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CLIMATE-RESILIENT WATER INFRASTRUCTURE:

GUIDELINES AND LESSONS FROM THE USAID BE SECURE PROJECT

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CLIMATE-RESILIENT WATER INFRASTRUCTURE:

GUIDELINES AND LESSONS FROM THE USAID BE SECURE PROJECT

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ABBREVIATIONS

Be Secure	Water Security for Resilient Economic Growth and Stability
BMP	Best Management Practices
BS	Billing Section
Cm	Centimeter
Cm3	Cubic Centimeter
FCSO	Frontline Customer Service Officer
FOM	Flush-O-Meter
Ft3	Cubic Feet
Gal	Gallon
GI	Galvanized Iron Pipe
GOCC	Government-Owned and Controlled Corporation
Gpm	Gallons per Minute
HET	High-efficiency Toilets
HEW	High-efficiency Washers
HVAC	Heating, Ventilation, and Air-conditioning
IPCC	Intergovernmental Panel on Climate Change
L	Liter
LFT	Low-flow Toilet
LPF	Liters Per Flush
LPM	Liters Per Minute
LWUA	Local Water Utilities Administration
M	Cubic Meter
Min	Minute
MISD	Management Information System Division
Ml	Milliliter
MRMS	Meter Reading Management System
MRS	Meter Reading Section
PD	Positive Displacement
PSA	Philippines Statistics Authority
Sec	Second
ULFT	Ultra-low-flow Toilet
WDM	Water Demand Management
WF	Water Factor
WSM	Water Supply Management
WTP	Water Treatment Plant
ZCWD	Zamboanga City Water District
ZWAT	Zamboanga City Water Audit Team

GLOSSARY OF TERMS

CLIMATE is an expression of the composite weather conditions (such as temperature, precipitation, or wind), including both statistical averages and the occurrence of extreme events, over a given period of time. The World Meteorological Organization recommends a 30-year period to adequately describe the climate of a given area.

CLIMATE CHANGE refers to a statistically significant variation in climate data or patterns over a given period of time, due to either natural climate variability or as a result of human activity.

CLIMATE CHANGE ADAPTATION describes measures taken in response to actual or projected climate change in order to eliminate, minimize, or manage related impacts on people, infrastructure, and the environment.

CLIMATE CHANGE IMPACTS on infrastructure are, for the purposes of this document, the resulting influence of climate change effects on the structural form or function of a water supply system.

CLIMATE CHANGE VARIABILITY is the short-term fluctuation in weather conditions, usually over a period of a year or a few decades.

CLIMATE DRIVER is the manifestation of a change in climatic conditions through one or more weather variables, such as a change in precipitation or sea level rise, to create an impact.

EXPOSURE refers to the extent to which a system comes into contact with a hazard or threat.

RESILIENCE, as defined by the Intergovernmental Panel on Climate Change, is the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through the preservation, restoration, or improvement of its basic structures and functions.

RISK is the combined function of the likelihood that a hazard will occur and the resulting consequences.

SENSITIVITY is the degree to which a built, natural or human system is directly or indirectly affected by or responsive to changes in climate conditions or related impacts.

THREATS are extreme climate or weather event that creates impact or causes damage, such as flooding, wind, or drought.

VULNERABILITY is the degree to which a system is susceptible to or unable to cope with adverse effects of climate change, including climate variability and extremes. It is often defined as a combined function of exposure and sensitivity to the effects of climate change, minus the adaptive capacity of a system.

INTRODUCTION

The Water Security for Resilient Economic Growth and Stability (Be Secure) Project in the Philippines is a four-year activity that seeks to improve water security to support resilient and stable economic growth in the Philippines. It is being implemented by AECOM International Development with funding from the United States Agency for International Development (USAID) in close coordination with the Government of the Philippines. The project promotes good governance, builds capacity in water security, improves access to water and sanitation services, and builds more resilient communities.

Be Secure is implemented in six focal areas: Basilan, Iloilo, Leyte, Maguindanao and Misamis Oriental Provinces and the Zamboanga Peninsula. At the national level, activities focus on strengthening water sector regulatory reform. For local and regional activities, the project works with local government units (LGUs) and water service providers (WSPs) at the watershed scale to improve capacities for integrating climate change adaptation and disaster risk reduction into local planning and the provision of water supply and sanitation services. Key counterparts include national government agencies, LGUs, and public and private WSPs. Be Secure also works in partnership with academic institutions as centers of excellence that can sustain project initiatives.

One of the initiatives of Be Secure is to develop climate resilient communities. USAID's Climate-Resilient Development Framework[1] has adopted the definition of "climate resilience" described by the Intergovernmental Panel on Climate Change (IPCC) as the capacity of a system to "anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions."[2]

Consistent with the guideline issued by the National Economic Development Authority (NEDA) on the Reconstruction Assistance on Typhoon Yolanda (Haiyan), Be Secure assisted partners in Leyte that were hard-hit by the Super Typhoon to plan and rebuild communities, and to not only repair damaged water systems but to make improvements and "build back better." Following the typhoon, the project worked with LGUs, WSPs and international agencies under the umbrella of the rehabilitation task force created by the national government to build stronger and climate-resilient water supply and sanitation infrastructure. Be Secure responded by helping communities replace leaking pipes and damaged faucets at schools; install cisterns; bury exposed water lines; and install steel water tanks. The project's assistance ensured that these water supply systems and facilities were built to withstand or are better protected from impacts of climate-related hazards such as typhoons, storm surge, and flooding.

This paper compiles data and information on the range of practices in infrastructure design found throughout the Philippines, and how the infrastructure was affected by climate-related events such as damaging storms like Yolanda, as well as droughts during El Niño periods. Using Be Secure's experience to build climate-resilient water supply infrastructure, the paper guides WSPs and LGUs on best practices for building and sustaining climate-resilient water supply systems. The lessons gleaned from the experiences illustrated herein are intended to be used as a learning tool for securing sustainable water supplies in a climate-altered future.

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[1] United States Agency for International Development (USAID), *Climate-Resilient Development: A Framework for Understanding and Addressing Climate Change* (March 2014). Washington, D.C.

[2] Intergovernmental Panel on Climate Change (IPCC), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (2012), *Cambridge University Press, Cambridge, UK, and New York, NY, p. 582.*

1. LESSONS THAT AFFECT DESIGN CONSIDERATIONS

The Intergovernmental Panel on Climate Change (IPCC) defines climate-change vulnerability as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. It is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and the adaptive capacity of that system[3]. The devastating impact of Typhoon Yolanda on water supply systems and services in Leyte highlighted the need to examine exposure and sensitivity of WSPs to climate-related hazards. Be Secure was able to assess water system vulnerabilities and design approaches to not only helping communities recover from the disaster, but enable rebuilt systems to withstand similar events that may reoccur with climate change. A summary of lessons learned that can be used for future water infrastructure designs are given below. These lessons demonstrate that to effectively adapt and become better prepared to address future climate impacts, WSPs need to improve the way they design and construct water supply systems and facilities. Design and construction must consider now more than ever impacts of current and future climate variability; location of assets with the goal of reducing their exposure; as well as asset condition, function, and design life with the goal of putting in place stronger and durable structures that can withstand climate impacts.

1. **Impacts are a function of current and future climate variability, location, asset design life, function, and condition.** Many characteristics of the asset and its location influence the likelihood and extent of climate impacts. As illustrated in the examples in this guide, many transmission pipes that had been precariously suspended over rivers or placed along steep slopes or unstable river banks were severely damaged by flooding and landslides during Typhoon Yolanda. Damage to the pipes leads to long service interruptions that exacerbate an already dire situation during emergencies.

2. **Extreme events can cause direct physical impacts on assets as well as indirect impacts including loss of service.** Changes in the pattern of extreme events can directly impact the physical integrity of water systems, causing loss of service. While Typhoon Yolanda damaged water supply infrastructure throughout Leyte Province, loss of water supply severely threatened health and hampered activities for households, schools, hospitals, businesses, and relief organizations.

3. **Current infrastructure design is based on historical data and climate variability or increased frequency of extreme events may mean that infrastructure is no longer optimally designed for even short-term purposes.** Most existing infrastructure assets were designed based on historical climate data, such as average rainfall and runoff in an area, or historic flood events. However, incidents of extreme weather events influenced by climate change in recent years mean that historic weather data may no longer be relevant for the engineering design of long-term infrastructure performance. As experienced with numerous recent damaging storms throughout the Philippines, climate change impacts may also cause shorter asset life spans or require early rehabilitation as infrastructure degradation accelerates. Taking into account long-term climate projections, Be Secure, for example, implemented many water improvements that involved the relocation of vulnerable pipes to higher elevations to minimize exposure to flooding events anticipated in the future.

4. **For new infrastructure assets, both the location of the asset and the level of service should take climate change into consideration – even if there is uncertainty in climate projections.** Asset location is particularly relevant in coastal areas, floodplains, and

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[3]

river basins. The capability of a water supply system to perform at full capacity may be impacted by changes in the environment or the resources (such as water) that it requires. Service demand may also change, such as increased water consumption as temperatures gradually rise or precipitation gradually decreases over time. When considering the design of an asset, the question of how high or how big is critical and not easily answered with available climate projections. To help overcome this, we need to consider the implications of failure. If it is critical that there be no interruption to service delivery, then considering the upper bounds of the possible risk (i.e., worst case climate projections) would be prudent. To illustrate, Typhoon Yolanda generated the highest wind velocities of any storm in recorded history. Be Secure engineers therefore considered the record wind speed of 315 kph as the design standard for engineering stronger water tower designs in Leyte. Alternatively, consideration should be given to the marginal costs and benefits of a design decision. The benefits of a stronger, reinforced pipeline may significantly outweigh the marginal cost

5. **Careful balance must be made between developing designs that reflect maximum climate resilience but with substantially higher costs, and other options.** A phased approach may be desirable in these situations, where designs are implemented according to short-term, mid-term and long-term needs sequentially. Safety and likelihood of consequences can be used to help assign options for a phased approach. For example, some of the earthworks required to prevent the Binahaan River in Leyte from forming an oxbow needed urgent attention. Other portions of the river bank could last for a few more years but will eventually need repair. In the case of the design of a 20 million liter per day (MLD) treatment plant for the Zamboanga City Water District (ZCWD), it was clear that cost of the treatment option was going to be a factor in adoption of adaptation options. Likewise, dual piping systems for all new residential developments should be included in the templates for city ordinances on new construction to allow for gray water re-use systems for landscaping. However, there may be a risk of rejection by developers or consumers due to cost. Phased approaches could be explored as a more realistic alternative.

6. **The trade-off between adopting new technologies or more traditional, "tried-and-true" approaches is a decision that each water district or LGU must consider carefully based on local capacity.** Be Secure experienced advantages with using both types of approaches in different contexts concerning computer modeling and geographic information system (GIS) data. While more complex systems substantially aided Be Secure to save time and effort while enhancing accuracy of analyses, not all stakeholders in the Philippines have access to the same technical capacity to use GIS models for non-revenue water (NRW) reduction programs. Another technological advance Be Secure utilized was a drone to take aerial photographs used to prepare topographical maps of the areas upstream and downstream of the developing oxbow in Leyte. While drones and the data they gathered added to the cost of the activity, the level of detail and accuracy in the final product was worth the expense. In another example, when Be Secure completed the NRW study in COWD, the water district not only had a state of the art GIS system, but also fully trained staff to use it. In other areas where Be Secure has worked, water districts have GIS systems, but rarely trained staff, which thereby renders the technological system virtually unusable.

7. **Appropriate selection of construction materials is vital for climate-resilient water infrastructure.** Buidling materials differ in sensitivity to climate change impacts. The devastating effects ofTyphoon Yolanda has proven that GI roofs and wooden frames are no match to strong winds and storm surge.

2. CLIMATE IMPACTS ON WATER INFRASTRUCTURE

Potential climate impacts on water supply infrastructure associated with extraction from surface and groundwater sources, treatment, storage, and piping or distribution structures (treatment facilities, reservoirs, and networks) include:

Reduced precipitation. Direct changes in precipitation patterns and indirect changes in land use within the catchment can negatively impact surface water and groundwater availability.

Changes in the seasonality of precipitation patterns may affect the reliable yields from surface water such as rivers and reservoirs.

Increased intensity of storms and extreme precipitation. Beyond the physical damage to structures, and the potential for flooding, the potential occurrence of such events requires increased attention to the siting and sizing of structures.

Droughts. Prolonged drought can cause groundwater levels to drop significantly, either temporarily or permanently, thereby affecting the performance of wells designed to withdraw groundwater at specific depths.

Sea level rise will directly threaten and flood coastal structures, while water extraction areas may also be impacted by increased salinity. Small coral or limestone islands and atolls often have a lens of freshwater floating on a transition zone of brackish water that lies on top of saltwater. Expected climate change impacts such as sea level rise and changes in tropical cyclone patterns may exacerbate the risks to freshwater lenses due to salinization.

Decrease in water quality. Multiple climate-influenced factors can negatively impact water quality, including increased siltation, algal blooms, and decreased capacity for dilution of water contaminants. This can be particularly important when selecting sites for water extraction. Changes in water quality can also hinder treatment processes and require more rigorous (and often expensive) measures. Increased salinity and reduced precipitation may impact shallow aquifers or reduce surface water dilution of salinity, impacting potable water supplies, or infrastructure longevity. Increased saline intrusion is also associated with climate change, especially in coastal areas affected by sea level rise.

Increased mean temperature. Evaporation losses from surface water reservoirs may be expected to increase as temperatures increases, thereby reducing yields and increasing storage losses.

Climate change impacts that threaten the structural integrity and service sustainability of water supply infrastructure in the Philippines are summarized in the table below.

Table 1: Climate Change Impacts on Various Components of Water Supply Infrastructure

CLIMATE DRIVERS AND EFFECTS	INFRASTRUCTURE IMPACTS AND CONSEQUENT RISKS
Increased Mean Annual and/or Intensity of Precipitation	
Higher intensity rainfall and flooding during storms Extreme precipitation events are location-specific and can cause flooding and landslides when downpours exceed the capacity of river or urban drainage systems. Uncertain climate projections, expected to	**River Water Resources** • Increased water turbidity after heavy storm events • Shifts in river morphology from increased erosive capacity of river during storm events may affect water withdrawal • Need for dredging to remove sediment, rocks and debris deposited after storm events

CLIMATE DRIVERS AND EFFECTS	INFRASTRUCTURE IMPACTS AND CONSEQUENT RISKS
intensify in some areas. 	**Water Impoundments** • Additional storage facilities needed to capture water during shorter, higher intensity storms • Higher turbidity of stored water due to erosion requires more treatment chemicals and time for clarification during treatment; temporary suspension of treatment of stored water may also occur in cases of extreme turbidity • Decrease in storage capacity of impounding reservoirs due to high sediment deposition **Wells and Spring Sources** • Well contamination from flooding • Physical damage to structures from flooding • Intake pipes on soft soils or steep slopes prone to landslides • Destruction of spring boxes on steep areas from landslides • Need for relocation of water intake structures due to shifting riverbed and sediments during storm events • Higher maintenance costs to keep water intake structures clear of debris deposited after storm events • Cracks in or total destruction of spring boxes from landslides **Storage Tanks** • Contamination due to flooding for cisterns • Physical damage due to landslides **Pipelines** • Corrosion of metal pipes weaken structures over time • Physical damage to pipes from flooding and landslides • Network contamination from pipes damaged by flooding or landslides **Treatment Facilities** • Physical damage to structures from flooding • Water damage to chemical supplies due to flooding • Lower treatment effectiveness due to higher than normal turbidity or disrupted/shorter treatment operation • Need for higher treatment plant capacity due to higher precipitation depending on capacity of transmission lines Auxiliary Services • Loss of power supply • Loss of telecommunication facilities • Loss of data
High Winds	
Higher intensity storms with higher wind velocities Severe weather systems involving damaging winds and heavy rainfall, including tornados, hailstorms, and typhoons.	**River Resources** • Massive tree falls in watersheds cause erosion that increase turbidity • Massive tree falls in watersheds cause large-scale erosion over the long term that can dramatically alter river morphology over time **Wells and Spring Sources** • Physical damage to spring boxes from falling trees and debris • Need for removal of fallen trees and debris that block water intake structures

CLIMATE DRIVERS AND EFFECTS	INFRASTRUCTURE IMPACTS AND CONSEQUENT RISKS
	• Intake pipes on soft soils or steep slopes are prone to damage over the longer term from erosion in areas where trees have been uprooted by high winds • Collapse or loss of roof structures that protect pump stations **Storage Tanks** • Physical damage and collapse of elevated water tanks **Pipelines** • Physical damage to exposed pipes from falling trees and structures • Physical damage to buried pipes entangled with tree roots that become uprooted with trees • Physical damage and contamination due to tampering by residents with malfunctioning water systems damaged by high winds **Treatment Facilities** • Long-term erosion from tree falls and changes in river morphology threaten the integrity of treatment facilities located on rivers • Collapse or loss of roof structures and treatment sheds from high winds • Exposure and damage to treatment chemicals from loss of roof structures • Loss of power from damaged power lines disrupts pumping, mixing and treatment operations **Auxiliary Services** • Loss of power supply • Loss of telecommunication facilities • Loss of data
Storm Surge	
Seawater inundation during storm surge The difference between the actual water level under the influence of a meteorological disturbance or storm tide and the level which would have been attained in the absence of the meteorological disturbance. Sea level rise can exacerbate storm surge height. 	**Wells and Spring Sources** • Contamination of freshwater supplies due to saltwater intrusion • Physical damage to structures from inundation and/or debris • Large amounts of debris deposited inland by storm surge **Storage Tanks** • Contamination of cisterns • Corrosion of steel tanks • Physical damage and collapse of elevated water tanks **Pipelines** • Physical damage from storm surge • Corrosion of metallic pipes exposed to seawater from inundation **Treatment Facilities** • Physical damage to coastal or low-lying structures from storm surge • Water damage to chemicals **Auxiliary Services** • Loss of power supply • Loss of telecommunication facilities • Loss of data
Sea Level Rise	
Gradual sea level rise over time	**All Structures and Systems** • Saline intrusion into freshwater supplies

CLIMATE DRIVERS AND EFFECTS	INFRASTRUCTURE IMPACTS AND CONSEQUENT RISKS
Anticipated sea level changes due to the greenhouse effect and associated global warming. Leads to changes in erosion and accretion, long-term inundation, and exacerbates storm surge and tsunami height. 	• Corrosion of metal structures and materials • Physical damage from coastal erosion • Eventual inundation
Drought and Decreased Mean Annual Precipitation	
More frequent drought conditions; increased evaporation and/or reduced soil moisture A prolonged dry period in a natural climate cycle which results in a shortage of water. Likely increase in drought conditions in some areas through a warming of air temperature and decrease in precipitation. 	**River Water Resources** • Decreased availability of surface water resources • Lower river levels affect water intake • Water systems designed using historical precipitation data are likely to be unsustainable for future projections of reduced precipitation • Competing demands for water from industrial, agricultural and urban sectors **Water Impoundments** • Increased evaporation decreases availability of surface water • Need for increased inter-annual storage capacity **Wells and Spring Sources** • Decreased availability of groundwater resources • Deeper groundwater tables • Decreased availability of surface water resources requires increased need for additional groundwater sources or deeper wells • Increased pumping costs to reach deeper groundwater tables **Storage Tanks** • Lack of inflow to storage tanks • Frequently emptied due to higher demand **Pipelines** • Decreased supply and intermittent or low pressure • Increased risk of contamination from wastewater intrusion • Increased demand for increasingly scarce water resources **Treatment Facilities** • Declining raw water quality due to drought-prone algal blooms or diminished runoff and flows that cause concentration of chemical pollutants • Increased treatment costs as pollutants become more concentrated
Increased Mean Annual Temperature/Extreme Heat/Heat Waves	
Extreme heat Extreme temperatures are location-	**Water Impoundments** • Reduced holding capacity of reservoirs due to increased evaporation and/or aquatic vegetation growth

CLIMATE DRIVERS AND EFFECTS	INFRASTRUCTURE IMPACTS AND CONSEQUENT RISKS
specific. Heat waves are prolonged periods of excessively hot weather. Likely increase in extreme air temperature and heat waves in most areas. 	• Reduced water quality associated with increased algal blooms triggered by heat waves **Pipelines** • Decreased, intermittent supply or low pressure delivery, with increased risk of contamination from wastewater intrusion **All Structures and Systems** • Increased maintenance requirements and part replacement as heat stresses material performance, durability and strength (e.g., rubber gaskets on valves crack and crumble)
Wildfires	
Wildfire A massive and devastating fire that destroys forests, grasslands and crops, kills livestock and wild animals, damages or destroys settlements and puts the lives of inhabitants at risk. 	**Water Impoundments** • Reduced water quality associated with increased particulate matter from fires in catchments • All structures and systems • Damage to facilities and above-ground structures

3. SENSITIVITY OF MATERIALS USED IN WATER SUPPLY CONSTRUCTION: FINDINGS FROM POST-YOLANDA DAMAGE ASSESSMENTS

Materials used in the construction of water supply systems are differentially affected by climate drivers. This is referred to as material sensitivity, or the degree to which something is directly or indirectly affected by or responsive to changes in climate conditions or related impacts Understanding how different materials withstand the stresses of wind, storm and landslide damage from extreme climate change-related events can be helpful in designing new climate-resilient systems. In the aftermath of Typhoon Yolanda in November 2013, Be Secure engineers conducted damage assessments and encountered the following:

- Corrugated metal roofing of houses were completely blown away by strong winds.
- Structures made of light materials (wooden frame) were severely damaged by storm surge and strong winds.
- Reinforced concrete structures weathered storm surge and strong winds with minor damage.
- Structural steel water towers held up against storm surge and strong winds with minor damage.
- Exposed transmission pipes were damaged by landslides and inundation.
- Leaks in reinforced concrete spring boxes resulted from landslides.
- School water systems with exposed pipe networks were damaged by inundation.
- Transmission pipe bridges were damaged by flooding.

Be Secure engineers used this experiential evidence to develop the table below summarizing materials sensitivity.

Table 2: Materials Sensitivity from Post-Yolanda Damage Assessments

Material	Flooding	Land- slides	Wind	Storm Surge	Sea Level Rise
Roofing					
Corrugated metal roofing	Low	High	Extreme	Extreme	N/A
Concrete roofing	Low	High	Low	Low	N/A
Piping					
Metal pipes (buried)	Low	Medium	Low	Low	Low
Plastic pipes (buried)	Low	Medium	Low	Low	Low
Metal pipes (exposed)	High	High	Medium	High	High
Plastic pipes (exposed)	High	High	Medium	High	High
Structural					
Reinforced concrete wall	Low	Medium	Low	Low	N/A
Concrete hollow block wall	Low	High	Low	Medium	N/A
Wooden walls	High	Extreme	High	Extreme	N/A
Water Storage					
Reinforced concrete water tower	Low	High	Low	Low	N/A
Structural steel water tower	Medium	High	Low	Low	N/A

4. STRATEGIC APPROACHES TO CLIMATE CHANGE ADAPTATON

Adaptation encompasses all the actions in response to actual or projected climate change impacts to reduce risks, vulnerability, and related future costs. These strategies can be categorized into four main approaches: accommodate and maintain, harden and protect, relocate and accept or abandon (Table 3).

Table 3: Approaches to Climate Change Adaptation Options

Strategic Approach	Adaptation Option	
	Rehabilitate Existing Structures to Higher Standards or Strength	**Build New Climate-Resilient Structures**
Accommodate and Maintain	Extend, strengthen, repair or rehabilitate over time Adjust operation and maintenance practices	Design and build to allow for future upgrades, extensions or regular repairs
Harden and Protect	Rehabilitate and reinforce Add supportive or protective features Incorporate redundancy	Use more resilient materials, construction methods, or design standards Design for greater capacity or service
Relocate	Relocate sensitive facilities or resources from direct risk	Site in area with no, or lower, risk from climate impacts
Accept or Abandon	Keep as is, accepting diminished level of service or performance	Construct based on historic climate conditions, accepting possibly diminished level of service or performance

Each of these approaches has unique advantages and disadvantages. In some cases, it might be adequate to alter operation and maintenance approaches to allow the system to perform to certain design specifications (accommodate and maintain). Adaptation strategies to harden and protect involve specific engineering measures that can be incorporated into the design of an infrastructure system to make it more resilient to climate change impacts – such as incorporation of redundancy, use of more resilient materials, building to a more robust standard (such as a higher wind speed), or the construction of flood protection measures. Adapting to climate change may require shifting the location of assets to avoid hazards, for example, or in extreme cases accepting the climate hazard and abandoning an asset. Table 4 in the section below describes strategies that may be implemented for different types of assets in response to various climate variables and their impacts.

5. CLIMATE CHANGE ADAPTATION OPTIONS FOR WATER INFRASTRUCTURE FOR DIFFERENT CLIMATE DRIVERS

Be Secure worked with WSPs and LGUs to evaluate climate change risks and identify the most appropriate adaptation options. The array of adaptation measures that are most applicable to WSPs, municipalities, and river basin managers in the Philippines, and examples of each, are provided in Table 4 below.

Table 4: Examples of Climate Change Adaptation Options for Water Supply Infrastructure

Climate Drivers and Effects	Climate Change Adaptation Options	Be Secure Examples (described in Section 6 below)
	River Water Resources	
Increased precipitation, flooding, landslides, wind	**Accommodate/Maintain** Assess flexibility to switch between different water sources Increase maintenance budget for cleaning/clearing debris at intake pipes Increase budget for dredging, river training following storm events Conduct regular aerial assessments to monitor changing river morphology **Harden/Protect** Stabilize landslide-prone areas by planting trees Construct river training structures **Relocate** Relocate or raise the elevation of conveyance and intake structures **Accept or Abandon** Consider other water sources if a water intake is threatened by landslides or changing river morphology	Oxbow study (Pastrana, Leyte)
Drought	**Accommodate/Maintain** Assess flexibility to switch between different water sources during times of drought **Harden/Protect** Plant more trees to help retain rainfall **Relocate** Relocate water intake structures or construct an infiltration gallery to tap water below the river bed **Accept or Abandon** Consider other water resources such as groundwater or other untapped river systems	Pre-Feasibility Study for an Impounding Dam with Conjunctive Hydroelectric Power Plant for Zamboanga City Rapid Feasibility Study for Tacloban North Bulk Water Supply Project Rapid Feasibility Study on Additional Water Source for Metro Cotabato Rapid Feasibility Study on Additional Water Source for Cagayan De Oro City
	Water Impoundment	
Increased precipitation, flooding, landslides, wind	**Accommodate/Maintain** Allocate emergency funds for repair works after an event Increase budget for maintenance work **Harden/Protect** Stabilize landslide-prone areas by planting trees Retrofit structures to be able to withstand stronger typhoons	Pre-Feasibility Study for an Impounding Dam with Conjunctive Hydroelectric Power Plant for Zamboanga City

Climate Drivers and Effects	Climate Change Adaptation Options	Be Secure Examples (described in Section 6 below)
	Relocate Construct new and climate-resilient facility **Accept or Abandon** Consider other facilities if retrofitting is not possible	
Drought	N/A, other than no water to store, drought has insignificant impact on impoundment facilities	
Wells and Spring Sources		
Increased precipitation, flooding, landslides, wind	**Accommodate/Maintain** Allocate emergency funds for repair work after an event Increase budget for maintenance work **Harden/Protect** Construct bund walls around centrifugal pumps and electrical control rooms to prevent ingress of flood waters Replace centrifugal pumps with submersible pumps Retrofit structures to be able to withstand stronger typhoons (reinforced concrete pump houses, generator sheds and chlorinator sheds) **Relocate** Construct new and climate-resilient facility **Accept or Abandon** Consider other facilities if retrofitting is not possible	Replacement of typhoon-damaged pump sheds, generator sheds and chlorinator sheds with reinforced concrete structures (Isabel and Ormoc, Leyte) Drilling of two wells in Malamawi Island for Isabela Water District (Isabela City, Basilan)
Drought	**Accommodate/Maintain** Assess flexibility to switch between different water sources during times of drought **Harden/Protect** Plant more trees to help retain rainfall Increase well depth **Relocate** Relocate or find new wells/springs **Accept or Abandon** Consider other water resources such as surface water	Drilling of two wells in Malamawi Island for Isabela Water District (Isabela City, Basilan) Installation of a fully embedded 300 mm diameter pipe from filter plant to the treated reservoir for Ormoc Waterworks in Ormoc, Leyte
Treatment Facilities		
Increased precipitation, flooding, landslides, wind	**Accommodate/Maintain** Allocate emergency funds for repair works after an event Increase budget for maintenance work **Harden/Protect** Stabilize landslide-prone areas by planting trees Construct bund walls around underground tanks to prevent ingress of flood waters Retrofit structures to be able to withstand stronger typhoons **Relocate** Construct new and climate-resilient facility **Accept or Abandon** Consider other facilities if retrofitting is not possible	Preparation of Design-build Tender Documents and Tendering Assistance for Zamboanga City Water District's 20 MLD Water Treatment Plant
Drought	N/A, other than no water to store, drought has insignificant impact on treatment facilities	
Storage Tanks		
Increased precipitation, flooding, landslides,	**Accommodate/Maintain** Allocate emergency funds for repair works after an event Increase budget for maintenance work	Repair and rehabilitation of the typhoon-damaged water system of schools and rural

Climate Drivers and Effects	Climate Change Adaptation Options	Be Secure Examples (described in Section 6 below)
wind	**Harden/Protect** Stabilize landslide-prone areas by planting trees Construct bund walls around underground tanks to prevent ingress of flood waters Retrofit structures to be able to withstand stronger typhoons **Relocate** Construct new and climate-resilient facility **Accept or Abandon** Consider other facilities if retrofitting is not possible	health units (various LGUs in Leyte)
Drought	N/A, other than no water to store, drought has insignificant impact on storage tanks	
Pipelines		
Increased precipitation, flooding, landslides, wind	**Accommodate/Maintain** Allocate emergency funds for repair works after an event Increase budget for maintenance work **Harden/Protect** Embed exposed transmission pipes where possible Raise exposed transmission pipes above maximum historical flood levels Encase exposed pipes in concrete when raising is not possible **Relocate** Transfer transmission pipes when area is vulnerable to landslides **Accept or Abandon** Consider new pipe alignment if retrofitting is not possible	Replacement of typhoon-damaged transmission pipe with a new concrete-encased pipe (Baybay and Carigara, Leyte) Raising of transmission pipe above maximum historical flood level (San Miguel, Leyte) Transfer of raw water pipe from the landslide prone river bank to the rocky river bank on the opposite side (San Miguel and Isabel, Leyte) Repair of typhoon-damaged suspended transmission pipe using stainless steel catenary, vertical and horizontal stay cables (Kananga, Leyte) Replacement of the exposed vulnerable pipe with a new embedded transmission pipe (Kananga and Ormoc, Leyte) Repair of typhoon- damaged spring box (Kananga, Leyte)
Drought	N/A, other than low flow through the pipes, drought has insignificant impact on storage tanks	NRW Reduction Strategy and Implementation (Cagayan De Oro Water District, Cagayan De Oro City)

6. ILLUSTRATIVE EXAMPLES IMPLEMENTED BY BE SECURE

Specific examples of climate-resilient repairs, construction, and other adaptation measures implemented by Be Secure are provided in the tables below. These examples describe how water systems in different settings were vulnerable to various climate impacts, and how Be Secure made them more climate resilient. It is intended that these examples will help other WSPs and LGUs make informed decisions on appropriate measures they can take.

6.1 CLIMATE-RESILIENT REPAIRS OF WELLS AND SPRINGS

Table 5: Metro Hilongos Water District, Leyte

VULNERABILITY AND DAMAGE	
	**Vulnerable Raw Water Source** Manlinao Spring is one of the sources of raw water of Metro Hilongos Water District. The spring eye discharges into an open pond before water flows by gravity into a concrete spring box. During storm events, runoff water finds its way to the pond, making the water too turbid for the filter plant.
	Local residents also fetch water from the pond.

	The open spring pond is vulnerable to pollution and vandalism.

CLIMATE-RESILIENT REPAIRS

	The exposed spring pond was enclosed with a reinforced concrete structure to prevent surface runoff from contaminating the water of the spring pond.
	To allow local residents continued access to the spring pond, a hand pump was installed.

Table 6: Kananga Waterworks, Leyte

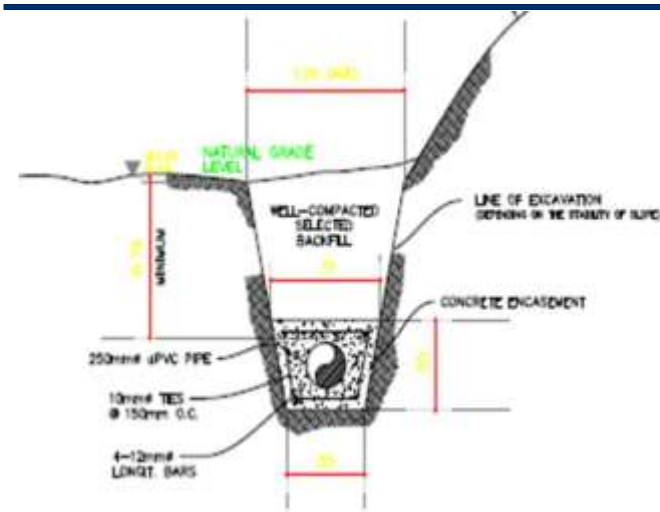
VULNERABILITY AND DAMAGE	
	**Vulnerable Raw Water Source** Water source No. 1 of Kananga LGU Water System comes from a spring box. Signs of leakage were found around the spring box. During summer, flow from the spring box is very low due to limited rain and exacerbated by the loss of water from the leaks.
CLIMATE-RESILIENT REPAIRS	
	During rehabilitation, Be Secure sealed the leaks in the spring box. An additional spring box was constructed to capture excess water during the rainy season to provide continuous supply during drier periods.

6.2 CLIMATE-RESILIENT REPAIRS OF PIPELINES

Table 7: Baybay City Water District, Leyte

VULNERABILITY AND DAMAGE	
	**Damaged Transmission Pipe** Baybay City Water District depends on a transmission pipe that brings water from the Busay River to many communities. Approximately 700 m of pipeline was damaged by flooding and landslide debris during Typhoon Yolanda. The damage disrupted the delivery of water, which was especially needed during the post-Yolanda emergency response and recovery period.
	The water district made short-term repairs to the newly exposed transmission pipes, but they remained vulnerable to future storm events.
	Landslides and flooding exposed and damaged this metal pipe.

CLIMATE-RESILIENT REPAIRS



Be Secure developed engineering designs to entrench the pipe and encase it in concrete.

The pipeline was adequately buried and fully encased with reinforced concrete.

Table 8: Metro Carigara Water District, Leyte

VULNERABILITY AND DAMAGE

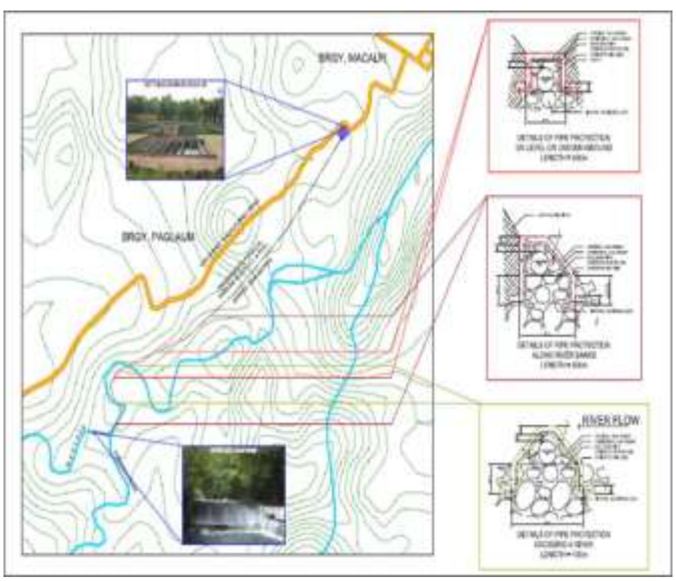
Damaged Transmission Pipe

Metro Carigara Water District maintains a set of parallel transmission pipes from its river source.

Approximately 250 linear meters of parallel pipelines were damaged during Typhoon Yolanda.

The water district made temporary repairs following the disaster, but the transmission pipe remained exposed along the steep and unstable river bank.

CLIMATE-RESILIENT REPAIRS



Be Secure developed engineering designs to strengthen the pipelines by encapsulating the pipe with reinforced concrete. The size and shape of the encasement varied along its length depending on the morphology of the river basin. This required detailed site assessments to map and measure the pipeline path along the river.

Aside from protecting the pipelines, the above-ground concrete encasement is used as a pathway by local residents.

Table 9: Isabel Water District, Leyte

VULNERABILITY AND DAMAGE

Damaged Transmission Pipe

The transmission pipe for the Isabel Water District crosses the river at two different points. Both of these river crossings make the transmission pipe vulnerable to flooding during storm events.

In addition, the position of the pipe far below the soffit of a neighboring box culvert makes it further exposed to risks of damage.

CLIMATE-RESILIENT REPAIRS

Be Secure re-engineered the section of pipe crossing the river to raise it to the same elevation as the soffit of a newly repaired box culvert.

Table 10: Kananga Waterworks, Leyte

VULNERABILITY AND DAMAGE	
	**Hanging Transmission Pipe Damaged by Typhoon Yolanda** Kananga Water System has a 75 mm diameter galvanized iron (GI) pipe suspended by vertical cable wires to a parabolic cable across a river spanning approximately 40 m. Some of the cables snapped during Typhoon Yolanda, leaving the pipe hanging precariously. The wind speed considered in the design is 315 kph, the recorded wind speed of Typhoon Yolanda. This wind speed is higher than the current design requirement of the 2010 National Structural Code of the Philippines, which is 200 kph for Leyte.
	**Vulnerable Pipe Near a Slope Prone to Landslide** A portion of the transmission pipe of Kananga Water System is mounted on the side of a slope prone to landslides, making it vulnerable during storms or floods.

CLIMATE-RESILIENT REPAIRS	
	The key is to hold the hanging pipe in place and prevent it from swaying during typhoons. To achieve this, Be Secure placed horizontal stay cables at four points along the pipe. These cables were anchored to reinforced concrete blocks constructed along the river banks. The design calls for a 14 mm diameter stranded stainless steel cable with a minimum breaking load of 173 kilonewtons. Stainless steel was selected because it doesn't require painting/maintenance works, and is ideal for structures where access is a challenge such as the location of this pipe. While the stranded stainless steel cables are more expensive than ordinary steel, they are cost effective because they are corrosion resistant and do not require maintenance. Design wind speed is 315 kph, the same strength as Typhoon Yolanda.
	Pipe along the steep hillside was embedded in stable ground.

Table 11: Macarthur Waterworks, Leyte

VULNERABILITY AND DAMAGE	
	**Damaged Transmission Pipe** A portion of the transmission pipe of MacArthur LGU Water System hangs precariously near a river bank. The pipe is vulnerable to flooding.
CLIMATE-RESILIENT REPAIRS	
	Designs show how the pipe was lowered and encapsulated in reinforced concrete.

Table 12: Ormoc Waterworks, Leyte

VULNERABILITY AND DAMAGE

Damaged Exposed Transmission Pipe

Ormoc LGU Waterworks System (OWWS) has a transmission pipe running from its filter plant to its reservoir; about 600 m was damaged by flood waters brought by Typhoon Yolanda disrupting much needed supply during the emergency. The pipe was repaired by the LGU but remains vulnerable as it was simply restored to its original alignment, simply lying on the ground.

Vulnerable Exposed Pipe Repair

Pipe replacement of OWWS is still exposed and remains vulnerable to inundation

CLIMATE-RESILIENT REPAIRS

Embedded Transmission Pipe

Transmission pipe was embedded in the ground as per LWUA Standards. Where pipe crosses the river, it was encapsulated with reinforced concrete below the river bed.

	**Additional Supply From the Embedded Pipe** The new embedded pipe increased the water production of OWWS and they now experience full reservoir, an event that has never happened before. Because of this, they are now able to rest some of their production wells as mitigation/preparation during summer and drought.

Table 13: San Miguel Waterworks, Leyte

VULNERABILITY AND DAMAGE	
	**Damaged Pipe Bridge** A 250 mm diameter GI Pipe of San Miguel Water System runs across a creek and is supported by a steel pipe bridge, which in turn is supported by concrete piers on each side. The pipe is about 1 m above the top of a nearby box culvert. However, the box culvert was overtopped by flood waters reaching up to the pipe and damaging the pipe bridge. The pipe was not damaged by the flood waters and the damaged bridge was actually hanging on the pipe.
	**Damaged Raw Water Pipe** Portion of the raw water transmission pipe of San Miguel LGU Water System is supported precariously at the side of a slope prone to landslide. Rains brought by Typhoon Yolanda triggered a landslide that damaged the pipe. The pipe was restored by the LGU along the same alignment which is prone to future landslide

CLIMATE-RESILIENT REPAIRS

Raised Transmission Pipe Above Flood Level

To minimize disruption of service, a temporary bypass pipe was installed before works on the raising of the pipe began. After taking down the damaged bridge and the pipe, holes were drilled into the top of the bridge pier to accommodate the reinforcing bars for the extension. Chemical anchors were used to ensure bond between the old structure and the reinforcing bars. After extending the concrete piers by 1 m, the pipe was reinstalled. There is no need for pipe support as the pipe was computed to be capable of carrying its own weight.

Realigned Transmission Pipe Along the Stable Bank of the River

New transmission pipe installed on the left bank of the river where there is rocky formation. The transfer of the pipe was strongly recommended by the local Mines and Geosciences Bureau (MGB) who confirmed that the right bank is very prone to landslides.

6.3 PUMP, GENERATOR AND CHLORINATOR SHEDS

Table 14: Isabel Water District, Leyte

VULNERABILITY AND DAMAGE	
	**Vulnerable Pump Shed** Isabel Water District has three pumps with sheds. The roofs and wall cladding were made of light materials and were blown away by Typhoon Yolanda and causing operation to stop for days. Temporary repairs were carried out by the LGU but the pump sheds remain vulnerable to high winds during typhoon events.
	**Vulnerable Generator Shed** Isabel Water District has one emergency generator. But as with the pump sheds, the generator shed remains vulnerable to high winds during typhoon events.
CLIMATE-RESILIENT REPAIRS	
	**Reinforced Concrete Generator Shed** GI roofing was replaced with reinforced concrete roof deck. The building envelope replaced with concrete masonry.

	**Reinforced Concrete Pump Shed** GI roofing was replaced with reinforced concrete roof deck. The building envelope replaced with concrete masonry.

Table 15: Kananga Waterworks, Leyte

VULNERABILITY AND DAMAGE	
	**Vulnerable Chlorinator Shed** The roofing of the chlorinator shed of Kananga LGU Water System is made of GI sheets. The GI sheets were blown away by strong winds brought by Typhoon Yolanda.

CLIMATE-RESILIENT REPAIRS	
	**Chlorinator Shed with Concrete Roof** GI roofing was replaced with concrete roof slab.

Table 16: Ormoc Waterworks, Leyte

VULNERABILITY AND DAMAGE	
	**Vulnerable Pump/Generator Shed** Ormoc LGU Water System (OWSS) has several Pump Sheds and Generator Sheds damaged by Typhoon Yolanda . The roofs and wall cladding were made of light materials and were blown away by Typhoon Yolanda disrupting much needed operation during emergency. Make do repairs were carried out by the LGU but the sheds remain vulnerable to high winds during typhoon events.

Vulnerable Shed Repair

Makeshift repair of generator shed by OWSS leaves the shed vulnerable to strong winds.

CLIMATE-RESILIENT REPAIRS

Reinforced Concrete Generator Shed

GI roofing was replaced with reinforced concrete roof slab. The building envelope replaced with concrete masonry.

Reinforced Concrete Pump Shed

GI roofing was replaced with reinforced concrete roof slab. The building envelope replaced with concrete masonry.

6.4 WATER SYSTEM AND STORAGE STRUCTURES

Table 17: Public Schools and Health Facilities, Leyte

VULNERABILITY AND DAMAGE	
	**Exposed Pipe Network Vulnerable to Flooding** Most schools and health clinics have exposed pipe networks that are vulnerable to flooding. The exposed pipes are also prone to tampering.
	**No Water in Toilets** Most schools and health facilities have exposed pipe networks that are vulnerable to flooding. The exposed pipes are also prone to tampering.
CLIMATE-RESILIENT REPAIRS	
	**Newly Installed Pipes Fully Embedded** Newly installed pipes are fully embedded to be more resilient against flooding.

New Water System Provides 24/7 Water Supply

A whole system was installed consisting of a cistern, a pump and an elevated tank which provides water 24/7.

The steel tower for the tank was designed to resist both seismic and wind forces. Design wind speed is 315 KPH, same as Typhoon Yolanda. The tank is fixed to the tower to prevent wind from blowing it away in case a typhoon happens when the tank is empty or has less water.

6.5 OTHER ADAPTATION OPTIONS

The following tables describe other climate change adaptation options that Be Secure implemented that may be useful to WSPs and LGUs.

STUDY ON PROTECTION OF RAW WATER SOURCE AT TINGIB INTAKE OF BINAHAAN RIVER (OXBOW STUDY, LEYTE METRO WATER DISTRICT)

Description: Engineering Design Aspects

The major water source of Leyte Metro Water District (LMWD) is the Binahaan River which has a total drainage area of approximately 37,126 hectares. A diversion weir dams the water and guides it through the Intake. Raw water from the river is conveyed from an Intake to a Water Treatment Plant (WTP) about 2 km downstream.

Upstream of the Intake is an Oxbow (or a river bend), which continues to experience erosion during flood events such as the ones caused by Typhoon Yolanda (November 2013) and Typhoon Senyang (December 2014). LMWD is particularly concerned that continued erosion of the "critical area" will eventually cause the river flow to bypass the Intake. If this happens, it will be catastrophic to the operation of LMWD as this will deprive the WTP of raw water to treat, thus depriving LMWD's customers with access to treated water.

Topographic survey, geotechnical investigation and hydraulic modeling were carried out to study the behavior of the river within a 3 km stretch upstream and downstream of the Intake, the Oxbow included. At the same time aerial mapping was carried out using drones (UAV) 25 km downstream and 25 km upstream of the intake. Following below are the results of the Oxbow Study:

- The aerial mapping downstream of the intake showed that there are no communities at risk in the event of the oxbow being completely eroded
- The aerial mapping upstream of the intake provided a clear picture of the vegetation of the watershed which is a vital information to the hydraulic model
- The hydraulic model showed that the oxbow is not at risk of being completely eroded as sediment deposition will occur within the area during flood events
- The hydraulic model was able to identify a specific location where erosion will take place, and this is

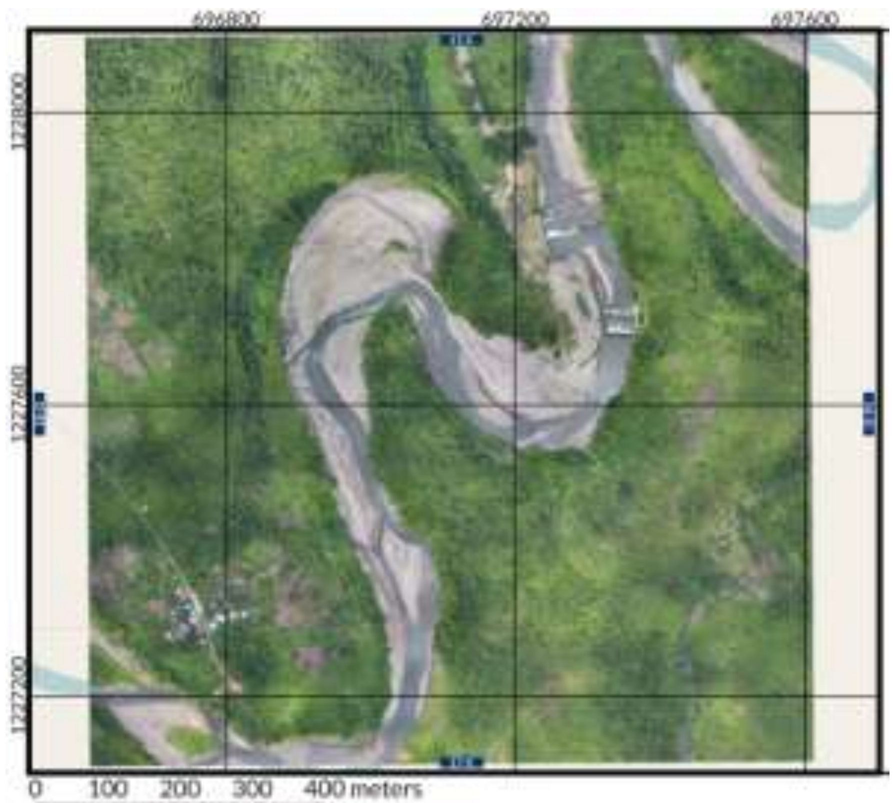
further downstream of the oxbow closer to the intake

- The hydraulic model showed that the existing spillway capacity is deficient to safely pass extreme floods considering that the climate forecast in Leyte is "more rains in the next 25 years"
- The hydraulic model showed that a stilling basin is required right after the apron of the diversion to prevent scouring that will lead to failure of the diversion weir

Based on the results of the Oxbow Study, Be Secure prepared design drawings for implementation by LMWD:

a) For short term implementation
    - Civil design drawings to provide protection to the oxbow (currently being implemented)
    - Civil design drawings to provide protection to the critical section downstream of the oxbow (currently being implemented)
    - Civil design drawings of the stilling basin to protect the diversion weir from scouring (for implementation)

b) For long term implementation
    - Civil design drawings to increase the capacity of the diversion weir to pass extreme floods (for implementation)



AERIAL MAP OF THE OXBOW TAKEN BY AN UAV

SHORT TERM MITIGATION BEING IMPLEMENTED BY LMWD BASED ON BE SECURE'S DESIGN

PRE-FEASIBILITY STUDY FOR AN IMPOUNDING DAM WITH CONJUNCTIVE HYDROELECTRIC POWER PLANT (ZAMBOANGA CITY)

Description: Engineering Design Aspects

Zamboanga City Water District (ZCWD) draws its raw water supply from Tumaga River through a diversion weir (Upper Weir) located in Pasonanca, about 4 km upstream of the 70 MLD Water Treatment Plant (WTP). Raw water from the Upper Weir is conveyed to the WTP through two conveyance pipes. Excess flow from the Upper Weir is also diverted by another weir downstream (Lower Weir) and goes to the 20 MLD untreated reservoir. Neither weir has storage capacity, thus, the raw water supply system of ZCWD can be considered a run-of-the-river type. There is abundance of water during rainy season and low to dry during summer. Also, the existing infrastructure can only cover 58 out of 98 Barangays of Zamboanga City.

Zamboanga City has experienced climate variability, with extreme rainfall causing floods and followed by dry months resulting to water rationing.

To help mitigate the variations of raw water supply due to changing rainfall patterns, ZCWD is planning to construct an impounding dam (Dam) and create a reservoir that will be big enough to impound water during rainy season for use during summer and ensure year-round availability of raw water to satisfy its current and future demand.

Be Secure carried out a Pre-Feasibility Study for an Impounding Dam with Conjunctive Hydroelectric Power Plant which resulted to the following findings:

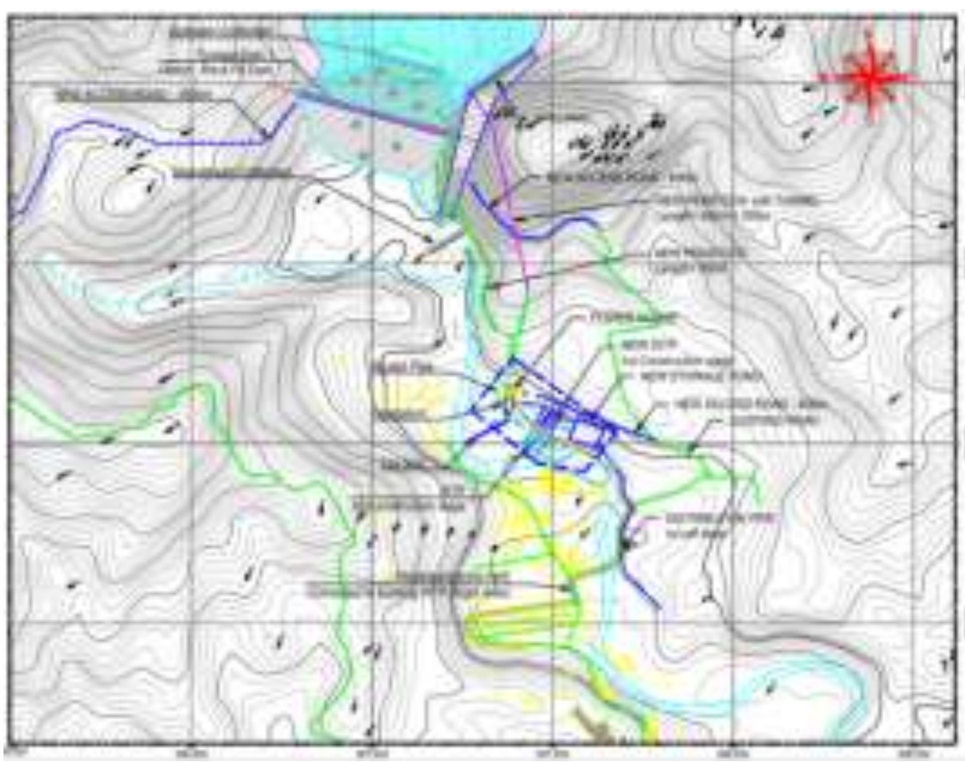
- Water demand of Zamboanga City is estimated to be 342 MLD (Million Liters per Day) by 2050 (Design Year)
- Among the four rivers initially considered, only Tumaga River has the catchment size to provide enough water for a year round supply considering both current and future demand of Zamboanga City

and also considering the effects of climate change

- A 90 m high dam is required with allowance for silt build up and evaporation loss
- The area that will be inundated is approximately 1.4 sq. Km, about 1.4% of the Tumaga catchment area
- About 3.6 MW can be possibly generated, considering the energy head provided by the dam

The Pre-FS has initially established the technical viability of the project. ZCWD will carry this forward to a Full FS to establish financial viability.

EXISTING SOURCE OF ZCWD IS A DIVERSION WEIR AND NO HOLDING CAPACITY, THUS, WATER IS WASTED DURING RAINY SEASON AND THE WEIR RUNS DRY DURING SUMMER EXACERBATED BY EL NIÑO.



PLAN SHOWING THE EXTENT OF THE 90M HIGH DAM. BECAUSE OF SEISMIC ISSUES, A ROCK-FILL DAM TYPE IS PROPOSED.

PREPARATION OF DESIGN-BUILD TENDER DOCUMENTS AND TENDERING ASSISTANCE FOR 20 MLD WATER TREATMENT PLANT (ZAMBOANGA CITY WATER DISTRICT)

Description: Engineering Design Aspects

ZCWD has three intakes at Tumaga River. Two are rated to produce 35-million liters per day (MLD) and one at 20-MLD. Water in the 35-MLD intakes goes through separate conventional water treatment plants while the 20-MLD intake has only a grit chamber located a few hundred meters away from the intake after which it fills an exposed reservoir about 3.2 km downstream through a 750mm diameter transmission main. Water in this existing reservoir is practically raw. All three systems run by gravity.

Water from the existing 20-MLD intake used to be of very good quality but has now experienced episodes of high turbidity. The source reportedly has to be shut down during rainy days, estimated to be about 30% of the time. The quality of the water coming from the 20-MLD intake affects the entire service area because all three intakes merge into one extensive distribution system. Thus all households, institutions and businesses, serviced by the ZCWD are affected. One of ZCWD's main thrusts Is to provide full water treatment to the 20-MLD water source, improving water quality for the entire service area.

Be Secure provided a Technical assistance to ZCWD for the "Preparation of Design-Build Tender Documents and Tendering Assistance for the 20 MLD WTP".

The proposed scheme includes:

- A pump station near the old reservoir that will pump water to the proposed 20 MLD WTP
- A 20 MLD Conventional WTP that includes automatic backwash and backwash recovery
- A sludge treatment facility that will be sized to include the sludge of the existing WTP
- A treated water reservoir

THE PROPOSED LAYOUT SHOWING THE OLD RESERVOIR, THE PUMP STATION, THE NEW 20 MLD WTP AND THE TREATED WATER RESERVOIR

NON-REVENUE WATER REDUCTION STRATEGY AND IMPLEMENTATION (CAGAYAN DE ORO WATER DISTRICT)

Description: Engineering Design Aspects

USAID Be Secure Project provided a Technical Assistance (TA) to Cagayan De Oro Water District (COWD) for its Non Revenue Water (NRW) reduction program. COWD was granted a loan from the Development Bank of the Philippines (PhP458M) and they needed assistance to make sure that the implementation will result to significant reduction of its NRW.

With focus on three heavily populated barangays, the TA included the following:

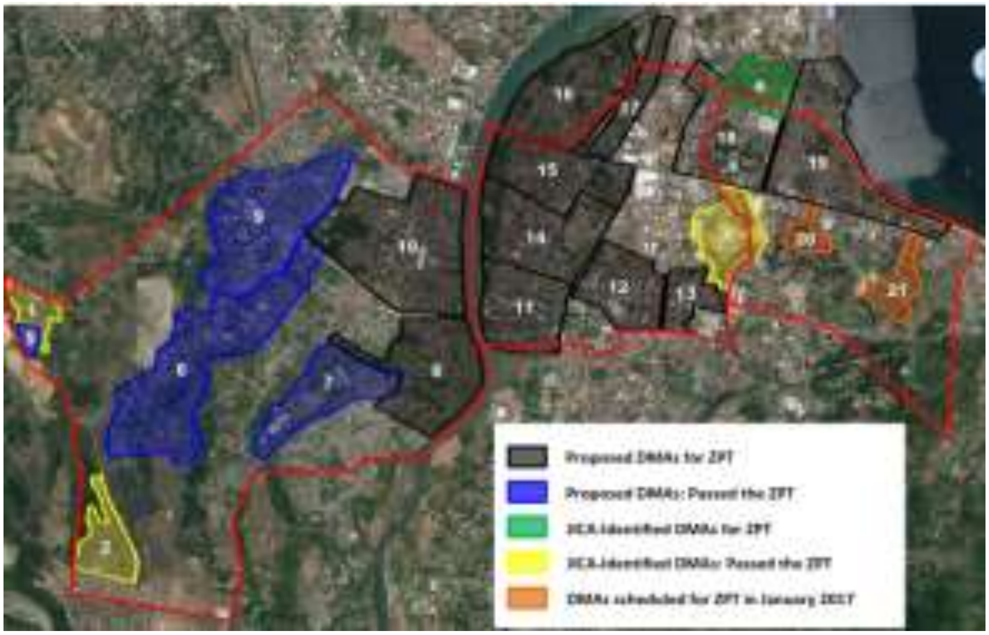
- Develop a GIS Data Base of the service area of COWD
- Develop a calibrated hydraulic model of COWD's network
- Identify sub-zones that can be individually developed into District Meter Area (DMA)
- Develop Standard Operating Procedures for a Sustainable NRW Management
- Provide oversight during the implementation of the identified DMAs

The project is still ongoing up to the time this report is written but initial results showed that:

- The volume of NRW is around 100,000 m3/day which is equivalent to 58% of the daily production of COWD
- The annual cost of the NRW is estimated at PhP500M which is equivalent to 81% of COWD's operating cost
- A 10-year program is laid out for COWD which aims to reduce the NRW from 58% to 18%
- The program will require significant CAPEX but is expected to be cash positive after the fourth year

System Input Volume 173,164 m3/d (+/- 1.7%)	Authorized Consumption 73,978 m3/d (+/- 1%)	Billed Authorized Consumption 72,593 m3/d	Billed Metered Consumption 70,207 m3/d	Revenue Water 72,593 m3/d
			Billed Unmetered Consumption 2,386 m3/d	
		Unbilled Authorized Consumption 1,385 m3/d (+/- 50 %)	Unbilled Metered Consumption 0 m3/d	Non-Revenue Water 100,571 m3/d (+/- 3%)
			Unbilled Unmetered Consumption 1,385 m3/d (+/- 50 %)	
	Water Losses 99,186 m3/d (+/- 3 %)	Commercial Losses 16,816 m3/d (+/- 6 %)	Unauthorized Consumption 2,000 m3/d (+/- 10%)	
			Customer Meter Inaccuracies and Data Handling Errors 14,816 m3/d (+/- 5%)	
		Physical Losses 82,370 m3/d (+/- 4 %)		

COWD'S WATER BALANCE SHOWING AN NRW OF APPROXIMATELY 100,000 M3/DAY



PROPOSED DMAS WITHIN THE FOCUS AREA

DIGITIZED CUSTOMERS AS INPUT TO THE GIS DATA BASE

RAPID FEASIBILITY STUDY FOR BULK WATER SUPPLY FOR TACLOBAN NORTH (TACLOBAN CITY)

Description: Engineering Design Aspects

Be Secure provided Technical Assistance to Tacloban City LGU for the conduct of a Rapid Feasibility Study for a Bulk Water Supply for Tacloban North. Tacloban North is the proposed relocation site of those affected by the storm surge caused by Typhoon Yolanda. The main objective is to provide water to the relocation site but services will also be made available to three municipalities traversed by the proposed transmission line, Tacloban City is served by Leyte Metro Water District (LMWD) but the coverage of LMWD in the city is limited to certain areas only and a significant portion has no reliable water supply. The projected water requirement of the Tacloban North water system is 46 MLD by 2040 that will good for about 40,000 households.

The FS was able to identify two water sources: Pongso River (43-70 MLD) and Cabayugan River (47-76 MLD) which are both located in Jaro town. Water rights were granted to the LGU at 25 MLD for each river. Thus, both rivers will be tapped to provide the required water volume. The proposed transmission line will cover a distance of about 43 km from the river sources all the way to Tacloban North.

The estimated investment is Php 3.3 billion, which includes both the bulk supply system and the distribution side.

CABAYUGAN RIVER WITH DISCHARGE OF 47-76 MLD

PONGSO RIVER WITH DISCHARGE OF 43-70 MLD

RAPID FEASIBILITY STUDY FOR A NEW WATER SOURCE (METRO COTABATO WATER DISTRICT)

Description: Engineering Design Aspects

Be Secure provided a Technical Assistance to Metro Cotabato Water District (MCWD) for the conduct of a Rapid Feasibility Study for a Bulk Water Supply. MCWD provides water services to Cotabato City, Datu Odin Sinsuat and Sultan Kudarat in Maguindanao. The current service area population is 155,775 and is expected to reach 361,516 by 2050. The water requirement was at 40 MLD in 2014 and this is expected to increase to about 105 MLD in 2050.

Two potential sources were identified: Rio Grande De Mindanao in Cotabato City and Simuay River in Sultan Kudarat. Both rivers have adequate supply capacities but Rio Grande was chosen as the preferred site because it is closer to the city and has better water quality.

The proposed improvements are estimated to cost a total of Php 746 million.

RIO GRANDE IN COTABATO CITY

SIMUAY RIVER IN SULTAN KUDARAT

RAPID FEASIBILITY STUDY FOR A NEW WATER SOURCE (CAGAYAN DE ORO CITY WATER DISTRICT)

Description: Engineering Design Aspects

Be Secure provided Technical Assistance to Cagayan De Oro Water District t (COWD) for the conduct of a Rapid Feasibility Study for Additional Water Source. COWD provides water services to Cagayan De Oro City (66%), Municipality of Opol (45%) and the Municipality of Tagoloan (7%). COWD plans to expand its coverage area by 20%. It also plans to phase out 40% of its ground water source. In order to do this, a new source will have to be developed.

The present water production of COWD is at 188 MLD and is projected to increase to 299 MLD by 2050. Various scenarios were considered and the following have to be pursued in order that the first 50-MLD bulk water can supply up to 2030:

- Reduction of production of wells should be deferred to the latter years (after 2030)
- Instead of just maintaining the existing output of the existing bulk supply or rescinding the contract, water from the existing bulk supplier should be increased

The new source will come from Cagayan De Oro River and the extraction point is in Barangay Cabula, upstream of Cabula Bridge. The total capital cost of the above improvements is about Php 2 billion. This includes the bulk water portion and that of the distribution system improvements.

CAGAYAN DE ORO RIVER SHOWING POSSIBLE ABSTRACTION POINTS

PROPOSED ABSTRACTION POINT AT BARANGAY CABULA

CONCLUSIONS

The devastation caused by Typhoon Yolanda has brought to the fore the negative impacts of climate change to water infrastructure. Likewise, the recent episode of a strong El Niño has exposed the vulnerability of our water supply. Standard water infrastructure design procedures that used to work in the past need reevaluation to be able to withstand more frequent severe storms and more prolonged drought anticipated with climate change. More resilient design measures must also be coupled with the need for behavioral change and encourage water efficiency from both the supply and the demand side.

This guide presents a range of climate change adaptation options that were applied during reconstruction efforts following Typhoon Yolanda to make water supply systems more resilient to future extreme events in Leyte. It is intended that the description of these experiences in Leyte can help other water districts construct new systems or rebuild older systems that have been damaged by climate change-related extreme events to make them more climate change resilient.

The range of available climate resilient options that were implemented through the Be Secure experience in Leyte is diverse and dependent on unique combinations of site specific characteristics and stakeholder needs. Making a decision on appropriate engineering approaches outlined in this guide requires a multi-step process to integrate numerous considerations of design, technology, and cost requirements. A water district must first carry out a risk assessment concerning the following factors to determine likely hazards and consequent impacts:

- Physical damage to supply systems – As described in the previous pages, climate change-related impacts threaten the integrity and productivity of water sources, conveyance networks, storage reservoirs, and treatment facilities. It is vital to identify vulnerable points in existing water systems and find appropriate solutions to lessen the risk of compromised water availability, reflected as either water quality or quantity.
- Changes in demand – While physical damage to water systems will certainly limit access to and availability of potable water for communities, changes in human behavior following a natural disaster or other disruption in service can also limit supply. The stress imposed by catastrophic events can promote hoarding water and other resources as people try to cope with crisis. Understanding the potential for such patterns in behavior can help service providers anticipate and manage not only water supply, but demand aspects of water provision as well.
- Maintenance requirements – Climate change resilience of water systems must also include assuring the provision of commodities and systems required to maintain the infrastructure. Through working on risk assessments, Water Districts and Be Secure team members identified numerous examples where treatment chemicals were stored in unsecured locations and were subsequently destroyed by flooding and building collapse during Typhoon Yolanda. In one instance, drums of treatment chemicals were stored on an open hillside, vulnerable to wind, rain, and potential landslides from flooding.
- Related infrastructure damage – Physical storm damage to power supplies that fuel water pumps and treatment facilities can bring water service delivery to a halt. This is an important consideration to address when physical damage to water infrastructure appears minimal. Leyte water systems were targets of physical destruction as people desperate for water attempt to break and tap into exposed pipes or steal faucets and other fixtures to enable gaining access through such measures. Developing ways to deter vandalism or to simply stock freshwater offer additional adaptive measures.
- Safety – Risk assessment must also consider aspects of health and safety to not only end users of water infrastructure, but also to the people responsible for water service provision during natural disasters or other crises.

Once the risks have been identified, utility operators or other stakeholders must determine acceptable levels of risk. Some potential impacts or consequences may seem insurmountable if they were to occur, while others will be viewed by communities as more tolerable or manageable. Final decision-making on the appropriate level of construction or rehabilitation will be driven by those risks that the community has identified as unacceptable.

A multi-criteria analysis may be used to determine the most acceptable adaptation option. Not all options will have the same degree of acceptance by local stakeholders and the community because of cultural, economic or environmental side effects, as well as behavior change requirements. The array of specific criteria that are used in such an evaluation is dependent upon stakeholder values and needs, and will therefore vary from one community of Water District to another. Considerations may include:

- Local site conditions that affect technical feasibility;
- Compatibility with anticipated climate change projections;
- Ease of construction;
- Maintenance requirements;
- Timeframe for implementation or for the life of the infrastructure asset;
- Cost;
- Anticipated number of beneficiaries;
- Perceived or realized benefits in health and safety.

Once a climate change adaptation strategy has been selected, climate change risks must continue to be assessed through a monitoring and evaluation system. Embedding climate change risks into the existing framework for monitoring water system performance is a preferred approach, rather than developing a stand-alone climate change risk monitoring and evaluation framework. The purpose of monitoring and evaluation will enable Water Districts to:

- Adjust the risk assessment and infrastructure management approach to new or changing climate risk projections;
- Identify unanticipated climate change impacts;
- Support development of effective risk treatments;
- Detect changes in external factors such as social behaviors, water demand, or power provision in the face of catastrophe; and
- Contribute to improvements in risk understanding and share lessons learned with other Water Districts.

Monitoring and evaluation should be based on robust, and simple to measure, quantitative and qualitative indicators. Careful consideration should be given to the cost efficiency and ease of measurement for the proposed measures. Information can be collected and analyzed through both participatory and external evaluation. Ongoing communication and consultation activities can support monitoring and evaluation to help ensure that climate risks are correctly identified, that stakeholders understand consequent risks, and that risk treatment based on the examples in this guide are tailored to each situation accordingly.