

Examples of design decisions:

- providing convenient and secure bike storage
- providing access to showers and lockers at work
- Green Travel Plan for residents, visitors and staff.

7.0 Waste Management

Objective: to ensure waste avoidance reuse and recycling during the construction and operation stages of development.

Examples of design decisions:

- preparation of a construction Waste Management Plan
- adoption of a demolition and construction material recycling target
- preparation of a operation Waste Management Plan.

8.0 Urban Ecology

Objective: to protect and enhance biodiversity and to encourage the planting of indigenous vegetation.

Examples of design decisions:

- maintaining / enhancing the site's ecological value
- creating resident amenity
- encourage biodiversity areas.

9.0 Innovation

Objective: to encourage innovative technology, design and processes in all development, so as to positively influence the sustainability of buildings.

Examples of design decisions:

- significant enhancements of best practice sustainable design standards
- introduction of new technology
- good passive design approach.

10.0 Construction and Building Management

Objectives: to encourage a holistic and integrated design and construction process and ongoing high performance.

Examples of design decisions:

- Building Users Guide that explains a building's sustainable design principles
- preparation of operation Environmental Management Plan
- contractor has valid ISO 14001 (environmental management) accreditation.

Source: City of Yarra. 2012. *Building Design for a Sustainable Future*. Sustainable Design Assessment in the Planning Process (SDAPP), 10 Key Sustainable Building Categories. p. 3. http://www.yarracity.vic.gov.au/planning--building/Environmentally-Sustainable-Design/ten-key-sustainable-building-categories/

The Yarra Council's best practices for developers to follow in landscaping and vegetation of their site and buildings aim to

- save energy and achieve seasonal heat control,
- reduce glare and ground temperature,
- reduce wind penetration and capture cooling breezes, and
- increase habitat and ecosystem services.

The best practice guide provides a wide range of landscaping, vegetation, and building innovations to enhance the town's urban ecology and resource materials which developers can refer to in preparing their site assessment and landscaping plan as part of the overall building and site development application.

3.2.5 Guiding Principle 5: Transit-Oriented Design

Transit-oriented design (TOD) locates development in a manner which maximizes access to public transport, reduces the size and dominance of roads and hard surfaces, and promotes walkable green urban areas. The overall goal is to reduce the reliance on private cars. TOD can encourage a much smaller carbon footprint through reduced dependence on private motor vehicles by providing easy access to high-quality public transport services and reducing the need to travel for employment, everyday goods and services, and to public open space. Private vehicle travel tends to decline

- where population and employment density is higher, particularly if it is concentrated in compact activity centers with increased land-use mix;
- in areas with connected street networks, which encourage pedestrian and cyclist movement;
- in areas with attractive and safe streets that accommodate pedestrian and bicycle travel and where buildings are connected to footpaths rather than set back behind parking lots;
- in areas with traffic calming and other measures that reduce vehicle traffic speeds; and
- when a strong, competitive public transit system is present, particularly when it is integrated with high-density development within 500 meters of transit stations.[32]

A TOD neighborhood typically has a center with a public transit station or stop surrounded by relatively high-density development with progressively lower-density development spreading outward from the center. It concentrates housing, shopping, and employment along a network of walkable and bikeable streets within a 5-minute walk of transit stations, or 400 meters in any direction (Figure 3.14).

The TOD principles need to be incorporated into planning for growth areas within towns and cities. The Government of Queensland embraces diversity in transport as an important TOD principle. Its guide to Queensland towns and cities stipulates that a TOD neighborhood should be easy to move around in, and be well connected to, other destinations by a range of different travel modes, including public transport, walking and cycling, and private vehicles. TOD neighborhoods should

- incorporate direct, attractive, and safe pedestrian links to transit stations, and between neighborhoods and employment centers, transit interchanges, and community facilities;
- provide high-quality intermodal connections with links between trains, buses, taxis, and other forms of transport;
- develop a coherent and legible streetscape that favors pedestrian and cyclist movement;
- allow for increasing levels of pedestrian movement and use of public transport as fuel costs rise;
- protect and enhance pedestrian and bicycle connectivity in the construction of new transit infrastructure; and
- provide equitable access for people with disabilities or restricted mobility along continuous paths of travel in the public domain and to all parts of premises to which the public is entitled access.[33]

[32] T. Litman. 2008. Valuing Transit Service Quality Improvements. *Journal of Public Transportation* 11(2): 43–63. http://www.nctr.usf.edu/wp-content/uploads/2010/03/JPT11-2Litman.pdf

[33] State of Queensland, Department of Infrastructure and Planning. 2010. *Transit-Oriented Development: Guide for Practitioners in Queensland*. Brisbane, Australia.

Case Study 10: Transit-Oriented Development Guidelines in Edmonton, Canada
Edmonton City Council in Canada has also adopted TOD guidelines to support implementation of Edmonton's Strategic Plan, Municipal Development Plan, Transportation Plan, and Environmental Strategic Plan. The TOD guidelines are organized under four categories:
(i) Land use and intensity guidelines
(ii) Building and site design guidelines
(iii) Public realm guidelines
(iv) Urban design principles

The Land Use and Intensity Guidelines identify minimum and maximum land-use expectations for new allowable uses. The Building and Site Design Guidelines describe qualities that foster the desired relationship between buildings and the street and provide appropriate transitions between shorter and taller buildings.

The Edmonton guide stresses the importance of the public realm for the success of TOD. A quality public realm attracts and stabilizes private investment and ensures consistency throughout the TOD neighborhood. The Public Realm Guidelines identify maximum block dimensions and configuration expectations and include the Public Boulevard Guidelines identifying minimum dimensions, restrictions, and pedestrian components required for new and improved public streets. The Urban Park and Plaza Guidelines identify sizes of public urban parks and plazas, as well as the types of amenities that need to be provided. The Bicycle Facilities Guidelines identify bicycle parking and bikeway requirements, and the Roadway Guidelines specify the dimensions and quality of improved streets, all applying green infrastructure principles. The prescriptions or development controls are very detailed.

For example, a detailed guide under the public realm block specifications requires *midblock access ways* for redevelopment and new development to break up blocks of 130 meters or more in length and

- result in development sites with more pedestrian and bicycle connections, visual permeability, and pedestrian-scaled building footprints;

Figure 3.14: Urban Design for Transit-Oriented Development in Paris, France

Source: Skyscrapercity.com. 2009. Top Architects Unveil New Paris. www.skyscrapercity.com/showthread.php?t=827526

- provide attractive linear amenities that serve as passive recreational spaces for adjacent housing, retail, and employment uses; and
- may include limited vehicle access for vehicle loading, drop-off and deliveries, and on-site private parking facilities (Figure 3.15).

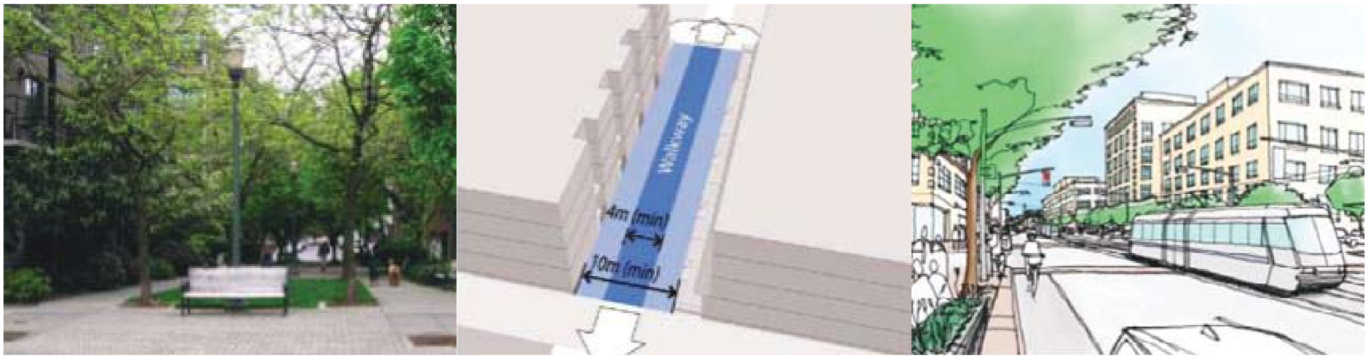
Case Study 11: Melbourne, Australia
Melbourne urban planners emphasize the importance of *connectivity* (or permeability) in the transport network. Connectivity affects the degree to which transportation networks such as streets, walking paths, and cycling paths connect people to their destinations (including intermediate destinations such as public transport services). Good connectivity provides easy access to key destinations for pedestrians. Excellent connectivity actively seeks to discourage car use by making local trips easier and more pleasant by foot than by car (Figure 3.16).

The Planning Institute of Australian and Local Government Association provide the following guidelines strategies for achieving excellent connectivity in towns:[34]

- Provide a grid path network. Spacing of pathways should optimize pedestrian

[34] Healthy Spaces and Places. http://www.healthyplaces.org.au

Figure 3.15: Examples of Transit-Oriented Design in Edmonton, Canada



Sources: City of Edmonton Sustainable Development and Transportation Services Departments. 2012. Transit Oriented Development Guidelines. https://www.edmonton.ca/city_government/documents/PDF/TOD_Guidelines_-_February_2012.pdf (left and middle); Dialog. n.d. Transformational Transit. http://www.dialogdesign.ca/assets/Edmonton-LRT-Sketch-Web.jpg

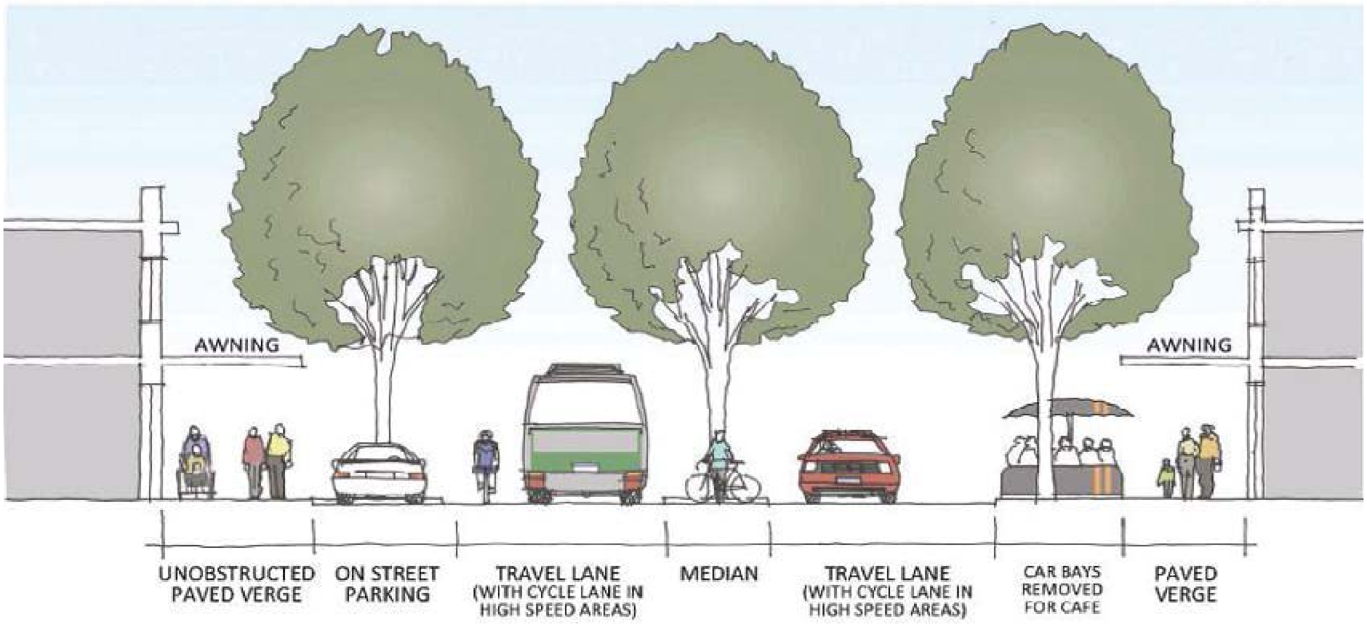
Figure 3.16: Laneways and Bikeways Provide Excellent Connectivity in Melbourne, Australia

Sources:

Top: Healthy Spaces and Places. 2009. Connectivity. July. http://www.healthyplaces.org.au/site/connectivity_full_text.php (left and middle); Bicycle Network. Protected Bike Lanes. https://www.bicyclenetwork.com.au/general/for-government-and-business/2845/ (right).

Bottom: Grayline. Melbourne City Tour. http://www.grayline.com/tours/melbourne/melbourne-city-tour-5913_57/ (left); Auckland Design Manual. St. Kilda Road, Melbourne. http://www.aucklanddesignmanual.co.nz/resources/case-studies/street_st_kilda (right).

Figure 3.17: Australian Guidance for Increasing Connectivity and Green Streets in Towns



Source: Street Cross-Section by TPG Town Planning and Urban Design, cited in Health Spaces and Places. Image Gallery: Connectivity. http://www.healthyplaces.org.au/site/image_gallery.php

movement and discourage car movement such as the use of cul de sac roads with pathways to enable pedestrian only access to the next street.

- Plan new subdivisions based on pedestrian and cyclist movement in the first instance before "fitting" the road network into the plan.
- Retrofit existing subdivisions by closing road space (particularly one leg of cross-intersections) while retaining cycling and pedestrian paths (this makes pedestrian movement safer and more attractive while also improving vehicle safety at these intersections).
- Provide footpaths on both sides of all streets except where the road surface is so narrow that cars are expected to share the space with pedestrians.
- Increase residential densities to support additional localized facilities (over 30 dwellings per hectare will sustain a basic level of facilities within walking distance).
- Ensure pathway and bikeway networks allow for longer distance travel within the town.
- Set a minimum standard footpath width of 1.2 meters as adequate for most road and street situations except in commercial and shopping environments (which is a national engineering standard, Australian Standard 1428 Parts 1 and 2, Part 13 of the AustRoads Guide to Traffic).

3.3 Urban Planning for Climate Resilience: Essential Components and Support Systems

This section describes the essential elements and processes in an urban planning framework for building resilience in Mekong towns. Five components cover the full spectrum of the urban planning process: from "visioning" through to the "development review process" and the steps in between (Figure 3.18).

Many towns and cities within the GMS already include some of these components in their urban planning processes. In those cases, the emphasis needed is on how to improve their performance and adjust them to address climate change through green infrastructure.

3.3.1 Building Resilience and Sustainability into the Town Development Vision

The visioning process is designed to establish a town's overarching development goal and approach. A vision can apply to a whole region

Figure 3.18: Essential Ingredients for Mekong Town Planning Frameworks

or city, a precinct or neighborhood, or even a particular site. Its purpose is to set the tone or direction for all subsidiary urban planning policies which guide development outcomes in the area.

In most instances, the visioning process involves consultation with residents, business owners, community groups, government departments, and other stakeholders. Gaining the views of the community through consultation helps urban planners to deliver outcomes consistent with community aspirations.

Community visioning is the process of developing consensus about what future a community wants, then deciding what is necessary to achieve it. A vision statement captures what community members most value about their community and the shared image of what they want their community to become. It inspires community members to work together to achieve the vision. A thoughtful vision statement is one of the elements needed to form a forward-looking strategic planning framework that gives local authorities the long-term-comprehensive perspective necessary to make incremental decisions on community issues as they arise. Community vision statements are typically crafted through a collaborative process that involves a wide variety of community residents, stakeholders, and elected officials.

Given the influential role of the vision statement, it is appropriate to consider how it might be used to address climate change. By referencing climate change in a high-level policy direction, it puts the onus on other layers of policy and plans to follow the lead set by the vision.

In September 2014, the climate change core groups from Battambang, Dong Ha, and Kaysone Phomvihane came together to discuss and develop “green vision statements” for their towns to address resilience through green infrastructure concepts. They used a list of descriptors to stimulate debate and reach consensus on the most appropriate terms to include in their visions.

The **Kaysone Phomvihane** Core Group focused on peace, environmental conservation, and stable economic development in formulating their vision statement. The group wished to see stronger commitment to the protection of nature and natural resources and to raising awareness within their community of the need for natural system conservation as an important strategy for development and for building climate change resilience.

Vision: *Build Kaysone Phomvihane as a clean city with strong economic growth, environmental sustainability, awareness of environmental protection, and improved natural resources conservation to reduce impacts of climate change.*

The **Dong Ha** Core Group reconsidered the relevance of each of the green infrastructure concepts for their town. The Dong Ha group concluded that climate change, though not explicitly mentioned in their existing town vision statement, is inherent in the term “green” which it adopted as a core concept for town development. It also promoted the concept of happiness to include fairness, social equity, and a healthy and enjoyable environment.

Currently, the Dong Ha Strategic Local Economic Development Plan, 2012 describes the vision for Dong Ha as “[a] dynamic and vibrant city serving as the regional economic growth centre for trade and investments in the southern economic corridor while optimizing its resource potentials for sustained economic

Kaysone Phomvihane Core Group Formulating a Green City Vision Statement

Source: ICEM.

development." The vision proposed by the core group reduces the overriding emphasis on the economy and promotes sustainability.

Vision: *Dong Ha is green, prosperous, happy, fair, equitable, and dynamic, and enjoys the benefits of sustainable development*.

The **Battambang** Core Group's interpretation of their town's vision embraced the concept of conservation, to include conservation of nature, architecture, and heritage.

Vision: *A city of beauty, safe water, clean air and high quality of life where communities, agencies, and infrastructure are made resilient to climate change through efficient and effective use of resources and the conservation of nature.*

An Australian example of a vision statement which addresses environmental sustainability and issues associated with climate change can be found in the municipality of **Moreland in Melbourne (Australia),** which states: "Moreland City Council seeks to create an environmentally sustainable and livable city, where people can shop, work and socialize locally. A city where a car and a high income or not necessary for a rich and rewarding quality of life. A city which will continue to provide a range of opportunities and choices for a diverse and prosperous community."[35]

The town of **Hull in Massachusetts (United States)** adopted a comprehensive vision statement including implementation strategies commencing with "We the people of Hull seek to shape a future for our town that preserves and enhances its natural features and rich heritage, while providing the services and amenities that characterize a healthy, dynamic community."[36]

The mayor and members of the **Edenton Town Council, North Carolina (United States)** gather regularly to review and update the council's 10-year vision statement. It outlines what the elected officials envision the town community being 10 years in the future. The vision statement includes strategies to help guide the town to achieving the vision. The strategies become the basis for new initiatives that are incorporated into the annual budget. For example, the vision directs the town to develop "a sound, stable infrastructure that meets the needs of citizens, businesses and industries. Such infrastructure includes well-maintained streets, a clean and reliable water supply, clean and reliable wastewater treatment, an environmentally-sensitive storm water treatment and a reliable electrical distribution system."[37]

Portland, Oregon (United States) conducted an extensive participatory process and arrived at a vision to "[i]mprove human and environmental

[35] Moreland City Council. 2006. *Moreland Planning Scheme, Local Planning Policy Framework*. http://www.dtpli.vic.gov.au/planning/planning-schemes/get-information-about-your-planning-scheme/planning-scheme-histories/ (amended 21 September 2006).

[36] Town of Hull, Massachusetts. n.d. *Wave of the Future: Hull Vision Statement*. http://www.town.hull.ma.us/Public_Documents/HullMA_townmgr/vision

[37] Town of Edenton, North Carolina. http://www.townofedenton.com/

Battambang Core Group Formulating a Green City Vision Statement

Source: ICEM.

health by creating safe and complete neighborhood centers linked by a network of city greenways that connect Portlanders with each other, encourage active transportation, integrate nature into neighborhoods, enhance watershed health and provide access to services and destinations, locally and across the city."[38]

The goal will be achieved by focusing on the following actions and policies:[39]

- **Prioritize human and environmental health and safety.** Decisions must consider impacts on human and environmental health and safety and prioritize actions to reduce disparities and inequities.
- **Promote complete and vibrant neighborhood centers.** The neighborhoods must provide businesses and services; housing that is easily accessible by foot, wheelchair, bike, and transit; healthy food; and parks and other gathering places.
- **Develop city connections, greenways, and corridors.** A system of habitat connections, neighborhood greenways, and civic corridors will weave nature into the city and sustain healthy, resilient neighborhoods, watersheds, and Portlanders.

Visions for Mekong towns, defined through an open and participatory process and which incorporate the ideas of environmental sustainability and climate change, provide a strong and transparent policy direction for guiding development through the urban planning process.

3.3.2 Building Resilience and Sustainability into the Town Strategy

The town strategy sits below the vision statement and helps to inform key elements of the vision in terms of things such as

- the location of major infrastructure investment,
- the location of major transport routes and nodes,
- the location of major employment nodes, and
- the location of areas of environmental sensitivity and natural assets and corridors.

In most cases, the town vision and strategy are developed together in one process. In the Mekong region, urban strategies often take the form of master plans that include strategic orientations and the actions required to implement them.

From a climate change adaptation perspective, it is the identification of areas of vulnerability and environmental sensitivity which is of most significance in the town strategy. In circumstances where towns are experiencing rapid growth, a long-term plan should identify and protect those areas that play a role in building resilience. Rivers, creeks, reservoirs, wetlands, and areas of native vegetation are all important in this respect, particularly when a town is confronting increased flooding and drought impacts due to climate change. By preserving these natural assets, there is greater opportunity for natural drainage systems to function effectively. Many of the existing problems faced by towns in the GMS are a consequence of the degradation of existing natural systems. The urban planning process and the city strategy in particular need to identify, rehabilitate, expand, and maintain these areas.

Case Study 12: City Strategy of Portland, Oregon, United States

A central theme in Portland's town strategy is building "connections for people, places, water and wildlife." The strategies that Portland has identified for achieving that goal include the following (Figure 3.19):[40]

[38] Portland City Council. 2012. *The Portland Plan: Summary*. p. 14. http://www.portlandonline.com/portlandplan/index.cfm?c=58776&a=405753

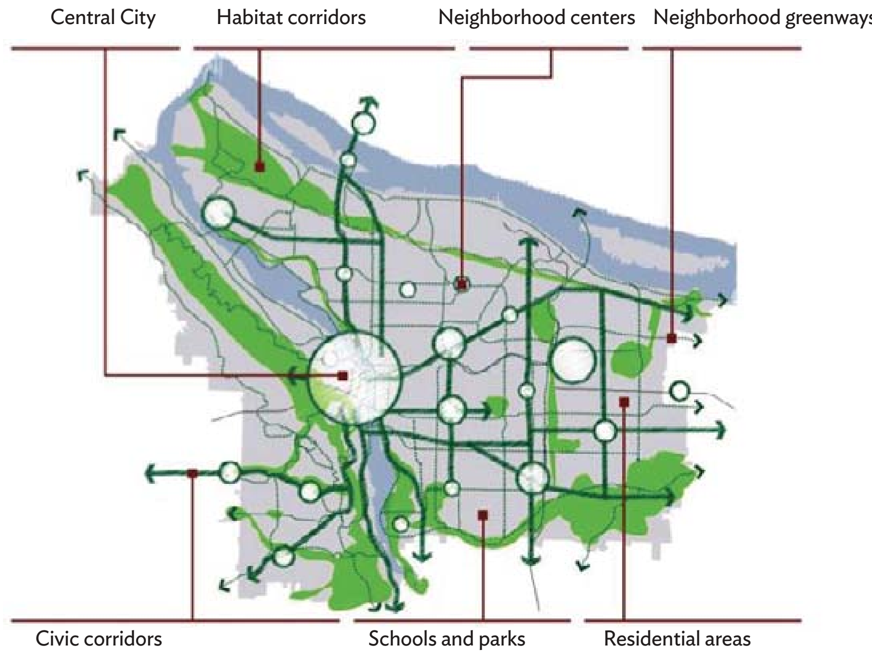
[39] Footnote 38, p. 88.

[40] Footnote 38, p. 88.

- Develop the network of habitat connections, neighborhood greenways, and plan for civic corridors as a spine of Portland's civic, transportation, and green infrastructure systems to enhance safety, livability, and watershed health and catalyze private investment and support livability.
- Preserve and restore habitat connections and tree canopy to link stream and river corridors, landslide-prone areas, floodplains, wetlands, and critical habitat sites into a system of habitat corridors. This provides connections for wildlife, supports biodiversity, improves water quality, reduces risks due to flooding and landslides, and supports Portland's adaptation to climate change.
- Plan, fund, and manage green infrastructure as part of the city's capital systems.
- Build on Portland's green street and bikeway efforts to create a citywide greenway network of trails and pedestrian and bike-friendly green streets. Locate neighborhood greenways to serve currently underserved communities, improve accessibility, and make connections to the central city, neighborhood hubs, major employment and cultural centers, schools and universities, community centers, parks, natural areas, and the Willamette and Columbia rivers.
- Design neighborhood greenways and civic corridors to integrate safe and accessible facilities for pedestrians and cyclists, sustainable stormwater facilities, tree planting, and community amenities.
- Transform prominent transit streets, and streetcar and light rail corridors into distinctive civic places of community pride that serve Portland's future multimodal mobility needs and are models of ecological design.
- Preserve older and historic buildings, public places, and parks along corridors, where appropriate, to enhance the pedestrian realm and create a unique sense of place and neighborhood identity.

Notes:
Central City is the region's center of jobs, high-density housing, transit, and other services. It also comprises a large portion of the Willamette River waterfront in the city. It benefits the entire city and has a key role as part of an interconnected system of neighborhood centers and city greenways.

Figure 3.19: Concept of the Healthy Connected City Network of Neighborhood Centers and City Connections in Portland, Oregon, United States



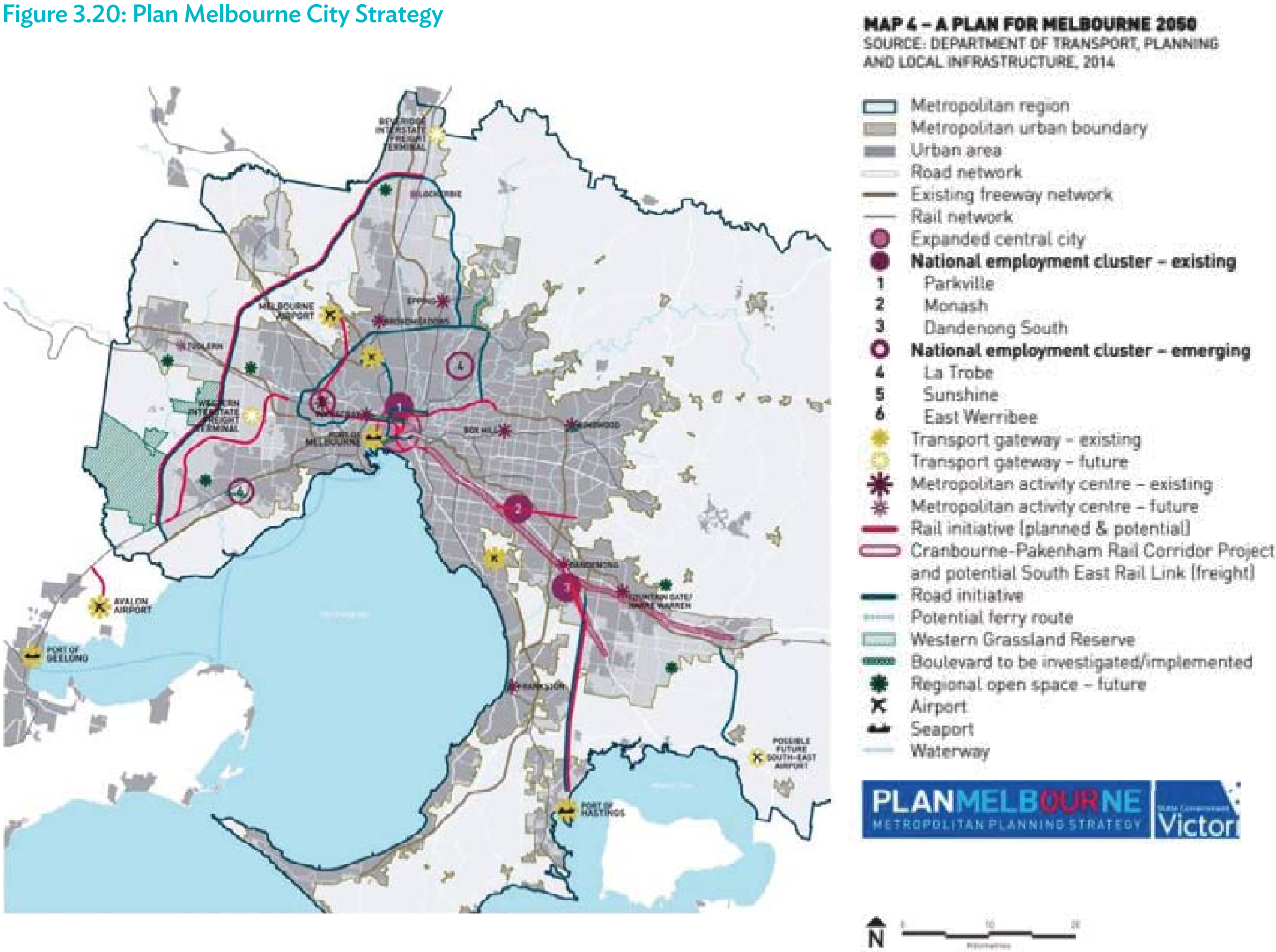
Source: City of Portland. 2011. The Portland Plan. October. www.portlandonline.com/portlandplan/proposed_draft/pplan-draft-integrated.pdf

Habitat connections are corridors and neighborhood tree canopy that weave nature into the city and connect to large natural areas like Forest Park. The habitat connections include anchor habitats and the connections between them. They provide corridors for residents and migrating wildlife. Anchor habitats are places with large, contiguous natural areas that serve as a safe and healthy home for resident and migratory animal species and native plants.

Neighborhood centers are places with concentrations of neighborhood businesses, community services, and housing and public gathering places, providing area residents with local access to services. They should be well designed, accessible, green, and pleasant areas to be in.

Neighborhood greenways are pedestrian and bike-friendly green streets and trails that link neighborhood centers, parks, schools, natural areas, and other key community destinations, making it easier to get around by walking, biking, or wheelchair.

Figure 3.20: Plan Melbourne City Strategy



Source: Department of Transport, Planning, and Local Infrastructure. 2014. Map 4: A Plan for Melbourne. http://planmelbourne.vic.gov.au/__data/assets/pdf_file/0006/131298/Map-04-Plan-Melbourne-May-2014.pdf

Civic corridors are major streets and transit corridors that link neighborhood centers to each other and Central City. In some cases, a civic corridor may not be a single street, but multiple parallel streets that serve complementary functions. Civic corridors are enjoyable places to live, work, and gather with bike and pedestrian facilities, large canopy trees, green infrastructure stormwater facilities, and place-making amenities.

Schools and parks are important community destinations that can be safely and conveniently reached from neighborhood greenways.

Existing residential areas are connected to neighborhood centers, the city center, employment areas, parks and natural areas, and other destinations through networks of neighborhood greenways and civic corridors.
Source: Portland City Council. 2012. *The Portland Plan: Summary*. p. 18. http://www.portlandonline.com/portlandplan/index.cfm?c=58776&a=405753

Case Study 13: Plan Melbourne (2014) – Metropolitan Planning Strategy

A similar approach has been adopted by the City of Melbourne, Australia. Its City Strategy or Plan Melbourne is intended to guide development through to 2050. Plan Melbourne is the City Council's primary policy and planning strategy. The intention of Plan Melbourne is to move toward a thriving and sustainable city. Four

Left to right: A walkway and cycle path network along Yarra River and Botanical Gardens to the central business district, urban sprawl on outer fringe, and walkways along the Port Phillip Bay shoreline.

Sources: Smaragd Reizen. 2003. Autorondreis Van Sydney Naar Melbourne. http://www.smaragd-reizen.nl/autorondreis-van-sydney-naar-melbourne (left); *Sydney Morning Herald.* 2010. Green Wedges Lost in the Woods. http://www.smh.com.au/federal-politics/political-opinion/green-wedges-lost-in-the-woods-20100113-m6g9.html (middle); David Wall Photo. Catani Gardens, St Kilda, Port Phillip Bay. http://www.davidwallphoto.com/detail/27142-Catani-Gardens,-St-Kilda,-Port-Phillip-Bay,-Melbourne,-Victoria,-Australia-_-aerial.html (right).

interrelated themes set the broad strategic directions for the City Strategy.[41] They are for Melbourne to be

- a connected and accessible city,
- an environmentally responsible city,
- an inclusive and engaging city, and
- an innovative and vital business city.

Plan Melbourne delineates areas of green reserve (green hatching) and green corridors, the extent of the urban area (dark grey hatching), and the areas identified for growth (light grey hatching) (Figure 3.20). Importantly, Melbourne uses a defined urban growth boundary (illustrated by the light brown line) to prevent development from encroaching into environmentally sensitive areas.

Plan Melbourne is supported by a range of subsidiary strategies and plans providing more detail for each of the main strategic themes. They include the Melbourne Green Plan and Urban Forest Strategy, the Sustainable Energy and Greenhouse Strategy, and the Sustainable Water Management Plan.

When preparing a city strategy for towns in the GMS, key natural assets need to be identified and earmarked for protection. The Battambang Future Greenery System Plan 2020 is an example of how a city strategy promotes connectivity through green street networks and along the Sangkae River (Figure 3.21). Identifying these areas at the city strategy or master plan level increases the likelihood of them being reflected in Local Area Plans when prepared. In the case of Battambang, more detailed guidance is needed on the methods and standards to realizing the green street concept.

3.3.3 Building Resilience and Sustainability into Local Area Plans

Local area plans are urban planning in a more targeted and detailed form. They can apply to a specific area within the town or to a strategic theme. They are intended to provide more specific development guidance, controls, and standards. For example, a local area plan might address an area around a train station as a “high-density residential area” needing special development guidance; or a natural drainage area, river, or creek within the town could be identified as an area of “high environmental sensitivity” and subject to more detailed treatment within a local area plan. Naturally, such local plans should be consistent with the city vision statement and strategy.

Case Study 14: Local Area Plan of Gisborne, Australia

Gisborne is a peri-urban township approximately 52 kilometers north of Melbourne. It is subject to significant growth. The area in Figure 3.22 was identified as being suitable in accommodating some of this growth by providing for between 300 and 330 new dwellings.

[41] Victorian State Government. 2014. Plan Melbourne. http://www.planmelbourne.vic.gov.au/Plan-Melbourne (last updated 20 October 2015).

Figure 3.21: Bird's Eye View of Future Greenery System (in 2020) for the Urban Area of Battambang, Cambodia

Source: Deutscher Entwicklungsdienst. 2007. Urban Planning on District Level: A Race against Time. http://www.forum-urban-futures.net/files/DED_Pilot%20DistrictBattambang.pdf

Figure 3.22: Aerial Photo of Study Area (left) and Select Site Photos (right)

Source: Hansen Partnership in collaboration with Cardno, Ecology & Heritage Partners, Tim Nott Economics Analysis & Strategy, and Macedon Ranges Shire Council. 2012. New Gisborne Development Plan. http://www.mrsc.vic.gov.au/files/bb66ed14-efde-443f-84d1-a2f400e200c6/26mar14-pe3-att1.pdf (all photos).

Figure 3.23: Local Area Plan of Gisborne Emphasizing Enhancement and Maintenance of Natural Systems

Source: Hansen Partnership, Melbourne. www.hansen-online.com.au

Given some of the drainage sensitivities of the area, the local authority opted to prepare a local area plan to help guide its development. The local area plan sought to

- avoid adverse impact to the site natural areas and maintain the current hydrological regimes,
- maintain the ecological values present in the marshlands reserve,
- utilize drainage lines to provide for a centrally located linear open green space corridor, and
- enhance the residential amenity of the growth area by providing desirable visual and physical connections with a site of environmental significance and beauty.

Figure 3.23 shows the planning and design principles underpinning the plan (left) and the final local area development plan itself (right). The pink hatching indicates land for residential purposes (with key access roads marked), while the green hatching demarcates areas around the drainage line for environmental protection.

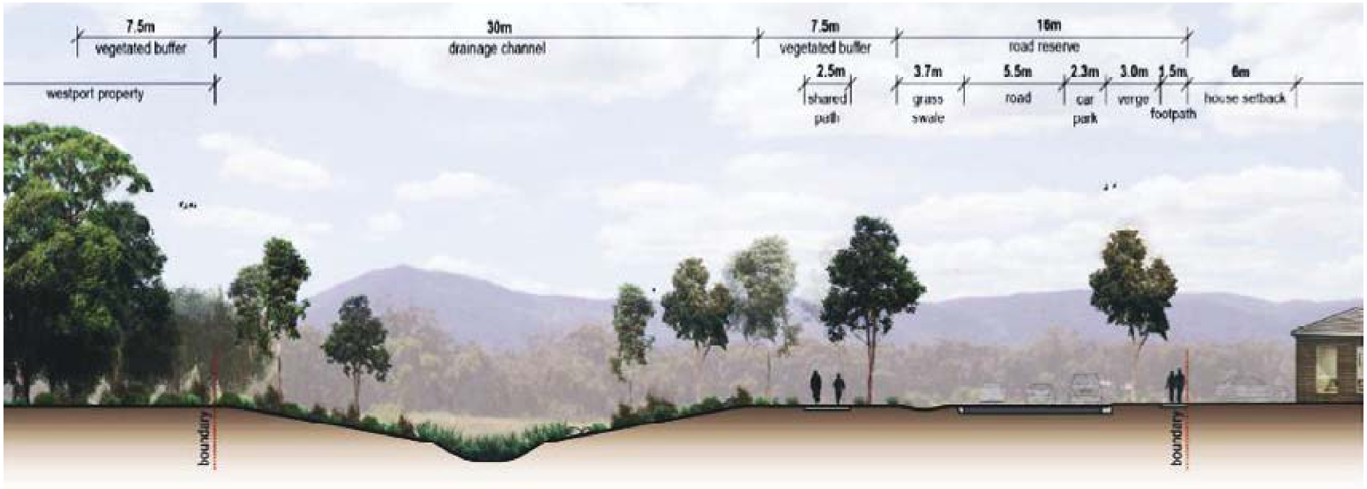
By setting aside the area around the existing drainage line for open space and requiring minimum setbacks to development, the local area plan protects the existing natural drainage system as well as providing a key asset for community benefit in the form of a green corridor parkway.

By providing targeted design guidance in the form of a local area plan, the local authority can create greater certainty for developers and the community over how the land will be utilized.

Local area plans are a particularly valuable tool in guiding development in areas where significant urban regeneration is proposed to occur. They can also be used to give specific direction to growth areas, as in Mildura (case study 15).

The approach described in the case study has the potential for widespread application for Mekong towns. Once drafted, local area plans can be utilized in a way which gives the local

Figure 3.24: An Indicative Cross-Section Showing How the Drainage Line Is to Be Protected



parkway with drainage channel

Source: Hansen Partnership in association with Aurecon Engineering. 2014. Mildura South (Sixteenth and Deakin West) Development Plan. http://dsewebapps.dse.vic.gov.au/Shared/ats.nsf/(attachmentopen)/4A4934ABE3418C70CA257DD400106FFF/$File/Mildura+C75+Mildura+South+(Sixteenth+&+Deakin+West)+Development+Plan+October+2014+Exhibition+Gazetted.PDF

authority, the community, and investors a clear, spatial understanding of what development goals they are required to comply with in a specific area. They allow pilot sites to be identified and planned in detail. From the perspective of building resilience to climate change, local area plans can be used to protect natural assets (e.g., creek corridors required for drainage) or a plan for their rehabilitation.

3.3.4 Building Resilience and Sustainability into Development Controls

Within contemporary urban planning, development controls can take a variety of forms including, for example, zoning plans with associated controls or safeguards, development plan overlays that set out conditions for land uses and the new built form relating to a specific area,[42] provincial or district planning policies, and local area planning policies. They can be either prescriptive or discretionary in nature with the distinction as follows:

- **Prescriptive**: Quantitative, can be mandatory, generally numerically specific (e.g., "New buildings must maintain a 15-meter setback from the riverbank.")
- **Discretionary**: Qualitative, open to interpretation, allows greater flexibility in the form of the response which can be taken to achieve compliance (e.g., "New buildings should ensure they fit in with the heritage character of the area.")

While the format of the control (and the terminology used to label it) may vary, their purpose is the same—that is, to shape urban development in a manner which helps realize the vision, the city strategy, or the local area plan (as most applicable).

In the Mekong region, there is little in the way of development controls in a form which resembles what is used and applied internationally. While sector design standards and building codes are relatively common—and these can be very detailed—there are few development control policies relating to specific urban areas, that is, that have spatial relevance. The one development control tool readily in use, however, is land-use zoning, typically in the form of a spatial land-use plan. These spatial plans offer broad guidance on what land uses

[42] A development plan overlay requires an overall plan to be prepared to coordinate land uses, development, and redevelopment change over a defined area. The specifics for such a plan are laid out in the schedule. A schedule to the overlay specifies what the development plan must include and can include requirements about pedestrian and road connections, where different land uses should be located and the design of new development on the land, among other things.

can occur in which locations but are usually weak in terms of more detailed development guidance and controls. Moreover, they are frequently ignored, particularly where large-scale investment is involved.

The following section introduces the zoning plan and what it ought to comprise and provides suggestions on how it can best be used to respond to climate change.

3.3.4.1 Land-Use Zoning Plans
A zoning plan is a type of development control frequently used by urban planners to manage urban development and plan for future growth. It comprises an illustrative map used to designate the location of different land uses or "zones" and a supporting written instrument which explains what each zone means and how it is to be applied.

In the case of the planning system in the state of Victoria, Australia, the written instrument supporting the zone map is set up to provide three components: a purpose, a use table, and safeguards. Each component requires a corresponding action from the urban planner applying it as explained in Table 3.2.

An example of a zoning tool from Mildura, Victoria including the illustrative map and extracts from the accompanying written document is provided as case study 15.

Table 3.2: Content of the Policy Instrument Supporting the Land-Use Zone Map

Component	Action Required
Purpose of zone: Defines the overarching objective of the zone.	Confirm the proposed development is consistent with the purpose of the zone.
Use table: Divides land uses into categories, e.g., permissible, prohibited, or permissible subject to conditions.	Determine if the proposed development is permissible, permissible with condition, or prohibited in the use table.
Safeguards: Guides and controls development within the zone; can be used to address various considerations such as flooding, environmental protection, urban design, and heritage conservation as relevant.	If the proposed development is permissible, assess it against the relevant safeguards and ensure that the design and management allow them to be met.

Source: Author's synthesis based on Victoria State Government. Victoria Planning Provisions. http://planningschemes.dpcd.vic.gov.au/schemes/vpps

Case Study 15: Zoning Plan and Safeguards in Mildura, Victoria, Australia
Mildura is a town of approximately 30,000 people, located on the Murray River in the northwest of the State of Victoria, Australia. It has a semiarid climate but is subject to serious flooding.

In preparing development controls for the town, the local authority used a combination of zoning and development safeguards to ensure no development was allowed in areas subject to severe flooding and limited development (subject to conditions) in areas that experience moderate flooding.

An aerial photo of Mildura and corresponding zoning plan are shown in Figure 3.25. The zoning plan illustrates that the low-lying areas closest to the river are designated as *public conservation and resource zones*, shown in green. These areas contain playing fields and green open space areas but are not permitted to contain any development. The *urban flood zones*, shown in light blue, are areas where development can occur subject to complying with particular safeguards. In this instance, safeguards are used to guide aspects of development such as setback distances, permeability requirements (i.e., extent of hard surfaces), and building materials and orientation.

Extracts from the plan state the purpose of public conservation and resource zones as follows:[43]

- To identify waterways, major floodpaths, drainage depressions, and high hazard areas within urban areas which have the greatest risk and frequency of being affected by flooding.
- To ensure that any development maintains the free passage and temporary storage of floodwater, minimizes floodwater, minimizes flood damage, and is compatible with flood hazard, local drainage conditions, and the minimization of soil erosion, sedimentation, and silting.

[43] See in particular Section 36.03 Public Conservation and Resource Zone of Victoria State Government. Mildura Planning Scheme. http://planningschemes.dpcd.vic.gov.au/schemes/mildura

Figure 3.25: Zoning Plan in Mildura, Victoria, Australia

Sources: Google Earth (left); Hansen Partnership. 2010. Ontario – Flora Precinct Land Use Vision and Urban Design Framework. http://trove.nla.gov.au/work/182387578?selectedversion=NBD51724786 (right).

- To protect water quality and waterways as natural resources.

This case illustrates how zoning and safeguards can be used as development controls to guide development in areas affected by flooding. The same approach can be applied to any urban area with differing characteristics and controls to promote and require the kind of development best suited to the area and the climatic and hydrological conditions it experiences.

A key strength of the zoning plan is that it can be customized to respond to different issues depending on communities' needs and area characteristics. For example, if a part of a town is growing rapidly, a zoning plan can be used to designate an area as an *urban growth zone*. The written instrument can set out the purpose of the zone, what levels of density are envisaged, which land uses are appropriate (and which are not), and any relevant safeguards, such as minimum setback requirements for buildings adjacent to a river.

Similarly, if there is an area which is in need of rejuvenation, it might be designated as an *urban renewal zone*. The written instrument could be drafted to provide incentives for investment, such as increased building heights, higher plot ratios, or reduced land taxes.

From a climate change adaptation perspective, there is good sense in towns and cities in the GMS giving thought to applying an *urban flood zone* (or similar) to areas subject to severe flooding. This can assist in making it clear to the community and investors that the area contains a flood risk and may be unsuitable for certain kinds of development. Towns will need to map past extreme floods and then seek expert support in defining the additional risks posed by climate change.

3.3.4.2 Development Safeguards

In circumstances where risks are less severe and a certain level of development may be appropriate, supporting safeguards can be used to guide development and ensure impacts are minimized. Safeguards provide a benchmark or rule against which new development is required to be assessed. They can be mandatory or discretionary in nature and can be tailored to suit particular conditions and address particular issues. In effect, they set the parameters under which development can occur prior to addressing detailed design matters covered by sector design standards and/or building codes. They can be part of the written instrument supporting the zoning tool (as described in case study 15) or potentially a stand-alone document relating to certain kinds of development or areas anywhere in the town.

Table 3.3 lists example safeguards dealing with flooding and environmental considerations. This is not an exhaustive list. The intention, rather, is to provide an idea of the types of safeguards that can be used by urban planners to help manage development.

The focus on flooding and environmental safeguards is reflective of key issues faced in the GMS likely to be affected by climate change.

The examples in Table 3.3 demonstrate the enormous potential for development controls such as zoning plans and accompanying safeguards to assist in building climate resilience and sustainability in Mekong towns.

When applied to a solitary site, requirements such as stormwater management (i.e., reducing the amount of rainfall runoff associated with a development) may be seem negligible. Yet, the impact ,when applied across a whole town through the contribution of many developments, particularly a town undergoing rapid growth, can be very significant.

These types of approaches are an effective means of

- reducing pressures on existing infrastructure;
- minimizing the environmental impacts of new development;
- managing growth; and
- delivering happier, healthier communities.

The introduction of these processes wherever possible are important in delivering climate change adaptation and sustainability to towns and cities within the GMS.

In different parts of the world, and even within countries, the terms used for the land-use zone plan and the associated safeguards document may differ. For example, in Sydney, Australia, local area plans are called local environment plans which include planning control maps (another term for zone maps). The local environment plan applies a zone (e.g., rural, environmental protection, residential, center, business park, industrial, recreation, infrastructure) to land within a municipality. The local environment plans are supported by development control plans which provide more detailed planning and design guidelines.

Table 3.3: Safeguards Dealing with Flooding and Environmental Considerations

Examples of Flooding Safeguards		
Category	Subcategory	Safeguard
Land Use	–	Development is prohibited from occurring on land subject to significant flooding.
Building Construction	Materials	All building materials used below the adopted design flood level must not be susceptible to water damage.
	Electrical supply	• All electrical wiring should be located above the design flood level. • All electrical wiring installed below the design flood level should be suitably treated to withstand continuous submergence in water.
	Freeboard	The minimum floor level of all new dwellings or of extensions greater than 20 square meters to existing dwellings must be 300 millimeters above the designated flood level.
	Storage	Commercial and industrial development should make adequate provision for flood-free storage areas for stock and equipment susceptible to water damage.

continued on next page

Table continued

Examples of Flooding Safeguards		
Category	Subcategory	Safeguard
Earthworks	Filling	• High hazard: Significant earthworks, including levees and raised roads, are inappropriate for floodway land. • Moderate hazard: Any fill of urban areas liable to flooding must not exacerbate flooding impact to surrounding properties.
Site Planning	Building orientation	Buildings should be aligned with their longitudinal axis parallel to the direction of flood.
	Permeability	• Building pads should be restricted as near as practicable to the building envelope. • The site area covered by pervious surfaces should be at least 20% of the site.
	Site coverage	The total footprint of all buildings and structures should not exceed more than 60% of the total site area.
Subdivision	–	• High hazard: Further subdivision is inappropriate, unless it can be shown that the land can be filled to the design flood level without creating any adverse effects. • Moderate hazard: All land, other than public roads and reserves, is to be filled to a minimum level of the design flood where an additional allotment is created.
Infrastructure	Stormwater management	• Post-construction stormwater runoff should be treated to remove 80% suspended solids, 45% total phosphorous, and 45% total nitrogen of typical urban annual load and maintain discharges for the 1.5-year annual recurrence interval at pre-development levels. • Stormwater quality treatment measures should be designed to prevent litter being carried to receiving waters. This includes appropriate design of waste enclosures and use of gross pollutant traps for development with potential to generate significant amounts of litter.
	Roads/ transport	• New roads are not to obstruct free movement of floodwaters. • Consideration should be given to incorporating treatment systems such as a rain gardens or vegetated swales in the upgrading of roads or streets.
Site Planning	Setbacks	No buildings and works are permitted within 10 meters of the bank of an identified watercourse or drainage corridor.
Subdivision	Public open space	• For subdivisions of three or more lots, a minimum 5% of the total land area should be set aside for public open space. A cash contribution may be provided in lieu of land being provided. • Open space should be aligned along natural drainage lines.
Asset Protection	Vegetation removal	Where native vegetation is permitted to be removed, an offset is to be provided in a manner that is equivalent to the contribution made by the native vegetation to be removed.
	Drainage	Areas containing natural water features should be protected and enhanced.
Building Design	Environmentally sustainable development	• All new buildings must achieve a minimum six-star energy efficiency rating. • Environmentally sustainable design initiatives are encouraged, including the use of solar hot water and natural ventilation, along with on-site collection and reuse of stormwater.

Source: ADB and ICEM.

Case Study 16: Development Controls in Kiama, New South Wales, Australia

In Kiama, a coastal town of New South Wales, the town council adopted the Development Control Plan 2012 to give detailed development guidelines and controls to specific types of development or areas of land throughout the municipality.[44] One set of controls relates to the preservation and management of trees and vegetation aiming to conserve important natural areas and individual trees. The controls support Clause 5.9 of the Kiama Local Environmental Plan by defining a prescribed tree or vegetation and the council's requirements for the submission, assessment, and determination of applications for the pruning and removal of tree(s) and other vegetation on public and private land within the Kiama Local Government Area.

The Kiama Development Control Plan also spells out detailed controls on site landscaping and the requirement to submit suitable landscape plans and documents for proposed

[44] Kiama Municipal Council. Kiama Development Control Plan 2012 (DCP 2012). http://www.kiama.nsw.gov.au/Planning-and-Development/Strategic-Planning/Development-Control-Plans

commercial, industrial, and medium-density developments within the municipality. Basic information and design considerations are provided, which help applicants in meeting the requirements of the environmental legislation when preparing development applications. The objective of this chapter of the Development Control Plan is to do the following:

- Provide a high standard of landscape design which complements the design of the development and integrates within the streetscape or rural setting in size, scale, mass, and bulk throughout the Kiama Municipality.
- Require landscaping to be considered in consultation with building and subdivision design as soon as possible in any development.
- Incorporate environmentally sustainable practices within the design.
- Reduce the impact of development activity on the landscape.
- Provide landscaping that requires low maintenance.
- Protect and enhance remnant native bushland areas by the retention and regeneration of indigenous flora.

The landscaping design guidelines for **industrial development proposals** are very detailed and in this case they are mandatory. They include a requirement for a developer to do the following:

- Provide planting beds minimum 3 meters wide across the front of the site and minimum 3 meters wide across the rear as well as 1-meter-wide side boundaries where it adjoins residential property or public spaces, to screen the development and reduce the bulk and scale of the building (additional guidance is provided for parking lot design and requirements).
- Incorporate indigenous tree and shrub planting in the buffer zone areas, if possible. A mix of planting forms and habits is desirable.
- Provide security fencing on street frontages of low visual impact, open design, and located within and screened by planting beds (additional guidance is provided on fencing design).
- Provide landscape treatment within or adjacent to the parking area which includes shade and screening.
- Separate landscaped areas from parking and driveway areas by devices that prevent vehicles from damaging the plants.

Source: Australia for Everyone: Sydney. www.visitsydneyaustralia.com.au

- Use raised planter areas to minimize the possibility of landscape areas being used for parking or storage areas.
- Provide mulch to garden beds and planted areas.
- Provide suitable edging materials to separate mulch and landscape from turf and hard surfaces.
- Screen waste and service areas with suitable plant and building materials.
- Use recessive colors if manufactured metal fencing is to be used.
- Maintain visibility of vehicular traffic moving in and out of the driveway.
- Consider the impact of the landscape on adjoining properties, for example, overshadowing, structural issues, and views, by the careful selection and location of trees.
- Require engineer's document for retaining walls over 600 millimeters high.

This kind of detailed design guidance is given for all land uses and zones. It also defines management obligations such as mandatory maintenance programs and periods. A project is considered completed when all the hard and soft landscape features or any work specified in the approved landscape plans have been installed and approved by a private certifying authority or council. The mandatory maintenance periods for various developments are specified: industrial – 52 weeks, commercial – 26 weeks, residential – 26 weeks, and rural – 52 weeks.

These maintenance periods may be extended for specific developments. A landscape maintenance program is required with the landscape plan. This is to describe the means of maintaining the landscaping during the maintenance period and must include plant establishment, watering, mowing, fertilizing, weeding, staking, pruning, mulching, pest and disease control, and generally maintaining the site in a neat and tidy condition.

3.3.4.3 Environmental Safeguards

Environmental safeguards aim to ensure the environmental sustainability of projects and to support the integration of environmental considerations into the project decision-making process. A policy regarding safeguards requires investors and contractors to identify project impacts and assess their significance; examine alternatives; and prepare, implement, and monitor environmental management plans. It also requires consultation with stakeholders likely to be affected by the project and disclosure of relevant information in a timely manner and in a form and in languages understandable to those being consulted.[45] Environmental safeguards can be linked to town master plans, to zones, and to specific categories of project proposals. They can also be referred to as development controls or standards as discussed and illustrated in the last section and Table 3.3.

For example, ADB's 2011 Safeguard Policy Statement builds the three previous safeguard policies on the environment, involuntary resettlement, and indigenous peoples into a consolidated framework. The Safeguard Policy Statement aims to promote sustainability of project outcomes by protecting the environment and people from projects' potential adverse impacts by avoiding, minimizing, mitigating, and/or compensating for them; and helping member countries to strengthen their safeguard systems and develop the capacity to manage environmental and social risks.[46]

ADB borrowers are required to meet the safeguard requirements when defining environmental safeguards for projects supported by the ADB. These requirements include assessing impacts, planning and managing impact mitigations, preparing environmental assessment reports, disclosing information and undertaking consultation, establishing a grievance mechanism, and monitoring and reporting.[47]

The experience gathered in the GMS has, however, highlighted issues in the application of safeguards regarding the environment. These problems can be summed up as follows:

- Safeguards are implemented as far as international funding agency (i.e., ADB or the World Bank) projects are concerned; rarely are they considered for other types of smaller, differently funded projects.
- Governments and communities do not have the capacity to apply some of the more sophisticated safeguards envisioned for the environmental aspects of projects.
- Project design and environmental assessment teams often work in isolation from local planners and communities.
- Seldom is there an effective follow-up or consultation to check if safeguards have been implemented and have worked to achieve their objectives.

Those problems place greater responsibility on Mekong towns to take the initiative in introducing adequate safeguard frameworks to promote green infrastructure and their goals for ecological sustainability and resilience—and then in ensuring they are implemented.

3.3.5 Development Review Process

Having addressed how resilience and sustainability measures can be introduced into the visioning, city strategy, local area plan, and development control aspects of urban planning, it is important to consider questions around their implementation. After all, there is little point in strengthening the urban planning framework to better respond to climate change, if it "falls down" at the point of implementation—the point when development actually occurs on the ground.

In most international examples, the implementation of an urban planning framework

[45] ADB. Environment Safeguards. http://www.adb.org/site/safeguards/environment

[46] ADB. 2009. *Safeguard Policy Statement*. Policy paper. Manila. http://www.adb.org/documents/safeguard-policy-statement

[47] Footnote 45

(and the ideas and controls it promotes) is achieved primarily through the development review process. The development review process refers to the decision-making processes by which proposals for new development or investment are considered by a government authority.

For development controls such as zoning or safeguards to be effective (whether dealing with climate resilience or any other matter), there needs to be a robust and preferably transparent process by which new development is assessed against the relevant controls and safeguards which apply.

Cities are largely the product of incremental development over time and without a robust system or process to determine what is appropriate on a development-by-development basis, it is difficult to achieve the identified city goals, such as building climate resilience.

In its more advanced form, the development review process can be set up to incorporate the views of residents and community groups (e.g., through public exhibition of development applications, public hearings and meetings, and a system for consideration of comments).

Figure 3.26 is an example of the development review process used in Melbourne, Australia.

Tribunals can be set up to consider disputes between parties or appeals against planning decisions to ensure they are fair and balanced, as in the example of the Victorian Civil and Administrative Tribunal referred to in the Figure 3.26 flowchart.

3.3.6 Impact Assessment as a Tool in Development Control

Conventional strategic environmental assessment (SEA) and environmental impact assessment (EIA) can be key tools for promoting effective responses to climate change and for ensuring that adaptation principles and approaches are followed.

Strategic environmental assessment: An SEA could be applied to town master plans to assess the overall adaptation strategies, safeguards, and spatial zoning approaches to promoting adaptation. It aims to ensure that policies, strategies, and plans are sustainable.

Figure 3.26: Development Application Review Process in Melbourne, Australia

The Planning Permit Process

Before making the application
- Find out about the planning scheme
- Talk to the council planner
- Talk to the neighbors
- Consider getting professional advice

Prepare and submit the application
- Application information
- Application form
- Fee

Council checks the application
- More information?
- Referral?

Application is advertised if required for at least 14 days
- Usually by letter to neighbors and a sign on-site
- People affected may object

Council assesses the application
- Considers any objections
- Holds mediation meeting if needed
- Considers any referral comments
- Assesses planning scheme provisions
- Negotiates with permit applicant
- Prepares report

Council decides the application

Permit with conditions	Notice of decision with conditions	Refusal

Review by VCAT if applied for
- By the permit applicant against conditions or refusal
- By an objector against notice of decision

VCAT = Victorian Civil and Administrative Tribunal.

Source: City of Melbourne. Planning Application Process Overview. www.melbourne.vic.gov.au/building-and-development/planning-and-building-services/planning-applications/Pages/planning-application-process-overview.aspx

SEAs of town master plans would address the broader strategic issues usually relating to more than one project. They would allow for green infrastructure and nature-based solutions to urban resilience to be built into master plans so that subsequent development is guided and shaped in a sustainable way.

SEAs follow similar steps to EIAs but have much larger boundaries in terms of time, space, and subject coverage. For the most part, an SEA is conducted before corresponding EIAs are undertaken for specific development proposals within a plan. The SEA is a tool to examine the broad strategic concerns which need to be resolved and decided prior to making project-specific decisions. This means that information on the environmental impact of a plan can cascade down through the tiers of decision making and can be used in an EIA at a later stage. This should reduce the amount of work that needs to be undertaken. Systems for SEA are in place in the People's Republic of China, the Lao PDR, Thailand, and Viet Nam.

Environmental impact assessment: EIA tools and processes are applied to assess the area-wide and cross-sector implications of development proposals. To consider climate change impacts and adaptation responses, the EIA process should

- evaluate a development proposal's potential environmental risks and impacts in its geographic area of influence against the town plan and its general and zone-specific safeguards relating to climate change;
- identify and evaluate potential impacts from climate change on the project's area of influence;
- identify and assess alternatives to meeting the project objectives;
- identify ways of improving project selection, siting, planning, design, and implementation by avoiding, mitigating, or compensating for adverse environmental impacts and the anticipated adverse impacts from climate change; and
- ensure adaption measures to address adverse environmental impacts and anticipated adverse impacts from climate change throughout project implementation are in place and are consistent with green infrastructure and ecosystems approaches to adaptation as spelled out in the town plan.

Adaptation impact assessment: Adaptation plans and adaptation measures may be subject to a formal SEA in the case of large-scale adaptation plans involving many individual and separate adaptation actions or developments and/or an EIA for individual adaptation actions depending on the SEA and EIA requirements in the country of implementation.

Adaptation plans seek to enhance resilience and sustainability in an area and of infrastructure systems. So inherently, they should have a positive influence on environmental conditions and community welfare. Normally, it is major infrastructure development proposals and not adaptation plans that are subject to an EIA. Adaptation in one sector or area, however, may have unplanned effects on other sectors or areas—an adaptation impact assessment (AIA) seeks to ensure those unwanted effects are avoided or mitigated. It also seeks to improve adaptation design and processes.

An AIA is a form of EIA, following EIA tools and steps. It is a process whereby the potential environmental impacts of proposed adaptation plans are assessed. An AIA should identify significant impacts and measures to mitigate the impacts of adaptation measures to avoid irreversible damage to the environment and ensure sustainable use of natural resources. They take the form of a checklist of questions that allow for an adaptation plan or measure to be examined against green infrastructure and ecosystem principles and approaches.

The AIA process should provide information to decision makers and the public about the environmental, social, and economic implications of an adaptation plan so that improvements can be made. For example, it may suggest measures to prevent or reduce undesirable impacts through modifications to the design or process of construction within the adaptation plan.

Assessing the impacts of an adaptation plan should form part of the adaptation planning process. This typically involves a rapid impact assessment of the effects an adaptation plan would have on other areas, sectors, or communities. This assessment helps to ensure that negative impacts of adaptation measures are avoided or mitigated and positive impacts are enhanced or replicated.

An AIA should be conducted as part of preparing and mainstreaming an adaptation plan. A rapid assessment of the impact of the adaptation plan on other areas, sectors, or communities is an important step in developing effective adaptation measures. The assessment should identify both positive and negative effects of adaptation measures and how negative effects can be avoided or minimized and how the benefits can be enhanced and replicated.

An SEA or EIA may not necessarily be required for adaptation plans or adaptation measures so a stand-alone AIA may be the main opportunity for checking and improving adaptation plans.

3.3.7 Indicators of Green Performance (Sustainability and Resilience)

Keeping track of a town's progress in achieving its sustainability and resilience goals and strategies—and associated safeguards—requires a process and capacities for monitoring against a framework of indicators. There is a growing body of experience in planning and implementing what are termed "green growth strategies" and much work has gone into considering how best to monitor their implementation and performance.

Green growth indicator frameworks for towns focus on a few key dimensions. They include human well-being, resource efficiency and productivity, economic transformation, and maintenance of environmental quality and natural capital.

Green growth strategies for Mekong towns require closer attention to indicators that explicitly address inequality, access to basic ecosystem services, and human capital investments (including traditional knowledge); urbanization patterns and infrastructure development; governance (transparency, accountability, and inclusiveness); resilience; and a sector perspective (including, in particular, agriculture).

Several indicators are well-known and widely accepted and for which data are available, while others require further definition and investment for harmonization of methodology and data collection. Government agencies and businesses need to define green growth indicators that address their particular circumstances and to adapt them to priority economic sectors and specific geographic circumstances.

Table 3.4: Most Common Environmental Topics in Urban Indicator Sets

Theme	Common Sustainability Indicator Topic
Land Use	• Size and growth of built-up area • Amounts and accessibility of public green space and open space
Urban Air	• Frequency of exceeding air quality standards • Emission of air pollution by source
Water Use	• Water consumption per capita • Connection rates to the supply network, services interruptions, and quality of drinking water
Urban Water Quality	• Connection rates to wastewater treatment and degree of treatment • Bathing water quality
Waste Management	• Generation and disposal of municipal solid waste • Recycling rates
Transport and Traffic	• Modal split • Network length of public transport systems
Climate Change and Energy	• Carbon emissions • Intensity of energy and electricity consumption by sector
Environmental Health	• Number of residents exposed to noise

Source: Organisation for Economic Co-operation and Development (OECD). 2011. *Urban Environmental Indicators for Green Cities: A Tentative Indicator Set*. Working Party on Environmental Indicators, ENV/EPOC/WPEI (2011) 6. Paris.

The Organisation for Economic Co-operation and Development (OECD) has reviewed the most common environmental indicators used in member country towns (Table 3.4). It found that the number of indicators for each topic varied greatly and that many were not expressed in a form which was readily measured. Also, responsibility for monitoring and the linkages with urban planning and development were weak.

The review found that issues relating to natural systems and to climate change in urban areas were not clearly expressed in indicators and rarely monitored and used to shape town master plans. In response, the OECD has developed a tentative set of indicators for countries organized around key sectors and policy issues or areas of intervention (Table 3.5). The new indicator framework gives much greater emphasis to ecological sustainability and quality of life with five main categories: four related

Table 3.5: Organisation for Economic Co-Operation and Development National Level Green Growth Indicators

Indicator Groups	Topics Covered
Environmental and Resource Productivity	• Carbon and energy productivity • Resource productivity • Multifactor productivity
Natural Asset Base	• Renewable stocks: water, forests, fish resources • Nonrenewable stocks: mineral resources • Biodiversity and ecosystems
Environmental Dimension of Quality of Life	• Environmental health and risks • Environmental services and amenities
Economic Opportunities and Policy Responses	• Environmental goods and services • Technology and innovation • International financial flows • Prices and transfers • Skills and training • Regulations and management approaches
Socioeconomic Context and Characteristics of Growth	• Economic growth and structure • Productivity and trade • Labor markets, education, and income • Sociodemographic patterns

Source: Organisation for Economic Co-operation and Development (OECD). 2011. *Towards Green Growth: Monitoring Progress*. OECD Green Growth Studies. Paris.

to the environment and the fifth providing the socioeconomic and growth context.

Those national indicators for the five sets need to be expressed in more practical terms for towns, so that, for example, the focus on environmental and resource productivity at the national level translates into measures of energy and resource use efficiency for a town. National indicators relating to the natural asset base become indicators relating to environmental pressures, such as consumption of energy, water, and undeveloped land. The environmental dimensions of quality of life translate into urban residents' health and access to basic services. Economic opportunities and policy responses are measured by the strength in production of green goods and services as well as the application of natural resource fees and charges. The work resulted in the definition of 80 indicators within those five fields for application and testing in towns and cities.

The intent of the OECD town green growth indicator framework is to foster economic growth and development through activities to promote ecological sustainability and resilience. They are a starting point for Mekong cities and towns which need to develop modest frameworks to be applied on a phased basis as capacities increase—the key need being to establish feedback mechanisms to influence planning and development decisions.

In Asia, the use of green growth indicators at the city level is in a pilot phase. Most countries are focusing on national frameworks. For example, the Republic of Korea was the first country to declare low-carbon green growth as a national vision and strategy in 2008. Subsequently, it set up a comprehensive institutional and legal framework to implement the vision and strategy. Statistics Korea selected 30 indicators to assess policy performance and the implementation of green growth based on three main criteria: policy relevance, analytical soundness, and data availability. The framework of indicators and the results of the assessment are presented in Figure 3.27.[48]

This framework has yet to be translated to indicators that would be of practical use to towns. The first priority of Mekong town is to start to promote and act on the green infrastructure principles in urban planning set out early in this chapter. They need to be expressed in terms of town master plans, zoning schemes, and development control standards and safeguards. They need to be applied to the way infrastructure is designed and managed and to the way development projects are reviewed. Progressively, a monitoring framework of the kind proposed by the OEDC can be introduced to measure how well Mekong towns are performing against their new green development strategic objectives.

48 United Nations Economic and Social Commission for Asia and the Pacific. 2013. *Green Growth Indicators: A Practical Approach for Asia and the Pacific*. ST/ESCAP/2674. Bangkok.

Figure 3.27: Green Growth Indicators in the Republic of Korea

3 Sectors	10 Policy Direction-Setting	Green Growth Indicators	2005~2009	
			Recent Trend*	Assessment
Climate Change Responses and Energy Self-reliance	Effective reduction of GHG emissions	GHG emissions per unit of GDP	↘ ↗	☀
		Total GHG emissions	↗	🌧
		GHG absorption by forests	↗	☀
	Enhancing energy self-reliance for post petroleum paradigm	Energy consumption per unit of GDP	↘ ↗	☀
		Share of self-development of oil and gas	↗	☀
		Share of new and renewable energy	↗	☀
	Enhancing climate change responses	Self-sufficiency rate of food	↘ ↗	☁
		Accuracy of rainfall forecast	↗ ↘	☀
		Government budget dedicated to disaster prevention	↗	☀
Creating New Growth Engine	Planning green technology development for growth engine	Share of green R&D in government R&D expenditures	↗	☀
		Share of GDP dedicated to total R&D expenditures	↗	☀
		Number of international patent applications	↗	☀
	Greening industries and fostering green industries	Domestic material consumption per unit of GDP	↘	☀
		Share of environmental industry sales	↗	☀
		New and renewable energy industries	↗	☀
	Enhancing industrial structures	Share of service industries VA	↗ ↘	☁
		Share of knowledge intensive industries VA	↗	☀
		Share of Information and Communications industries VA	↗	☀
	Forming foundation for green economy	Government-purchased GHG reduction	↗	☀
		Number of ISO14001-certified businesses	↗	☀
		Share of environmental taxes in overall revenues	↘ ↗	☁
Improving Quality of Life and Enhancing National Status	Creating green territory & transportation	Urban green space per capita	↗	☀
		Share of public passenger transportation	↗ ↘	☀
		Share of GDP dedicated to environmental protection expenditures	↗	☀
	Green revolution in life	Household energy consumption per capita	↘ ↗	☀
		Municipal water use per capita	↘	☀
		Municipal waste generation per capita	↗ ↘	🌧
	Becoming a role model nation of green growth	GHG reduction certification under CDM	↗	☀
		Share of ODA in GNI	↘ ↗	☁
		Share of green ODA in ODA	↗	☀

* Marked as a small arrow in case that a recent indicator is out of existing trend.

CDM = Clean Development Mechanism, GDP = gross domestic product, GHG = greenhouse gas, GNI = gross national income, ODA = official development assistance, R&D = research and development, VA = value added.

Source: Statistics Korea. 2012. *Korea's Green Growth Based on OECD Green Growth Indicators*. Seoul. http://kostat.go.kr/koreasGreenGrowth/EBook.htm (accessed 10 November 2013)

3.4 Conclusions

Urban planning presents a vehicle for delivering resilience and sustainability in towns of the GMS. Urban planning encompasses a wide range of issues, from broad-scale environmental protection measures to individual site design and architectural detailing. Therefore, it has potential to influence outcomes at multiple stages and levels of the development process.

Within the GMS context, there are considerable opportunities to strengthen urban planning processes. For many countries, provinces, and towns in the region, the use of development safeguards in the manner advocated in this volume is largely uncharted territory and would require considerable resources and training to deliver effectively. Yet, more concerted work on initiating and implementing them is needed throughout the region.

In the short term, Mekong towns need to think critically about their existing spatial zoning plans and incorporate basic measures which will build in climate resilience and sustainability, such as

- identifying areas vulnerable to climate threats (including using participatory mapping) and determining whether any changes to land use zoning are required in response;
- strengthening how zoning can influence development through the preparation of a clearly defined purpose and use table for each zone;
- identifying those natural systems throughout the town and surrounding areas which contribute to climate resilience and ensuring they are protected in the land-use zoning plan; and
- promoting the use of green infrastructure in new development projects.

In Viet Nam, for example, there is already a process in place for town master plans to be reviewed every 5 years. It is therefore important that any results and recommendations that might result from a vulnerability assessment are fed into this process so that changes can be incorporated into future updates.

Readers are encouraged to reflect on the ideas presented here and begin to put them into practice in their own town planning and development processes.

3.5 Additional Reading

Readers may also find the following materials useful:

Asian Development Bank (ADB). 2012. *Green Growth, Resources and Resilience: Environmental Sustainability in Asia and the Pacific*. United Nations and Asian Development Bank publication ST/ESCAP/2600, RPT124260. Bangkok. http://www.adb.org/sites/default/files/publication/29567/green-growth-resources-resilience.pdf

ADB. 2014. Enabling Green Cities: An Operational Framework for Integrated Urban Development in Southeast Asia. *ADB Southeast Asia Working Papers Series*, No. 9. Manila.

Council for Scientific and Industrial Research (CSIR). 1996. *Strategic Environmental Assessment (SEA): A Primer.* CSIR Report ENV/S-RR 96001. Stellenbosch, South Africa.

Department of Environmental Affairs and Tourism (DEAT). 2004. *Strategic Environmental Assessment, Integrated Environmental Management, Information Series 10*. Pretoria.

B. Doberstein. 2003. Environmental Capacity-Building in a Transitional Economy: The Emergence of EIA Capacity in Viet Nam. *Impact Assessment and Project Appraisal* 21(1): 25–42.

ICEM – International Centre for Environmental Management. 2010. *MRC Strategic Environmental Assessment (SEA) of Hydropower on the Mekong Mainstream: Summary of the Final Report*. Ha Noi, Viet Nam.

ICEM. 2013. *Climate Change Adaptation Methodology: Infrastructure Guide.* Ha Noi, Viet Nam.

Institute for Social and Environmental Transition (ISET). 2011. *Catalyzing Urban Climate Resilience.* Boulder, CO. http://www.acccrn.org/sites/default/files/documents/ISET_CatalyzingUrbanResilience_ allchapters.pdf

L.H. Nam. 2010. Development of EIA System in Viet Nam 1993 –2010. Presentation at the 3rd Meeting of Signatories to SEA Protocol and 14th Meeting of Working Group on EIA, 22–26 November, Geneva, Switzerland. Agency for

EIA and Appraisal, Vietnam Environment Administration, Ministry of Natural Resources and Environment, Viet Nam.

Open Development Cambodia (ODC). Environmental Law and Environmental Impact Assessments. http://www.opendevelopmentcambodia.net/briefing/eia/ (last updated 19 September 2014).

United Nations Department of Economic and Social Affairs (UNDESA). 2012. *Shanghai Manual – A Guide for Sustainable Urban Development in the 21st Century*. Shanghai, People's Republic of China. http://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=633&menu=35

United Nations Human Settlements Programme (UN-Habitat). 2014. *Planning for Climate Change: Guide – A Strategic, Values-Based Approach for Urban Planners*. Nairobi. http://mirror.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3530&AspxAutoDetectCookieSupport=1

S. Wayakone and I. Makoto. 2013. Evaluation of the Environmental Impacts Assessment (EIA) System in Lao PDR. *Journal of Environmental Protection* 3(12): 1655–1670.

World Bank. 2011. *Guide to Climate Change Adaptation in Cities*. Washington, DC. http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1318995974398/GuideClimChangeAdaptCities.pdf

World Bank. 2013. *Energizing Green Cities in Southeast Asia: Applying Sustainable Urban Energy and Emissions Planning*. Washington, DC. http:// dx.doi.org/10.1596/978-0-8213-9837-1

Chapter 4

Vulnerability Assessment and Adaptation Planning Guide for Building Resilient Mekong Towns

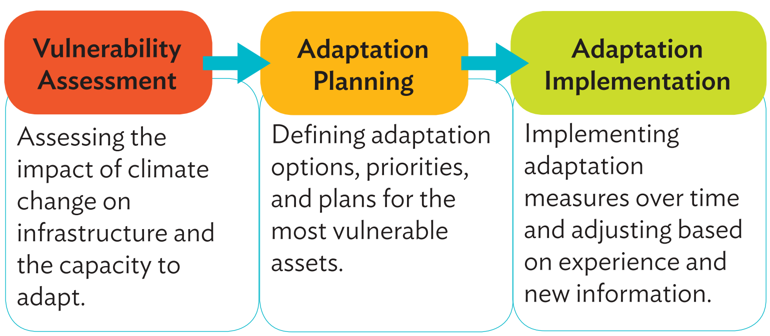
4.1 Introduction

This chapter lays out a step-by-step process for readers to assess vulnerabilities in their town and to plan and implement ways of adapting to those vulnerabilities. The goal is to increase resilience to climate change and other impacts. Whether working with smallholder farmers or sophisticated engineers, the process is the same. Though there is much to gain from going into the field, the process can also be completed by a single officer at a desk.

The chapter includes templates that you can fill out in the office or in the field. As few or as many as necessary ca be used to get a clear picture. Once you have recorded the information in the templates, the data can be transferred to the relevant matrix to help with ranking and prioritization. The templates and data will also add legitimacy to plans when dealing with decision makers.

It is possible for a single person to complete the process outlined in the chapter. However, if you are working with a team of practitioners, it is useful to consider including team members from a variety of technical backgrounds and stakeholder groups. The importance of coordination in planning, project design, and implementation increases as you move through the process, so there is value in creating a team with that coordination in mind.

Figure 4.1: Vulnerability Assessment and Adaptation Process



Source: ADB and ICEM.

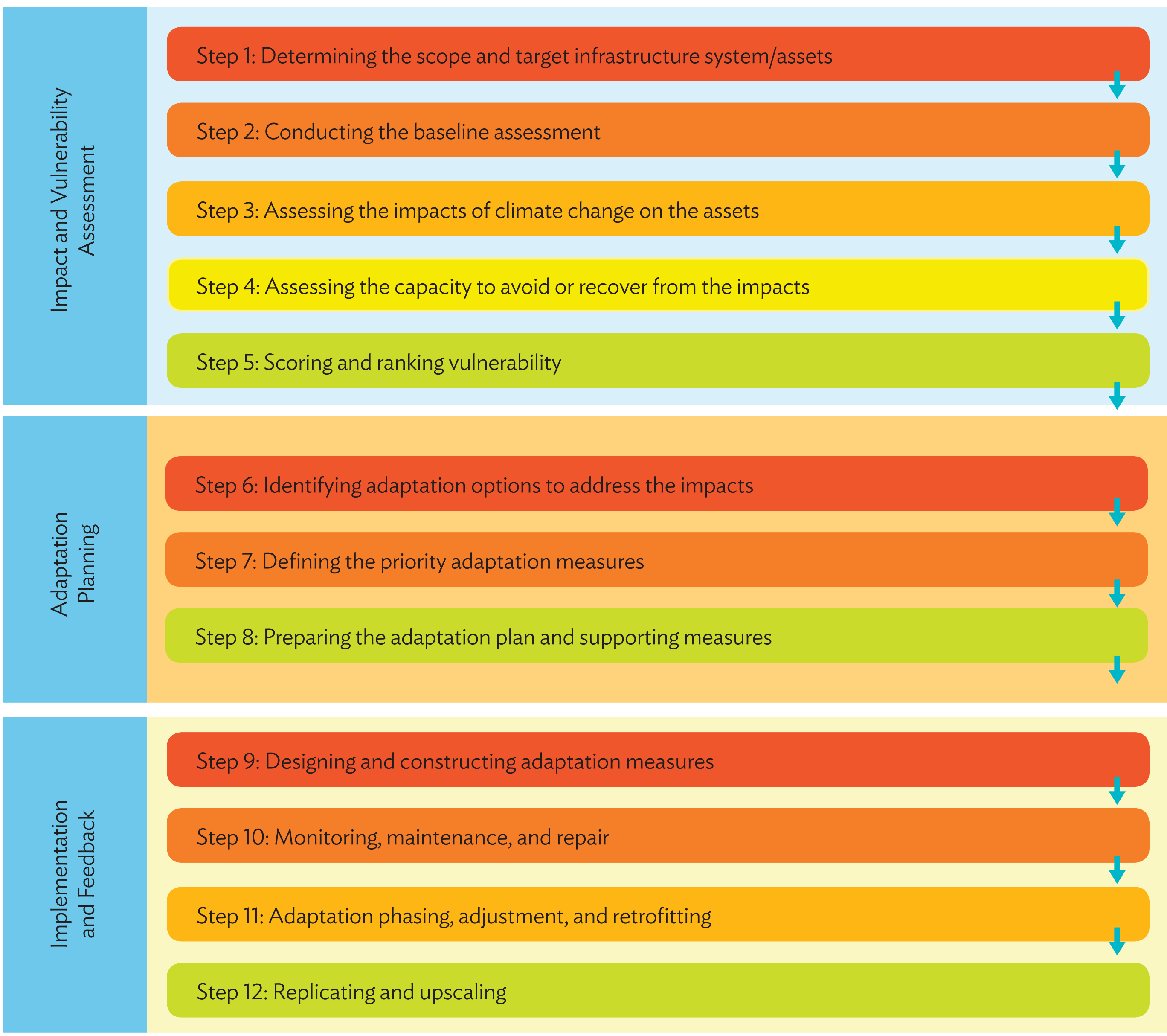
Who Will Find This Guide Useful?

It is also important to keep in mind that this guide includes two streams of activity: process and tools. The process includes each of the vulnerability assessment and adaptation steps from scoping through to implementation and replication. Tools are the activities you will use to gather the data and information necessary to complete each step. The number of tools you include will vary depending on the size of your target system and team. No matter how many tools you employ, the process will remain the same; you can use the steps as guideposts to keep you and your team on track.

Notes
Notes will appear in light blue boxes. Notes include experience, expertise, and advice that can help expand your understanding of the process.

Tools, Methods, and/or Inputs
Tools, Methods, and/or Inputs will be separated into blue boxes like this. The information in these boxes will help add depth to your process.

4.2 Vulnerability Assessment and Adaptation Steps



Source: ADB and ICEM.

4.3 Impact and Vulnerability Assessment

The impact and vulnerability assessment phase consists of five main steps. Each will help you understand and document the impacts of climate change threats and opportunities on existing and planned infrastructure (Figure 4.2).

Step 1: Determining the Scope and Target Infrastructure Assets

The first step in any planning process is to set the boundaries or scope of what is being assessed. No one organization can address everything, so it is important to define boundaries to focus your resources and energy. Scoping can be done by one practitioner or by a team and can be completed in the office. It is best that all stakeholders agree on the scope of the assessment; otherwise, misunderstandings can arise. Scoping tends to be an ongoing process. As you learn more through your vulnerability assessment and adaptation planning, or as more details come to light through your work on the project, you may find that you need to adjust your scope.

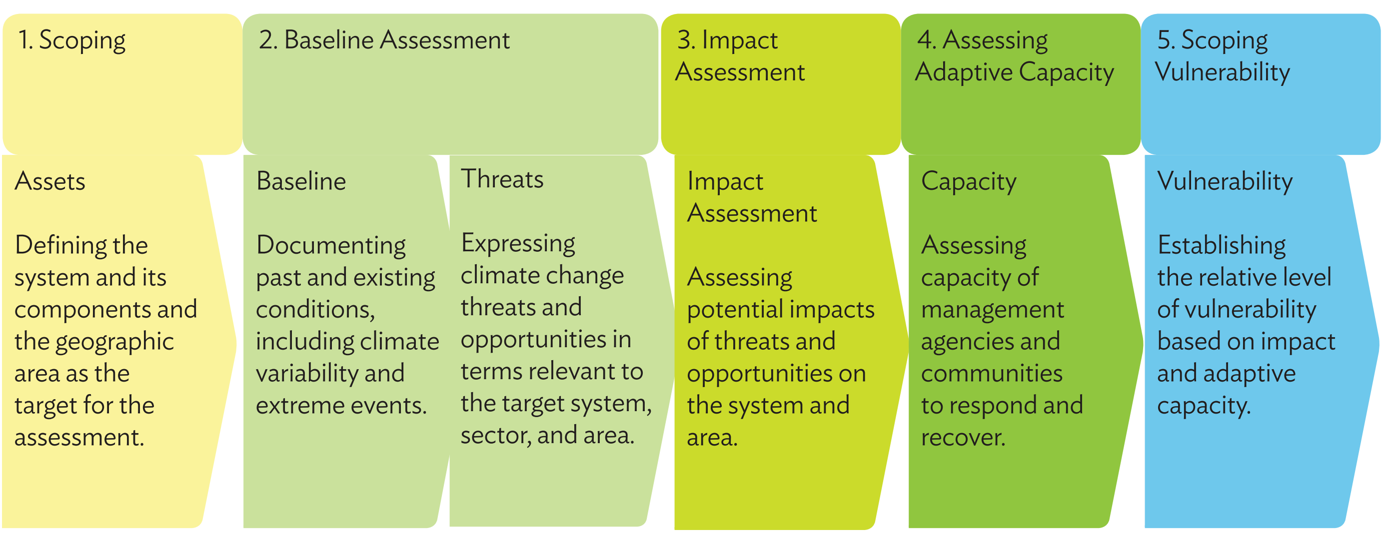
Scoping relates to a range of variables including: **The infrastructure asset or system under focus and its components – what asset or component(s) is to be assessed?** For example, an irrigation system is made up of many parts—the catchment, water intake, sediment trap, distribution canals or piping, pumping facilities, and command area. Climate change will affect each of the components differently with implications for system effectiveness. All need to be included in the assessment.

The linked assets which influence the effective functioning of the target system – what other assets need to be covered as part of the target system? For example, a floodgate operation depends on the condition of the canal system leading to and away from it, on the condition of the dike slopes in which the gate is embedded, and on surrounding land uses. All these would be impacted by climate change with knock-on effects on the gate.

The geographic area – what geographic boundary(ies) should be defined for the assessment? A problem with infrastructure design and management is that it can be too narrowly focused and not recognize that it is part of a wider system which can shape effectiveness of design and operation. For example, drainage culverts under roads can be washed out if their design is not sufficient for the catchment area, especially if the watershed is degraded or road embankments unstable.

The stakeholders to be involved – what line agencies and community groups need to take part in the assessment and adaptation planning? The assessment can be undertaken as an in-house activity or one that is inclusive of affected stakeholders, such as other

Figure 4.2: The Impact and Vulnerability Assessment Process



Source: ADB and ICEM.

line agencies and local residents. Ideally, stakeholders should be involved at various stages in the assessment through field meetings, public hearings, and workshops. The scope for participation may depend on the budget and resources available to the assessment team. At a minimum, the groups who need to be involved in the implementation of adaptation measures should be consulted and kept informed during the assessment.

The time period covered – what past and future time period should be considered? In many towns, there is little information on climate change projections affecting their area or the information they have is not readily translated into practical guidance for adaptation. In such situations, it is best to document and assess the impacts of past extreme events—and regular seasonable events—on the target area and assets. When considering climate change, how far out into the future should projections go and other influences in that time period need to be considered.

To help keep you and your team on track, be sure to save your scoping analysis and decisions in a scoping report. A simple table outlining your target infrastructure system, the geographic area, and any additional scoping issues such as the need to consider overall watershed influences will suffice. Saving your scope in a document helps you to remember how and why scoping decisions were made and to revise your scope when necessary.

Defining the target infrastructure "system": Once you have defined the initial scope of the assessment, it is time to create a more detailed description of your target infrastructure system.

The system description should include

- details of the main infrastructure components (e.g., an irrigation system might include the water source and catchment, sediment trap, pumps, canals, culverts, distribution pipes, and command area);
- services provided by the system's assets;
- involvement of local communities in management and maintenance; and
- the natural and social system components linked to the asset and affected by its condition and resilience (e.g., agricultural fields, school buildings, market, and other infrastructure systems).

For some sectors, defining the target infrastructure system and its components is not straightforward. It requires interpretation and judgments by the assessment team. For example, a local feeder road that connects town A and town B may be 100 kilometers long. The entire road might be identified as the target infrastructure system, and all of its culverts, bridges, and associated slope and drainage protection measures would be its elements. Or the assessment team might decide to choose a short section of the road that has proved to be especially vulnerable to past extreme events such as floods and landslides. In that case, the "system" would be the road section and the few elements within that section. Assessment teams will need to carefully define the boundaries of the assessment and the components of special interest.

Defining the infrastructure system objectives: What does your target infrastructure system do? Once you have identified your system, it is important to establish its objective or purpose and how each component contributes to that objective.

For example, a small irrigation system might deliver about 0.9 liters per second per hectare of water to a command area of 300 hectares. Each element will have its own role in contributing to this overall objective which needs to be described, such as how the sediment trap objective is to keep sediment from entering and blocking the distribution piping and canals.

In your scoping report, write down your target infrastructure system's main objective. Then list each of the components that are part of that system and how each one contributes to that objective.

Including these details within the scoping report will help you remember why particular scoping decisions were made and will help you define vulnerabilities and adaptation measures in subsequent steps.

A system or component may have more than one objective. Taking the time to define primary and secondary objectives will also help you draft a more thorough vulnerability assessment and create a more effective adaptation plan.

The following suggests guidance for defining the scope of the vulnerability assessment:

Table 4.1: Guidance for Defining the Scope of the Vulnerability Assessment

Infrastructure asset or system under focus:
• Existing projects vulnerable to past climate variability or extreme events. • Infrastructure of strategic importance to the nation, town, or local community (e.g., road links to market or airport). • Poor quality or damaged infrastructure which needs to be replaced or repaired (e.g., repeatedly damaged by floods). • New infrastructure of strategic importance or affecting a large area or number of people • Representative of an infrastructure category and therefore valuable as a pilot for replication.
Linked assets influencing the target system:
• Other assets upstream, downstream, or near the target system which influence its operation (e.g., drainage corridor, canal or river banks, dike, agriculture, or residential uses). • Degraded assets already affecting the condition of the area or existing infrastructure. • Assets which will be impacted by the proposed infrastructure system.
Geographic area:
• Area served by the target system (e.g., irrigation command area). • Area with potential to affect the target system. • Area exposed to past extreme events and projected climate change threat. • Area with potential as an accessible and representative demonstration for replication.
Stakeholders to be involved:
• People potentially affected by the existing or proposed infrastructure system. • Area where communities are committed to participate in adaptation management, monitoring, and repair. • Line agencies which will need to have a role in adaptation implementation or which will need to provide essential information or approvals.
Time period covered:
• Historical record of temperature and rainfall as validation period for climate change projections. • Time of past, more extreme events affecting the target area. • Time slice for climate change projections (e.g., 2030, 2050). • Lifetime of existing or proposed target infrastructure.

Step 2: Conducting the Baseline Assessment

The baseline assessment of the target infrastructure system provides a strong foundation for the entire vulnerability assessment and adaptation process. It establishes the evidence base, justification, and credibility for all the judgments and decisions that follow. The baseline assessment step can be the most time- and resource-consuming of the vulnerability assessment process. Once completed, your baseline will describe the past and existing situation, trends, and drivers that affect the target systems and will provide an analysis of the changes to the system that will occur whether the climate changes or not (Figure 4.3).

Field assessment: To complete the baseline assessment, conduct a field visit to your target infrastructure system and complete the baseline assessment field template. Be detailed when you fill it out. The information you include will be used in subsequent steps in the process. The template is included as Appendix 1 in this chapter.

Your assessment will include the following:

- A short description of your target infrastructure system, which you can pull from your scoping documents.
- A description of the watershed in which the system functions.
- A description of the system's location and any human-made or geographical attributes.
- A description of the state of the infrastructure (e.g., new, functioning, damaged, or under repair).
- Descriptions of any human-made elements in the system, including photos and illustrations where possible.
- A description of known past extreme events that impacted the system.
- Any adaptation responses to those extreme events, including recovery efforts.

- Expert judgment on the design and form of those human-made elements to withstand extreme events.

Creating a climate threat profile: Once you have collected all of the necessary information on past extreme events and the stability of the system, you can begin to apply climate change projections and variability to see how it may impact on your system and its surrounding area.

Preparing a climate change threat profile for the target area will be based on understanding and documenting the nature and impacts of past extreme events, for example, past storms, floods, or droughts.

Tools, Methods, and/or Inputs

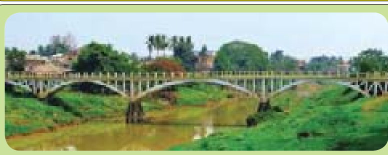
It is often the case that information on past extreme events, such as floods and drought, and the design details of existing strategic infrastructure is not available. Consider consulting with local people, experts, and government officials to fill in your knowledge gaps.

You may also engage in participatory mapping exercises to glean the necessary information. See Appendix 8 for more information on participatory mapping.

Figure 4.3: Baseline Assessment Components

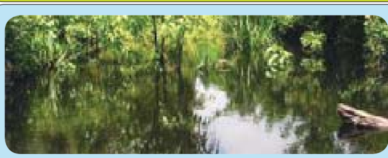
Asset inventory and priority setting
- Provide a description of the existing and proposed assets in the sector or area
- Describe the condition of the infrastructure systems

Past climate variability and extreme events
- Describe the most significant past extreme events affecting the sector or area
- Describe the impacts of that event

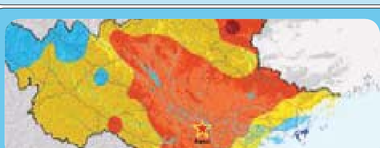


Adaptation audit of past protection measures
- Describe measures taken to learn from past from past extreme events
- Assess the effectiveness of those past "adaptation measures"

Socioeconomic status and trends assessment
- Identify stakeholder "users" and affected communities
- Describe socioeconomic trends of relevance to the asset



Natural systems status and trends
- Describe natural systems that affect the asset (e.g., catchments, rivers)
- Describe the status and trends in those systems of relevance to the system



Climate change threat and opportunities profile
- Gather all existing climate change projections relating to the area
- If feasible, conduct fresh climate change and hydrological modeling

Sources: (from top) Café Science Dundee. www.cafesciencedundee.co.uk; Armadillo Projections. armadilloprojections.files.wordpress.com; Lotzacurlscambodia. 2.bp.blogspot.com; and Malaysia Wetlands. archive.wetlands.org

To determine future climate threats, you will need to consult your national hydrometeorology agency or institute for downscaled climate change and hydrological modeling for your area. If these are not available, then conclusions drawn from national projections on likely trends and ranges in changes affecting the target area will be adequate for the local vulnerability assessment.

To help keep track of all of these new data, note the following in the vulnerability assessment matrix (Appendix 3):

- the particular change to the climate,
- the elements and/or system that this change will impact,
- how that impact will occur (the threat), and
- the projection or modeling that you used to determine this result.

This matrix acts as a record of your assessment and helps guide the plans you will draft based on your assessment. It can be used to add weight and legitimacy to your decisions when dealing with decision makers.

Notes

It is not necessary to cover all climate change parameters. Focus on those which are most relevant to the target infrastructure system and its surrounding area.

Some changes in climate may also prove beneficial. For example, increased rainfall may improve crop yields in a dry agricultural area. Any assessment should take care to consider parameters which might have positive effects.

Tools, Methods, and/or Inputs

If you have the time and resources, you can conduct new climate change and hydrological modeling to ensure you have the most up-to-date information.

Figure 4.4: Examples of Climate Change Threats

Flooding (e.g., fluvial and flash floods) and increased precipitation: threat of physical damage from intense flow and inundation, increased destabilization of nearby land, erosion, landslides

Storms, strong winds, hail, and lightning: physical damage to natural and built assets (e.g., houses, crops)

Drought: reduced water availability, sedimentation of canals, threat to productive crops, animal loss, drying/ movement of soil/foundations leading to damaged structures, dust storms

Low temperatures, frosts, cold snaps: crop losses, animal losses, damage to built infrastructure (e.g., expansion of ice and loss of structural integrity)

Temperature range changes: loss of species that are unable to adapt to temperature changes

Heat waves: crop losses, forest fires, damage to physical infrastructure through heat expansion/cracking (e.g., pipes)

Source: ADB and ICEM.

Step 3: Assessing the Impacts of Climate Change on Your System

A vulnerability assessment matrix (Appendix 3) provides the framework for documenting the assessment results. Table 4.1 provides an example of a completed vulnerability assessment matrix for a small irrigation scheme. This matrix acts as a record of your assessment and is the basis for your adaptation planning. It can be used to add weight and legitimacy to your decisions when dealing with decision makers. Footnoting of reasons for various judgments made in each column of the matrix is a necessary part of building the case for your adaptation recommendations.

In the impact assessment, you determine the effects of the identified climate change threats on the target system by considering its exposure and sensitivity to them.

Table 4.2: Vulnerability Assessment Matrix

Example: Irrigation system with 68-hectare command area.
Major system components:
1. Concrete weir across river with scouring sluice gate
2. Gated off-take into main canal 3.5 kilometers in length
3. Main canal concrete-lined for 270 meters across landslide zones and incorporating retaining wall over 15 meters
4. One aqueduct, two footbridges, and four division boxes to assist distribution of water
5. One inlet/outlet box to catch additional drainage flows from upstream into the main canal

Threat	Interpretation of Threat	Impact					
		Exposure	Sensitivity	Impact Level	Impact Summary		
Change and shift in regular climate	Interpretation of the threat for the system or area	refer to table			Written explanation of what the impact is, and why it was scored (very low to very high)	refer to table	
Increase in maximum temperature and evapotranspiration	• Increased crop water demand • Frost incidents decreased	1,2H	L	M	• Water required at intake slightly increased particularly for paddy land preparation • Second potato crops less susceptible to frost damage • Alternative cropping pattern could be introduced	M	M
Increased rainfall	• Precipitation increase during early and mid-monsoon period •No impact on infrastructure	3L	L	L	• Could reduce water demand from the stream during monsoon period • Little effect on crop production	H	L
Increased river flow (intake)	• Increases significantly during early monsoon	4M	M	M	• Little impact on crop production • Increased flow could damage system infrastructure	H	M
Change and shift in events							
Flash floods (intake)	• Increase in bed load during flash floods – might block or damage intake • Stream bed mostly rock so little chance of degradation	5H	6H	H	• Blockage of intake, leading to temporary restriction of irrigation water • Sediment entering main canal will restrict its carrying capacity	7M	H
Flash floods (aqueduct)	• Increased flood flows • Scouring of cross drainage channel bed and pier foundations	H	8L	M	• Canal water unable to be supplied to downstream areas	9L	M
Storms	• Increased rainfall intensity over cropped area	H	10L	M	• Crops could be damaged and difficult to harvest • Level terraces will absorb increased rainfall • Terrace banks protected with soybean. Only vulnerable at start of monsoon	H	M
Drought	• Reduction of water availability in stream during late dry season and delay of monsoon flows	11M	M	M	• Could affect yields for the second potato crop and preparation for paddy crops • An alternative to the second potato crop could be introduced	12M	M
Landslides	• Where main canal passes crosses steeper land • Adjacent to streams or aqueduct structure	M	13H	M	•Washout of main canal leading to loss of water supply to full irrigated area (there is no command area above this location, so if this one is damaged the whole system is at risk	14L	M

1 Evapotranspiration increases throughout the year with total demand over the paddy season May–October increasing by up to 380 millimeters.

2 Minimum temperature increase of up to 3°C in March–April and frost probability in February reduced to only 5%. Less likelihood of damage to second potato crop.

3 Monthly average daily rainfall increases slightly during early monsoon period (maximum of 5 millimeters in July). However, it decreases post monsoon and during winter periods.

4 River flow increases by about 80% during May–July. A 20-year return period flow could occur every 2 years. The rest of the year, little change.

5 100-year return period flood could increase in size by up to 100%. Rainfall intensity will increase by 60%. Catchment area mostly forest.

6 Well-designed weir across stream with scouring sluice. No spindle to adjust intake gate height to prevent sediment entering the main canal during flood flows.

7 Sediments collected in main canal can be manually shifted relatively easy with local labor.

8 Gabions protecting cross-channel bed and channel has adequate capacity for increased flows. New piers provided to support aqueduct.

9 Farmers cannot redesign or repair without technical assistance:
- Cost $10,000 to recently rehabilitate.
- As recently improved. It will have low priority for future funding.

10 Wind damage to traditional rice crops only from storms prior to harvesting.

11 River flows reduced by 50% with negligible flows predicted in March/April.

12 Department of Agriculture providing agricultural extension services in the area.

13 Remedial works already undertaken in sensitive areas to support the main canal against landslides:
- No catch drainage above landslide areas to reduce water logging of upper slopes.

14 Farmers cannot repair damage by themselves:
- As a recently improved system, it will have a low priority for funding.

Source: Author.

Exposure is the extent to which a system is exposed to the climate change threat. Sensitivity is the degree to which a system will be affected by, or be responsive to, the exposure. The potential impact is a function of the level of exposure to climate change threats, and the **sensitivity** of the target assets or system to that exposure.

Exposure to a threat depends on the following:
- **Location** of the system with respect to the threat, for example, distance from the flood zone or river bank
- **Threat intensity**, for example, how deep and fast flowing is the floodwater, how heavy is the rain, how strong is the wind?
- **Frequency,** for example, the “return period” of large, destructive floods – every 5 years, every 10 years?
- **Duration,** for example, the flood threat lasts for 1 day, floodwaters remain for 5 days.

Judgments based on the information on past extreme events need to be adjusted to account for the expected effect of climate change (e.g., increases in frequency and intensity of flood events).

The rating system for exposure and other parameters uses a score from *very low* to *very high*. Rate the system and each component using your expert judgment and scientific data:

Sensitivity: The next step in the impact assessment is to rate the sensitivity. Sensitivity is the degree to which exposure to a threat will negatively affect the operation of the system.

Sensitivity may be influenced by the following:
- **Integrity of design:** Is the asset designed robustly and with features to mitigate against threats? For example, powered irrigation system to protect crops against drought; crop varieties resilient to frost/drought; drainage around buildings, roads, and fields; buildings raised above the flood line.
- **Integrity of materials and construction:** Does the asset contain strong, durable, appropriate materials in light of the expected threats? For example, buildings constructed of bamboo or concrete, unsealed.
- **Geotechnical character:** For example, bank stability, soil condition, drainage capacity and volumes, vegetation, and existing

Exposure Scale

Very Low	Low	Medium	High	Very High
very low intensity/ severity and/or very infrequent and/or very short duration	low intensity/ severity and/or infrequent and/or short duration	medium intensity/ severity and/or average recurrence/ average duration	high intensity/ severity and/or frequent and/or long duration	very high intensity/ severity and/or very frequent and/or very long duration

Sensitivity Scale

Very Low	Low	Medium	High	Very High
very good integrity of design, materials, and construction	Good integrity of design, materials, and construction	average integrity of design, materials, and construction	poor integrity of design, materials, and construction	very poor integrity of design, materials, and construction

stability measures. May require more formal geotechnical assessment or visual inspection.

Taking into account these variables, rate your system sensitivity from *very low* to *very high*:

Impact: Assessing impact is the most important stage of the vulnerability assessment. Use the impact scoring matrix to score and document your results carefully on the impacts column of the vulnerability assessment matrix (Appendix 3). Insert detailed footnotes explaining your choices in the matrix, as these will come in handy in the next step.

Impact = Exposure **X** Sensitivity. To determine the impact rating for your system, take your results from your exposure and sensitivity scoring and line them up along the impact scoring matrix. For example, a system element that is assessed as having *medium exposure* and *low sensitivity* will generate an impact rating of *medium*.

Impact Scoring Matrix

Sensitivity of system to climate threat \ Exposure of system to climate threat	Very Low	Low	Medium	High	Very High
Very High	Medium	Medium	High	Very High	Very High
High	Low	Medium	Medium	High	Very High
Medium	Low	Medium	Medium	High	Very High
Low	Low	Low	Medium	Medium	High
Very Low	Very Low	Low	Low	Medium	High

The detailed impacts you list in the vulnerability assessment matrix will help define your adaptation responses in the next steps. When describing Impacts, remember there are of two kinds: (i) direct impacts, like a damaged road, and (ii) indirect impacts, where that damaged road prevents produce from reaching the market or children from getting to school. Listing both direct and indirect impacts will help you define adaptation options that address the most significant of both kinds of impacts.

Step 4: Assessing the Capacity to Avoid or Recover from the Impacts

Adaptive capacity: Once you have completed the impact assessment, you must assess the capacity of the managing organization or community to prepare for and respond to the impacts. You will include the results of this assessment in the same vulnerability assessment matrix that you worked with in Step 3. This step can be completed from your office.

To complete the assessment, take each of the impacts you listed and consider them against the appropriate factors in Table 4.3. Using these considerations, rank the organization's adaptive capacity on a scale from *very low* to *very high*. List your results in the vulnerability assessment matrix using footnotes to explain your scores.

This scale is an example of an organization delivering and/or managing the infrastructure system (e.g., a road, irrigation system, or water supply intake and pumping station).

Table 4.3: Factors to Consider When Assessing Adaptation Capacity

1. Crosscutting factors	2. Infrastructure
• The range of available deputation technologies such as bioengineering approaches. • Management and response systems in place. • Availability of relevant technical staff and knowledge. • Suitable financial resources to support climate change adaptation.	• Availability of physical resources for repair (e.g., materials and equipment). • Regularity of system maintenance. • Existence of backups in place (e.g., alternative routing for failed roads or bridges). • Presence of other infrastructure negatively affecting the system.
3. Natural Systems	**4. Social Systems**
• Condition and stability of watershed affecting the asset. • Riverbank slope stability. • Water quality (e.g., in the case of irrigation and water supply assets).	• Availability of insurance and other financial resources to respond to impacts. • Existence of “user groups” and other community arrangements. • Access to alternative services.

Source: ADB and ICEM.

Adaptive Capacity Scale

Very Low	Low	Medium	High	Very High
very limited institutional capactiy and no access to technical or financial resources	limited institutional capacity and limited access to techincal and financial resources	growing institutional capacity and access to technical or financial resources	sound institutional capacity and good access to technical and financial resources	exceptional institutional capacity and abundant access to technical and financial resources

Notes
It is not necessary to consider all impacts. The factors to consider will depend on the nature of your target system and the organizations involved in its operation. When assessing adaptation capacity of the responsible infrastructure department the most important factors are those of a cross cutting nature and those relating directly to the asset and its repair and/or construction.

When deciding on ratings for exposure, sensitivity, impact, and adaptive capacity, it is important to include justifications and explanations of your decisions in the vulnerability assessment matrix. Notes included in your matrix will help others understand the reasoning behind your scores and increase the credibility of your final rankings. Also, reasons given for the exposure and sensitivity scores help you complete the impacts summary column of the matrix (Appendix 3).

Tools, Methods, and/or Inputs
The information you need to assess adaptive capacity may not be readily available. Seek out information from the community and other experts to fill any knowledge gaps.

Step 5: Scoring and Ranking Vulnerability

The final vulnerability score is determined by considering the impact and adaptation capacity together. To do so, take the impact and adaptive capacity results of each of your threats and plot them on the vulnerability scoring matrix. Note your results in the vulnerability matrix.

An important point to keep in mind is that with increasing severity of impact, the vulnerability of the target infrastructure system increases. Adaptation capacity has the opposite effect; with increasing adaptive capacity, an infrastructure system would have decreasing vulnerability. The vulnerability scoring matrix takes that inverse relationship into account.

Vulnerability Scoring Matrix

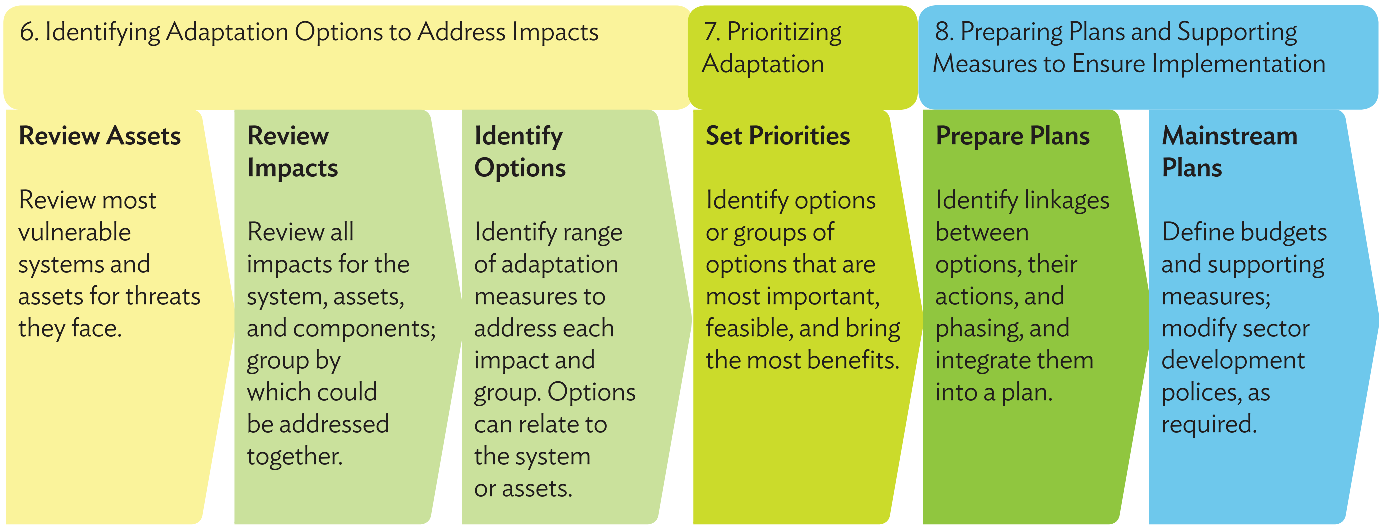
Adaptive Capacity \ Impact	Very Low Inconvenience (days)	Low Short disruption to system function (weeks)	Medium Medium disruption to system function (months)	High Long term damage to system, property (years)	Very High Loss of life, livelihood, or system integrity
Very Low Very limited institutional capacity and no financial resources	Medium	Medium	High	Very High	Very High
Low Limited institutional capacity and limited access to technical and financial resources	Low	Medium	Medium	High	Very High
Medium Growing institutional capacity and access to technical and financial resources	Low	Medium	Medium	High	Very High
High Sound institutional capacity and good access to technical and financial resources	Low	Low	Medium	Medium	High
Very High Exceptional institutional capacity and abundant access to technical and financial resources	Very Low	Low	Low	Medium	High

The aim of the adaptation planning process is to guide the preparation of an integrated adaptation plan to build resilience in the target infrastructure system or area that will ultimately be supported and funded.

Adaptation to climate change refers to actions taken by households, businesses, governments, and communities to respond to the potential impacts of climate change. It can include actions taken to prevent, avoid, or reduce the risks of those impacts (proactive adaptation), or in response to impacts as they happen (reactive adaptation). It can mean retrofitting and upgrading existing infrastructure and building adaptation measures into sector- and area-wide plans and into new infrastructure. Adaptation includes taking advantage of the opportunities that may arise due to climate change, as well as responding to negative impacts.

It involves developing a range of adaptation options for each of the main impacts you determined during your vulnerability assessment and then determining priorities for implementation that are built into an integrated adaptation plan. With limited resources, it is not possible or necessary to do everything at

Figure 4.5: Adaptation Planning Process



Source: ADB and ICEM.

once; choices must be made on what is feasible and necessary now and what can be left to later planning cycles.

Adaption planning has three main steps:
(i) Defining the options.
(ii) Setting priorities among them.
(iii) Preparing adaptation plans and integrating them into established development plans and budgets (Figure 4.5).

Similar to the vulnerability assessment phase, adaptation planning uses a matrix and a number of other tools to guide scoring. This adaptation planning matrix (Appendix 4) is applicable no matter what kind of target infrastructure system or area you are dealing with, whether it is a road or water supply scheme, or an urban settlement or river basin.

Your final adaptation plan does not need to follow the matrix outcomes precisely. Other factors may influence adaptation priorities. Also, in some cases, the matrix results may appear counterintuitive. If an adaptation measure is critical to the operation of an entire infrastructure system but only scores medium priority for adaptation because of its high cost, then the final plan should override the matrix result and stress its importance. This highlights the importance of using the vulnerability assessment and adaptation planning matrices as a guide to influence but not dictate the final decisions on adaptation priorities.

Notes
It is feasible to go directly from the vulnerability assessment phase to defining an adaptation plan without using the adaptation planning matrix. The matrix provides an additional set of tools to identify the most significant problems that need to be addressed and to choose which adaptation responses should receive attention in situations of scarce resources. Each team charged with taking climate change into account when preparing plans for areas or designing infrastructure systems needs to consider the level of effort and justification required in setting adaptation priorities. Completing the adaptation planning matrix gives you another tool that you can use to add legitimacy to your adaptation plan when communicating with decision makers.

4.4 Adaptation Planning

Step 6: Identifying Adaptation Options to Address Impacts

Reviewing the threats and impacts:
The adaptation planning phase focuses on the most vulnerable assets and areas identified during the vulnerability assessment. First, review the threats and impacts identified for the system elements that scored *high* or *very high* on the vulnerability scoring matrix. Transfer these impacts on to the adaptation planning matrix; you will be working with these impacts

throughout these steps. The intention is to confirm the vulnerability assessment findings and ensure that all the most serious impacts are addressed.

Identifying adaptation options: Adaptation options are shaped by

- existing conditions at the target location,
- the climate change threats,
- the potential impacts on the infrastructure systems being assessed, and
- the capacity of the system to recover from the impact.

Adaptation options fit within four scales:

1. Area-Wide Adaptation

The first response is to look broadly at the entire area where the target system is located. This may mean, for example, looking at the host town, commune, catchment, river basin, or protected area and thinking through an overall area-wide approach to adaptation. Setting a framework of broad principles for adaptation may help shape the more specific measures for the target system and its elements. It also promotes integration of adaptation measures across sectors and areas and seeks to avoid mistakes that could reduce resilience in other areas.

2. System-Wide Adaptation

The second response is to identify adaptation options for the target infrastructure system, whether that is an irrigation scheme, river embankments, or feeder road, etc.

3. System Component Adaptation

The third response is to determine the adaptation requirements for each of the key system components that you outlined in your scoping document. For example, if your target infrastructure system is a road, you may need a culvert bridge. A river dike system may require bioengineered slope stabilization.

4. Supporting and Facilitating Adaptation Measures

The fourth response is often overlooked because it can be the most complex and involve many authorities and stakeholders. To be effective, many of the measures defined for the area or system may require supporting actions by other sectors, areas, resource managers, or levels of government. It may involve establishing new decision-making and management structures. It may involve introducing new procedures like spatial planning and zoning for safeguards. It may involve more detailed modeling of hydrology to better inform infrastructure location and design. A comprehensive adaptation plan needs to be a combination of mutually reinforcing actions using natural, built, social, economic, and institutional systems.

At this stage, when filling out the adaptation planning matrix, list all options regardless of how feasible they seem. You will refine your list at a later stage. You do not need to develop detailed designs for your options yet, but it is important to establish certain guiding principles at the outset. In general, it is best to consider adaptation options that take wider ecological, social, and economic factors into account as early as possible. Green infrastructure options contribute to overall sustainability beyond just the target infrastructure system and should be implemented as much as possible.

Chapter 2 contains more than 25 green infrastructure techniques. Including solutions from the chapter will ensure that your list contains strong, viable, and sustainable adaptation options.

Table 4.4: Adaptation Planning Matrix

Threats	Impacts	Adaptation Options	Priority Adaptation		
Insert all high and very high threats, first for the system as a whole and then for each of the high and very high components.	Insert the impacts recorded for the high and very high threats (only consider direct impacts)	Listing of the adaptation options in addressing each of the most significant impacts – focus on structural and bioengineering options	Feasibility cost, skills, staff, equipment	Effectiveness how well does it avoid, reduce or eliminate the threat	Priority

Source: ADB and ICEM.

When listing your adaptation options, be sure to footnote how the action will modify vulnerability, either by minimizing exposure, reducing sensitivity, or building adaptive capacity.

Your main focus should be on defining adaptation measures for the target infrastructure system; supporting measures such as policy and institutional reforms can be an ongoing consideration once you move into more mature phases of the adaptation planning process.

Notes
It is important to draw from international, regional, and local experience to find out what has worked in building resilience to extremes in the past.

Reviewing international experience can expose planners to new approaches, technologies, materials, and even institutional arrangements and policies that have worked well in other countries.

Finally, to ensure best results, identify measures that fit within the mandate of your immediate stakeholders. Then progressively identify what others can do to reinforce your core measures and to promote their sustainability and replication.

Table 4.5 illustrates categories of adaptation options and the key actors responsible for implementation.

Tools, Methods, and/or Inputs
Identifying adaptation options requires the involvement of a cross-sector group of specialists as well as affected stakeholders. In most cases, adaptation will require action and commitment from local affected groups, so their involvement at each step should be facilitated. As in other phases of the process, the extent and nature of consultation will depend on resources available, urgency for action, and the level of decision making.

Table 4.5: Adaptation Option Categories and Examples

Adaptation Category	Specific Measures	Main Responsibility
Bioengineering Measures	• Flood protection: dike drainate system; flood storage reservoir; erosion protection; bridges; road culverts, etc. • Water storage (e.g., dams, tanks) for use during dry months • Reinforcing existing structures or building new ones to withstand severe estorms and wind	From district to national level government, can involve local user groups
Traditional local adaptation measures	• Bamboo stakes and vegetation in riverbanks • Maintenance of traditional water sources and water user groups • Use local natural mateirals and designs in construction of houses, rock walls, and windbreaks • Re-vegetating foredunes and mud flats with local native species and re-estabilishing mangroves to combat erosion • Maintaining fish traps and reviving community gardens that diversify livelihood options • Traditional seed storage facilities	Land owners, user groups, local govenrment level
Economic instruments	• Natural resource and land use taxes • Payments for ecosystems services • Grants and tax reductions • Conditions on licenses and permits	National or provincial government
Natural systems management	• Revegetation of watersheds • Rehabilitation of river embankments and floodplains • Establishing biodiversity corridors • Effective management of protected area network and buffer zones • Greening of urban areas • Agro-forestry practices to increase species complexity and stability • Water allocation systems to share limited water supplies during drought	National or provincial government with delegated responsibilities to user groups

continued on next page

Table continued

Social responses	• Resettlement programs • Livelihood and crop diversification • User groups for maintenance and management of facilities and resources • Seasonal and planned migration • Education and awareness programs	Local communities, national or provincial governments
Policies and regulations	• Zoning for development control (e.g., no major structures) • Regulatory requirements for structural integrity of buildings, material controls, floor height restrictions • Sector design standards (e.g., of culverts, materials, setbacks) • Urban zoning and safeguards • EIA and SEA provisions and tools which consider climate change	National or provincial government
Research and development	• Research into drought or saline-tolerant crops • New porous surface materials to allow for water penetration in urban areas • Tolerance levels and adaptive capacity in wild species and ecosystems	National or provincial government, institutes
Industrial responses	• Formation of local user groups for management and maintenance of infrastructure facilities • Structures for promoting partnerships with business and the community • Programs to integrate climate change within disaster risk management agencies • Creating inter-agency networks on climate change that encourage collaboration between organisations	National or provincial government

EIA = environmental impact assessment, SEA = strategic environmental assessment.

Source: ADB and ICEM.

Step 7: Defining the Priority Adaptation Measures

Fundamentally, adaptation planning is all about prioritizing. It is not possible or necessary to do everything at once. Some investments need to be made immediately or soon, while others can be left until more resources become available. Your first priorities should fit within available funds and address the most serious vulnerabilities in the systems and elements that are most important to your target area, sector, or community.

Your first priorities should also lay the foundation for future adaptation investments and facilitate future additions and modifications as the climate continues to change. The best adaptation measures facilitate future adaptation within and outside your target infrastructure system instead of making them more difficult or expensive.

Strategic options for adaptation: There are four approaches to adaptation:

(i) Build now for lifetime adaptation.
(ii) Plan for phased adaptation over project lifetime.
(iii) Progressive modification to design.
(iv) Build to repair.

Table 4.6 describes those options and their operational and financial implications. In most cases, planning for a phased approach to adaptation over the lifetime of a project is the most effective approach. It may not be a matter of choosing between options but staging them; some will need to be implemented before others are feasible.

Once you have developed a full list of adaptation options and chosen which of the four approaches your adaptations will follow, you can begin to prioritize. It will not be feasible or necessary to implement all possible solutions. Some of the options may cancel each other out. For example, it may not make sense to build a flood retention dam as well as raise the level of a downstream bridge. Also, resource limits and policy or regulatory limits and standards may favor certain options over others.

The next step in the adaptation planning matrix is to assess the feasibility and effectiveness of each adaptation option to arrive at a rating of priority.

Feasibility of an adaptation option: Feasibility is the extent to which each option can be accomplished or implemented. Factors

Table 4.6: Four Approaches to Design of Adaptation Measures in Infrastructure

Adaptation Approach	Description of Adaptation Approach	Expected Financial Implications
Build now for lifetime adaptation	• Build all adaptation measures immediately to last the project lifetime.	• Relatively high investment initially. • No additional investment for subsequent adaptation required. • Long-term security is dependent on actual climate change not exceeding predictions.
Plan for phased adaptation over time	• Fully plan an upgrade program to progressively adapt the design as climate change occurs.	• Medium-level initial investment. • Investment required during asset life cycle. • Implementation of project adaptation phases will occur as designed.
Progressive modification to design	• Redesign and reconstruct as required in response to verified climate change. • Initial design may not provide functionality to adapt over life span. • Redesign and reconstruction required prior to damage or failure.	• Lower initial investment. • Climate changes will force redesign costs and investments for reconstruction during asset life cycle to avoid catastrophic failure. • This is potentially an expensive approach.
Build to repair	• Accept that there will be damage and repair is required. • Initial design does not incorporate adjustments to respond to climate change projections. Should the asset be damaged, asset manager accepts damage and carries out repairs.	• Low initial investment. • Likely financial loss due to damage of asset. • Relatively high repair cost during lifecycle but overall may lead to lower whole life costs if climate change does not cause substantial damage. • This is the cheapest up-front option but comes with the largest risk and potential cost.

Source: ADB and ICEM.

that influence feasibility include technical complexity, capacity of the infrastructure management agency and user community, and the cost.

1. **Technical complexity and demands:** Does the affected community or lead government agency have the knowledge and skills to use the technologies involved? Is the technology available within the country? Does it come with high maintenance demands and costs? Will it require investment in time and resources to understand how it can best be applied locally?

2. **Time to implement:** Implementation time can be a critical factor in situations where past and existing extreme events have caused damage or threaten strategic infrastructure and facilities. Also, some options such as a riverbank dike may need to be fully in place to be effective, whereas others can or need to be implemented over several years. For example, to stabilize a bank with bioengineering methods may take a short time to put in place, but years to mature and increase in strength and resilience.

3. **Capacity of local communities:** If local communities are an essential force in building, managing, and monitoring the adaptation measure, many issues will need to be considered through consultation and survey. Who within the community will take on the responsibility? Will special management groups need to be assembled? Will the key actors be able to manage work and home roles with new duties? Will compensation be needed? It is not necessary for the adaptation team to resolve all issues relating to local community involvement, but it is important to discuss how much effort will be required to establish community management.

4. **Capacity of government:** In most cases, even for national infrastructure assets, local government will have a role in adaptation management, monitoring, and repair. If

Flexibility Rank

Very Low	Low	Medium	High	Very High
requires additional R&D, very lengthy implementation, very limited technical and institutional capacity, cost vastly outweighs potential effectiveness	may require additional R&D, lengthy implementation, limited technical and institutional capacity, cost outweighs potential effectiveness	established technique, implementation matches effectiveness, growing technical and institutional capacity, cost in line with potential effectiveness	established and tested technique, implementation matches or better effectiveness, sound technical and institutional capacity, costs match or better potential effectiveness	established and tested technique in GMS, implementation matches or betters effectiveness, exceptional technical and institutional capacity, costs match or better potential effectiveness

GMS = Greater Mekong Subregion, R&D = research and development.

responsibilities fall to local agency staff, duty statements and performance evaluation criteria will need to be revised, new budget items introduced and sourced, and equipment and supplies drawn together to meet the demands. Information and capacity strengthening activities may also be needed.

5. **Cost:** Cost has been left to last in this list because it can be a "showstopper." High cost can easily prevent action or lead to suboptimal adaptation strategies, especially when important options require phased funding over the long term. It may be tempting to score expensive measures as having low feasibility, even if they are critical to the effective functioning of a system or the safety of affected communities. It may be best to leave cost out of your feasibility assessment at this stage. Like adaptation plans, budgets are all about prioritizing, and you may find that you have enough funding once your whole plan has been prepared.

While the above factors do not require official scoring, the feasibility rank can act as a guide. Once you and your team have established a feasibility rank for each of your options, note the results in the adaptation planning matrix. Be sure to record how you established the rank as these notes will add legitimacy to your choices when communicating with decision makers.

Tools, Methods, and/or Inputs
The final ranking from very low to very high feasibility is made based on expert judgments of the information gathered during the baseline and impact assessment phase. Establishing feasibility is a matter of discussion and consensus. In a workshop situation, for example, feasibility and effectiveness can be defined through group sessions over a few hours by drawing from the baseline assessment, vulnerability assessment matrix, and field visits.

Effectiveness of adaptation options: The next step in priority ranking is to determine the degree to which each adaptation option would produce the desired result. You will establish how successful each option would be at avoiding or reducing the negative impacts of climate change and enhancing any benefits. Implementing options that reduce negative impacts while enhancing benefits effectively build resilience into your target infrastructure system.

The best adaptation options will also increase the well-being of affected communities, especially disadvantaged groups, and the natural systems they live in.

Effectiveness Rank

Very Low	Low	Medium	High	Very High
will not eliminate or reduce the impact, many years to take effect, short life span	will only marginally reduce impact, slow to take effect, short life span	moderate reduction in impact, some time to take effect, medium life span	reasonable reduction impact, quick to take effect, medium to long life span	eliminates or near eliminates impact, immediately effective, medium to long life span

Ask the following questions to assess how effective an adaptation option will be at eliminating or reducing the impact:

- Will it eliminate the impact?
- If not, by how much will it reduce the impact?
- Will it take some time to become effective (e.g., several years for the root system to establish in a bioengineered slope)?
- How long will the adaptation measure last?

Use the effectiveness rank tool to establish a rank for each adaptation option.

Once you have ranked each of your adaptation options, note the results in the effectiveness column of the adaptation planning matrix. Be sure to record how you reached each rank, as these notes will add legitimacy to your choices when communicating with decision makers. You can also use the notes to help develop monitoring and evaluation indicators in the next steps of this process.

Ranking priority: Priority is a function of feasibility and effectiveness. To determine a priority ranking for each of your adaptation options, take the results from your feasibility discussions and the results from your effectiveness ranking and plot them on the priority of adaptation matrix. Note the final rank in the adaptation planning matrix.

Priority of adaptation = Feasibility of adaptation action **X** Effectiveness in addressing impact

Notes

In some cases, important adaptation measures will not score well on your priority of adaptation matrix. Cost, time to implement, and other factors may reduce a score even when expert judgment has established that the measure is critical. If through your community consultations, a particular measure or set of measures has emerged as necessary, it should be considered high priority even if it has not scored as such on the matrix.

Priority Scoring Matrix

Feasibility of action	Effectiveness in dealing with impact					
		Very Low	Low	High	High	Very High
	Very High	Medium	Medium	High	Very High	Very High
	High	Low	Medium	Medium	High	Very High
	Medium	Low	Medium	Medium	High	Very High
	Low	Low	Low	Medium	Medium	High
	Very Low	Very Low	Low	Low	Medium	High

Step 8: Preparing the Adaptation Plan and Supporting Measures

There is no "right" way to structure an adaptation plan. Your plan will depend on the size and complexity of your target infrastructure system. If it is a large system with many elements and managing bodies, your plan will consist of many pages and components. However, if your target infrastructure system is something smaller, like a reinforced streambank, your plan may come in the form of a short brief.

The templates and matrices you have filled out along the way will help you in crafting your plan. You have defined what you will need to implement, how, when, and with whom to make your target infrastructure system more resilient to climate change and other impacts. Now it is a matter of taking those details and assembling them in an integrated way.

Lay out your adaptation plan:

Scope: It is best to start your plan by laying out the scope, which you defined in the first step. Your scope may look different now than it did in the beginning of your process. Be sure to include the most up-to-date version of your scope to account for any changes.

Target infrastructure system: Using materials from your baseline assessment, describe your target infrastructure system. Describe its main elements and overall objectives.

Adaptation measures: Take the adaptation measures that scored well in your adaptation planning matrix and arrange them in roughly the order you identified in your prioritizing step. Describe them in detail, including how each measure pertains to either a particular element or the system as a whole. Taking information from your vulnerability assessment matrix and your adaptation planning matrix, explain how each measure will address impacts and build resilience in the system.

Adapting to opportunities: Identify any positive climate change effects and opportunities and what "adaptation" measures are needed to take advantage of those opportunities.

Institutional arrangements and responsibilities: Describe how the adaptation plan will be implemented. Include the agencies involved, any special institutional arrangements, and any local user groups or community organizations. Include funding sources where possible.

Time: Estimate how much time each measure will take. Set your measures up in phases:
(i) Immediate (1 year)
(ii) Short (2 years)
(iii) Medium (5 years)
(iv) Long Term (10 years or more)

Identify the urgent measures and those that need to be taken before others are possible.

Adaptation impact assessment: Describe how your adaptation plan as a whole will help avoid or minimize negative impacts and enhance benefits.

Other development influences: Development does not happen in a vacuum. Describe other development factors that could affect implementation or influence the system and its adaptation measures. Identify additional actions needed to control or work with other influences.

Sectoral reforms: Identify any adjustments that should be made within the target sector to implement or replicate your adaptation measures and plan. This could include revising guidelines, improving design standards, and strengthening policies. This section provides the opportunity to make recommendations to help mainstream adaptation so that measures can be rolled out more efficiently in other areas.

Collaborative approaches: There may be measures that are outside the capacity and authority of a single national and local government agency. These will require a more coordinated, all-government approach. In these cases, identify the bodies you envision will need to be involved and describe how you imagine that kind of collaboration would work. This will help identify who you will need to have discussions with in your implementation phase.

Figure 4.6: Adaptation Implementation and Feedback Process

9. Design and Construction with Consultation	10. Monitoring with Regular Maintenance and Repair	11. Phasing, Adjustment, and Retrofitting	12. Audit, Replicate, and Commit to Cyclical Adaptation
Design and Construct Design may involve hot spot avoidance, bioengineering, rehabilitation of natural systems, development controls, and setting up community management and maintenance processes.	**Monitor and Repair** Investment in monitoring of the landscape and system, early warning of potential of failure, effectiveness of adaptation, and a program of regular maintenance involving communities.	**Phase and Adjust** Keep to planned phasing of adaptation measures based on latest climate change information and lessons from implementation, make adjustments, retrofit, and invest in responses.	**Replicate and Repeat** Conduct adaptation audits and replicate what works well in other areas, ensure policies and procedures are in place to lock vulnerability assessment and adaptation into the development and planning cycle.

Source: ADB and ICEM.

4.5 Adaptation Implementation and Feedback

Ultimately, the goal with adaptation and implementation is to integrate this kind of process into regular development. Monitoring, periodic impact assessments, and improvements need to be instituted and budgeted for. By making these activities a normal part of development, you are mainstreaming climate resilience and sustainability.

More than the previous sections, this section is a work in progress. It reflects cutting-edge strategies in global adaptation implementation.

Figure 4.6 describes the four main steps in adaptation implementation.

Step 9: Designing and Constructing Adaptation Measures

There are several good guides that describe the processes involved in building and maintaining infrastructure. Chapter 2 contains several case studies that explain how others have implemented large and small adaptation plans.

Design: At its heart, design and construction take the plans you drafted in the previous stages and turn them into a set of instructions for implementation. Your instructions will fall into two categories:

(i) Structural
(ii) Nonstructural

Structural instructions encompass designs of physical interventions. For example, if you are using live fascines (see section 2.4.3) to stabilize a streambank, engineering instructions will cover the details of how those fascines will be implemented, the amount of materials needed, and the skills required. At the procurement stage, it is important to hire contractors and workers who have some familiarity with bioengineering and climate-resilient construction. Either that or you will have to arrange for training.

Nonstructural instructions will cover how to implement the necessary policy changes, training regimes, and institutional activities that you outlined in your adaptation plan. These nonstructural instructions will become more important in your monitoring and maintenance phases.

Notes

The most important consideration at this stage is to ensure that the measures identified to adapt to impacts outlined in the vulnerability assessment are not forgotten. If you have been working alone up to this point, or if you have not had construction experts as part of your team, it is crucial that you communicate how important it is that adaptation measures be designed in such a way that they actually perform the functions that you need them to.

Strong links between the vulnerability assessment team and the design and construction team will help ensure that adaptation needs are met. That way, you can take designs and weigh them against the elements and objectives that you outlined in your scope and vulnerability assessment. Do the designs account for each of the vulnerabilities and threats you identified? Has anything been overlooked or left out?

In the other direction, strong links will also ensure that you are made aware of any changes that become necessary if design and construction reveal new information. If you receive new information quickly enough, you will be able to refine your adaptation plan without losing too much time.

Step 10: Monitoring, Maintenance, and Repair

One of the main challenges in implementing adaptation measures is ensuring that new technologies are properly operated and maintained. Keeping your adaptation plan in place and functioning well requires monitoring and attention to detail.

Effective monitoring programs are an essential part of adaptation. They track how well, or if, your adaptation measures are mitigating the impacts they were intended to address and provide you with the data you will need to adjust as climate and other circumstances change. If you have a phased approach to your adaptation plan, monitoring will alert you to when key infrastructure pieces are finished so the next ones can begin. Monitoring programs also alert you to any weaknesses in the system so you can repair them before they cause further damage.

Appendix 7 provides a template to help you organize your monitoring and maintenance efforts.

Here are a few things to keep in mind while putting together a monitoring and maintenance program:

1. **Human resources** A strong monitoring and maintenance plan depends on high-quality inputs from affected local communities and the agencies responsible for managing your target infrastructure system. Local community assistance is especially important in vulnerable areas where government capacity and resources are limited.

You will have already identified possible community partners in your adaptation planning process. Now is the time to engage and organize those partners.

You will also have identified the government divisions that are responsible for your target infrastructure system. If at all possible, ensure that you coordinate local community efforts with those of government specialists and experts, or delineate responsibilities.

Table 4.7: Monitoring and Maintenance Framework

Adaptation Measure	Monitoring Focus	Frequency	Responsible Entity	Organisational Indicators	Technical indicators
Short-term Measures					
Long-term Adaptation Measures					

Source: ADB and ICEM.

2. **Capacity building:** Your community groups and local experts may not be trained in green infrastructure or climate-resilient development. To ensure high-quality monitoring, you will have to engage in skill-building efforts. These efforts should be tailored to your specific adaptation measures and your measurable indicators. You can also equip them with tools like "Walking the Route" included in Appendix 8 that outlines how to audit a road or slope, what to look for, and how to record the findings.

3. **Measureable indicators:** Your community groups and local experts will do little good if they have no guidelines and nothing to measure. These indicators may be process-based to measure progress in implementation or outcomes-based to measure the effectiveness of your adaptation plan. Developing indicators at the project level is relatively straightforward. Many infrastructure projects come with established monitoring and evaluation systems with proven indicators that already exist. Furthermore, your scoping process and vulnerability assessment already indicated the objectives of your target infrastructure system and its elements and the specific impacts you intend to address. However, monitoring and evaluation on a broader scale—for example, for an entire town or catchment—can be more complex and will require creativity and strong coordination across sectors.

4. **Feedback mechanisms:** High-quality monitoring depends on a clear description of the objectives of the adaptation measures and how they link to the broader goals. Once collected, your monitoring teams need a way to relay that information back to the decision makers. Your plan should include means by which your teams can communicate their findings, be they regular meetings, web-based feedback forms, or other systems. Having access to your team's findings will equip you with the data you will need to procure funding for repair and rehabilitation.

5. **Funding:** Most countries include a major budget item dedicated to covering the costs of maintaining and repairing infrastructure after normal wear-and-tear or after catastrophic weather events. Rooting your monitoring and maintenance program into this budget item will help to mainstream the process and ensure that you have adequate funding to repair any weaknesses you find.

Figure 4.7: Components of a Monitoring and Maintenance Plan

- Human resources
- User and oversight groups, involvement of local community
- Specialists, staff from government division responsible for infrastructure

- Capacity building
- Training for community members in running groups, monitoring
- Training for local staff and other experts in climate-resilient building

- Measurable indicators
- Impacts on elements, objectives from vulnerability assessment
- Health and stability of implemented adaptation measures

- Feedback mechanisms
- Systems to collect and synthesize data generated by community and experts
- Links to filter results to decision makers

- Funding
- Major budget items for disaster recovery, infrastructure repair
- Embed maintenance for adaptation into normal repair processes

Source: ADB and ICEM.

Notes

Practical difficulties in conducting a monitoring program stem from a general lack of financial, human, and technical resources and capacities; a lack of baseline data and historical trends; uncertainty in projected climate change impacts; and insufficient sharing of information across stakeholder groups, levels, and sectors. As a result, monitoring is one of the weakest areas of adaptation practice. This entire process equips you with the materials necessary to help overcome these challenges. The goal is to mainstream this type of adaptation planning and monitoring into existing development frameworks.

Tools, Methods, and/or Inputs

Core groups such as those whose stories are included in this publication may provide you with a viable monitoring and maintenance model. While your monitoring team may be smaller than the core groups discussed, the groups cover a breadth of technical skills and community perspectives that may prove to be necessary for thorough, consistent monitoring and regular feedback. Links between similar groups in the region could also complement in-house capacity building, as could visits to other sites employing similar techniques.

Step 11: Adaptation Phasing, Adjustment, and Retrofitting

A successful monitoring and maintenance program should lead to progressive improvements in your target infrastructure system. As technology and expertise improve, your monitoring program should highlight areas where you can implement these advances, thus allowing you to keep up with the times. It should also help shape any future adaptation measures, as you will be progressively learning from the adaptation and implementation process and applying new knowledge to new adaptation plans.

Phasing: Some of the adaptation measures you identified in your adaptation plan may be scheduled for implementation in later phases of the infrastructure system. This can be for many reasons, including

- the need for supporting infrastructure pieces to be in place first;
- planned funding that comes later than your initial investments;
- time needed to increase education, capacity, and training among community and local experts; or
- verification that the impacts of extreme events are occurring as projected.

A well-functioning monitoring program will alert you to when, and if, your subsequent phases should be implemented. You will be able to check your monitoring results against budgets, community realities, and new trends in climate change and climate projections.

Your monitoring program will also alert you to when you need to make adjustments to your plan. To adjust effectively, you need

- capacity in national and local governments;
- capacity in communities;
- a policy commitment to take action on adaptation monitoring and review findings and recommendations;
- the skills and technology necessary to rehabilitate, retrofit, and reconstruct infrastructure components as needed; and
- funding.

Adjustment and renewal: Some adaptation measures identified in adaptation plans are scheduled for implementation at later phases of the infrastructure system's life depending on climate change projections. The need for those later measures should be kept under review based on regular updating of climate change and hydrological information and regular on-site inspections of assets and surrounding conditions. One tool described in Appendix 8, "Walking the Route," is designed for that kind of site and asset inspection.

The results from an effective monitoring program should lead to progressive improvements in infrastructure performance and help shape future adaptation measures. This requires capacities in national and local governments, as well as in communities to take actions to make those adjustments on a regular basis. There needs to be a commitment in policy to take action on adaptation monitoring and review findings and recommendations, the budgets to do so, and all the necessary skills and technologies to rehabilitate, retrofit, and reconstruct infrastructure components as needed.

Infrastructure departments already spend a large part of their budgets in maintenance and repair, most often when failures occur following landslides, floods, drought, and other extreme events. It is necessary to build on that considerable effort by making it more proactive and anticipatory so that interventions are possible before major failures occur. For that to be possible, investments are needed in regular updating of climate change downscaling, in hydrological modeling by catchments, and in providing practical information to infrastructure sectors on demand and tailored to their needs. The benefits of that improved service will begin to show in more sensitive infrastructure siting and design.

Step 12: Replicating and Upscaling

Adaptation auditing: The experience with implementing adaptation measures should be documented in regular adaptation audits. "Audits" can describe case studies of what has and has not worked. They can focus on measures that have been long practiced in the region, for example, bioengineering techniques for slope and riverbank stabilization.

They can also be conducted every few years for adaptation approaches used in recent infrastructure development and which might involve new technologies and materials. The aim is to build on and replicate the best examples of good adaptation through the sector infrastructure programs.

Upscaling of good adaptation field practices means making the necessary reforms to policies, institutional arrangements, and procedures at higher levels, which will enable good practices to be applied systematically within the sector and in other areas.

Green Infrastructure: The other prerequisite to realizing anticipatory adaptation is through intensive attention to testing and demonstration of fresh approaches. A guiding principle for that piloting is to respect and build on natural features and systems. This often means using measures that are based on traditional knowledge and practices, as well as those which have been practiced by sector agencies for many decades. These techniques are often called bioengineering methods or, more broadly, green infrastructure.

Green infrastructure is about changing the way roads, drains, floodgates, river embankments, water supply and sanitation facilities, power supply services, and buildings are designed and managed to be ecologically sustainable and resilient to climate change. As detailed in Chapter 2, green infrastructure includes an array of products, technologies, and practices that use natural systems—or engineered systems that mimic natural processes—to enhance the overall environmental quality, the infrastructure, and its resilience to climate change.

Progressively, infrastructure line agencies need to take on the responsibility for review and adjustment to their own planning and management instruments to accommodate climate change adaptation on a regular and cyclical basis. For that, each sector will need to embrace the preparation and regular review of sector adaptation plans of action in keeping with the cycles of their development planning and budgeting.

4.6 Optional Steps and Tools for Large-Scale Plans and Projects

In cases of large-scale projects, programs of national strategic importance, or projects that affect large populations or areas, a vulnerability assessment team can add rigor to the vulnerability assessment by

(i) taking a quantitative approach to the scoring rather than applying the *very low* to *very high* rankings, and/or
(ii) adding a step following the vulnerability assessment to assess the significance of the impacts.

When large investments are involved, the government may call for added certainty and justification of the team's adaptation recommendations. Adding either or both of these methods can provide further evidence to justify and refine specified courses of action.

The quantitative approach to the vulnerability assessment scoring is not described in this chapter. It is set out in an accompanying publication. Here, the significance assessment step is presented.

Estimating the significance of the Impacts (risk assessment): A vulnerability assessment identifies the direct and indirect impacts of various climate change threats on a system and its components. It can be valuable for a team to think through in greater detail the impacts they have identified and to understand and document them more fully. Determining the significance of those impacts can lead to a more detailed ranking of impacts and assist in setting adaptation priorities. Furthermore, it can inform decision makers of the level of risk associated with the impacts.

"Significance" is a term widely used and understood among environmental impact assessment practitioners. In the field of disaster risk management, however, the equivalent term is "risk assessment." The challenge with that term from disaster risk management is that it has many meanings and associated methodologies and is used in many sectors and industries. For example, it is the foundation of the life insurance sector. For the purposes of this chapter, the estimation of significance can be viewed as a risk assessment method.

Significance is a function of the likelihood of an impact occurring and the seriousness of the impact. The resulting significance of each impact provides a first guide to priority setting among adaptation options. Significance is assessed on a scale of very low to very high interpreted as follows:

Likelihood is the chance or probability of something happening. If an impact is very significant, but there is little probability of it happening (e.g., catastrophic failure in a hydropower dam), a team of planners need to make a judgment on what is an acceptable level of risk for each potential impact. The assessment of likelihood provides the team with the initial information needed to make that judgment.

It is a challenging stage of adaptation planning. Even if there is very little chance of an event happening, the consequences could be so serious in terms of potential loss of life and property that a team could choose to override the matrix results and assign highest priority to adaption measures designed to avoid the impact. Dam failure, for example, can have such serious impacts that, even if unlikely to happen, it would necessitate extensive safeguards and adaptation measures.

Seriousness criteria used for assessing seriousness of impacts include

- loss of life;
- loss, damage to, or destruction of property;
- loss of productivity and income; or
- impediments to socioeconomic functions.

Environmental criteria may also be important for some areas. If your target area is in a forested

Significance of Impact = Likelihood of impact happening X Seriousness of impact

Significance Scoring Matrix

Likelihood of impact occuring	Seriousness of impact				
	Very Low	Low	Medium	High	Very High
Very High	Medium	Medium	High	Very High	Very High
High	Low	Medium	Medium	High	Very High
Medium	Low	Medium	Medium	High	Very High
Low	Low	Low	Medium	Medium	High
Very Low	Very Low	Low	Low	Medium	High

Significance		
Likelihood The chances of the impact occurring	Seriousness of the Impact Loss of life, property etc	Significance of the impact
L	M	M
H	H	H
L	L	M

Significance Rank

Very Low	Low	Medium	High	Very High
very low impact that does not require an adaptation response	low impact that can be dealt with as and when they happen or as budget allows	moderate impact that can be addressed by adaptation measures on a phased basis	high importance requiring immediate remedial action and further study	extreme impact requiring urgent action – to be given highest priority for adaptation

area, seriousness might encompass degradation to endangered species habitat or resources essential for local livelihoods.

To "score" significance, plot your likelihood and seriousness rankings on the significance matrix.

Valuation of impacts: The financial cost will vary in its importance—whether an assessment is being undertaken for a poor rural village or a large urban center, for example. It can be difficult to estimate cost. For important impacts, a detailed cost–benefit assessment may be required. Estimates for damage and financial losses may be available for past disasters which can be used as cost coefficients.

The following is an example of the low and high end of the scale of seriousness for rural infrastructure: Low significance:

- No loss of life.
- No injuries.
- No destruction of property.
- Some damage to property up to $500.
- Minimal loss of productivity and income up to a total of $1,000 across the community.
- Minimal impediment to socioeconomic
- function of community (up to 1 day).

Very high significance:

- Severe loss of life.
- Many severe injuries.
- Destruction and damage to property above $100,000.
- Loss of productivity and income above $250,000 across the community.
- Impediment to social/economic function of community longer than 7 days.

Additional tools which can provide more information, rigor, and scientific evidence inputs at various steps of the vulnerability assessment and adaptation process are described in Appendix 8 with a detailed summary of economic analysis methods provided in Appendix 9.

The vulnerability assessment and adaptation process set out in this chapter can be conducted as a rapid assessment based mainly on expert and stakeholder judgments and knowledge through to a more rigorous and lengthy process requiring the establishment of a comprehensive scientific evidence base. It will depend on the size and importance of the projects and plans being considered, and on the funds and staff resources the sector has made available for the process.

A glossary of terms used in the vulnerability assessment and adaptation planning process appears as Appendix 10.

4.7 Additional Reading

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Building Climate Change Resilience in Battambang, Cambodia

Battambang town is the capital of Battambang Province lying close to the northwest corner of Tonle Sap Lake in central Cambodia. About 74% of the town is agricultural land, producing rice, vegetables, livestock, poultry, and fish. The town has experienced rapid industrial and commercial growth but remains part of Cambodia's agricultural heartland.

It is a river town connected to Tonle Sap Lake by the Sangker River, with a population projected to grow by almost 70,000 people—or roughly half the current population—by 2030. Incremental and poorly controlled developments have raised the town on the west bank of the river so that drainage of large areas now flows away from rather than into the Sangker River. This results in regular flooding.

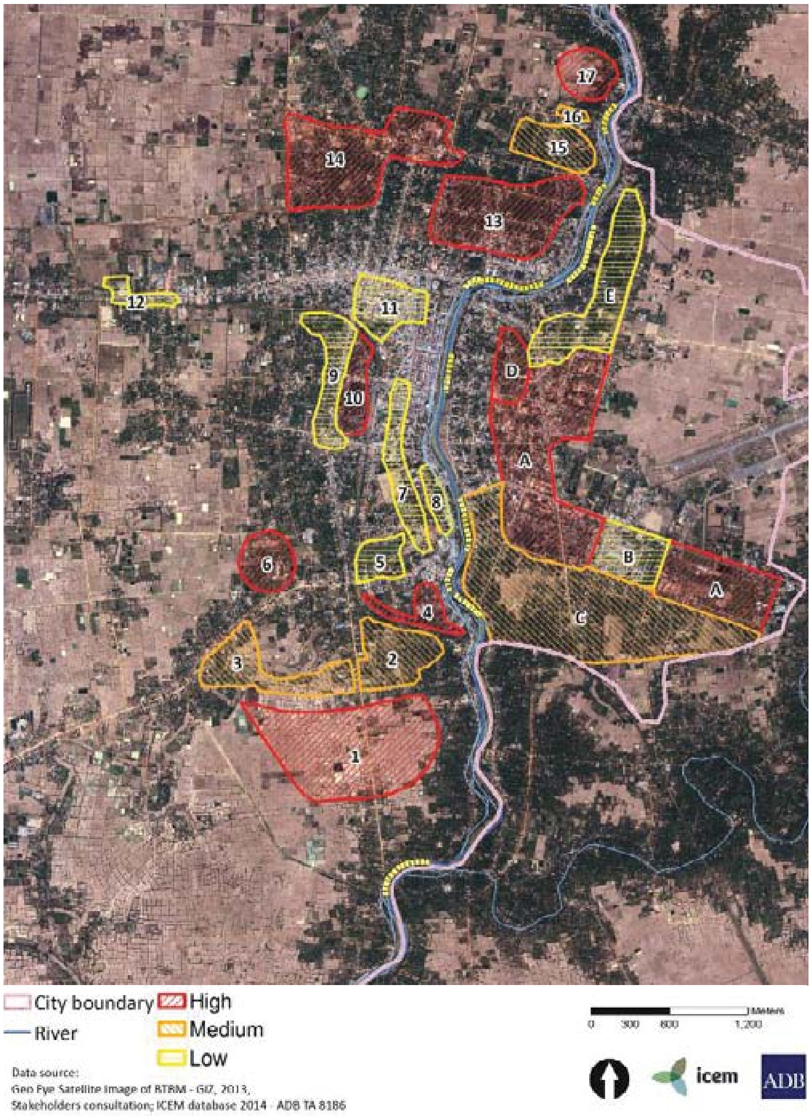
5.1 Overview

- Battambang is part of the greater natural landscape of the Cardamom region, which forms a complex network of interconnected landscapes and watersheds that provide important ecosystem services to nearby communities.
- Battambang Province has a medium vulnerability to floods and a very high vulnerability to drought.
- Floods have been recorded in every commune of the town and typically occur during the rainy season from June to December.
- Battambang is projected to experience significant climate changes that will have a range of impacts, including changes to hydrology and the frequency and intensity of floods and drought.
- The adaptive capacity of the town remains weak in terms of infrastructure, institutional arrangements, community involvement, and technical and financial capacity.
- The vision of the Town Strategic Development Plan (2011–2015) is "a green and healthy town for living, prosperity, employment and tourism with improved security and pubic order, promotion of education and gender equality."

5.2 The Work of the Climate Change Core Group

- As part of an Asian Development Bank project, a technical Climate Change Core Group was established to ensure that representatives from key sectors and levels of government work together to
  - discuss and map past and future climate extremes,
  - assess climate change threats and vulnerability of critical infrastructure in the town, and
  - develop locally appropriate climate change adaptation measures to address the potential impacts.

Figure 5.1: Climate Change Hot Spots in Battambang



- The key steps taken by the core group in defining climate change hot spots were the following:
  - Documenting past extreme events and regular flooding through participatory mapping, with detailed information for various flood zones on duration, depth, and source—localized rainfall and/or river overtopping. The core group mapped floods as far back as 2000, including the six river overtopping events that occurred between 2000 and 2011.
  - Defining the climate change profile for the site based on results from previous work by ICEM – International Centre for Environmental Management on the 2013 Mekong Adaptation and Resilience to Climate Change (ARCC) Climate Change Impact and Adaptation Study, which used modeling and downscaled data from the Intergovernmental Panel on Climate Change to project changes in temperature and precipitation at the regional level.
  - Superimposing the mapped climate change profile onto the past extremes map to identify the town's climate change hot spots.
- The main steps taken by the core group in identifying development controls and safeguards were to
  - overlay the climate change hot spots on the town zoning plan,
  - adjust the designations and boundaries of each zone as required, and
  - define development controls and safeguards for each zone (starting with the zones most affected by the hot spots).

5.3 Case Studies

The Battambang Climate Change Core Group undertook case studies to assess the river embankments, the central railway station, and the canal along the town's western border.

The 8.5-kilometer-long canal runs from south to north, beginning at the Sangker River water intake not far from the Kampong Seima Pagoda and ending in Sla Kaet District, where it discharges back in to the Sangker River.

The 20-meter-wide canal was built during the Khmer Rouge regime for irrigation. While not systematically maintained, it remains a key facility for irrigation, fishing, water supply, sewage treatment, and drainage. Increasingly, it also serves as a flood retention and protection system for the town.

The canal is largely overgrown and increasingly impeded by encroachment, blockages, and illegal settlement. The core group's vulnerability assessment found the system as a whole to be highly vulnerable to the threat of flooding caused by increased rainfall with climate change.

The key objective of the canal system rehabilitation is to create a green belt for the town that can be used for a variety of purposes. These include a green walkway and bicycle path

Government funded embankments on the western side of the Sangkae River

Source: Cambodia Watch. 2.bp.blogspot.com

along the canal banks connected to a riverbank path network around the town, clean water supply, fishing, irrigation, natural stormwater and flood management, and bioretention and pollution treatment.

5.3.1 River Embankments

The riverbanks near the Sor Kheng Bridge were specifically selected for their strategic location in the heart of the city. To the north of the bridge, the riverbanks have been reinforced; to the south, they remain in a natural state.

The northern embankments on the western side of the river have been hardened with masonry cladding. The riverbank on the east side has eroded and subsided due to floods in 2013 that compromised Road 159D which runs alongside the river.

The banks of the river collapse regularly, endangering buildings and residents, as well as the main hospital and other key road and bridge infrastructure.

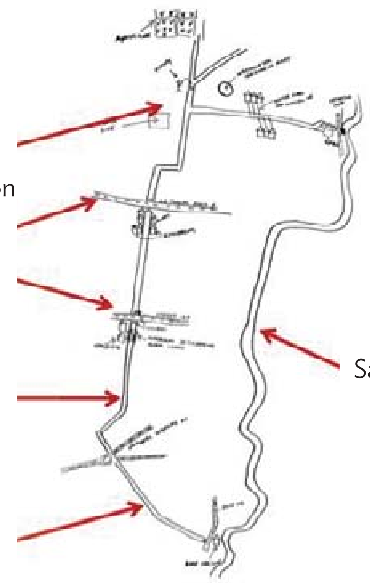
The core group found the system as a whole to be moderately vulnerable to the threat of flooding caused by increased rainfall and overtopping due to climate change both within the town and upstream. The group found that the riverbank on the east side is highly vulnerable to floods and erosion. This location has been one of the central areas for recreation, tourism, and hotel services.

Under the core group's adaptation plan, this area in central Battambang would form part of a major urban renewal and redevelopment zone based on green infrastructure principles, beautification, and multiple uses. It would become a central area of green walkways, shops, cafés, and restaurants with the river park at one end connected to the railway station wetlands park at the other—all designed to enhance town flood protection and resilience.

Figure 5.2: Kampong Seima Irrigation Canal System

Key components

- Kray Porn canal section and major agricultural production area
- Section at National Roads No. 5 and 57
- The main canal made from the 10 kilometers
- Main canal from Kampong Seima to Damnak Loung: 2500 meters with concrete embankment



Source: ICEM.

5.3.2 Railway and Surrounding Wetland Settlements

The case study area includes the unused town railway station buildings and adjacent informal settlements around wetlands that flood every year. Unregulated construction has filled in lakes and natural drainage, exacerbating floods and health problems associated with waterborne diseases.

The railway lake is locally known as Boeung Ra and is located in Tuol Ta Ek village in Battambang. There are two temporary

The rail yards and maintenance buildings
Source: Stig Berge, Panoramio. static.panoramio.com

communities living in this lake without official legal land title recognition from the government.

Railway Station Lake is located on the western part of the Sang Ke River and next to the railway station. The lake supports rich biodiversity including fish, snakes, edible plants, waterbirds, and other aquatic resources. The water quality of the lake is heavily polluted from residential waste.

The entire railway and wetlands area is a flood and climate change hot spot with a high severity ranking in terms of flood threat. The core group found the system as a whole to be very highly vulnerable to the threat of flooding caused by increased rainfall with climate change.

The core group's adaptation plan is to develop the area as an urban renewal and multiuse zone with natural drainage infrastructure that incorporates low-cost but attractive housing for the current residents of the informal settlements. The goal is to create a tourism and recreation area in the heart of town that is linked to the river and its green walkways.

5.4 Key Conclusions and Lessons Learned

- Climate change vulnerability assessment and adaptation planning should be mainstreamed into townwide master planning and infrastructure planning processes, including the use of participatory mapping approaches involving communities and representatives from key agencies as was reflected in the composition of the core groups.
- Town master planning and zoning must include a step of overlaying past extreme climatic events and projected climate change to ensure appropriate boundary definitions and designations, and development and design of suitable townwide and zone safeguards to ensure land uses and structures are resilient.
- The town master planning should be formally adopted as a cyclical process with review and revision at least every 5 years and a statutory period within which the provincial and national governments must approve the plan. Adaptation planning needs to be an integral part of the master planning process.
- The core group will be an important cross-sector technical group for the town. It will act as a technical advisory group on climate change, providing monitoring and evaluation to ensure that all developments consider climate change, assessing proposed infrastructure development projects, and providing technical advice in the town master planning process.
- Community engagement at all stages of adaptation to climate change is key to its success.
- Green infrastructure and bioengineering have much to offer in building town resilience to climate change and should be actively promoted and demonstrated through formal policy commitments in the town plan and development controls, and through a formal vision statement for Battambang's development.
- Informal migrant settlements and linked climate change impacts are a major issue for Battambang: the town's migrant settlements are located in some of the most vulnerable areas to climate change. Managing these settlements effectively will be vital to advancing the town's development vision and also to increasing its resilience.
- There are significant opportunities to build on the project with the new governor as mentor: Battambang has a new governor: former Deputy Governor Sieng Em Wounzy. Governor Wounzy is an architect and planner by training who championed this project as deputy governor. As governor, he will prove to be a strong and influential advocate for climate-sensitive development in the town creating an important opportunity

to showcase good adaptation in urban infrastructure.

- The long-term presence of the embedded geographic information system team within the governor's master planning department also provides an important opportunity to showcase Battambang and green infrastructure as a Greater Mekong Subregion-wide demonstration for building climate change resilience.
- When conducting participatory mapping, which is a critical part of climate change vulnerability assessment, it is important to separate mapping of historical flooding caused by pooling and the flooding caused by river overtopping because these have very different flood characteristics in terms of depth, duration, and impact, and they require different responses.

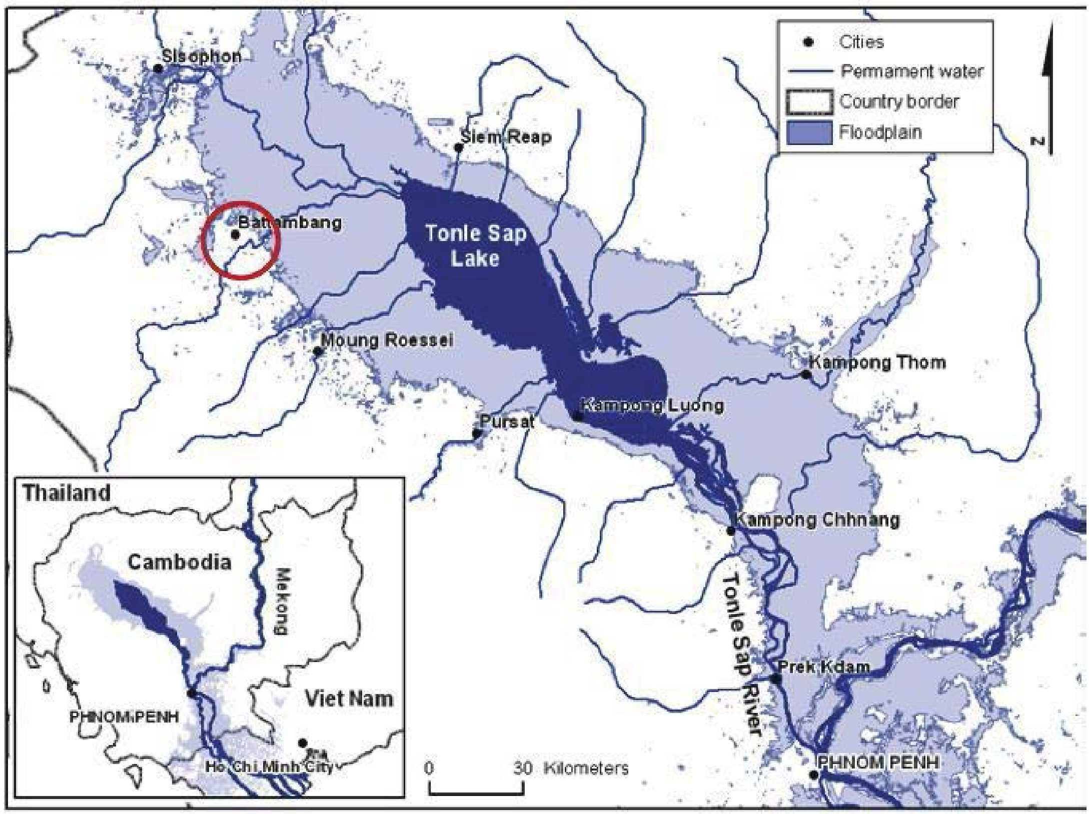
5.5 Battambang Core Group Members

Ear Kimchheng	Deputy Director, Provincial Department of Environment
Kem Sokuntheary	Deputy Director, Provincial Department of Public Works and Transport
Khoeu Sophal	Deputy Director, Provincial Department of Urban Planning, Construction and Cadastral
Nou Chharvivann	Chief of Office, Drainage System and Water Pollution Treatment of Provincial Department of Public Works and Transport
Chea Vong Narith	Chief of Office, Legal and EIA of Provincial Department of Environment
Mao Sok San	Chief of Office of Meteorology of Provincial Department of Water Resource and Meteorology
Nou Sean	Chief of Office of Provincial Technical Unit of Water Supply
Iv Ngorn	Medical Officer, Provincial Department of Health
Ya Sophat	Deputy Chief, Provincial Red Cross
Kea Chhun	Chief of Office of Agricultural Extension, Provincial Department of Agriculture
Yan Bophay	Deputy Director, Provincial Electricity Transmission line
Seng Sorath	Deputy Office Chief of Technical Unit of Provincial Water Supply
Phok Sinmary	Deputy Governor
Song Soeung	Chief of Office of Municipal Public Works
Sok kinna	Chief of Office of Urban Planning, Construction and Cadastral, Municipality
Nou Chamroeun	Chief of Office of Municipal Beauty and Waste Management
Thuch Vannarath	Chief of Office of Administration and Finance
Chheng Sivutha	Chief of Office of Planning and Commune/Sangkat Support
Nhek In Rotha	Chief of Office of Urban Development
Tuy Rong	Chief of Office of Tourism
Ty Kim Heng	Deputy Chief of Office of Urban Planning, Construction and Land Management
Pich Leakhena	Deputy Chief of Office of Social Affairs and Rehabilitation
Kun Ratanak	Officer at Office of Administration and Finance
Keo Putchenda	Officer at Office of Social Affairs and Rehabilitation
Chhoeung Vuthy	Officer at Office of Administration and Finance
Soeung Bora	Project Manager, Cambodian Education and Waste Management Organization
Yong Tonghan	Local expert on temporary resettlement
Chin Vuthy	Director of Aphivath Srey

continued on next page

Table continued

El Sales	Chief of Sla Ket Sangkat
Kim Chorng	Chief of O Char Sangkat
Touch Monyroth	First Deputy Chief, Prek Preah Sdech Sangkat
Kok Han	Councilor of Chamkar Samrong Sangkat
Horm Heng	Councilor of Ratanak Sangkat
Samrith Chhorn	1st Deputy Chief, Toul Ta Ek Sangkat
Sourn Sokhen	1st Deputy Chief, Svay Por Sangkat
Mao Siny	Councilor, Kdol Dountiev Sangkat



Source: Wikimedia Commons. commons.wikimedia.org

This summary is part of a series that comprises the Resource Kit for Building Resilience and Sustainability in Mekong Towns. The resource kit was developed with the Climate Change Core Groups from each town to promote nature-based solutions and integrated green infrastructure approaches for building resilience in Mekong towns.

Source for all material in this summary: ICEM – International Centre for Environmental Management. 2015. *Building Urban Resilience in Battambang, Cambodia*. Volume 5 of the Resource Kit for Building Resilience and Sustainability in Mekong Towns. Prepared by ICEM for the Asian Development Bank and Nordic Development Fund. Ha Noi, Viet Nam.

Case Study 2

Building Climate Change Resilience in Kaysone Phomvihane

Kaysone Phomvihane is the capital of Savannakhet Province in the Lao People's Democratic Republic. The town is the largest in the province with a population of 76,307 and is bounded to the west by the Mekong River and Thailand. The town covers an area of 779.03 square kilometers and is mostly flat and undulating land.

Savannakhet has long been a center of trade and power. The name *Savannakhet* derives from the old Pali language, meaning "land of gold." People here have cultivated rice in the largest plain in the country and fostered rich arts and culture. Today the average economic growth rate is 9.97% per year with services, industry and handicrafts, and agriculture being the dominant sectors.

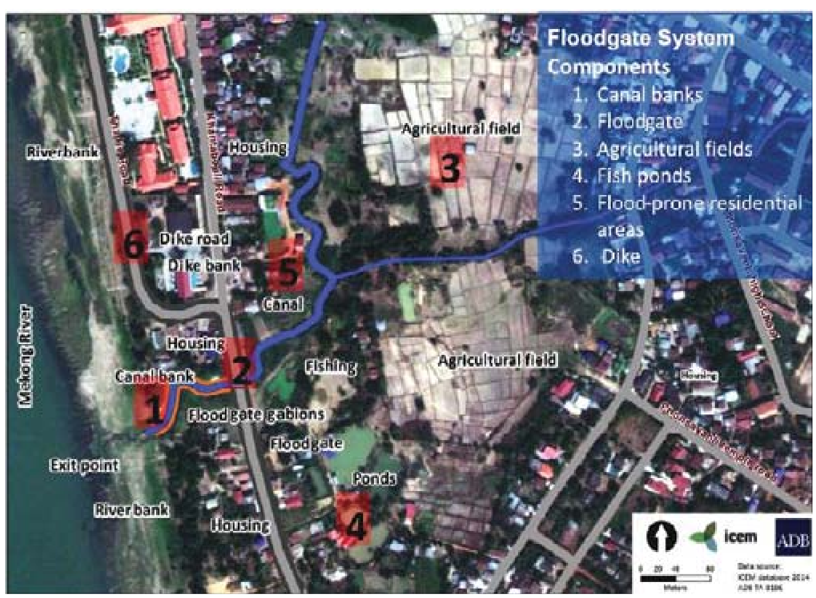
6.1 Overview

Kaysone Phomvihane experiences floods and drought on an annual basis. Its location on the banks of the Mekong River make it susceptible to increased flooding from riverbank overtopping and backing up of floodwaters along tributaries and drainage corridors combined with regular intensive rainfall on the town and its catchment. It also experiences periodic tropical storms. These factors hinder economic growth.

As part of an Asian Development Bank project, the Kaysone Climate Change Core Group was formed to identify past and future flood-prone areas in the town and what adjustments were required to increase town resilience. The core group also assessed two key pieces of infrastructure: the southern flood gate and canal system and the Savanxay Market and drainage network.

6.2 Case Study Site 1: Southern Floodgate and Canal

The floodgate Houy Longkong is located in Thahae Village, just 120 meters from the Mekong River. The system is in poor condition and does not function effectively in meeting multiple demands, including flood protection,



Source: ICEM.

agricultural water supply, town drainage, recreation, and beautification.

The southern flood gate and canal system was found to be highly vulnerable to the threat of flooding caused by increased rainfall in the canal catchment and higher Mekong water levels with climate change.

The core group recommended installing operations and monitoring equipment like pumps and stream gauges, as well as rehabilitation of drainage canals and slopes around the flood ate culvert using bioengineering techniques.

The core group's plan takes an area-wide approach, including addressing issues with the canal, the dike and road, the steep banks, and the linked land uses. It emphasizes bioengineering measures to reduce bank collapse and erosion to bring back the natural stream drainage corridor and character. Solid waste, which builds up around the gate entrance, will be regularly cleared. Houses in the area will be raised on stilts, and government and community monitoring and maintenance systems will be instituted to help manage the gates and canal.

6.3 Case Study Site 2: Savanxay Market

Savanxay Market is located in Ban Houamouang, Kaysone Phomvihane, and extends over 2 hectares. It began service in 1991. There is a main road on either side of the market, which consists of three buildings and a surrounding hard surface area for stalls. Located in the heart of the town, Savanxay Market is a hub of economic activity.

Source: ICEM.

Although the building itself is in fairly good condition, the surrounding access roads are seriously degraded, reflecting the drainage problems and intensive use of the area. The market has serious flooding and drainage challenges with implications for public health, as well as economic and livelihood impacts. This also affects the surrounding area.

The market buildings lack gutters and downpipes to store or drain water away from on-site market areas that become locally flooded. Market operation and management is poor with lack of wastewater treatment, poor solid waste management, and an inadequate stormwater drainage system. The site is highly vulnerable to regular pluvial flooding resulting from increased rainfall and from the Mekong River flooding in extreme events due to climate change.

The aim of the core group's adaptation plan is to drain waste and stormwater into the Mekong and to improve on-site waste treatment and drainage. It will also provide an area of high-quality amenity and beauty for vendors, customers, and tourists, with green space and walkways to the Mekong River. The plan includes wastewater recycling, walking paths, proper drainage, and green space. It also includes an educational component to improve the understanding of climate change impacts and adaptation among local people.

6.4 Key Conclusions and Lessons Learned

- Broad consultation is key to adaptation success: Townwide and site-specific climate change vulnerability assessment and adaptation planning is a process that needs to involve local, provincial, and national government; the private sector; and local communities. All levels of government, local communities, and the private sector will have an essential role in plan definition and implementation.
- Siting of strategic infrastructure away from flood-prone areas: Care is required in building resilience into the Mekong River exit points

and the proposed treatment plant near the market. The very important drainage gully and exit area to the Mekong River from the market is degraded and will require special treatment. The core group questioned the wisdom of constructing a treatment work close the Mekong River rather than requiring the private sector owner of the market to install and manage an on-site treatment facility.

- Area-wide approaches to adaptation in specific infrastructure assets: Additional adaptation measures are required for the northern floodgates along the lines proposed for the southern floodgates. The entire creek waterway leading from the town to the Mekong River through the floodgate is severely degraded. It would be essential for bioengineering and natural system rehabilitation to take place as part of an overall adaptation strategy for this drainage system and flood control infrastructure of the town.
- National and local government collaboration on adaptation and urban planning: Core group members raised the problem of a lack of coordination and consultation between the national and provincial governments on urban planning and management issues in towns—especially important now with projected climate change.
- Participatory mapping of past extreme events: Mapping of past extreme events and flooding as well as overlaying a defined climate change profile for the town enabled the core group to overcome the constraint that no flood or climate change maps had been prepared for Kaysone Phomvihane. Moreover, the economic development plan and master plan of the town did not have the benefit of accurate assessments of flooding potential and its implications for land uses.

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Case Study 3

Building Climate Change Resilience in Dong Ha

Dong Ha is the political, economic, and sociocultural center of Quang Tri Province with nine wards covering an area of about 7,300 hectares. The city has a strategic location at the intersection of National Road 1 A and the Trans-Asian Road, one of several development corridors identified for infrastructure and investment support to enhance trade between the Mekong countries.

Historically, Dong Ha is known as a trading point on the national road. The Dong Ha market was famous in the north as a center for consumer goods from the south and from the Lao People's Democratic Republic and Thailand. Even during times of national economic stagnation, Dong Ha was one of the few locations in Viet Nam which experienced growth.

Flooding is a natural threat for Dong Ha due to the climatic and topographic conditions of the area. With climate change, flood and drought conditions in Dong Ha are expected to become more frequent and extreme. Therefore, it becomes a question of how best to live with the floods by minimizing their impact on the city and its citizens.

As part of an Asian Development Bank project, the Dong Ha Climate Change Core Group was formed to identify past and future flood-prone areas in the town and what adjustments were required to increase town resilience. The core group also assessed two areas: the box canal and drainage basin of Ward 5 and the market-to-port zone.

7.1 Case Study Site 1: The Box Canal and Drainage Basin of Ward 5

The Le Loi drainage system has a core zone—the drainage channel—and a surrounding zone of residential and commercial buildings and road and services infrastructure. This includes a box canal system linked to an upstream former reservoir. The box canal has constricted runoff and flow in this major drainage corridor and now causes more severe and frequent flooding of surrounding residences, shops, and roads and is a dangerous area for children and animals living close by.

The current structure of the Le Loi box canal is inadequate to cope with minor frequent flood events and certainly cannot handle conditions equivalent to past extremes and those projected with climate change. It has made flooding in the surrounding residential and agricultural area substantially worse. The system as a whole is highly vulnerable to the threat of flooding caused by increased rainfall with climate change.

The core group's overall approach to adaptation is to redesign the whole 285-hectare basin as a new urban development center, which has an attractive green core zone with multiple functions: as a drainage corridor, water retention facility, landscaped recreation area, and water and air purifier. The development of a green and modern urban renewal area will increase the total value of the basin and a part of this added value can be invested in improvement of the green infrastructure system.

Case Study Site 1: Le Loi Street Box Culvert and Canal - Dong Ha City - Quangtri - Viet Nam

Data source:
ICEM database 2014
Workshop & Fieldwork in Dong Ha, Nov.2013
ADB TA 8186

7.2 Case Study Site 2: The Market-to-Port Zone

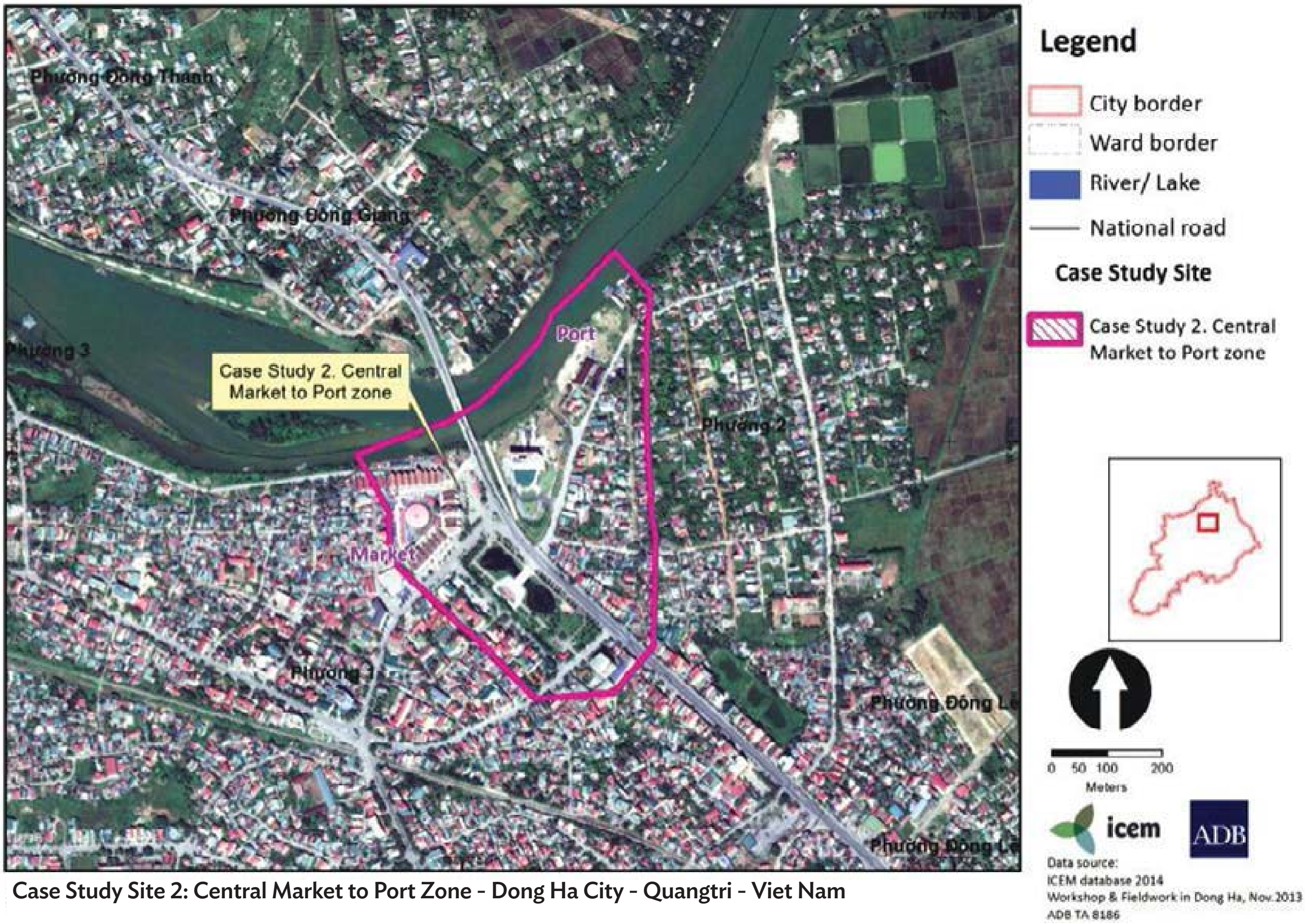
Located in the center of Dong Ha, the area is a strategic development zone covering the central market to the new port area. The port is just downstream of the market with the main Dong Ha Bridge spanning the Hieu River between them.

The zone contains a potential natural drainage point in Le Duan Park, which could play an important role in helping to alleviate pluvial flooding in the area by linking it to the river. Given its location and economic resources, this zone could become an important center of trade, tourism, and commercial activity, from which economic resources could be drawn to strengthen the town's adaptive capacity.

The area's strategic and prominent location at the center of town and along the Hieu River would make it an accessible and highly visible demonstration site for good adaptation. The area has a favorable location with many important facilities critical to a future trade and service center enabling Dong Ha to realize its vision as a prominent economic corridor and riverside city.

Due to climate change, Dong Ha is projected to become wetter in the wet season and hotter in the dry season. This will lead to increased incidence and severity of flooding at the site in the wet season and more intensive drought and heat effects in the dry season.

The core group's adaptation plan includes expanded green space, footpaths, and riverside recreational facilities. It increases permeable surfaces, rehabilitates the port as a recreation and tourism center, and retrofits the market to recycle stormwater and manage solid and liquid wastes on-site.



Case Study Site 2: Central Market to Port Zone - Dong Ha City - Quangtri - Viet Nam

7.3 Lessons Learned

- Green infrastructure is a critical component of ecologically sustainable urban development. Dong Ha is situated in a risky topographical and climatic region. However, green infrastructure can help to limit damage from natural disasters and climate change impacts.
- The destruction of Dong Ha's natural system foundations through urbanization that replaces natural functioning systems with hard engineering solutions has considerably increased the vulnerability of the city.
- The protection of Dong Ha's remaining natural systems and their enhancement with green infrastructure should be the highest priority in the overall city vision.
- Local government as well as the Asian Development Bank and the World Bank seem to prefer hard engineering solutions because they are standardized and relatively easy to deliver. However, with the serious problems associated with and caused by these hard measures, a shift toward softer and bioengineering solutions is needed.
- The core group can act as a mediator between the decision makers and the community and demonstrate methods for wider community engagement.
- A climate change threats and impacts database is needed to support adaptation planning. Climate change is recognized by the provincial and Dong Ha governments, but there is a lack of detailed data on the nature and extent of the threats and their impacts. One important task for the future is to develop an accurate database and geographic information system (GIS) products on specific threats and impacts on different areas of the town.
- Urban heat and its consequences need further study. They were not covered in this study which focused mainly on

flood protection and drainage. Given the projections for increasing incidence of higher temperatures and severity of drought in Dong Ha, an important task for the future will be to investigate this issue more thoroughly.

- Current urban planning in Dong Ha does not consider climate change. Safeguards and standards are only applied to planning new urban zones. Existing zones and unplanned development are not covered by the same safeguards and standards.
- The box canal case study has made it clear that even on higher ground severe local flooding can happen when poorly planned development leads to destruction of natural infrastructure.

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Appendixes

Appendix 1: Baseline Assessment Field Report Template

Purpose: To collect information to be able to undertake vulnerability assessment and adaptation planning.

NAME OF TARGET SYSTEM: ____________________

DISTRICT: ____________________

SECTOR: ____________________

DATE: ____________________

NAME: ____________________

1. **Provide short description of the system, its components and its location**

1. 2. 3.

2. **Describe the watershed context of the system**

Describe the location of the system within the watershed, the watershed condition, and experience of past extreme events in the watershed (e.g., landslides and floods). Document with photographs and sketches any past or existing conditions which illustrate the problems that have arisen.

1. 2. 3.

3. **Describe the specific location**

Include the geographic and human-made features, any slopes, the vegetation, the soil type, proximity to any water bodies, and any areas of instability.

1.
2.
3.

4. **Describe the condition of the system and its components**

Include description of signs of degradation and apparent causes and/or implications, and existing approaches to maintenance and repair.

1.
2.
3.

5. **Describe the design and form of any human-made components in the system**

Include description of current component/asset design and materials. Provide drawing and photographs of the asset design and condition.

1.
2.
3.

6. **Describe past extreme events and impacts on the system**

Include event dates, biophysical description of the events, and impacts on the system and its components.

1. 2. 3.

7. **Describe past adaptation responses to the impacts of past extreme events**

Include description of adaptation responses, drawings if appropriate, and a description of the success of the adaptation response.

1. 2. 3.

8. **Provide expert judgment of the design and/or form appropriateness of the human-made components to withstand extreme events**

1. 2. 3.

Appendix 2: Vulnerability Assessment Field Report Template

CLIMATE CHANGE THREATS

Change and shift in regular climate
Increase/decrease in temperature
Increase/decrease in precipitation
Increase/decrease in flow

Change and shift in events
Riverine flooding
Extreme localized pooling/flooding
Flash floods
Storms
Landslides
Droughts

DESCRIPTION OF THREATS:
Circle relevant threat in list provided and describe how it relates to the target system and its components.

EXPOSURE Description	**SCORE**
SENSITIVITY Description	**SCORE**
IMPACT Description	**SCORE**
ADAPTIVE CAPACITY Description	**SCORE**
VULNERABILITY SCORE: Refer to guiding matrix to help identify the vulnerability score	

Appendix 3: Vulnerability Assessment Matrix

System:
Major components:
1.
2.
3.
4.
5.

Threat	Interpretation of Threat	Exposure	Sensitivity	Impact	Impact Summary	Adaptive Capacity	Vulnerability
Change and shift in regular climate	Written description of how the threat relates to the system	Refer to table			Written explanation of impact and explanation for score	Refer to table	
Change and shift in events							

1 *Include footnotes*
2
3
4

Summary

Threat	Exposure	Sensitivity	Impact Level	Adaptive Capacity	Vulnerability
1					
2					
3					

Concluding statement

Command area least vulnerable to increased temperature and rainfall while intake most vulnerable to flash floods. The main canal is more vulnerable to sedimentation and landslide problems.

Notes on completing the vulnerability assessment matrix:

- It is important to be precise in the threats being considered. For example, with storms, you will need to notate specific characteristics of storms, wind, intense rainfall, lightning, etc.
- In situations where the technical information is poor, you will need to rely more on expert judgment and knowledge.
- Similarly, local communities and user groups need to be consulted as an important source of experience and knowledge
- It is useful to conduct separate assessments for each of the main components as the impacts of various climate change threats may be distinctive. A more focused assessment will allow more precise targeting of adaptation options and priorities.

Appendix 4: Adaptation Planning Matrix

Target Infrastructure System: Description, including objectives and main elements.								
Threats	Impacts	Significance			Adaptation Options	Priority Adaptation		
Insert all high and very high threats, first for the system as a whole and then for each of the high and very high components.	Insert the impacts recorded for the high and very high threats (only consider direct impacts)	Likelihood The chances of the impact occurring	Seriousness of the Impact Loss of life, property etc	Significance of the impact	Listing of the adaptation options in addressing each of the most significant impacts – focus on structural and bioengineering options	Feasibility cost, skills, staff, equipment	Effectiveness how well does it avoid, reduce or eliminate the threat	Priority

1 *Include footnotes*
2
3
4

Appendix 5: Vulnerability Assessment Scoring Tools

Impact Scoring Matrix

Sensitivity of system to climate threat \ Exposure of system to climate threat	Very Low	Low	Medium	High	Very High
Very High	Medium	Medium	High	Very High	Very High
High	Low	Medium	Medium	High	Very High
Medium	Low	Medium	Medium	High	Very High
Low	Low	Low	Medium	Medium	High
Very Low	Very Low	Low	Low	Medium	High

Vulnerability Scoring Matrix

Adaptive Capacity \ Impact	Very Low Inconvenience (days)	Low Short disruption to system function (weeks)	Medium Medium disruption to system function (months)	High Long term damage to system, property (years)	Very High Loss of life, livelihood, or system integrity
Very Low Very limited institutional capacity and no financial resources	Medium	Medium	High	Very High	Very High
Low Limited institutional capacity and limited access to technical and financial resources	Low	Medium	Medium	High	Very High
Medium Growing institutional capacity and access to technical and financial resources	Low	Medium	Medium	High	Very High
High Sound institutional capacity and good access to technical and financial resources	Low	Low	Medium	Medium	High
Very High Exceptional institutional capacity and abundant access to technical and financial resources	Very Low	Low	Low	Medium	High

Appendix 6: Vulnerability Assessment Report Contents Description

District assets and/or system priorities

- Short brief on the sector in the district; for example, summarize the different types of infrastructure in the sector for the district and overall status.
- Restate the criteria for identifying priority assets and/or systems for the vulnerability assessment.
- Describe each priority system and its components.

Vulnerability assessment method

- Short summary of method and/or process (no more than 1 page).
- Explain use of the method in this sector; for example, the interpretation of the criteria for sensitivity, exposure, impact, and adaptive capacity.
- Describe how the climate change threat profiles were interpreted for the sector; what projected changes are important for the sector in this district?

Vulnerability assessment results

- Present the results for each system in turn referring to the appended matrix.
- For each system and its components:
    - Go through each step in the vulnerability assessment and draw out the most significant issues and interpretations.
    - Pay special attention to describing the impacts column, both direct and indirect.
    - Draw together the results for each system (e.g., some components are more vulnerable than others and why).
    - Repeat those analytical steps for each system.

District vulnerability summary

- Provide a summary of the results (including a summary matrix, like an irrigation project summary matrix).
- Describe which systems are the most vulnerable and why.
- Describe the components of each asset and/or system which are most vulnerable and why.
- Draw out the main lessons that can be applied to the different types of systems and different components.
- Identify linkages with other sectors or geographic areas within the district.

Appendix 7: Monitoring and Evaluation Framework

Adaptation Measure	Monitoring Focus	Frequency	Responsible?	Organisational Indicators	Technical Indicators
Short-Term Measures					
Long-Term Adaptation Measures					

Appendix 8: Tools Supporting the Vulnerability Assessment and Adaptation Process

Key climate change vulnerability assessment and adaptation tools include the following:

Climate change downscaling and modeling: The downscaling of predicted climate change and global circulation models (GCMs) enable spatial assessment to quantify future climate, using both statistical and dynamic approaches. Once the capacities of the Department of Hydrology and Meteorology, Ministry of Science, Technology and Environment are in place, results from multiple GCMs and multiple downscaling techniques can be made available to infrastructure sectors on a regular and on-demand basis through the Department of Hydrology and Meteorology portal and as a result of regular consultation with them.

Hydrological modeling: One of the most important effects of climate change is on hydrological processes and a reason why it is necessary to link projected climate changes with hydrological analysis.

Hydrological modeling is used in developing baselines and assessing changes in basic hydrophysical processes, including precipitation, hill slope runoff subsurface infiltration and groundwater interactions, stream flow and water levels, and sediment transport. Catchment-scale hydrological modeling includes flooding, water resource utilization, and land-use change. The ICEM integrated water resources management model is a physical model which provides an advanced geographic information system (GIS)-compatible framework for integrated modeling of water resources and water utilization in both local and basin-wide scales.

Hydrodynamic modeling: Hydrodynamic modeling enables threats to be quantified. By running detailed three-dimensional (3-D) models of lakes, river channels, and floodplains, it is possible to quantify erosion, sediment dynamics, stratification of the water column, nutrient transport pathways, water quality, and productivity. Hydrodynamic modeling can also be applied to atmospheric environments for 3-D analysis of pollutant dispersion and emissions modeling.

GIS analysis: A range of GIS techniques are available for assessing the impacts of climate change and development, including zone of influence mapping, sector overlays, hot spot mapping, and vegetation or land-use identification mapping using satellite imagery. All modeling tool outputs and socioeconomic analysis can be linked directly to GIS analysis making it a critical tool in the vulnerability assessment and adaptation process in this guide. For participants at all levels, GIS maps can bring to life the relationships between projected changes and infrastructure systems and areas and make the impact assessment process more credible.

Two important GIS tools for vulnerability assessment and adaptation tools are the following:

- **Participatory mapping:** When detailed hydrological modeling of past extreme events and of projected climate changes are not available, past extreme events such as floods and landslides can be mapped with the input of local communities and local government experts who were present at the time. For example, in June 2013, continuous rain in upper catchments of Nepal caused the water level in the Seti River east of the Mahakali to rise from 6.94 meters (m) to 11.56 m and 5.53 m to 12.81 m in the Karnali at Chisapani within a 24-hour period. The discharge in the Mahakali River rose from 139,000 to 440,716 cubic feet per second, causing riverbank collapse and loss of life and property. Local residents and government officials have a vivid memory of depth, duration, and extent of the floodwaters and would be able to draw their memories on base maps. Those sketches can be digitized on GIS maps and then checked for accuracy through participatory exercises. Often, the flood hot spot maps which result are more accurate than maps coming from detailed hydrological modeling. Hot spot maps based on past extreme events are a good foundation for understanding conditions with climate change.
- A next step in participatory mapping can be the definition of climate change hot spots.

Simple calculations of increased water volume and flow can be made by considering projected rainfall increases and the size of catchments affecting the target area. That additional information can be discussed by participants who can then rank flood hot spots and interpret the effects of climate change projections on them.

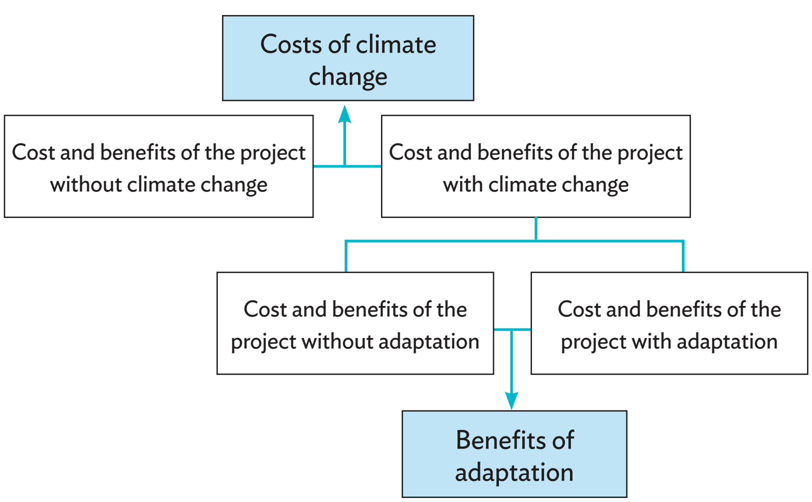
- **Hazard or hot spot mapping:** The process of establishing geographically where and to what extent particular hazards such as floods and drought are likely to pose a threat to infrastructure and to local communities. Hazard mapping can be conducted as a participatory exercise and/or as an output of detailed modeling against various scenarios of climate change.

Macroeconomic assessment and valuation: Macroeconomic assessment examines the effects of climate change on individual sectors and the economy and cross-sector implications of adaptation options. Valuation assesses impact costs and compares adaptation options through cost–benefit analysis, cost-effectiveness analysis, sensitivity analysis, and trend analysis.

Economic assessments of climate change serve to justify appropriate adaptation response and identify the investment required to make adaptation effective. For infrastructure departments, economic assessments can cover two critical steps (Figure A8.1):

- Establishes the costs of climate change with respect to the infrastructure project: comparison of the net present value (NPV) of the project without climate change to the NPV for the project with climate change. The difference between the former and the latter represent the costs (or benefits) of climate change.
- Determining the benefits of adaptation: comparison between the NPV of the project with climate change, but without adaptation, and the NPV of the project with climate change and with adaptation.

Figure A8.1: Economic Assessment of Climate Change Impact and Adaptation



Integrated spatial assessment: Practical integrated assessment models such as Dyna-CLUE are designed for undertaking integrated spatial assessments and suited to focused climate change assessments for specific areas. The core of the model is spatial land-use projections capable of integrating demand for different land uses, location conditions (including climate change), and policy scenarios. The model output can be read directly to assess the environmental consequences of the simulated changes. Integrated spatial models are used, for example, when considering alternative routing of a major road or the siting of water intakes, pump stations, and canals in an irrigation scheme.

Impact assessment matrices: Impact assessment matrices for climate change allow the prioritizing and weighting of options and recommendations. They are technical and capacity building tools that promote ownership by stakeholders of the process and its results.

Geotechnical surveys: Identifying where the likely points of failure are in different road routings, riverbank dikes, water supply reservoirs, and intakes, for example, may require field-based geotechnical surveys. These are conducted by infrastructure sector engineers familiar with geotechnical issues of slope stability. In its simplest form, it involves "walking the route" and recording observations in a field sheet against key variables such as existing road cross-section, natural slope condition and failures, and existing earthworks (Figure A8.2). In a practical tool developed by ICEM, the field observations are scored allowing for the identification and mapping of hot spot zones along the route where failures are likely. In a road section of 10 kilometers, for example, there may be five key points which need to be given priority for adaptation measures.

Monitoring and evaluation tools: Monitoring and evaluation (M&E) is critical to continuous learning and adjustment to adaptation measures based on performance and changing conditions. An M&E framework needs to be defined as part of the adaptation plan. The framework needs to identify responsibilities, frequency, and indicators for measuring performance and identifying potential for failure. Adaptation audits conducted at regular intervals are needed to consolidate monitoring results and to propose further adaptation action and safeguards.

Community consultation tools: Consultation with affected communities and users of infrastructure is important in conducting vulnerability assessments and adaptation planning, especially in situations where the scientific and technical information is limited. The Ministry of Science, Technology and Environment manual on conducting local adaptation plans of action is a rich source of participatory and consultative tools which can be drawn from in conducting infrastructure vulnerability assessments and adaptation plans.

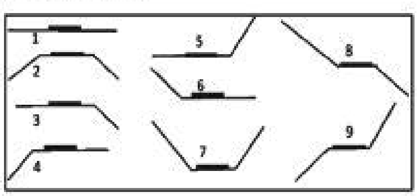
Walking the Route

Over the years, ICEM has conducted a number of slope stability assessments in various environments. Through this work, it has developed the following geotechnical survey data code for field assessments. The code outlines aspects to pay attention to when conducting a slope stability assessment. By following the code and noting each applicable aspect, you will ensure your slope stability assessment is detailed and thorough.

Figure A8.2: Geotechnical Survey Data Code

10. Structure
0 None
1 Pipe culvert
2 Box culvert
3 Bridge
4 Retaining wall

11. Cross-section



12. Ditch
0 Not required
1 Effective
2 Partially Blocked
3 Blocked
4 Missing

14. Access Condition
1 No issues
2 <10% access affected
3 10-25% access affected
4 25-50% access affected
5 >50% access affected

15. Water Channel
1 Gully/dry watercourse
2 Unlined stream
3 Lined ditch/stream
4 river

16. Earthwork Type
1 Cut
2 Embankment
3 Dumped spoil

17. Earthwork Angle
0 0
1 1-10
2 10-20
3 20-45
4 45-75
5 >75

18. Earthwork Height
0 0
1 0-3m
2 3-6m
3 6-12m
4 12-25m
5 >25m

19. Earthwork material
1 Silty clay
2 Silt
3 Clay
4

20. Earthwork Condition
0 No issues
1 Minor surface erosion
2 Minor slopeface failure
3 Severe gulleying
4 Moderate slope failure
5 Major slope failure

21. Vegetation
1 Bio-engineered slope
2 Mature trees/shrub/grass
3 Grass/shrubs
4 Sparse Grass/shrubs
5 Essentially none

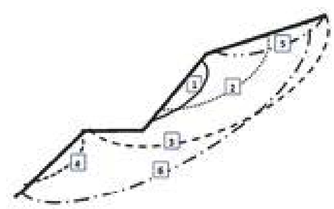
22. Natural Slope Length
1 <5m
2 5-20m
3 20-100m
4 100-500m
5 >500m

23. Natural Slope Angle
0 0
1 1-10
2 10-20
3 20-45
4 45-75
5 >75

24. Natural Vegetation
0 0
1 Mature trees/shrub/grass
2 Grass
3 Dry cultivation
4 Sparse Grass
5 Irrigated cultivation

25. Natural Slope Condition
0 No issues
1 Minor erosion
2 Minor surafce failures
3 Significant Upslope Instability
4 Significant Downslope Instability
5 Instability across alignment

26. Slope failure

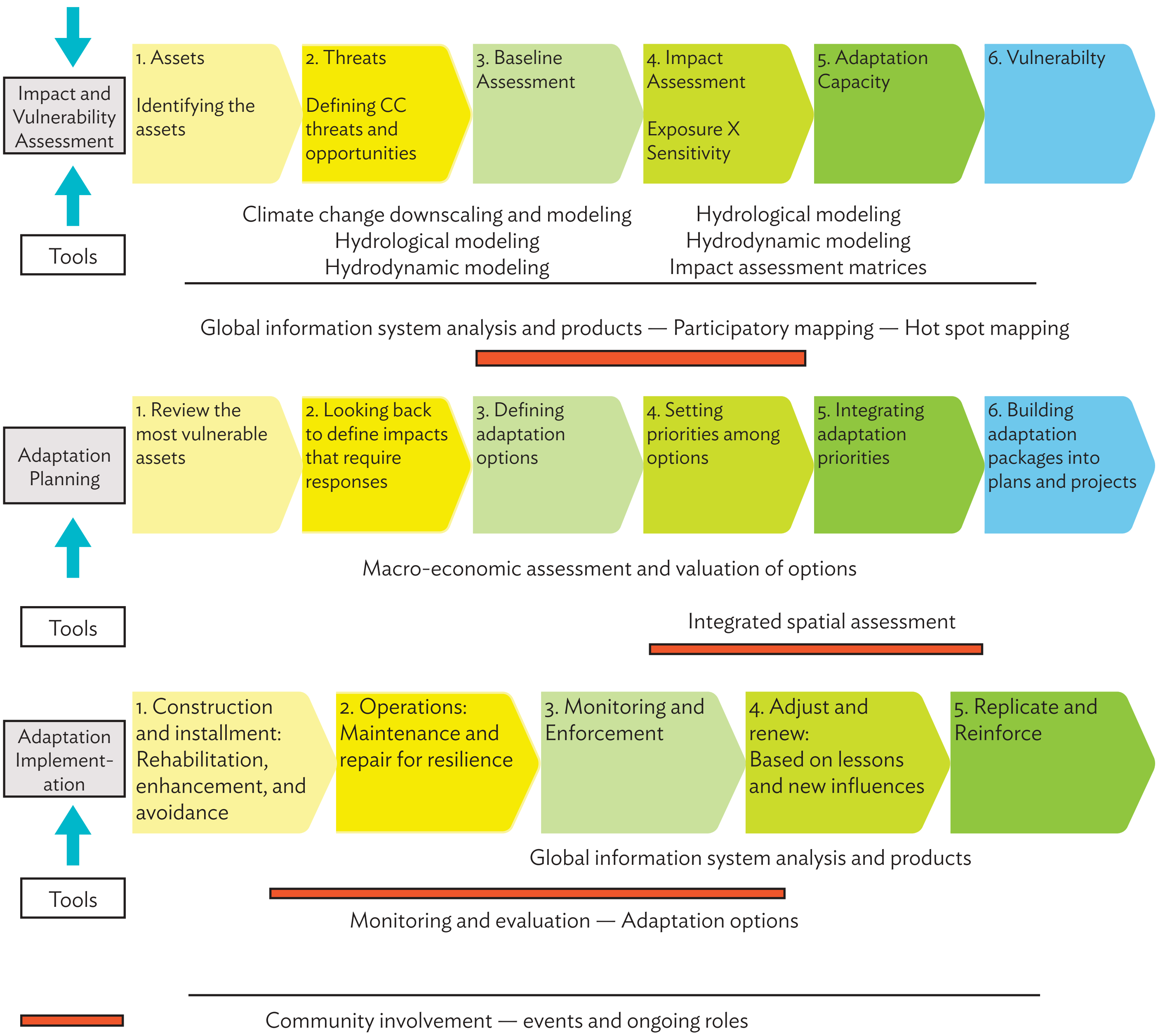


Notes legend
Buildings
Bridge
C—C Culvert
Road
Ditch
S—S Stream
R—R River

Source: ICEM.

Application of Tools in the Vulnerability Assessment and Adaptation Process
This chapter and its appendixes present a number of tools that can be applied in your vulnerability assessment process. These tools work together and in sequence to deliver the assessment and adaptation plan that most suits your needs.

The following diagram presents a summary of these tools in a potential sequence and in relationship to one another.



Appendix 9: Approach to Economic Analysis of Adaptation Options

A9.1 Introduction

Once a vulnerability assessment has been conducted for an asset or area and adaptation options have been identified, the options have to be appraised and prioritized. Economic assessments are useful in the process of evaluating and prioritizing well-defined adaptation options using economic criteria.

Each adaptation option should be regarded as an investment. The economic analysis identifies which of the solutions proposed will create the highest benefit at reasonable costs and within budget. Decision makers need to optimize budget allocation especially in situations of scarce resources.[49]

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change defines adaptation costs as "the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs," and defines benefits as "the avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures."[50]

According to a German International Development Agency (GIZ) report by Noleppa et al. (2013, p. 9): "The objective often is to model climate change impacts and their associated costs and benefits. Such economic assessments are classified according to the type of model used. There are two main typologies: The first typology classifies models with respect to their economic (i.e., market and/or sector) coverage. Model inputs and outputs are mainly monetary values such as prices, revenues, rents, costs, etc. ... [They are] principally able to analyse costs and utilities (benefits) based on the standard concept of welfare economics. The second typology does not use a pure economic concept, but combines economics with physics and other sciences. Models first provide information on physical indicators (such as yields, occurrence of health problems, number of damages, etc.), which – endogenously or exogenously depending on the model – can often be related to monetary values. Important approaches are very specific physical models (such as a crop model) and so-called Ricardian models. ... [These are generally] not considered main economic approaches for the assessment of climate change adaptation options because they are not specifically designed to prioritise among alternative options."

To evaluate the benefits of each proposed adaptation option, the impacts of climate change and quantify the costs of implementation of the options need to be assessed. Note that adaptation solutions usually will not completely eliminate impacts of climate change. It is important to take into account the costs of residual damage. Adaptation options that have the highest net benefits will be selected.[51]

When undertaking the economic assessments, planners need to consider the main purpose and core objectives of the adaptation options. For example, planners must decide if their objective is to

- minimize or avoid all or only part of the expected or observed impacts;
- return levels of human well-being to pre-climate change levels; or
- maintain current levels of risk or as a minimum reduce them cost-effectively within agreed budgets or predefined acceptable levels.

In practice, objectives vary between regions, countries, and communities, and trade-offs will need to be made between adopting all possible measures, and living with the risks.

There are three main techniques to be applied in the economic assessment of climate change adaptation options:

- cost–benefit analysis (CBA);
- cost-effectiveness analysis (CEA); and
- multicriteria analysis (MCA).

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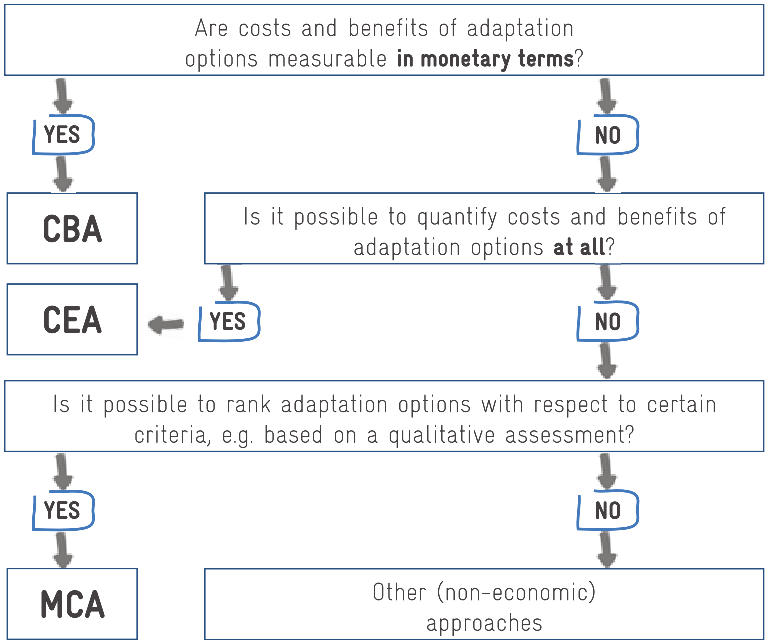
[49] S. Noleppa. 2013. *Economic Approaches for Assessing Climate Change Adaptation Options under Uncertainty*. Bonn and Eschborn, Germany: GIZ.

[50] Intergovernmental Panel on Climate Change (IPCC). 2007. Glossary. In *Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the IPCC*. Cambridge, UK: Cambridge University Press. p. 869.

[51] United Nations Framework Convention on Climate Change (UNFCCC). 2012. *Assessing the Costs and Benefits of Adaptation Options*. Nairobi.

Figure A9.1: Selecting the Suitable Economic Approach for Assessing Climate Change Adaptation Options



CBA = cost-benefit analysis, CEA = cost-effectiveness analysis, MCA = multicriteria analysis.

Source: S. Noleppa. 2013. *Economic Approaches for Assessing Climate Change Adaptation Options under Uncertainty*. Bonn and Eschborn, Germany: GIZ; United Nations Framework Convention on Climate Change (UNFCCC). 2012. *Assessing the Costs and Benefits of Adaptation Options*. Nairobi; I. Niang-Diop, and H. Bosch. 2011. *Formulating an Adaptation Strategy*. Dakar: University Cheikh Anta Diop.

All three approaches are able to analyze and prioritize adaptation options.[52]

Figure A9.1 illustrates the decision process among the three main techniques mentioned.

The three methods are presented in the following section alongside three case studies relative to the Asia and Pacific region. All case studies are taken directly from the United Nations Framework Convention on Climate Change (UNFCCC) work on impacts, vulnerability, and adaptation to climate change.[53]

A9.2 Methods

A9.2.1 Cost–Benefit Analysis

CBA can rank activities and determine the optimal use of scarce resources in efficiency terms, and, because CBA weighs costs against benefits, it determines whether benefits outweigh costs, allowing a decision on whether implementation is in the interest of the national or local economy. This clear "yes" or "no" answer, the fact that measures across sectors can be compared and that CBA can be used to optimize measures makes this technique superior to CEA and MCA.[54]

A drawback of CBA is that it requires that benefits are measurable and can be expressed in monetary terms and that the emphasis is on economic efficiency alone. If there is no market for the goods or services provided by the activity, often prices can be estimated in indirect ways.

The following are the main steps in assessing adaptation options using the CBA:[55]

- Establish a baseline. A baseline needs to be defined—that is, the situation without the adaptation intervention being carried out—as well as the situation with successful implementation of the adaptation option to determine the costs and benefits by comparing the two. The baseline is not the same as the present situation; it requires defining and projecting a "without" situation.
- Quantify and aggregate the costs over specific time periods. Costs of an adaptation action include direct costs (e.g., investment and regulatory) and indirect costs (e.g., social welfare losses and transitional costs).
- Quantify and aggregate the benefits over specific time periods. Benefits of an adaptation intervention should include the avoided damages from climate change impacts and co-benefits, where relevant. If there is no market for the goods or services provided by the adaptation activity, benefits can be estimated in indirect ways through

[52] See footnotes 49 and 51; also Global Climate Chance Alliance Support Facility (GSF). 2011. *Costing, Assessing and Selecting, Adaptation and Mitigation, Options and Measures*. Training workshop on mainstreaming climate change: module 6. Broomfield, CO: MWH; I. Niang-Diop, and H. Bosch. 2011. *Formulating an Adaptation Strategy*. Dakar: University Cheikh Anta Diop.

[53] See footnote 51.

[54] UNFCCC. 2002. *Annotated Guidelines for the Preparation of National Adaptation Programmes of Action*. Bonn, Germany.

[55] See footnote 51.

"nonmarket-based" approaches, such as contingent evaluation.
- Compare the aggregated costs and benefits. The bottom line for choosing an adaptation option is the comparison of the monetized elements of costs and benefits. The costs and benefits need to be discounted to properly calculate their present value. Adaptation planners can choose between three indicators of whether their options are efficient:
- The net present value (NPV) is the difference between the value of the benefits and the value of the costs, calculated at their present value. The NPV should be greater than 0 for an option to be acceptable. The better the economic value of an adaptation measure, the larger the NPV becomes. However, a larger NPV does not necessarily indicate higher efficiency.
- The benefit–cost ratio (BCR) is the ratio of the present value of the benefits to the present value of the costs. Benefits and costs are each discounted at a chosen discount rate. The BCR indicates the overall value for money of a project. If the ratio is greater than 1, the option is acceptable. The larger the BCR becomes, the better the adaptation option is judged to be.
- The internal rate of return (IRR) can be considered the interest rate an adaptation option would generate for society. Technically speaking, the IRR is the discount rate at which the NPV becomes 0. Hence, a resulting IRR higher than the discount rate to be chosen is a good result.

Case Study - Nepal: Assessing Adaptation Options for Freshwater Resources Using Cost-Effectiveness Analysis

Overview
Practical Action undertook the "Mainstreaming Livelihood-Centred Approaches to Disaster Management" project in Nepal between 2007 and 2010. A CBA was undertaken following the implementation of the project, which focused on community-level project activities and did not include indirect long-term benefits that could arise.

Various adaptation measures were implemented, including investment in irrigation facilities to reduce drought sensitivity, installation of electrical fencing to reduce wildfire intrusion risks and flood risk reduction investments.

The costs included the direct project costs and the opportunity costs of human and material resources contributed by the target households and other local stakeholders. Benefits were measured by comparing the present value of real income gains to a 'no-project' baseline. The present value of the benefits was always higher than the present costs.

Lessons Learned
In order to assess the benefits of reducing damage from future climate-related disasters as part of pre-project CBA assessment, it is advisable to obtain and record information on past disaster frequencies and associated damages as part of the baseline vulnerability assessment. Gaps in official statistics on this type of information are likely at the community level so that participatory methods will be required to obtain the necessary information.

Source: United Nations Framework Convention on Climate Change (UNFCCC). 2012. *Assessing the Costs and Benefits of Adaptation Options.* Nairobi.

A9.2.2 Cost-Effectiveness Analysis

If the benefits are difficult to express in monetary terms (as is the case, for instance, of human health, extreme weather events, and biodiversity and ecosystem services), CEA is the appropriate method to compare alternative measures to find out how an objective can be reached in the most cost-effective way. The objective needs to be sharply defined.[56]

The following are key concepts to bear in mind to properly conduct a CEA:[57]
- Just as in a CBA, costs need to be quantified in monetary terms to conduct a CEA. The procedure is identical to the cost assessment used in a CBA.
- For a CEA, the unit in which benefits are measured has to be carefully defined.[58]

[56] See footnote 54.

[57] See footnote 49.

[58] Global Climate Chance Alliance Support Facility (GSF). 2011. *Costing, Assessing and Selecting, Adaptation and Mitigation, Options and Measures.* Training workshop on mainstreaming climate change: module 6. Broomfield, CO: MWH

Examples are the number of animals preserved in a biodiversity program or the area of pristine forest protected in a conservation program.
- Quantifying (monetary) costs and (nonmonetary) benefits means that the unit costs can be calculated as the ratio of total (discounted) costs to total benefits if, as in the case of a CBA, incremental costs and benefits (attainable by comparing a baseline scenario and one or more adaptation scenarios) rather than absolute costs and benefits are taken into consideration.[59] The output indicator of a CEA is therefore also a cost–benefit ratio (CBR). The most cost-efficient option is the one with the lowest CBR, that is, the lowest costs per unit of benefit. The inverse, a BCR, can also be taken as an indicator; in such a case, the highest BCR directly indicates the most economically promising adaptation option.
- Beware that, if more than one type of benefit results from an adaptation option, a CEA can still be conducted as long as benefits can be expressed in the same unit to be compared and accumulated.

Case Study – Pacific Islands: Assessing Adaptation Options for Freshwater Resources Using Cost-Effectiveness Analysis

Overview

As part of the Capacity Building to Enable the Development of Adaptation Measures in Pacific Island Countries project, adaptation measures were implemented at nine pilot sites on four islands in the Pacific (Cook Islands, Fiji, Samoa, and Vanuatu) following intensive community consultations and cost-effectiveness analyses. Communities in the pilot sites identified water resources as their greatest concern. Vulnerabilities were noted in terms of immediate quality and quantity, and in terms of the sustainability of supply. Freshwater resources are threatened by increasing salinity. Communities are suffering because inhabitants have to spend a considerable amount of their day fetching water. Health problems are also increasing and agricultural yield is decreasing.

Among the options identified by the communities were the installation of desalinization systems, rainwater harvesting, and watershed protection measures, including contour farming, planting trees on hillsides, planting fruit trees within crop plots to provide shade for the plants, or reinforcing salt-tolerant vegetation buffers.

Lessons Learned

All three communities selected rainwater harvesting as their preferred adaptation option. It was deemed to be the most cost-effective option (i.e., yielding the desired quantity and quality of water at the least cost). In addition, rainwater harvesting was determined to be the most practical, easily implemented, and sustainable measure. Other measures were either too expensive, such as desalination systems, or did not promise the desired quality and quantity of water, such as watershed protection measures.

Source: United Nations Framework Convention on Climate Change (UNFCCC). 2012. *Assessing the Costs and Benefits of Adaptation Options*. Nairobi.

A9.2.3 Multicriteria Analysis

When benefits cannot be measured quantitatively or when multiple diverse benefits cannot be aggregated, an MCA can be used by assessing the different adaptation options against a number of criteria. Similar to a CBA and CEA, an MCA is able to rank and thus prioritize among multiple adaptation options. However, contrary to a CBA, ranks resulting from an MCA are not based purely on economic calculations but on a qualitative assessment of criteria such as feasibility, cost-effectiveness, co-benefits, ease of implementation, acceptability to local population, and resources required.[60]

The following are the steps in assessing adaptation options using MCA:[61]
- Agree on the decision criteria. Each criterion needs to be described, including the unit and span of possible scores, so as to ensure that those involved in the assessment process have a shared understanding.

[59] see footnote 58.

[60] See footnote 49.

[61] See footnote 51.

- Score the performance of each adaptation option against each of the criteria. Once this is completed, standardization is required in case scores of the various criteria differ in units (e.g., monetary or qualitative values) or spans (e.g., 1–5 or 0–100). Transformation of scores into similar units allows for effective comparison of the criteria.
- Assign a weight to criteria to reflect priorities. In case some criteria are perceived to be more important than others and the priorities are known, criteria can be assigned different weights, thus indicating their relative importance.
- Rank the options. A total score for each option is calculated by multiplying the standardized scores with their appropriate weight. Finally, weight-adjusted scores are aggregated and compared.

The main result of an MCA is a rank order of adaptation options and an appreciation of the weaknesses and strengths of the attributes of each of the options. An MCA can also be conducted in conjunction with other assessment approaches (CBA and CEA) to provide a more solid foundation for informed decision making.

Case Study – Bhutan: Assessing Adaptation Options Using Multicriteria Analysis

Overview

Bhutan assessed its vulnerability to climate change and possible adaptation options during the development of its National Adaptation Programme of Action (NAPA). A task force team consisting of representatives from key sectors including agriculture, biodiversity and forestry, natural disaster and infrastructure, health, and water resources identified and ranked possible priority adaptation projects using multicriteria analysis.

In the beginning, a total of 17 adaptation options were identified based on the framework of climate-induced hazards. The nine shortlisted options were ranked based on the following four criteria (the first three constitute benefits and the last, costs):

- human life and health saved and/or protected by the intervention;
- arable land with associated water supply (for agriculture and/or livestock) and productive forest (for forestry and forest products collection) saved by the intervention;
- essential infrastructure saved by the intervention such as existing and projected hydropower plants, communication systems, industrial complexes, cultural and religious sites, and main tourist attractions; and
- estimated project cost.

Initially, the benefits of the different adaptation projects were scored to be able to rank them. Following that, the scores were standardized on a scale from 0 to 1 to proceed with the analysis and to allow costs to be included. The last step of the multicriteria analysis was assigning weights to different benefits.

Source: United Nations Framework Convention on Climate Change (UNFCCC). 2012. *Assessing the Costs and Benefits of Adaptation Options*. Nairobi.

A9.3 Conclusions

Adaptation planners should consider the strengths and weaknesses of the various economic assessment approaches for assessing adaptation options according to their objectives and circumstances. In some situations, a number of approaches could be applied in a complementary fashion.

Table A9.1 clusters the different assessment approaches and their main strengths and weaknesses.

Table A9.1 Strengths and Weaknesses of the Different Approaches Presented

	Cost-Benefit Analysis	Cost-Effectiveness Analysis	Multicriteria Analysis
Description and/or outputs	CBA assesses benefits and costs of adaptation options in monetary terms. Outputs include net present values, internal rates of return or benefit-cost ratios.	CEA identifies the least-cost option of reaching an identified target and/or risk reduction level or the most effective option within available resources.	MCA assesses adaptation options against a number of criteria, which can be weighted, to arrive at an overall score.

continued on next page

Table continued

	Cost-Benefit Analysis	Cost-Effectiveness Analysis	Multicriteria Analysis
Strengths	CBA can provide concrete quantitative justification for adaptation options rather than just relative information. It allows for a comparison between different aspects using a common metric (e.g., US dollars).	CEA can assess options, using units other than monetary units, thus it is good for effects that are difficult to value. It can be applied within the context of routine risks (e.g., health effects) as well as major climate risks.	MCA can consider monetized and nonmonetized costs and benefits together. It also allows for considering a wide range of criteria including equity.
Weaknesses	CBA focuses on efficiency, when other criteria may be importan (e.g., uncertainty or equity). It has difficulties with nonmonetized costs and benefits and may need a subjective input into the choice of discount rate.	CEA is unable to offer an absolute analysis or common metrics. It deals insufficiently with uncertainty or equity. The selection of thresholds or target risk levels is not always easy or objective.	Scoring and ranking of options in MCA is subjective and not easily comparable.

CBA = cost-benefit analysis, CEA = cost-effectiveness analysis, MCA = multicriteria analysis.

Source: ADB and ICEM.

Appendix 10: Glossary

Adaptation – A process by which strategies to moderate, cope with, and take advantage of the consequences of climatic events are enhanced, developed, and implemented. Adaptation measures may be used to increase the resilience of infrastructure and other assets to withstand increasing intensity and frequency of climate events. Adaptation might include more regular and effective maintenance and protection measures, through to redesign and rerouting to avoid potential impacts. Adaptation may also include building the capacity of the people and institutions to prepare for and respond to the impacts of extreme events.

Various types of adaptation can be distinguished, including anticipatory, autonomous, and planned adaptation:

- Anticipatory adaptation – Adaptation that takes place before impacts of climate change are observed. Also referred to as proactive adaptation.
- Autonomous adaptation – Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.
- Planned adaptation – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve desired resilience.

Adaptation audit – Documenting adaptive measures taken by government or communities in response to past extreme events. Also, assessing their effectiveness as a guide to future adaptation on the principle of learning from the best of what is in place. Adaptation audits are normally conducted as part of the baseline assessment. They can also be conducted at regular intervals (e.g., every 3 years) for measures put in place in response to climate change as part of adaptation monitoring and evaluation programs.

Adaptation impact assessment – Adaptation measures can have unwanted impacts on other geographic areas and on other sectors which undermine their resilience. Also, measures taken now might rule out future adaptation options. Adaptation impact assessment is conducted on the measures in adaptation plans to avoid or mitigate those unwanted effects.

Adaptation deficit – The adaptation deficit is those measures which need to be taken to address the known impacts from past climate variability and extreme events irrespective of climate change, but which would build resilience to future conditions. The adaptation deficit includes many actions required as basic ingredients of good development such as maintenance of drainage systems, effective sediment trapping in irrigation schemes, and use of bioengineering methods to strengthen slopes and banks associated with roads and dikes.

Adaptive capacity – The ability to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. One way to enhance adaptation is by building "adaptive capacity."

Asset – A resource with economic value that an individual, community, corporation, or country owns or controls with the expectation that it will provide future benefit. Assets include infrastructure or the basic equipment, utilities, productive enterprises, installations, and services essential for the development, operation, and growth of an organization, city, or community. In the context of adaptation planning, an asset is any piece of infrastructure or resource for which a sector department has responsibility for its construction and maintenance, and for ensuring its long-term sustainability.

Baseline – The baseline is the state against which change is measured. It might be a "current baseline," in which case it represents observable, present-day conditions. It might also be a "future baseline," which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines.

Basin – The drainage area of a stream, river, or lake.

Capacity building – In the context of climate change, capacity building is developing the technical skills and institutional capabilities to enable active participation in all aspects of adaptation to, mitigation of, and research on climate change.

Climate – Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization.

Climate change – Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines "climate change" as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." See also climate variability.

Climate change scenario – A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships and assumptions of radiative forcing, typically constructed for explicit use as input to climate change impact models. A "climate change scenario" is the difference between a climate scenario and the current climate.

Climate forecast – A climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, for example, at seasonal, interannual, or long-term timescales. See also climate projection and climate change scenario.

Climate model – A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity; that is, for any one component or combination of components, a hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical, or biological processes are explicitly represented, or the level at which empirical parameterizations are involved. Coupled atmosphere/ocean/sea-ice general circulation models (AOGCMs) provide a comprehensive representation of the climate system. More complex models include active chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal, and interannual climate projections.

Climate projection – The calculated response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based on simulations by climate models. Climate projections are distinguished from climate forecasts, in that the former critically depend on the emissions, concentration, radiative forcing scenario used, and therefore on highly uncertain assumptions of future socioeconomic and technological development.

Climate sensitivity – The equilibrium temperature rise that would occur for a doubling of carbon dioxide concentration above pre-industrial levels.

Climate threshold – The point at which external forcing of the climate system, such as the increasing atmospheric concentration of greenhouse gases, triggers a significant climatic or environmental event which is considered unalterable, or recoverable only on very long timescales, such as widespread bleaching of corals or a collapse of oceanic circulation systems.

Climate variability – Climate variability refers to variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). See also climate change.

Downscaling – A method that derives local- to regional-scale (10–100 kilometers) information from larger-scale models or data analyses.

Drought – The phenomenon that exists when precipitation is significantly below normal recorded levels, causing serious hydrological imbalances that often adversely affect land resources and production systems.

Dike – A human-made wall or embankment along a shore to prevent flooding of low-lying land.

Effectiveness – The effectiveness of a proposed adaptation action to address a potential impact can be measured by assessing whether it will eliminate the impact completely, whether it will reduce the impact and by how much, and whether it will take some time to become effective.

Erosion – The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds, and underground water.

Exposure – is a measure of the extent to which the asset is exposed to the potential threats or existing hazards. Exposure in the context of climate change is limited to potential climate threats. The exposure may depend upon the relevance of the threat (e.g., increase in temperature) to the type of asset, and the extent to which the threat will increase (e.g., in intensity and frequency)

Extreme weather event – An event that is rare within its statistical reference distribution at a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called "extreme weather" may vary from place to place. Extreme weather events may typically include floods and droughts.

Feasibility – A measure of how feasible an adaptation measure may be—whether it is technically feasible and/or whether there is sufficient time and materials available to do the work. Includes cost considerations—how expensive the measure is and/or whether there is government budget available—and the capacities of community and government.

Groin – A low, narrow jetty, usually extending roughly perpendicular to the shoreline, designed to protect the shore from erosion by currents, tides, or waves, by trapping sand for the purpose of replenishing or making a beach.

Hazard – A hazard is an existing source of danger that may cause harm, damage, or loss, or poses a danger to a system vulnerable to the hazard. A hazard may be a static physical obstruction, such as a landslide, or it may be a temporary danger, such as strong winds from a storm. A hazard is different from a threat in that a threat is a potential future event, such as the threat of landslide posed by the combination of heavy rains and a steep, unstable slope.

Impact assessment – The practice of identifying and evaluating, in monetary and/or nonmonetary terms, the effects of climate change on natural and human systems.

Impacts – The effects of climate change on natural and human systems or assets. Often, reference is also made to secondary and tertiary consequences. For example, climate change can result in less rainfall, which will inhibit crop growth. This is either because it means less water falling on plots, less groundwater recharge, or less water in streams from which water is taken to irrigate crops. The secondary consequence of this is less crop product, which can lead to economic difficulties or hunger. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts:

- Potential impacts – All impacts that may occur given a projected change in climate, without considering adaptation.
- Residual impacts – The impacts of climate change that would occur after adaptation.

Infrastructure – The basic equipment, utilities, productive enterprises, installations, and services essential for the development, operation, and growth of an organization, city, or nation.

Integrated water resources management (IWRM) – The prevailing concept for water management, which, however, has not been defined unambiguously. IWRM is based on four principles that were formulated by the International Conference on Water and the Environment in Dublin, 1992: (i) fresh water is a finite and vulnerable resource, essential to sustain life, development, and the environment; (ii) water development and management should be based on a participatory approach, involving users, planners, and policy makers at all levels; (iii) women play a central part in the provision, management, and safeguarding of water; and (iv) water has an economic value in all its competing uses and should be recognized as an economic good.

Landslide – A mass of material that has slipped downhill by gravity, often assisted by water when the material is saturated; the rapid movement of a mass of soil, rock, or debris down a slope.

Likelihood – The likelihood of an occurrence, an outcome or a result, where this can be estimated probabilistically. In this context, the likelihood of an impact is a combination of the probability of climatic events happening and that these events will have the predicted impact.

Mitigation – An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks. The term mitigation in the climate change context should not be confused with the "mitigation measures" used to address environmental and social impacts of developments.

Projection – The potential evolution of a quality or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions to emphasize that projections involve assumptions concerning, for example, future socioeconomic and technological developments, that may or may not be realized, and are therefore subject to substantial uncertainty. See also climate projection.

Resilience – The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.

Riparian – Relating to or living or located on the bank of a natural watercourse (such as a river) or sometimes of a lake or a tidewater.

Risk – The probability quantifiable damage, injury, liability, loss, or any other negative occurrence that is caused by a threat or hazard. The probability of something happening multiplied by the resulting cost or benefit if it does. Sometimes used interchangeably with "hazard" and "threats," the risk can be reduced through adaptation and addressing the impacts, even if the threats of climate change and the hazards they bring remain the same.

Risk management framework – The overall system for managing the impacts resulting from climate change and extremes of climate involving identifying the climate threats to a structure or asset, assessing the vulnerability and potential impacts, and then developing adaptation options and plans for its protection.

Scenario – A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships in respect to climate. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a "narrative storyline."

Scoping – A critical, early step in climate change impact and vulnerability assessment, and in the final preparation of an adaptation plan. The scoping process identifies the boundaries of the assessment and plan in terms of its infrastructure focus, geographic area coverage, and temporal dimensions. Assets and issues that are likely to be of most importance and relevance to the assessment are described and those that are of little concern are eliminated. In this way, the assessment focuses on the significant effects, and time and money are not wasted on unnecessary investigations. The scoping process will involve roundtable consultations with local government sector experts and local leaders and effected communities. It is based on an initial understanding of the effects of past extreme climate and hydrological events in the target areas.

Sensitivity – The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by more frequent flooding due to increased water flow and volume in rivers during extreme flood events).

Seriousness – The seriousness of an impact is a measure of what would happen if the impact occurred. This might include loss of life, the damage to the asset and how long it would take to repair and at what cost, the loss of the services provided by that asset, and the economic implications (loss of life, loss of property, i.e., destruction of property, damage to property, loss of productivity and income, or impeding of function). This can range from trivial (very low) to catastrophic (very high).

Significance – The extent to which something (the impact) matters; its importance. In a risk management framework, the significance of the impact is assessed from a consideration of the likelihood that it may occur with the seriousness of the impact.

Stakeholder – A person or an organization that has a legitimate interest in a project or entity, or would be affected by a particular action or policy.

Streamflow – Water flow within a river channel, for example, expressed in cubic meters per second. A synonym for river discharge.

Surface runoff – The water that travels over the land surface to the nearest surface stream; runoff of a drainage basin that has not passed beneath the surface since precipitation.

Threat – Something that may cause damage or harm (to the asset) in the future.

Threshold – The level of magnitude of a system process at which sudden or rapid change occurs. A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels.

Uncertainty – An expression of the degree to which a value (e.g., the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behavior. Uncertainty can therefore be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgment of a team of experts).

Vulnerability – Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change (i.e., threats and hazards), including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Nature-Based Solutions for Building Resilience in Towns and Cities

Case Studies from the Greater Mekong Subregion

Urban populations are projected to increase from 54% to 66% of the global population by 2050, with close to 90% of the increase concentrated in Asia and Africa. Cities and towns—a growing source of greenhouse gas emissions—will need to address challenges posed by climate change. A nature-based approach in identifying climate change vulnerabilities and developing relevant adaptation options was conducted in three towns of the Greater Mekong Subregion. Working with local governments, nongovernment organizations, women's groups, and professional associations, town-wide adaptation measures were defined by overlaying climate change projections on town plans and zoning schemes for strategic infrastructure. This publication captures valuable experience and lessons from the project.

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