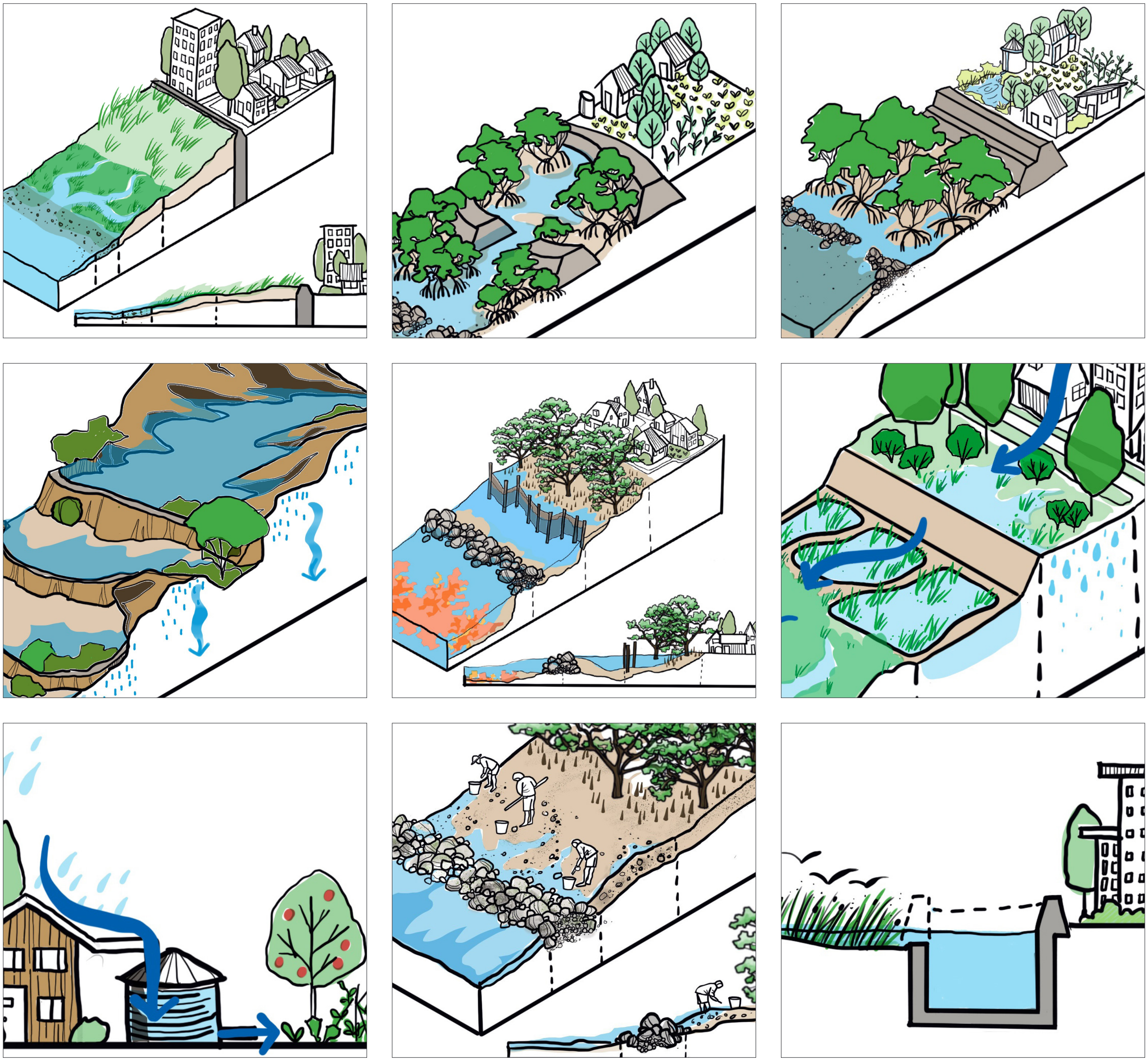

A Practical Guide to Implementing GREEN-GRAY INFRASTRUCTURE

August 2019

CONSERVATION INTERNATIONAL

Coordinators of the Green-Gray Infrastructure Practical Guide

CONSERVATION INTERNATIONAL

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FRONT COVER:

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INTRODUCTION

Extreme weather events brought about by climate change are one of the most dangerous risks facing humanity.[1] Reducing this threat to vulnerable communities is a critical challenge of our time. These events have already caused devastating impacts on communities in many parts of the world, affecting people's lives and infrastructure in an unprecedented manner.

In the Philippines these impacts have been particularly severe. According to the United Nations, the Philippines is the third most at-risk nation to the effects of climate change. This extreme vulnerability was demonstrated by the scale of the devastation caused by Typhoon Haiyan in 2013, when more than 6,000 lives and 900,000 homes were lost. With 50% or more of the 1,500 cities and municipalities in the Philippines lying along the coast and 62% of the country's population living in coastal zones, there is a critical need to find preemptive, innovative, and scalable solutions to mitigate these natural disasters. **Green-gray infrastructure has the potential to be one such solution, especially for the most isolated and vulnerable of the coastal communities in the Philippines.**

This Practical Guide includes information that can apply to any stage in the development of a green-gray infrastructure project. This Practical Guide is adaptable to different regions, countries, and geographic settings, because many of the challenges and applicable solutions are similar across the globe, for example between the Philippines, Indonesia, Suriname, and New Caledonia. Though each place is unique, the general set of tools and adaptation principles described in this Practical Guide can still apply. The Practical Guide will be updated based on user feedback and experiences implementing green-gray infrastructure projects. The guide will be available for download at conservation.org.

1 World Meteorological Organization (WMO) Statement on the State of the Global Climate in 2017.

Green-gray infrastructure combines conservation and/or restoration of ecosystems with the selective use of conventional engineering approaches to provide people with solutions that deliver climate change resilience and adaptation benefits.

By blending "green" conservation with "gray" engineering techniques, communities can incorporate the benefits of both solutions while, through a hybrid approach, minimizing the limitations of using either individually. The green-gray infrastructure design approach can apply in coastal, freshwater, and terrestrial settings.

Purpose of Practical Guide

This Practical Guide provides tools for identifying, planning, designing, constructing, and monitoring green-gray infrastructure projects with the goal of increasing the resilience of vulnerable communities. These tools are based on Conservation International's (CI) field experiences in the Philippines and globally, and includes input from local communities, local and national governments, non-government partners, technical experts, and construction and engineering companies.

The Practical Guide is intended as

- an education and outreach tool; and
- a resource for selecting, designing, and constructing green-gray infrastructure projects.

Who is the target audience?

This Practical Guide will be a tool for local and national governments, consultants, and civil society organizations. Including:

- Local Governments
- Local Contractors
- National Governments
- Policy Makers
- Non-government organizations (NGOs)
- Engineers / Designers

The Green-Gray Infrastructure Practical Guide will be distributed to these diverse audiences using a variety of communication tools including workshops and a website portal.

How to use the Practical Guide?

This document is divided into six modules, each begins with the module's purpose and objective.

1. Green-Gray Infrastructure Solutions - Defines the green-gray adaptation approach, benefits, and example applications in coastal, freshwater, and terrestrial settings.

2. Identifying Sites - Describes a process and tools for evaluating a communities' climate vulnerability, engaging stakeholders and evaluating potential project sites.

3. Site Selection Tool - To evaluate, rank and select green-gray infrastructure project locations that considers stakeholder priorities.

4. Design Development - Steps to develop concept sketches into ready-to-build, approved design plans.

5. Construction - Alternative construction models, activities, and potential risks to consider early in the design development phase.

6. Monitoring, Maintenance, and Adaptive Management - introduces a multi-step feedback process linking project monitoring and evaluation frameworks, maintenance strategies, and adaptive management.

Other approaches similar to green-gray infrastructure

There are many terms and concepts similar to green-gray infrastructure. Here we mention a few, along with their similarities and differences to green-gray infrastructure. One of the most closely related approaches, is Ecosystem-based Adaptation. **Ecosystem-based Adaptation** means the use of biodiversity and ecosystem services in the context of a global adaptation strategy, to help people adapt themselves to the negative effects of climate change.[2] Green-gray infrastructure is a type of Ecosystem-based Adaptation that includes gray infrastructure.

2 IUCN (International Union for Conservation of Nature): Position Paper, Ecosystem-based Adaptation (EbA), UNFCCC Climate Change Talks, 28th September – 9th October 2009, Bangkok, Thailand

Conservation International has developed Guidelines for Designing, Implementing and Monitoring Ecosystem-based Adaptation Interventions[3]. This Practical Guide is a complement to those Guidelines with new tools for site selection and project design.

Eco-Disaster Risk Reduction (DRR) is the sustainable management, conservation and restoration of ecosystems to reduce disaster risk, to achieve sustainable and resilient development[4]. Eco-DRR considers human and natural disasters, not only climate induced disasters (e.g., geologic disasters like earthquakes, landslides, volcanic eruptions). Eco-DRR is different from green-gray infrastructure because Eco-DRR doesn't necessarily include gray infrastructure.

Nature-Based Solutions (NbS) are defined by IUCN as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". Nature-Based Solutions don't necessarily provide climate change adaptation strategies nor include gray infrastructure.

Nature-based Engineering approaches such as Building with Nature, Engineering with Nature and Ecological Engineering are most similar to green-gray infrastructure because they often include ecosystem restoration and/or conservation and often provide disaster risk reduction and/or climate change adaptation solutions.

Building with Nature - a new approach to hydraulic engineering that harnesses the forces of nature to benefit environment, economy and society.

Engineering with Nature - the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes.

Ecological Engineering - the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both.

3. Donatti, C.I., Martinez-Rodriguez, M.R., Fedele, G., Harvey, C.A., Scorgie, S., Andrade, A., Rose, C., Alam, Mahbub. 2018. Guidelines for designing, implementing and monitoring ecosystem-based adaptation interventions. Conservation International.

4 Monty, F., Murti, R., Mithapala, S. and Buyck, C. (eds.). 2017. Ecosystems protecting infrastructure and communities: lessons learned and guidelines for implementation. Gland, Switzerland: IUCN.x + 108pp.

Key Concepts & Terms

Adaptation - an adjustment in social or ecological structures and processes to respond to the actual or expected impact of climate change.

Adaptive Capacity - the pool of assets (social, physical, financial, natural, human, and cultural) and resources (technological, knowledge and governance) which an individual, household or community may mobilize to build resilience to climate change impacts.[5]

Carbon Capture - the removal of carbon dioxide from the atmosphere.

Climate Change - rising temperatures and altering rainfall patterns in many regions, leading to more frequent and intense extreme weather events, such as droughts, floods, and cyclones.

Climate Hazard – e.g., typhoons, storm surge, wind waves, floods.

Coastal Protection - measures to reduce the risk of coastal hazards.

Conservation - Strategies to conserve the function, structure and species composition of ecosystems, recognising that all components are inter-connected.

Climate Related Disasters – a climate hazard becomes a disaster when a community can no longer recover on their own and requires external resources to return to service.

Disaster Risk Reduction (DRR) - decrease the damage caused by natural hazards like earthquakes, floods, droughts and cyclones, through an ethic of prevention.[6]

Exposure - risks faced by vulnerable populations, such as from reduced agricultural productivity, risks to unique and threatened systems, increased exposure to disease vectors and extreme weather events.[7]

Flood Risk Management - strategies intended to reduce risk or damage caused by rivers when they overtop their banks.

Gray Infrastructure – human-designed and built solutions with no ecosystem restoration and/or conservation and with fixed years of service (or useful life) before repair or replacement is needed.

5 C. Bachofen and E. Cameron, Accessed March 2019
6 United Nations Office for Disaster Risk Reduction
7 C. Bachofen and E. Cameron, The World Bank, The Social Dimensions of Climate Change, Vulnerability: exposure, sensitivity and adaptive capacity. Accessed March 2019.

Green-Gray Infrastructure (GGI) - combines conservation and/or restoration of ecosystems with the selective use of conventional engineering approaches to provide people with solutions that deliver climate change resilience and adaptation benefits.

Green Infrastructure - A network of conserved and/or restored ecosystems that strengthen biodiversity, mitigate emissions of greenhouse gases, enable societal adaptation to climate change, and deliver a wide range of other ecosystem services.[8]

Livelihoods – means of support or subsistence.[9]

Resilience - an ability to recover from or adjust to change.

Restoration - Improving and assisting the recovery of ecosystems that have been degraded, damaged or destroyed.

Spatial Prioritization - the use of information about a geographic area to identify opportunities that align with project goals.

Sensitivity - results from dependence on the environment for livelihoods, food, shelter and medicine; lack of access to decision making and justice, geographical context, and/or a range of intersecting inequalities including financial, socioeconomic, cultural and gender status.[10]

Sustainable Management - Managing resources in ways that promote the long-term sustainability of ecosystems and the ongoing delivery of essential ecosystem services to society.

Vulnerability - The propensity or predisposition to be adversely affected; encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.[11]

Water Security - The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.[12]

8 Silva, J., E. Wheeler. 2017, Ecosystems as Infrastructure, Perspectives in ecology and conservation.
9 Merriam-Webster
10 C. Bachofen and E. Cameron, Accessed March 2019
11 IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts,Adaptation, and Vulnerability.

1. GREEN-GRAY INFRASTRUCTURE SOLUTIONS

As climate changes, communities need to adapt to build social and ecological resilience. It is essential to identify effective adaptation strategies, appropriate to specific settings that take advantage of ecosystem properties.

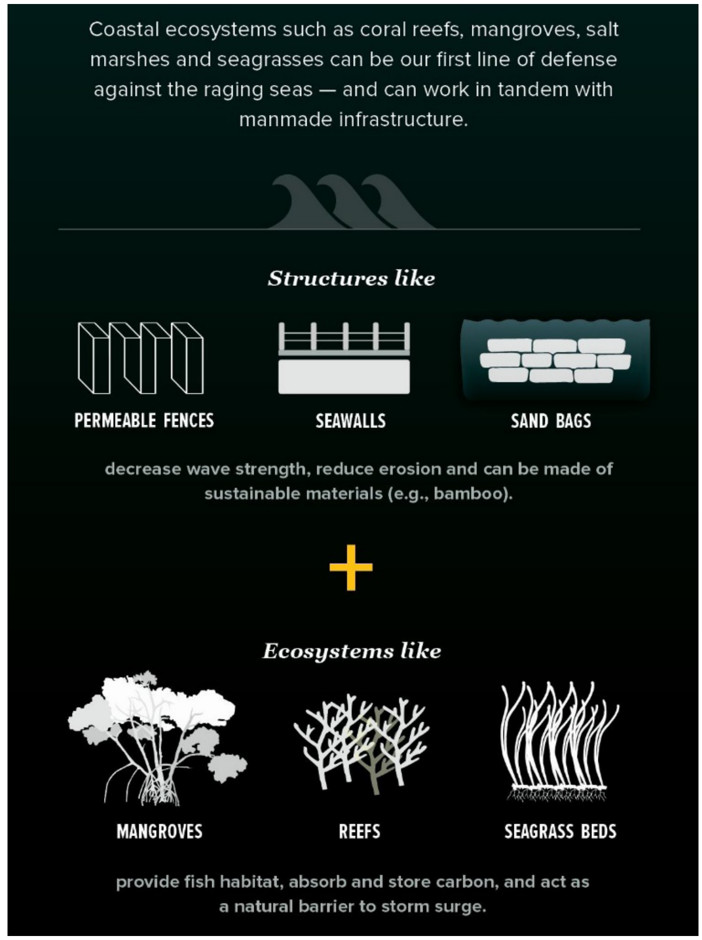
This module defines the green-gray adaptation approach, benefits, and example applications in coastal, freshwater, and terrestrial settings.

What is green-gray infrastructure?

Green-gray infrastructure combines conservation and/or restoration of ecosystems with the selective use of conventional engineering approaches to provide people with solutions that deliver climate change resilience and adaptation benefits. By blending "green" conservation with "gray" engineering techniques, communities can incorporate the benefits of both solutions while minimizing the limitations of using either individually. The green-gray infrastructure design approach can apply in coastal, freshwater, and terrestrial settings.

For example, a combination of mangrove restoration with limited geoengineering approaches, such as breakwaters, combines the wave attenuation and flood control value of mangroves – in addition to the fisheries, biodiversity, water quality and numerous other benefits of this ecosystem – with the benefits of engineered structures to stabilize the coastal zone, reduce flooding and attenuate waves. **The combined solution can therefore be more comprehensive, robust and cost-effective than either solution alone.**

Monitoring, maintenance, and adaptive management are integral to green-gray infrastructure project design and implementation.



What are the benefits of using green-gray infrastructure?

Green-gray infrastructure projects can provide multiple benefits, depending upon the project and the setting, such as:

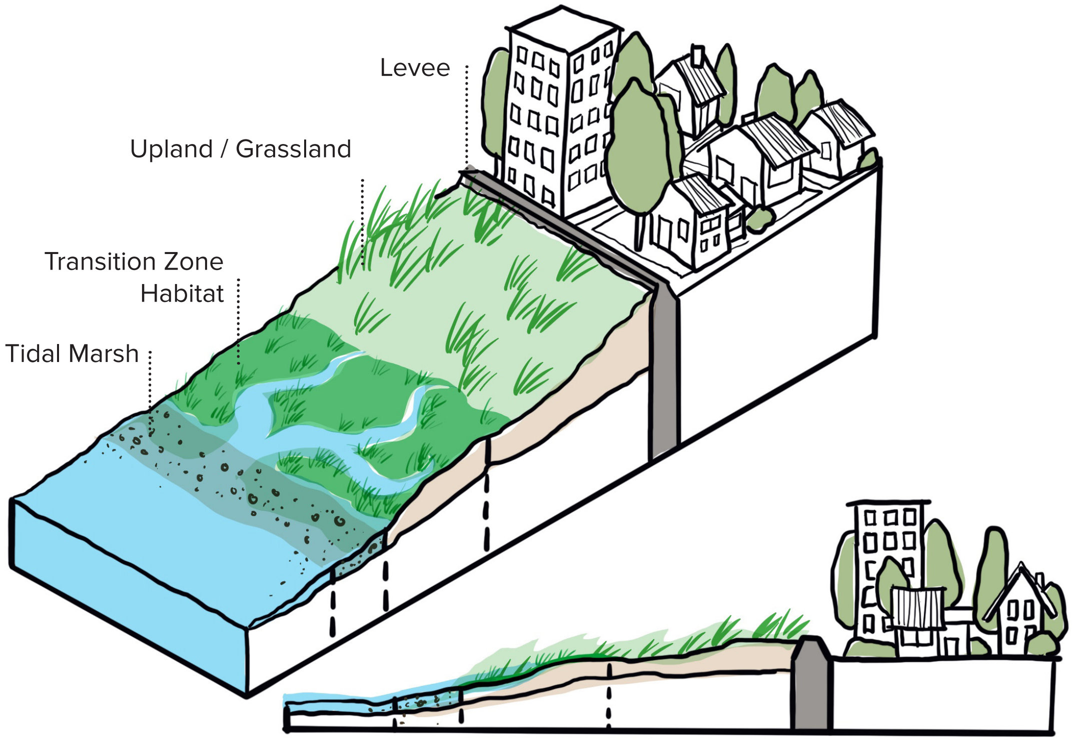
- Maximizing ecosystem benefits;
- Climate change adaptation through disaster risk reduction;
- Coastal protection;
- Water security;
- Flood management;
- Food security for agriculture by supplying irrigation water;
- Improving water quality by filtering pollutants;
- Providing supplemental livelihoods; and
- Capturing carbon.

Green-gray infrastructure is also often a more cost effective alternative compared to a purely gray infrastructure solution. One reason for this is because of the suite of ecosystem services provided by the restored and/or conserved habitat. When combined as part of a disaster risk reduction project, green-gray infrastructure also improves a community's adaptive capacity by providing organizational development and supplemental livelihoods support.

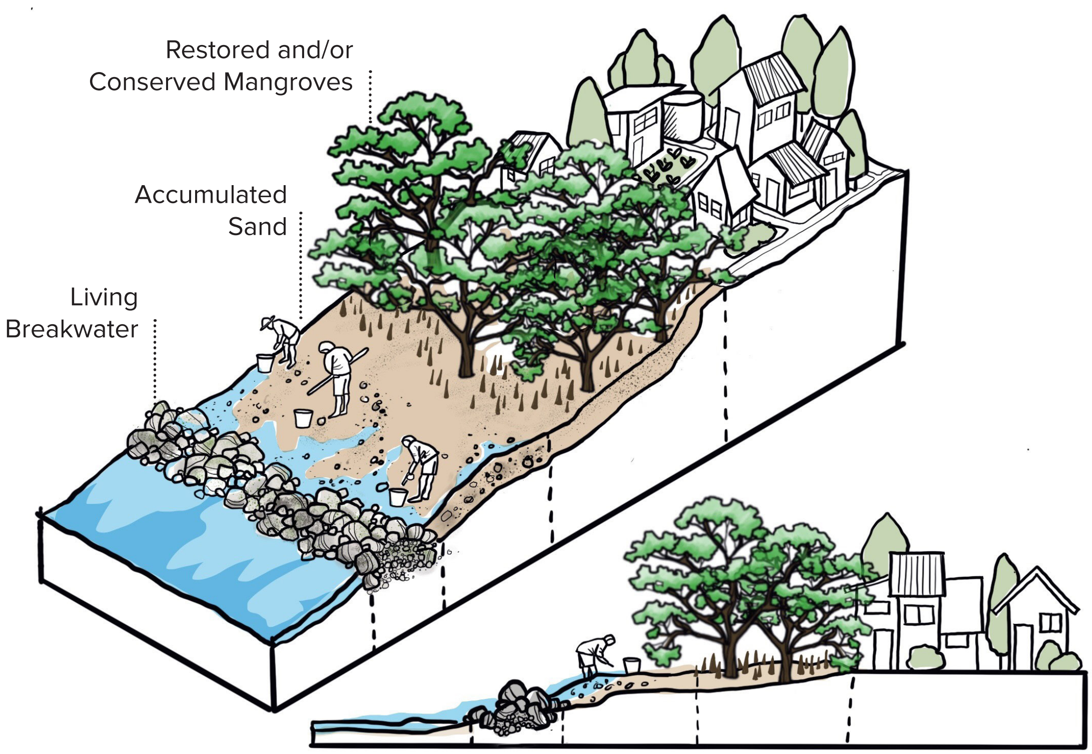
Where can green-gray infrastructure be applied?

The green-gray infrastructure design approach can apply in coastal, freshwater, and terrestrial settings.

COASTAL GREEN-GRAY EXAMPLES

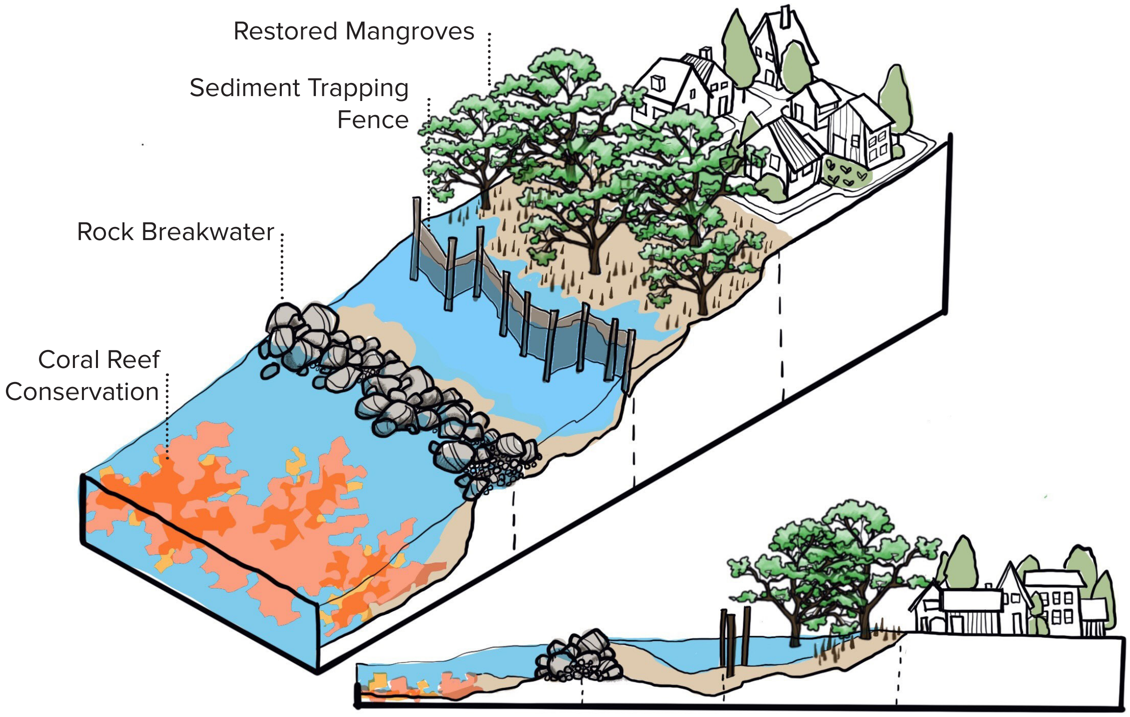


HORIZONTAL LEVEES integrate coastal ecosystem restoration and/or conservation with traditional levee design to achieve greater protection from floods and sea level rise than if either solution was applied alone.

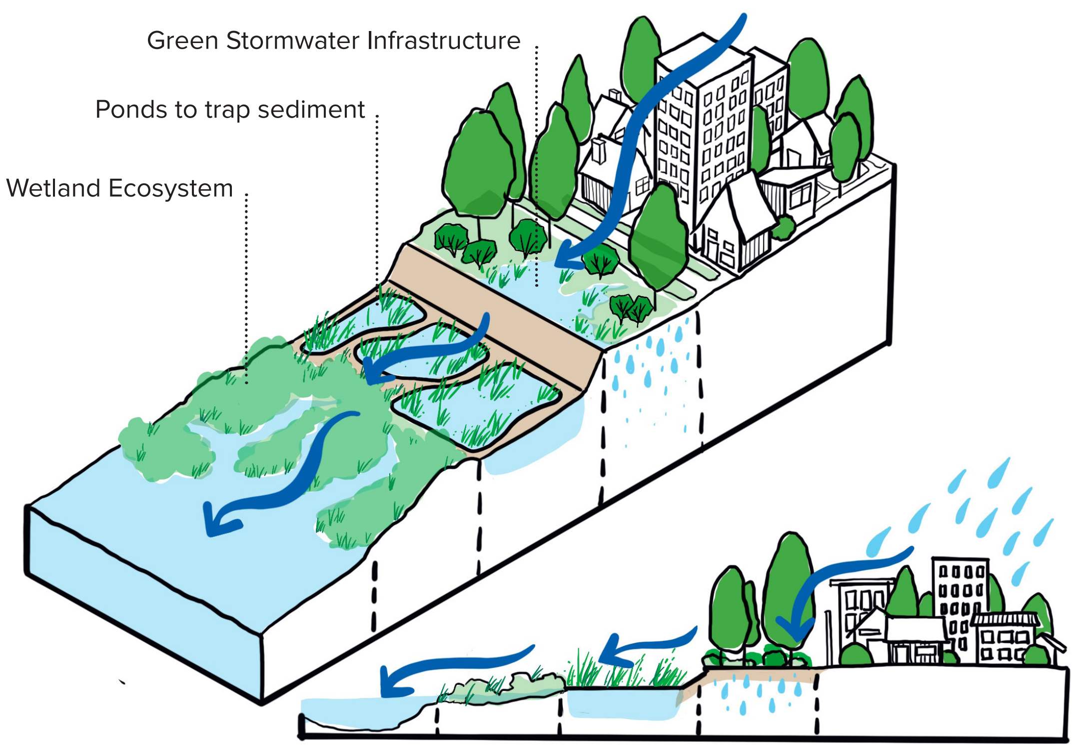


OYSTER REEFS / LIVING BREAKWATERS reduce wave energy, facilitate sediment accumulation, and encourage colonization by shellfish to diversify livelihoods of local community members.

COASTAL GREEN-GRAY EXAMPLES

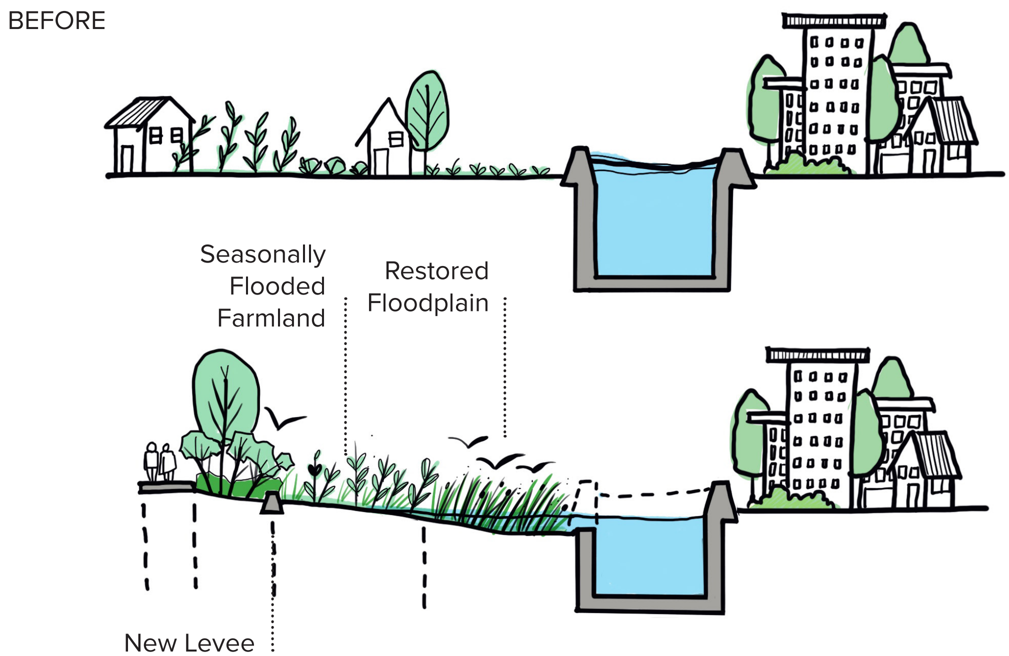


BREAKWATERS reduce wave energy to buffer impacts of weather events to vulnerable communities and facilitate sediment accumulation for ecosystem restoration, such as for mangroves.

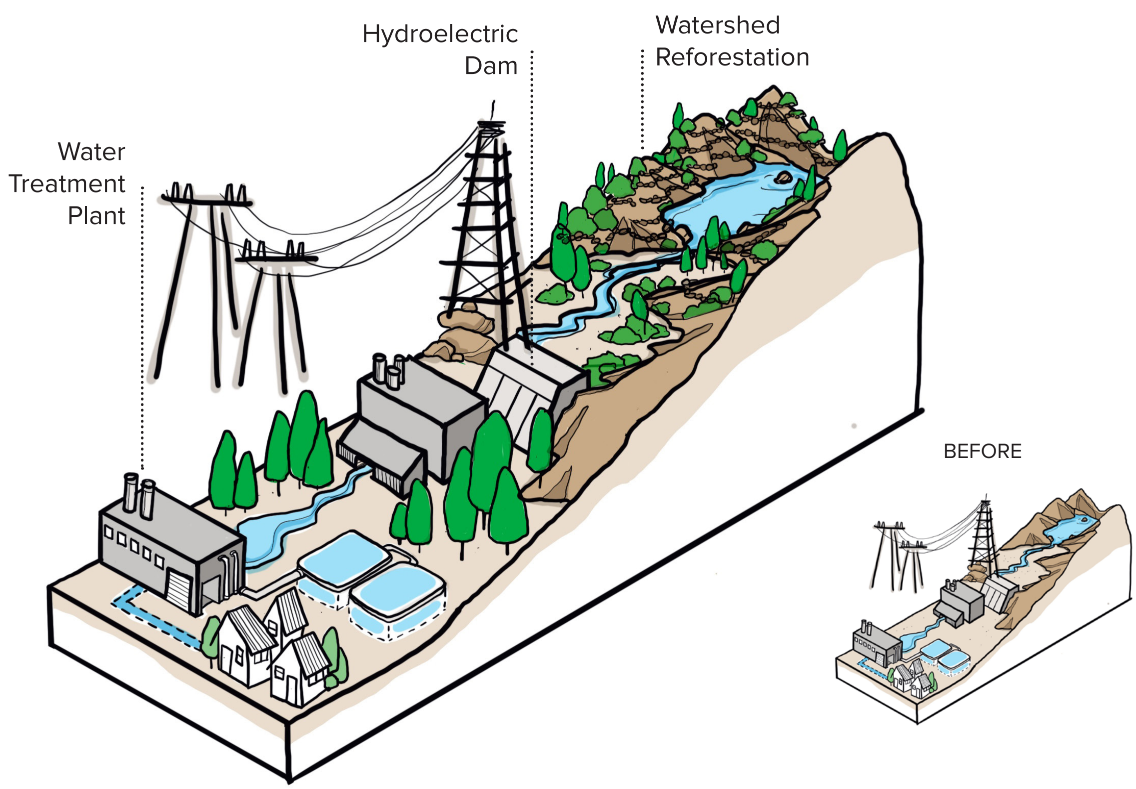


WATER QUALITY WETLANDS use natural processes to clean stormwater, graywater, and/or wastewater resulting in improved habitat and biodiversity. Stormwater wetlands clean runoff from urban spaces, reduce flooding, and can also create spaces for people to access nature.

FRESHWATER GREEN-GRAY EXAMPLES

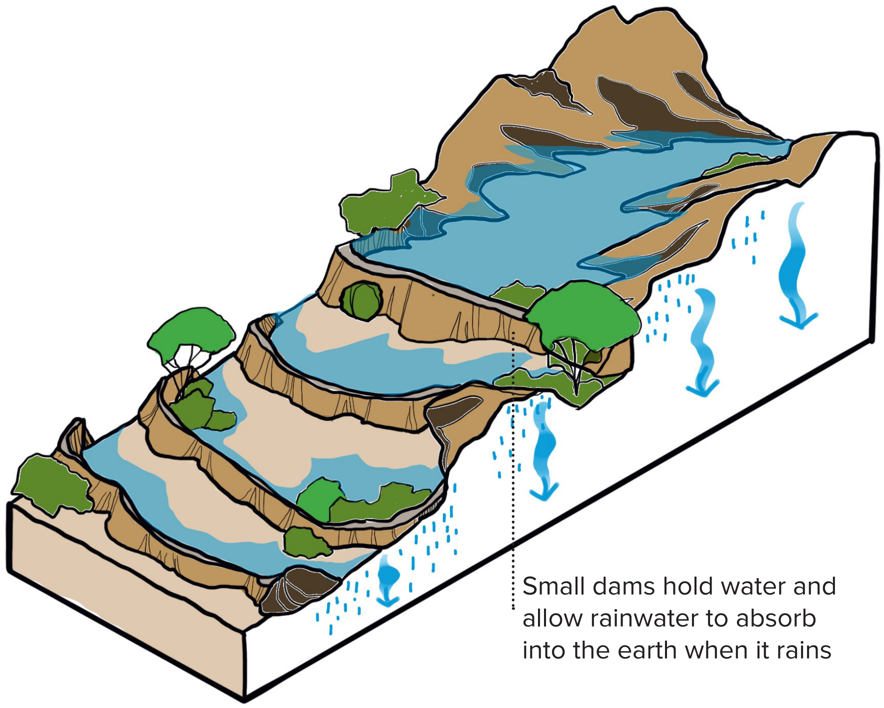


RIVER RESTORATION FOR FLOOD MANAGEMENT restores hydrologic function through a variety of approaches, such as building terraced levees that reduce flooding, create habitat, improve water quality, and

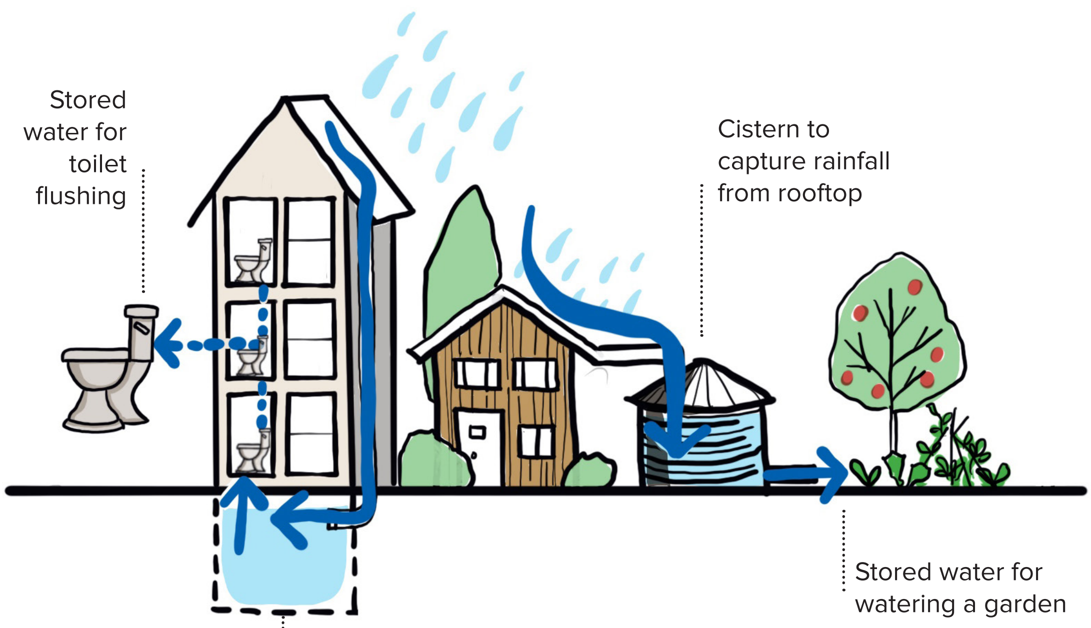


REFORESTATION AND FOREST CONSERVATION reduce sedimentation and help regulate flows to hydropower plants, while also making water cleaner, and cheaper for downstream water treatment plants to clean for communities to drink.

TERRESTRIAL GREEN-GRAY EXAMPLES



INFILTRATION AND TREATMENT-BASED LANDSCAPES increase groundwater infiltration to recharge aquifers, manage flood risks, and reduce erosion.



RAINWATER HARVESTING is the practice of collecting and using rainwater from roof surfaces or other man-made above ground surfaces. Rainwater harvesting has been employed by communities for centuries, today, rainwater harvesting is becoming more common as people look for ways to increase local resilience and use all water resources more efficiently.

2. IDENTIFYING SITES

Critical to identifying a green-gray infrastructure project is a communities' need for a climate adaptation strategy and stakeholders' willingness to support the project.

This module describes a process and tools for evaluating a communities' climate vulnerability, engaging stakeholders and evaluating potential project sites.

How to identify communities with green-gray infrastructure opportunities?

The following three approaches can be used to initially identify communities with potential for green-gray infrastructure implementation. After which the project team would meet with communities to conduct site assessments and evaluate applicability of green-gray infrastructure solutions.

A. Applying a **spatial prioritization framework** to identify green-gray infrastructure opportunity locations. On a regional or country map, a spatial prioritization framework estimates the viability of the roles ecosystems and engineered solutions might play in reducing disaster risk. The resulting maps enable the identification of suitable areas for green-gray infrastructure site assessments. Examples of inputs to a coastal framework include information about land use, presence of an engineered shoreline, width of coastal vegetation, sediment dynamics, wave climate, and sea level change. Use of this tool to identify communities with potential for green-gray infrastructure assumes a spatial analysis using a spatial database of climate vulnerable areas has already been completed.

B. Identifying vulnerable communities from a spatial database of **climate vulnerable areas**. A map of climate vulnerable areas presents populations with low, medium, and high vulnerability and the associated climate change and/or extreme weather events they are vulnerable to. There are many ways to measure vulnerability, most methods account for exposure, sensitivity and capacity, where:

$$\text{Climate vulnerability} = \frac{\text{exposure x sensitivity}}{\text{adaptive capacity}}$$

Figure 2.1 provides a visual of how physical, societal and climate factors contribute to the exposure and sensitivity of a community, which affects the potential impact of a climate event. The higher the community's adaptive capacity the less vulnerable they are to the impact. Vulnerability Assessment tools applied in a participatory manner at the community scale can provide a relative evaluation of potential climate change impacts and adaptive capacity. For example, the Integrated Coastal Sensitivity, Exposure, and Adaptive Capacity to Climate Change Vulnerability Assessment Tool offers a scoping and rapid reconnaissance of the vulnerabilities of integrated ecosystem services to synergistic climate change impacts.[13] Information from Vulnerability Assessment tools can inform the green-gray infrastructure site selection and concept design development process.

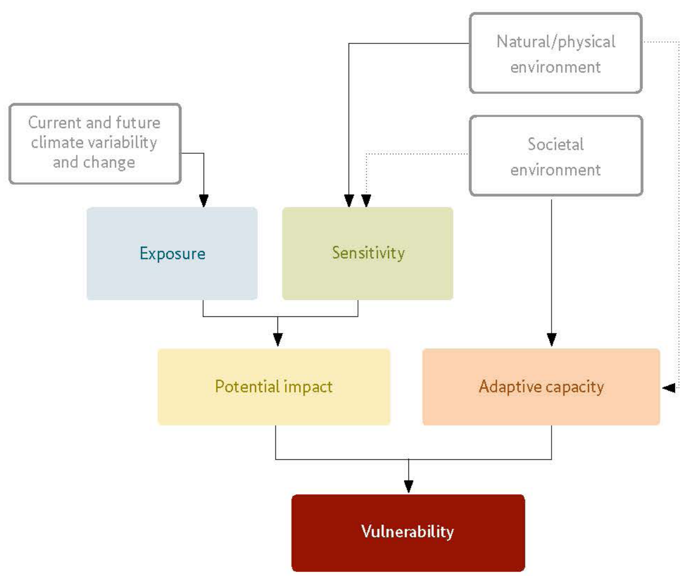


Figure 2.1. Components of climate change vulnerability (source: GIZ, The Vulnerability Sourcebook, Concepts and guidelines for standardized vulnerability assessments, August 2014)

C. Identify communities that have a **high exposure and/or have recently been severely and negatively impacted by a climate-related disaster**.

13. MERF. 2013. Vulnerability Assessment Tools for Coastal Ecosystems: A Guidebook. Marine Environment and Resources Foundation, Inc.: Quezon City, Philippines, pp 161.

How to select sites where green-gray infrastructure is appropriate once a target community has been identified?

The site assessment and identification process start with initial meetings with local governments and community members to select sites for field evaluation of potential for a green-gray infrastructure solution. As part of the initial site assessment, consultation meetings will be conducted with local governments and community members to introduce green-gray infrastructure concepts and to identify potential sites within the area of interest. Field evaluators will meet with key staff of local government units and community leaders to hold a series of workshops, described in Table 2.1. The outcome of these workshops will be a list of sites for field evaluation for applicability of a green-gray infrastructure solution.

Conduct a consultation workshop with relevant local government representatives and community stakeholders.

Note: The team needs to be careful about raising false expectations about the objectives and outcomes of the scoping activity. The role of the interviewer and facilitation team is to collect information for analysis and NOT dictate solutions.

Table 2.1. Summary of Community Consultation Workshops

Activity/Workshop	Purpose	Methodology
Overview and objective of the site assessment	➢ Enhance understanding of objectives and purpose of the scoping study ➢ Share methodology of the spatial prioritization study and insights into why this community was identified as a potential green-gray 'hotspot'	Powerpoint presentation
Resource Mapping	➢ Create a visual representation of resources and their uses in the area ➢ Establish a starting point for participatory problem analysis and planning.	Divide attendees into smaller groups. Using a prepared map (tarpaulin), ask the participants to overlay a plastic cover and draw the different resources present in their community.
Hazard mapping and analysis	➢ Identify hazards (particularly climate induced hazards) present in or affecting the community, specifically showing threats to lives, properties and livelihoods	Using the resource map from the earlier workshop (tarpaulin) overlay a plastic cover on it and ask the participants to identify and draw the different hazards that are present and are threatening in their area.
Vulnerability Analysis (Exposure and sensitivity	➢ Identify the elements at risk in the community due to the exposure of their location to hazards (e.g., households within 40 meters of the coastline) ➢ Determine their degree of exposure to hazard/s of each identified elements at risk and importance to community life and survival ➢ Determine their sensitivities to different climate related hazards	Using a vulnerability assessment matrix, ask the participants to describe the degree of exposure of each identified element at risk to each hazard/s.

Prior to conducting the consultation workshop, it is important to obtain existing background or secondary data – including compiling existing spatial datasets.

Examples of documents to compile prior to the consultation workshop:

- Disaster Risk Reduction Plan
- Local Climate Change Adaptation Plan
- Provincial or Municipal Development
- Relevant maps such as:
  - Water and Forest Land Use Maps
  - Marine Protected Area Maps
  - Resource Maps (Current and Historical)
  - Topographic Maps
  - Bathymetric maps
  - Contingency Plans
  - Floodplain maps
- Long Term Climate Projection
- Habitat Assessments Study

Who to invite to the consultation workshop:

- Environment or Agriculture/Fisheries Officer (municipal & provincial depending upon resources)
- Planning and Development Officer (municipal & provincial depending upon resources)
- Disaster Risk Reduction Officer (municipal & provincial depending upon resources)
- Engineering Officer (municipal & provincial depending upon resources)
- Key community leaders (village government and community organizations)
- Regional representatives from the national government (Environment and Natural Resources, Public Works and Highways)
- Water Authority

These stakeholders (municipal or provincial staff) can be pre-interviewed to identify particularly vulnerable municipalities or communities and ensure representatives from these communities attend the workshop.

If funding is not available for a larger workshop, interviews with these attendees can be conducted to identify sites for field evaluation.

Attachment A to the Practical Guide includes a detailed list of Guide Questions for interviews and/or to ask during a facilitated workshop. The purpose of these questions is to guide the selection of sites to visit during the site evaluation process.

During the consultation workshop, identify the team needed for the site assessment. Team selection will depend upon the type of ecosystems (e.g., mangrove), vulnerabilities (e.g., freshwater supply and/or coastal protection), and infrastructure present (e.g., seawall, deep well).

What information should be collected when evaluating a potential green-gray infrastructure site?

Once sites are identified, a multi-disciplinary design team conducts site visits to evaluate existing site conditions and green-gray infrastructure opportunities and constraints. The design team should include an engineer who understands the importance of integrated green-gray solutions and specialists familiar with the target ecosystems to restore and/or conserve.

The goal of the site visit is to systematically analyze links between ecosystems, livelihoods and climate change, to better understand vulnerability to climate change and the role of ecosystems and engineering solutions in adaptation.

Information collected during site evaluations includes:

(1) Site Location – proximity to basic services;

(2) Physical characteristics – wind patterns, rainfall patterns, geology, slopes, water source, wastewater treatment, built infrastructure, easements;

(3) Social characteristics – demographics, economic activities, existing social organizations, gender roles, basic services available i.e. healthcare, communications and transportation options, existing (and quality of) contingency, DRR-CCA plans, evacuation plans, coastal resource management plans;

(4) Ecosystem characteristics – location, extent, condition, resource use, threats, existing management, historic ecosystem information (not recommending restoration in areas where the target ecosystem does not exist in the past);

(5) Description of climate change problems or threat that the green-gray infrastructure concept will need to address - including information about exposure, sensitivity, and adaptive capacity as described in Table 2.2;

(6) Description of the target ecosystems for restoration and/or conservation;

(7) Description and sketch of concept design of potential green-gray infrastructure solution/s (the initial step in design development described in module 4); and

(8) Take photos/videos of the site(s), including aerial views if drones are available.

Attachment B to the Practical Guide includes specific questionnaires for coastal, freshwater, and terrestrial site evaluations.

A number of other tools exist to evaluate potential Ecosystem-based Adaptation sites and can be considered or used in tandem with the approach proposed here. One example is ALivE, the Adaptation, Livelihoods, and Ecosystems PLanning Tool, available through the International Institute of Sustainable Development.

Table 2.2. Methods to assess components of climate change vulnerability (source: Donatti et.al., 2018)

Component	Description	Ways to assess it
Exposure	Refers to changes in climate or weather (e.g. rainfall changes, temperature changes, changes in sea level, increased incidence of hurricanes and droughts, etc.) that are affecting/will affect the region where the target population lives.	- historical climate-related data -modeling work on how temperature and rainfall may change or studies/interviews on people's perceptions of changes in weather and climate. -Potential sources of data include: Climate wizard;
Sensitivity of the system or ecosystem services	Refers to the impacts that changes in climate or weather cause on the livelihoods of the target population (e.g. by affecting crop production, fisheries, etc). and by affecting ecosystem services that they rely on (i.e. water, wild food, pest control, ecotourism)	-modeling of how changes in temperature and precipitation may affect crop production, provision of water and other ecosystem services -interviews of stakeholder's perceptions on how extreme weather events have changed crop productivity, water availability or other aspects of their livelihoods. - Potential sources of data include: IPCC reports, NAPAS and NAPs of countries, World Bank's Climate Change knowledge portal.
Adaptive capacity of the target population	Refers to whether the target population is able to adjust to the changes in climate and weather and its impacts. Capabilities include human, social, financial, physical, and natural capital, institutions and entitlements, knowledge and information, decision-making and governance (e.g. Africa Climate Change Resilience Alliance's Local Adaptive Capacity Framework, Holland et al. 2017).	- census data that can inform the adaptive capacity of the target population (i.e. literacy, income, ownsership of assets) that are available to the target population. - interviews with local communities' members or local experts to get information on aspects related to adaptive capacity when census data is not available or incomplete - Potential sources of data include: Living Standards Mearument Study; IPUMS; Ci's Resilience Atlas

3. SITE SELECTION TOOL

After identifying climate vulnerable communities and visiting numerous sites with potential for green-gray infrastructure projects, the project team has the task of selecting sites for green-gray-gray infrastructure project construction.

This module describes a tool to evaluate, rank and select green-gray infrastructure project locations that considers stakeholder priorities.

What selection criteria should be used to select sites for green-gray infrastructure implementation?

The site selection tool provides a structured and objective method to separate high and low priority green-gray infrastructure project opportunities. A site evaluation matrix organizes into an order of importance by assigning a numerical value to the priority of each item. The benefit of this approach is its flexibility to add sites in the future and (re)evaluate/compare using the same criteria. The spreadsheet approach is also easy to update when additional site information becomes available, for example about biotic, cultural or geologic constraints.

Three (3) criteria have been selected to assess each site using a rating scale.

1. **Climate Vulnerability**

   Climate vulnerability measures the degree to which a community is susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes (IPCC 2007). It is expressed as a function of the sensitivity, exposure and adaptive capacity of the ecosystems and human communities therein.

   The three principal vulnerability indicators are (1) the human/social dimension (sensitivity), (2) climate related hazard/risk (exposure), and (3) economic safeguards/ecosystem quality (adaptive capacity), where:

   $$\text{Climate vulnerability} = \frac{\text{exposure x sensitivity}}{\text{adaptive capacity}}$$

   The assigned weight of the Climate Vulnerability selection criterion can be modified based on community and stakeholder input; the initial weight is 30%.

2. **Community Commitment**

   This criterion evaluates the local government and community's interest and long term commitment to the project and their organizational capacities.

   The assigned weight of the Community Commitment selection criterion can be modified based on community and stakeholder input; the initial weight is 35%.

3. **Green-Gray Infrastructure Applicability**

   This criterion evaluates the suitability of a green-gray infrastructure solution to address site-specific challenges. It is possible that particular sites are more appropriate for a purely green infrastructure or a purely gray infrastructure solution versus a hybrid approach.

   The assigned weight of the Green-Gray Infrastructure Applicability selection criterion can be modified based on community and stakeholder input; the initial weight is 35%.

What specific questions or data are needed to evaluate a site using the selection criteria?

Each of the three (3) criteria has a more detailed description of what each criterion considers. Table 3.1 summarizes each of the selected criteria, sub-questions and associated rating scale. The higher the point assignment for a particular criterion indicates agreement with the question or in the case of climate vulnerability, a lower point assignment indicates decreased sensitivity and exposure and a higher adaptive capacity.

Table 3.1. Summary of Green-Gray Infrastructure Site Selection Criteria

Criteria	Criteria Weight	Sub-Questions	Rating Scale	Score
Climate Vulnerability	30%	**Human/Social Dimension (Sensitivity)**	2= community sensitive to specific climate hazard	Score = Sum of (Criteria Weight x Points) out of total possible score of 10
			0 = community not sensitive to a specific climate hazard	
		Climate Related Hazard/Risk (Exposure)	2 = site exposed to a specific climate hazard	
			0 = site not exposed to a specific climate hazard	
		Economic Safeguards/Ecosystem Quality (Adaptive Capacity)	6 = community has low physical, social and/or ecosystem resiliencey	
			0 = community has high physical, social and/or ecosystem resiliencey	
Community Commitment	35%	**Local Government and Community Commitment to Project**		
		Is the local government willing to endorse the project and work collaboratively with the project lead (e.g., Conservation International) and the local community to implement the project?	1 = local government endorses project	
			0 = local government not supportive of the project	
		Is the local community committed to monitoring, maintaining, and possibly also constructing, the project?	1 = community willing to make long-term commitment to project	
			0 = community not willing to make long-term commitment to project	
		Are local community socio-economic indicators positive?	4 = all socio-econmic criteria satisfied	
			0 = missing critical social-economic criteria	
		Project Beneficiaries		
		How many people will directly benefit from the project?	2 = the most people will benefit, relative to other projects considered	
			0 = the least people will benefit, relative to other projects considered	
		How many people will indirectly benefit from the project?	1 = the most people will indirectly benefit, relative to other projects considered	
			0 = the least people will indirectly benefit, relative to other projects considered	
		Critical Infrastructure at Risk		
		What critical infrastructure will be affected, or damaged, if the green-gray infrastructure project were not to be constructed?	1 = critical infrastructure will be damaged without the project	
			0 = critical infrastructure will not be affected without the project	
Green-Gray Infrastructure Applicability	35%	**Site Conservation and/or Restoration Potential**		
		Are the site conditions favorable to conserve and/or restore ecosystems?	2 = site conditions are favorable for ecosystem restoration and/or conservation	
			0 = site conditions are not favorable for ecosystem restoration and/or conservation	
		Area available for restoration and/or conservation	2 = a large area is available for ecosystem restoration and/or conservation, relative to other projects considered	
			0 = a small area is available for ecosystem restoration and/or conservation, relative to other projects considered	
		Integration of "Green" and "Gray" Engineering Techniques		
		Do the "gray" project elements complement the restoration/conservation outcomes while also building resilience?	2 = gray project elements are complementary and build resilience	
			0 = gray project elements are not complementary nor do they build resilience	
		Is the green-gray infrastructure solution cost-efficient in terms of its cost-benefit ratio (considering ecosystem, social, and economic costs and benefits)?	2 = the green-gray solution is cost-efficeint, relative to other projects considered	
			0 = the green-gray solution is not cost-efficeint, relative to other projects considered	
		Climate Change Adaptation Potential		
		Will the proposed GGI solution, in combination with other adaptation solutions such as evacuation plans and supplemental livelihood development, deliver climate change resilience and adaptation benefits?	2 = the project will deliver climate change resilience and adaptation benefits	
			0 = the project will not deliver climate change resilience and adaptation benefits	

1. **Climate Vulnerability** – What climate hazard will the project address? For example, extreme weather events increase storm surge and wave heights, and drought can lead to reduced water security.
   a. Human/Social Dimension (Sensitivity) – Build questions that evaluate specific conditions that make a community (or portions of a community) more sensitive to the specific climate hazard. For example,
      i. How many households are constructed with light building materials? or
      ii. How many households are likely to receive less water during a drought? or
      iii. How many households are without back-up or alternative water supplies?
   b. Climate Related Hazard/Risk (Exposure) – Apply a scale of relative exposure to the climate related hazard or risk at each site. Some sites have different exposures for the same hazard (e.g., storm surge from typhoons) whereas some hazards bring the same exposure to all sites. An example scale to compare exposure to typhoons,
      i. What is the anticipated storm surge at each site, measured in meters?
   c. Economic Safeguards/Ecosystem Quality (Adaptive Capacity) – Identify the physical, social, and ecosystem indicators that measure a community's resilience to a specific climate hazard. Note: for this criterion, the higher the adaptive capacity, the lower the assigned points in the site evaluation matrix. For example,
      i. What is the presence, quality, and abundance of ecosystems that will buffer the impact of extreme weather events (e.g., mangroves and/or coral reefs)?
      ii. Table 3.2 lists example physical, social, and ecosystem indicators of adaptive capacity

Table 3.2. Example indicators of Adaptive Capacity

Are any of the following indicators present in the community:								
Physical	yes	no	**Social**	yes	no	**Ecosystem**	yes	no
Evacuation Center			Evacuation and/or Disastor Risk Reduction Plans			Mangroves		
Sea Wall(s)						Coral Reefs		
Road Networks			Watershed Management Plan			Sea Grass		
Alternative Water Supply			Coastal Resource Management Plan			Groundwater Recharge Features		
Water Treatment			Community has first responder training			Streams Connected to Floodplains		
						Well-Vegetated Watersheds		

2. **Community Commitments** are critical to proceeding with project evaluation and design development.

   a. Local Government and Community Commitment to Project

      i. Is the local government willing to endorse the project and work collaboratively with the project lead (e.g., Conservation International) and the local community to implement the project?

      ii. Is the local community committed to monitoring, maintaining, and possibly also constructing, the project?

      iii. Are local community socio-economic indicators positive? (e.g., answer yes to all question in Table 3.3)

   b. Project Beneficiaries

      i. How many people will directly benefit from the project?

      ii. How many people will indirectly benefit from the project?

   c. Critical Infrastructure at Risk: What critical infrastructure will be affected, or damaged, if the green-gray infrastructure project were not to be constructed?

Table 3.3. Example Socio-economic criteria to consider for site selection Source: Community Based Mangrove Rehabilitation Training Manual, ZSL Living Conservation & Philippine Tropical Forest Conservation Foundation, Inc.

Socio Economic Check-List			
Would you consider the community:	Yes	No	Notes
Open minded			
Collaborative			
Easy to work with			
Willing to provide counterpart funds			
Willing have their staff trained	*should be yes to proceed*		
Share a common vision with the project	*should be yes to proceed*		
Is a community organization:			
Present on site			
Registered			
Have constitution and by-laws			
Have structure			
Have a complete set of officers			
If no existing community organization:			
Does the community express willingness to organize			
Are partners (e.g., BFAR, DENR, academe):			
Willing to provide technical/other support and guidance			
Do community members:			
Have access to financial services (normal times)			
Have access to after-disaster relief (finance, housing, etc.)			
Have insurance			

3. **Green-Gray Infrastructure Applicability**

a. Site Conservation, Sustainable Management and/or Restoration Potential

i. Are the site conditions favorable to conserve or restore ecosystems that will provide people with solutions that deliver climate change resilience and adaptation benefits.? For example, if the target ecosystem is mangroves –

1. Can the hydrology and soil conditions be feasibly modified to allow mangrove restoration?

2. Are there nearby sources of mangrove seedlings?

3. Are there conflicts with proposed restoration and/or conservation and existing land ownership or land use?

ii. Estimate (in hectares) the area available for restoration and/or conservation.

b. Integration of "Green" and "Gray" Engineering Techniques

i. Do the "gray" project elements complement the restoration/conservation outcomes while also building resilience?

ii. Is the green-gray infrastructure solution cost-efficient in terms of its cost-benefit ratio (considering ecosystem, social, and economic costs and benefits)?

Table 3.4 summarizes example data types needed to value project benefits and co-benefits.

c. Climate Change Adaptation Potential

i. Will the proposed green-gray infrastructure solution, in combination with other adaptation solutions such as evacuation plans and supplemental livelihood development, deliver climate change resilience and adaptation benefits? For example, will restored mangroves attenuate wave energy from extreme weather events or will restored floodplains reduce flooding impacts?

How to apply a Site Evaluation Matrix to identify priority projects?

Using Table 3.1 as a template, points are assigned to specific sub-questions based on specific site and/or community conditions. Each point value is multiplied by the weight of the associated criteria. The site score is the sum of all the points x criteria weights. The sites are ranked based on score. The sites with the highest scores have the highest potential for implementing successful green-gray infrastructure solutions.

The ranked sites should be reviewed, and based on available budget, sites selected for green-gray infrastructure design development. The site evaluation matrix provides a transparent process to assign weights to subjective criteria and prioritize where best to focus design funds.

Benefits/co-benefits	Indicators and data needs	
	Physical measurements	**Economic valuation**
All provisioning services	Quantity harvested annually	Market price and shadow price
Carbon	Tons of carbon sequestered or emitted	Social cost of carbon; Carbon price
Water quality regulation	Changes in water quality parameters such as dissolved nutrients	Changes in water purification cost
Tourism	Changes in the number of tourist visits	Changes in the income of local businesses; Revenue earned
Water provision	Amount of water supplied for different sectors such as irrigation, domestic water	Beneficiary-specific value of water, such as tariff for domestic water consumption
Erosion control	Sediment loads in irrigation channels, hydroelectric dams etc.	Dredging costs or equipment depreciation costs
Pollination	Changes in crop productivity	Cost of replacing natural pollination
Non-timber forest products	Total volume harvested by communities	Equivalent market price

Table 3.4. Example data types needed to value project benefits and co-benefits.

Source: Guidelines for Designing, Implementing and Monitoring Ecosystem-Based Adaptation Interventions, Donatti, et.al, Conservation International

4. DESIGN DEVELOPMENT

With a site selected, the design development process begins, and includes:

1. Clearly defining the problem and project goals;
2. Forming a design team with ecosystem, engineering and green-gray expertise;
3. Collecting information about the site and becoming familiar with the local community;
4. Soliciting community input on early design concepts, and throughout the design development process;
5. Receiving approvals from applicable local, regional, and federal agencies overseeing the region or ecosystem where the project is proposed; and
6. Finalizing the design plans with material and construction specifications.

Following the steps described in this module will advance concept sketches into ready-to-build, approved design plans. Though depicted as a series of steps, the design process is often iterative. New information, models, or stakeholder input can require previous assumptions to be revisited and design adjustments.

What initial steps are needed to develop a green-gray infrastructure design?

The purpose of these initial steps is to assemble a design team that can clearly define the problem the green-gray infrastructure solution is intended to address and develop with community input initial design concepts to meet the project goals.

1. Create a design team that includes:
   a. restoration/conservation specialist(s) with expertise in the specific target ecosystem(s)
   b. trusted community liaison
   c. project manager / team facilitator
   d. engineer(s), one of whom will be the responsible engineer for the project (e.g., stamping and signing design drawings and overseeing construction). The responsible engineer could be the local municipal engineer or a hired consulting engineer.
   e. technical advisory committee consisting of respected professionals with expertise in the target ecosystem, approach, geography, etc.
2. Share all existing site information and concepts collected through the site identification and selection process.
3. Arrange site visits so all team members are familiar with the conditions and can meet community representatives and receive input of the concept developed during the site evaluation.
4. Conduct a design review workshop with the design team to review the site specific green-gray infrastructure opportunities and constraints. Outputs of the design review workshop include one or two design alternatives with cost estimates and identified data needs to complete the designs.
5. Once design alternatives have been identified, many projects will seek additional funds to collect needed data, finalize designs, construct the project and provide long term project monitoring, maintenance, and adaptation.

An overview of the design development process, that represents one possible project path is summarized in Table 4.1.

What data is needed to develop a green-gray infrastructure Design?

The data needs will be project and solution specific. It is recommended to only collect data or conduct modeling that will directly inform the design and to use efficient and economical methods to collect the needed data. Examples of types of data that can be collected to inform a green-gray infrastructure design are:

- bathymetry and/or topography data, including mapping of existing infrastructure such as water or wastewater systems and significant natural or man-made features or landmarks

Table 4.1. Overview of Green-Gray Infrastructure Design Development Process

Overview of GGI Design Development Process	
Design Phase	**Description**
Concept	Concept sketches produced after collection of existing data, initial site evaluation and site visit by project design team. Often at this stage concepts could include 3-5 alternative approaches.
Design Alternatives	Based on review of concept sketches by the community and design team, one or two design alternatives generated along with updated estimates of project cost, and identified data gaps and next steps to complete the design.
Permit Package	The design package at this stage incorporates all input from the community on teh prefferred design alternative, and is often sufficient to seek permit approvals. The design package can include a specifications outline (or scope-of-work) that describes construction methods and materials, along with an updated construction cost estimate.
Final Design	Refined design based on input from permit approval process, technical reviewers, and community stakeholders. Complete material and construction specifications along with identified safety measures to implement during construction.
Construction Documents	Final design prior to construction that incorporates all comments from previous design deliverables and reviewers.

- sediment and/or subsurface soil characteristics
- ecosystem mapping (existing and historic), including location, size, type, and health
- key plant and animal species, including native species and endangered ones
- inundation extent (e.g., from floods, typhoons, or sea level rise)
- tourism infrastructure critical to the communities' livelihood strategies

When designing a green-gray infrastructure project, the design team should address many factors during each design phase, such as:

- Affordability;
- Technical feasibility;
- Political feasibility;
- Maintenance approach and costs;
- Monitoring approach and cost;
- Flexibility to adaptively manage the constructed project; and
- Cultural appropriateness

What permits or approvals are needed before construction can begin?

Permits or approvals are given by agencies overseeing the region where your project is located or agencies that regulate the type of project you are proposing to construct. For example, different agencies may require permits depending upon if you are completing a green-gray infrastructure project in a coastal, freshwater, or terrestrial environment or if you are proposing work in the near-shore or along a roadway. Typically, the project proponent, or applicant, completes a permit application and submits it to the permitting agency for review and approval. Each permit or approval application typically requires a unique set of information and the amount of time to review and approve the application can vary depending upon the agency, project type, time of year, and quality of information submitted with the application.

The design team, usually the project manager, should consult with local and national jurisdictions to identify the project permits and approvals required before construction can begin. Permits specific to the Philippines within the three potential green-gray infrastructure settings are summarized in Table 4.2. Other approvals that may be needed prior to construction:

- Internal constructional approvals (e.g., CI Construction Memo);
- Endorsements from technical advisors and local municipality officials; and
- Funder approvals, for example, if contracting with the local community to complete the construction, is outside the normal acquisition policy.

What stakeholder and community engagement and educational outreach is needed as part of a green-gray infrastructure project?

Green-gray infrastructure is complemented by other adaptation solutions such as (but not limited to) livelihoods diversification, disaster risk reduction and adaptation capacity building, renewable energy and transport, partnership and alliance building. Once a green-gray infrastructure site is selected, the information collected during the site assessment phase should be evaluated to identify the institutional capacity of stakeholders, particularly communities and the local government. If gaps are identified in terms of the communities' ability to implement the green-gray intervention, the project team will need to tailor appropriate outreach and capacity building measures.

- Through the site identification and site selection process, ensure that a functioning community based organization exists in the community where the green-gray infrastructure project is proposed.
- Community members, stakeholders, and local governments will likely need additional organizational and capacity building to understand the project benefits and consider endorsing project implementation.
- Depending on the green-gray infrastructure construction model, communities may need additional organizational development.

The design development timeline must consider parallel efforts for educational, organizing, and capacity building activities. Specifically:

- Regular community meetings (monthly throughout the project)
- CCA-DRR trainings (in the first 6 months of the project)
- Financial management and leadership trainings for all key community leaders (2-3 day workshops) with on-going mentoring

Table 4.2. Summary of Green-Gray Infrastructure Permit Requirements [This table will be completed during round table discussions with regional and national permitting agencies in the Philippines over the next 6 mos]

Philippines GGI Permit Requirements (to be confirmed on a project-by-project basis)				
GGI Project Type	Permit Name	Submit to Whom (e.g., divisions)	Documents Needed in Permit Submittal	Time to Process Permit
Coastal				
Freshwater				
Terrestrial				

5. CONSTRUCTION

Construction is often the largest cost in an overall project budget and selecting the best contractor to match a project's demands and budget is critical to delivering a successful project.

This module describes alternative construction models, activities, and potential risks to consider early in the design development phase.

What are green-gray infrastructure construction options?

Three options are described in this module: Community-Build, Design-Build, and Contractor Build.

1. Community-Build – this model is specific to the community where the green-gray infrastructure project will be implemented. CI is piloting a community-build model in the Philippines that emphasizes a people centered approach. The model provides livelihood grants to community members to implement, maintain and monitor green-gray infrastructure projects. The immediate target groups that will benefit from this approach are the communities where the pilot projects are located and local governments where the green-gray infrastructure projects will be installed.

To implement this community-build model

- The design team determines if the community has the capacity and skill-set necessary to construct the project;
- The community liaison and representatives from the community organization prepare a cost estimate to complete the work; and
- The community hires a foreman with appropriate qualifications and experience with similar projects to manage the construction activities.

Table 5.1 summarizes the anticipated activities, responsible parties and actions to mitigate risk in the Community-Build model.

2. Design-Build – once a design alternative has been selected, but before a permit package is prepared, a design-build contractor is hired. The design-build contractor becomes a member of the design team. The team works collaboratively to finalize the design, often finding innovative solutions to improve the design based on the design-build contractor's input about constructability and material availability.

3. Contractor-Build– a traditional construction model where a contractor is hired once the construction documents are completed. The lead contractor typically hires sub-contractors to complete specific and specialized elements of the project construction. The model is initiated with a request for tender to outside contractors.

When selecting a construction option consider:

- If specialized equipment or skills required for the implementation;
- Where materials will be procured, how materials will be delivered to the site, and where materials will be stored;
- Time of year when the project will be constructed, and if delays due to weather are possible;
- What erosion controls will be needed;
- The types of insurance coverages that will be required; and
- The workplace safety risks, safety prevention and training measures, and protocol for workplace injury.

Table 5.1. Example Community-Build activities, responsibilities and risk mitigation actions.

#	ACTIVITY	RESPONSIBLE PARTY	RISK MITIGATION
PREPARATION, INCLUDING DESIGN/DRAWINGS, CONTRACTING, PERMITTING, PROCUREMENT, INSURANCE COVERAGE			
1	Grant Agreement	CI-Philippines and Fisherfolk Associations	Flow down appropriate provisions from prime agreement.
2	Permitting	Community Fisherfolk Association	CI-Philippines will support coordination and acquisition of necessary approvals and permits
3	Design/Drawings	Municipal Engineer, hired by the Fisherfolk Association	CI-Philippines will support the Fisherfolk Association to coordinate design development consistent with the provided scope-of-work
CONSTRUCTION ACTIVITIES			
4	Build Green-Gray Project	Fisherfolk Association	The Municipal Engineer will review and approve all work products for consistency with the design and scope-of-work
MONITORING; ACCEPTANCE OF MILESTONES BY QUALIFIED PARTY			
5	Monitoring	Fisherfolk Association	Per a Monitoring plan provided by CI-Philippines
6	Maintenance	Fisherfolk Association	As agreed, upon in the Grant Agreement between CI-Philippines and the Fisherfolk Association

What are pros/cons of each green-gray infrastructure construction option?

1. Community-Build

Engaging the local Community organizations to build, monitor, and maintain the green-gray pilot projects has numerous benefits:

- Promotes ownership and responsibility for the projects and structures;
- Keeps resources local – both labor and materials;
- The community members are familiar with the area and local conditions;
- Engaging the community is cost efficient because there is no need to transport and/or lodge workers from elsewhere;
- The process builds community members construction skills by providing experience that can lead to supplemental livelihoods;
- As a result of leading the construction the community is knowledgeable about monitoring and maintaining the systems and adapting the systems as needed.

The Disadvantages, and associated risk mitigation action, to engaging the local community organizations to build, monitor, and maintain the green-gray pilot projects include:

- Inexperienced community workers could be injured during construction. To mitigate this risk work with communities to review construction best practices and safety measures.
- Communities may not have enough skills to construct and/or maintain the structures. Provide additional training to mitigate this risk.
- Possible that not everyone in the community has construction experience before project starts.

2. **Design-Build**

Benefits of a design-build construction model include:

- Usually good continuity and information communication occurs throughout the design and construction process.
- The build teams' input during design can result in time and material savings.
- If unexpected conditions are encountered during construction, a design-build team can be more flexible to respond and adjust.
- More construction specialized construction experience and access to specialized equipment, than in the community model.

Disadvantages of the design-build construction model include:

- Committing to a contractor during the design phase, when the full scope of the project is not finalized.
- May be more appropriate for medium-large scale projects, but not for small scale.
- Reliance on people with expertise coming from outside the communities where the work will be done.
- The design-build team can be unknown and potentially untrusted by the community and be unfamiliar with local conditions and culture.

3. **Contractor-Build**

Benefits of a contractor-build construction model include:

- More specialized construction experience and access to specialized equipment, than in the community-build model.
- At a large scale, contractors can realize material, equipment, and time efficiencies that result in cost savings.

Disadvantages of the contractor-build construction model include:

- May be more appropriate for medium to large scale projects, but not for small scale projects.
- Reliance on people with expertise coming from outside the communities where the work will be done.
- The contractor team can be unknown and potentially untrusted by the community and be unfamiliar with local conditions and culture.

How to get feedback from the community during and after construction?

A visible placard or board can be posted at the site that identifies the project partners along with contact information. Community members and stakeholders are encouraged to contact the project representative(s) to report any issues or comments about the project.

The project's social monitoring framework, described in module #6, can also document the community's perception of the project before, during and after construction.

6. MONITORING, MAINTENANCE, AND ADAPTIVE MANAGEMENT

Green-gray infrastructure is intended to work in and with living ecosystems. Monitoring, maintenance, and adaptive management of both the living ecosystems and the gray infrastructure are integral to ensure project function.

- Monitoring should be designed to directly measure and evaluate the project's intended outcomes;
- Maintenance is critical to the longevity and effective function of a project; and
- Adaptive management iteratively improves the ability of a project to achieve its goals.

This module introduces a multi-step feedback process linking project monitoring and evaluation frameworks, maintenance strategies, and adaptive management.

What are the elements of a project Maintenance Plan?

Project monitoring, maintenance, and adaptive management are connected in a multi-step, feedback process that is outlined in a project maintenance plan. The elements of a maintenance plan include:

1. Defining the "green" ecosystem and gray infrastructure assets to be maintained
2. Identifying for each asset (1) guidelines (2) indicators, and (3) metrics.
3. Detailing the location of each asset, actions to be undertaken, and a maintenance schedule
4. Applying a cooperative approach to exchange information with stakeholders, and help define and implement maintenance and monitoring practices
5. Establishing training programs for technical and field staff on the maintenance activities
6. Monitor performance of the assets, according to a Monitoring & Evaluation framework, and report results and findings to the design team and contractors.
7. Based on the results, modify the management to improve the project function.

Figure 6-1 provides a visual of the integrated elements of a project maintenance plan.

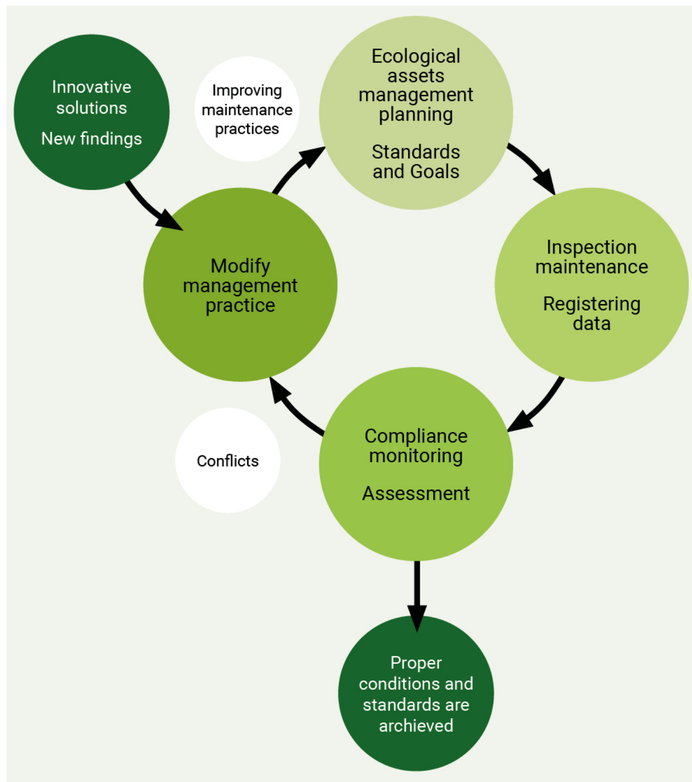


Figure 6.1. An iterative approach to adaptive management

(source: Infrastructure and Ecology Network Europe, Wildlife and Traffic, A European Handbook for Identifying Cofflicts and Designing Solutions, accessed August 2019)

What aspects of the project should be monitored?

Monitoring should be designed to directly measure and evaluate the project's intended outcomes. The project monitoring and evaluation (M&E) framework is based on the desired project results and should measure the ecological and social benefits of the green-gray infrastructure projects. M&E is often required for climate adaptation projects that require an initial vulnerability assessment and then monitoring to demonstrate improved resilience.

Selected monitoring indicators should measure two components of the adaptation outcome:

1. Desired state of the ecosystem and associated gray infrastructure - specifically measuring how management, restoration and/or conservation are affecting ecosystems and ecosystem services
2. The reduced vulnerability and increased adaptive capacity of people to manage the identified climate risks - specifically measuring the ability of people to take advantage of opportunities or to respond to damages associated with climate hazards, changes and uncertainty.

When designing a project M&E framework[14]:

- Collect baseline data that describes the pre-project condition prior to constructing the project;
- Involve local communities and stakeholders in monitoring to achieve buy-in and enhance local capacity; and
- Develop a plan and budget for how the M&E framework will be implemented, potentially well past the time the project ends. Consider:
  - How the information will be collected?
  - Who will collect the information?
  - When will the information be collected and at what time interval?
  - Where will the information be collected?

As green-gray infrastructure is a nascent and an innovative climate adaptation technology, tangible measurements documenting the effectiveness of the intervention will lead to broader adoption of green-gray infrastructure projects that emphasize conservation and restoration of natural ecosystems. Additionally, project monitoring is critical to documenting and understanding the strengths and weaknesses of each project. Monitoring data will inform (1) recommended design adaptations for similar techniques proposed at other sites and (2) any modifications needed at the project sites to ensure long-term rehabilitation.

Ecological Monitoring

The specific ecological benefits that will be monitored post-project depend upon the project design and target ecosystem for restoration/conservation. For mangrove restoration, ecological monitoring could include for example sediment accumulation and sediment stabilization, reduction of wave energy, and mangrove seedling survival and growth. In this example, ecological monitoring will occur in (1) a control area, with no existing mangroves and outside the influence of the proposed green-gray infrastructure measures, (2) within the project area, and (3) in an existing natural mangrove area.

Social Monitoring

A social monitoring framework should be designed to provide quantitative and qualitative documentation of the short- and long-term social benefits of the green-gray infrastructure projects. Potential indicators to measure short- and long-term social benefits include:

- Community members' reduced vulnerability;
- Community members' perception of security or safety if an extreme weather event were to occur (e.g., perceived risk before and after project);
- Reduced damage (e.g., fatalities and infrastructure loss) after an extreme weather event as compared to a similar event pre-project;
- Community members' knowledge of what actions would be taken if notice of an impending extreme weather event were received;
- Community members' sense of well-being;
- Total community income over time as compared to trends in comparable communities; and
- Percent of community income derived from different livelihood types.

Social monitoring can be conducted through workshops or household surveys.

If monitoring reveals an unintended consequence, the project design team should reconvene to visit the site, evaluate the impact and recommend modifications to the green and/or gray infrastructure elements.

14 Donatti, C.I., Martinez-Rodriguez, M.R., Fedele, G., Harvey, C.A., Scorgie, S., Andrade, A., Rose, C., Alam, Mahbub. 2018. Guidelines for designing, implementing and monitoring ecosystem-based adaptation interventions. Conservation International.

How to plan for maintenance during design development?

Planning for maintenance can begin in the project design phase, starting with identifying the necessary maintenance activities, access routes, and temporary material storage areas on the design plans.

As the project design evolves consider the type and frequency of maintenance that will be required to confirm with site managers and community members that staffing, skills, and equipment will be in-place to perform the required maintenance once the project is installed.

Also during the design phase, identify how the maintenance will be paid for to ensure there is a long term strategy to adaptively manage the project and ensure the project goals are achieved.

ATTACHMENT A

Community Interview / Workshop Questions

ATTACHMENT B

Coastal Green-Gray Infrastructure Site Assessment Worksheet