National Water Resources Board
Philippine Nuclear Research Institute
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Investment Needs for Resource Assessment Capability in the Philippines to Improve the Planning and Management of Water Infrastructure

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PNRI
Philippine Nuclear Research Institute

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Foreword

Effective management of water resources and the identification and development of sustainable new sources of water are critical components of the 'Water Infrastructure Subsector' of the Philippine Development Plan 2011-2016. An inadequate scientific assessment, however, limits the ability of many countries, including the Philippines, to fully and sustainably use their water resources. The International Atomic Energy Agency (IAEA) has launched the Water Availability Enhancement Project (IWAVE Project) to strengthen Member States' capabilities to understand and map their own water resources. The Philippines is one of three Member States where IWAVE is being implemented as a pilot project. The Philippines National Water Resources Board (NWRB) is leading this project in close collaboration with the Philippines Nuclear Research Institute (PNRI) including national government agencies, private water concessionaires, Water Districts, academic institutions and other stakeholders. In March 2011, a forum was provided for all stakeholders to identify the national gaps in hydrological understanding, data, and information. These are gaps considered to be the primary hindrance to the capability of the Philippines to conduct comprehensive assessments of the national water resource.

As a first outcome of the IWAVE Project in the Philippines, this report identifies and describes the knowledge and data gaps, and the investments required to bridge the gaps. These proposed investments present opportunities for collaboration among Philippine agencies and stakeholders, and with potential international scientific and donor agencies, in order to achieve the objective of the development plan to accelerate infrastructure development in the water subsector. A number of these investments have already begun under the on-going IWAVE Project.

An inter-agency Technical Working Group comprised of 19 members (PNRI, NWRB, MGB, LWUA, PAGASA, EMB, RBCO, NAMRIA, NPC, DOH, MWSS and its two concessionaires, NIA, BRS, UP-NIGS, BSWM, DILG, WDs) has been responsible for implementing the IWAVE Project in the Philippines. The staff members responsible for this work are S. Abano for NWRB, S. Castaneda for PNRI, and C. Dunning for IAEA.

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MGB	MWCI	NPC	DILG
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LIST OF **ACRONYMS AND ABBREVIATIONS** USED

ASTI	Advanced Science and Technology Institute
BCM	Billion Cubic Meters
BFAR	Bureau of Fisheries and Aquatic Resources
BOI	Board of Investments
BRL	Bureau of Research and Laboratories
BRS	Bureau of Research and Standards
BSWM	Bureau of Soil and Water Management
BWSA	Barangay Waterworks and Sanitation Association
CCIM	Climate Change Impact Modelling
CL	Chlorine
CUSEMA	Consortium on the Urban Subsurface Environment Management in Asia
CRCSI Australia	Cooperative Research Centre for Spatial Information, Australia
DA	Department of Agriculture
DAO	DENR Administrative Order
DAR	Department of Agrarian Reform
DBP	Development Bank of the Philippines
DEM	digital elevation model
DENR	Department of Environment and Natural Resources
DENR-FASPO	Foreign Assisted Special Project Office
DILG	Department of Interior and Local Government
DILG–WSSPMO	DILG-Water Supply and Sanitation Program Management Office
DILG-PMO	DILG-Project Management Office
DOE	Department of Energy
DOF–CDA	Department of Finance - Cooperative Development Authority
DOH	Department of Health
DOJ	Department of Justice
DOST	Department of Science and Technology
DPWH	Department of Public Works and Highways
DPWH-PMO-RWS	Project Management Office-Rural Water Supply
DPWH-FCSEC	Flood Control Sabo Engineering Center
EC	Electrical Conductivity
EHS	Environmental Health Services
EMB	Environmental Management Bureau

EO	Executive Order
EOHO	Environmental and Occupational Health Office of DOH
ERDB	Ecosystems Research and Development Bureau
ET	evapo-transpiration
FAO	Food and Agriculture Organization
FMB	Forest Management Bureau
GDP	Gross Domestic Product
GIT	Geo-spatial Information Technologies
GMAP	Geo-hazard Mapping and Assessment Project
GNP	Gross National Product
GTZ	German Technical Cooperation Agency
HUDCC	Housing and Urban Development Coordinating Council
IAEA	International Atomic Energy Agency
IAH	International Association of Hydrogeologists
IATFGI	Inter-Agency Task Force on Geographic Information
ISSP	Information System Strategic Plan
IWRM	Integrated Water Resources Management
IWRMPF	Integrated Water Resources Management Plan Framework
JICA	Japan International Cooperation Agency
KOICA	Korea International Cooperation Agency
LGU	Local Government Unit
LLDA	Laguna Lake Development Authority
LWUA	Local Water Utilities Administration
MDGF	Millennium Development Goal Fund
MDG	Millennium Development Goals
MGB	Mines and Geo-sciences Bureau
MMDA	Metropolitan Manila Development Authority
MTPDP	Medium-Term Philippine Development Plan
MWSS	Metropolitan Waterworks and Sewerage System
MWCI	Manila Water Company, Inc.
MWSI	Maynilad Water Services Inc.
NAMRIA	National Mapping and Resource Information Authority
NAPC-WASCO	National Anti-Poverty Commission – Water Supply and Sanitation Coordinating Office
NCC	National Computer Center
NCR	National Capital Region
NEDA	National Economic Development Authority

NEHAP	National Environmental Health Action Plan
NEPC	National Environmental Protection Council
NHRC	National Hydraulic Research Center
NIA	National Irrigation Administration
NOA	Nationwide Operational Assessment of Hazards
NPC	National Power Corporation
NRW	non-revenue water
NSO	National Statistics Office
NWDCN	National Water Data Collection Network
NWIN	National Water Information Network
NWRB	National Water Resources Board
OCD-NDCC	Office of Civil Defense – National Disaster Coordinating Council now the **NDRRMC** – National Disaster Risk Reduction and Management Council
ODA	Official Development Assistance
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PAWB	Protected Area and Wildlife Bureau
PCAARD	Philippine Council for Agricultural and Aquatic Resources Development
PCEEM	Philippines-Canada Environmental and Economic Management
P.D.	Presidential Decree
PEMC	Philippine Electricity Market Corporation
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PEZA	Philippine Economic Zone Authority
pH	Potential of Hydrogen
PhilWATSAN	Philippine Water Supply and Sanitation Sector Portal
PHIVOLCS	Philippine Institute of Volcanology and Seismology
PNRI	Philippine Nuclear Research Institute
PPA	Philippine Ports Authority
PPD	Policy and Program Division
PPP	Private-Public Partnership
PRRC	Pasig River Rehabilitation Commission
PSALMC	Power Sector Assets and Liabilities Management Corporation
PTA	Philippine Tourism Authority

PW4SP	Provincial Water Supply, Sewerage and Sanitation Sector Plan
PSWR	Public Sector Workforce Relations
PWSSR	Philippine Water Supply Sector Roadmap
R.A.	Republic Act
RBCO	River Basin Control Office
RBIIMS	River Basin Integrated Information Management System
RDC	Regional Development Council
RDP	Regional Development Plan
RIHN	Research Institute for Humanity and Nature
RWSA	Rural Waterworks and Sanitation Association
SDI	Spatial Data Infrastructure
SuSEA	Sustainable Sanitation in East Asia
SWIM	Small Water Impounding Structure
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
UN	United Nation
UNESCO	United Nations Educational, Scientific and Cultural Organization
UP-NIGS	University of the Philippines National Institute of Geological Sciences
US-EPA	United States Environmental Protection Agency
WD	Water District
WMO	World Meteorological Organization
WQMA	Water Quality Management Area
WRR	Water Resources Region
WRRTD	Water Resources Research and Training Department
WSP	Water Service Provider
WSSS	Water Supply and Sanitation Sector

Investment Needs for Resource Assessment Capability in the Philippines to Improve the Planning and Management of Water Infrastructure

Executive Summary

Water is one of five infrastructure subsectors addressed in the *Philippine Development Plan 2011-2016*. The plan states that to meet existing and future demand, sustainable new sources of water must be identified and developed. The National Water Resources Board (NWRB), the Philippine Nuclear Research Institute (PNRI), and other government agencies are collaborating with the International Atomic Energy Agency (IAEA), within the framework of its *IAEA Water Availability Enhancement Project* (*IWAVE Project*), to improve the availability and sustainable use of water resources. This report presents the investments in national capability to assess the water resources that are critical for the planning and management of the Philippine Water Infrastructure Subsector.

Current challenges in managing water resources

President Benigno S. Aquino III directed the National Economic and Development Authority (NEDA) to formulate the *Development Plan* to serve as the guide in formulating policies and implementing development programs for the years 2011 to 2016. The plan adopts a framework of inclusive growth, defined as a high rate of growth that is sustained, generates mass employment, and reduces poverty.

The *Development Plan* makes clear that a major constraint on achieving inclusive growth in the Philippines during recent decades has been the persistence of inadequate infrastructure. In his Preface to the *Development Plan*, NEDA Director-General Cayetano W. Paderanga, Jr. describes five key strategies of the plan, the third of which is to "invest massively in infrastructure".

In the Philippines, water is considered to be a basic need and therefore receiving basic water services is a right of every person. Even though the country is endowed with abundant water resources it faces the threat of resource scarcity, particularly with respect to groundwater for which demand substantially exceeds supply. As noted in the *Development Plan* "lack of urban planning, indiscriminate urban development, lack of investment in water, problems of water resource management, and the impact of climate change threaten water security and sustainability. Rapid and uncontrolled urban development has reduced aquifer recharge and has eventually resulted in the decline of groundwater levels as well as saltwater intrusion."

In addition to meeting basic services related to water, inclusive economic growth requires meeting the water supply, sewerage, sanitation, and irrigation and flood management needs for centers of priority growth and production. Efficient and effective management of water resources, including the development of new sources of water, is

fundamental to achieving the desired inclusive economic growth of the *Development Plan* while ensuring a sustainable environment.

A number of challenges exists that make assessment of national water resources difficult. One important challenge acknowledged in the *Development Plan* is the fragmentation of the missions, authority, and capabilities of water-sector institutions resulting in generally poor integration of hydrological data and inadequate resource assessment.

Meeting the challenges in managing water resources

The *IWAVE Project* has the goal of enhancing water availability and sustainability within Member States. The PNRI and the NWRB have joined with the IAEA in leading the *IWAVE Project* in the Philippines, which has been underway since 2010. Substantial time and effort have been invested by water-sector stakeholders through workshops and participation in IWAVE Technical Working Groups, with the result of identification of the national-level gaps in hydrological understanding, data, and information in the Philippines. These are gaps currently hindering a comprehensive assessment of the national water resources.

The gaps in hydrological understanding identified through the *IWAVE Project* have been grouped under the major categories of a comprehensive water-resource assessment (***Water Supply, Protection of Water Supply,*** and ***Water Production, Development, and Use)***. Specific gaps in data and information which underlie each gap have been identified and profiled in detail, and remedies and investments to fill the gaps have been proposed.

Water Supply

- *Insufficient understanding of the quantity and spatial/temporal distribution of surface and groundwater resources*

Surface water

Hydrography

- *the need to understand the national hydrography with sufficient detail and certainty to fully support the Integrated Water Resources Management Framework Plan*
- *the need to understand the limnologic changes occurring to lakes and the vulnerability of lakes to a range of identified and potential stresses.*

Streamflow

- *the need to increase the understanding of streamflow in gauged and ungauged basins*
- *the need to understand surface-water storage and routing on a national scale, and the need to understand the effect of scenarios of extreme weather and climate*

Flood and drought risk

- *the need to quantitatively understand the extent and characteristics of flood- and drought-prone areas in all priority basins, and the need to understand how flood waters might be harnessed to lessen the severity of the impact of droughts*

Groundwater

Hydrogeological setting

- *the need to understand subsurface geology, and aquifer thickness and extent, in sufficient detail and scope to support hydrogeologic investigations and fully assess the groundwater resource of the Philippines*

Aquifer characteristics

- *the need to understand aquifer characteristics in sufficient detail to effectively conduct resource supply assessments and management activities*

Groundwater storage and flow

- *the need to understand the quantity and flow of available groundwater and the effect of extreme weather and climate on groundwater storage and flow*

Water Budget and Global Climate Change

Precipitation

- *the need to have an appropriately advanced level of understanding of the spatial and temporal distribution of precipitation and of extreme events for early warning forecasting and risk assessments*

Runoff and recharge

- *the need to understand runoff and recharge processes, origin of recharge, and residence time of groundwater at national and appropriate local scales*

Evapotranspiration

- *the need to understand evapotranspiration in sufficient detail to support water-resource assessments and management needs*

Surface and groundwater interaction

- *the need to understand the interaction of surface water and groundwater, and to develop a unified understanding of the entire water budget at various scales (spatial and temporal) to support inclusive economic growth and the integrated water-resource management needs of the Philippines*
- *the need to understand with reduced uncertainty the effects on the entire water budget of weather and climate, and global climate change*

Protection of Water Supply

- *Insufficient understanding of the water quality status and trends, and the benefit of sustainable wastewater management*

Surface-water and Groundwater quality

- *the need to understand the baseline and trends of surface-water and groundwater quality and pollution; understand the current and potential vulnerability of surface-water supplies to pollution (natural and anthropogenic)*

Water Production, Development, and Use

- *Insufficient understanding of water use and allocation*

Withdrawal rate and location and Consumptive use

- *the need to understand the withdrawal rates in all use categories across the Philippines, and in particular the magnitude and distribution of consumptive use by both regulated and unregulated water users*

Conveyance rate and loses

- *the need to understand conveyance rates and losses (non-revenue water and agriculture sector losses) in detail sufficient for effective water-resource management*

Reclaimed wastewater

- *the need to understand the potential value of reclaiming wastewater to sustaining water resources, protecting the environment, and ensuring adequate and efficient supply of water*

The recommendations of this report can be used by NEDA and NWRB to plan for specific investments in people and resources to fill the identified gaps. Filling these gaps will lead to greatly strengthened national capability to conduct comprehensive water-resource assessments and to the identification of new and sustainable sources of water; this is a necessary and critical step in the "massive investment" for the Water Infrastructure Subsector called for in the *Philippine Development Plan 2011-2016.* Equally important is that the strengthened national capability will enable more effective and efficient planning and management of the Water Infrastructure Subsector into the future.

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1. Introduction

In early September 2010, President Benigno S. Aquino III issued Memorandum Circular No. 3 directing the National Economic and Development Authority (NEDA) to coordinate the formulation of the *Philippine Development Plan 2011-2016* (*Development Plan*). The *Development Plan* is intended to reverse the Philippine record of slow socioeconomic development and is guided by the President's "Social Contract with the Filipino People" in which he envisions "a country with an organized and widely shared rapid expansion of our economy through a government dedicated to honing and mobilizing our people's skills and energies as well as the responsible harnessing of our natural resources". A critical element of the Development Plan is to accelerate infrastructure development nationally, including the water infrastructure subsector.

Also in early September of 2010, a meeting was hosted by the Philippine Nuclear Research Institute (PNRI) to undertake the first pilot study of a new initiative of the International Atomic Energy Agency (IAEA). This IAEA initiative is called the *IAEA Water Availability Enhancement Project* (*IWAVE Project*) and is intended to enhance the availability of freshwater in Member States through science-based, comprehensive assessments of national water resources.

In March 2011, as a part of the Philippine *IWAVE Project*, a forum was provided for all representatives of Philippine water agencies and associated organizations to identify the national gaps in hydrological understanding, data, and information. These are gaps considered to be the primary hindrance to the capability of the Philippines to conduct accurate and comprehensive assessments of the national water resource. Participating in identifying and profiling these gaps was a broad spectrum of national and international experts, as well as representatives from national agencies, the academe, private water concessionaires, and the water districts.

Subsequently, the Technical Working Group (TWG) members evaluated in detail these identified gaps and described the remedies and investments needed to fill the gaps. This report is a synthesis of the work of the TWGs conducted during the 2011 and 2012 inter-agency effort directed by the NWRB. The remedies and investments proposed in this report present numerous opportunities for collaboration among Philippine agencies and stakeholders, and with potential international scientific and donor agencies.

An action plan, based on the information synthesized for this report, has already begun to be implemented to fill identified gaps and strengthen national capability to conduct comprehensive and accurate assessments of Philippine water resources. This strengthened capability directly supports the goal of the *Development Plan* to accelerate infrastructure development in the water subsector.

Chapter 2 of this report provides an introduction to the *Philippine Development Plan 2011-2016* and the Philippine *IWAVE Project*. Chapter 3 provides a brief overview of the water-resource potential of the Philippines. Chapter 4 provides a brief discussion of the challenges of water planning and management and the national response in terms of water sector plans and policies, and national institutions. Also discussed in Chapter 4 is the importance of water-resource assessments to Philippine water institutions and to national water-resource plans and policies. The elements that comprise a comprehensive water-resource assessment are presented in Chapter 5 as prologue to Chapter 6, the core of the report, which enumerates the gaps in hydrologic understanding, data, and information in the Philippines, and proposes the necessary remedies and investments.

2. Investing in Water Resources Assessment Capability

2.1 Philippine Development Plan 2011-2016

The *Philippine Development Plan 2011-2016* is the guide in formulating policies and implementing development programs for these six years. Specifically, the *Development Plan* adopts a framework of inclusive growth, defined as a high rate of growth that is sustained, generates mass employment, and reduces poverty

The *Development Plan* makes clear that a major constraint on achieving inclusive growth in the Philippines during recent decades has been the persistence of inadequate infrastructure. In his Preface to the *Development Plan*, NEDA Director-General Cayetano W. Paderanga, Jr. describes five key strategies of the plan, the third of which is to "invest massively in infrastructure".

In the Philippines, water is considered to be a basic need and therefore everyone has the right to have access to basic services related to water. The country is endowed with abundant water resources as evidenced by the estimate that the country's watersheds and aquifers could supply about 146 billion cubic meters (BCM) of water annually (126 BCM surface water, 20 BCM groundwater) if fully exploited (NWRB 1998). However, in spite of this relative abundance of water, the country faces the threat of emerging resource scarcity, particularly with respect to groundwater the demand for which substantially exceeds supply. As noted in the *Development Plan* "lack of urban planning, indiscriminate urban development, lack of investment in water, problems of water resource management, and the impact of climate change threaten water security and sustainability. Rapid and uncontrolled urban development has reduced aquifer recharge and has eventually resulted in the decline of groundwater levels as well as saltwater intrusion."

The 2010 Philippines' Millennium Development Goals Progress Report shows the proportion of the Philippine population with access to safe water has risen at a moderate rate, increasing from 73.8 per cent in 1991 to 81.4 per cent in 2008. If the trend continues, the 2015 target (86.9%) is attainable. However, meeting this target remains a major challenge for reasons which include the significantly low investments for water supply and sanitation relative to overall public spending (World Bank 2005), and the bias of spending which often targets Metro Manila and other urban areas instead of rural communities for water supply and sewerage infrastructure.

In addition to meeting basic services related to water as measured by the Millennium Development Goals, inclusive economic growth itself must be supported by meeting the water supply, sewerage, sanitation, irrigation and flood management needs of centers of priority growth and production. Efficient and effective management of water resources, including the development of new sources of water, is fundamental to achieving the inclusive economic growth desired while ensuring a sustainable environment.

A number of challenges exist that make assessment of national water resources difficult. One important challenge acknowledged in the *Development Plan* is the fragmentation of the missions, authority, and capabilities of water-sector institutions resulting in generally poor integration of hydrological data and inadequate resource assessment.

Further, to address the issues on equity and efficiency of access to water, one of the strategies focus is to practice Integrated Water Resources Management (IWRM) in the sector. It is recognized that the establishment of a comprehensive and accessible information is necessary to ensure coordinated planning and implementation.

2.2 IAEA Water Availability Enhancement Project

The *IAEA Water Availability Enhancement Project* has been undertaken with the intent of enabling Member States to enhance the availability of freshwater through science-based, comprehensive assessments of national water-resources. The *IWAVE Project* strengthens technical capabilities of Member States and assists in gathering and using scientific information to fully assess the availability and quality of water resources.

The NWRB has been overseeing the Philippine *IWAVE Project* collaboratively with the PNRI and the IAEA. Water-sector stakeholders have participated through forums and TWGs to identify and profile in detail the gaps in hydrological understanding, data, and information. Through the TWGs the stakeholders have also proposed specific remedies and investments necessary to fill the gaps.

The recommendations of this report can be used by the NEDA and the NWRB to plan for the specific investments in people and resources to fill the identified gaps. Filling these gaps will lead to greatly strengthened national capability to conduct comprehensive water-resource assessments and to the identification of new and sustainable sources of water; this is a necessary and critical step in the “massive investment” for the Water Infrastructure Subsector called for in the *Philippine Development Plan 2011-2016.* Equally important is that the strengthened national capability will enable more effective and efficient planning and management of the Water Infrastructure Subsector into the future.

3. Water Resource Potential

Fresh-water supplies in the Philippines come from surface-water and groundwater resources. The total annual resource potential of the Philippines is estimated to be 145,990 million cubic meters, 86 per cent of which is surface water and the remaining 14 per cent is groundwater (Table 1). The estimated water resource is unequally distributed among the Water Resource Regions due primarily to differences in land area, physical setting, and local climate.

Table 1: Total Annual Resource Potential of the Philippines (in MCM per year)

Water Resources Region	Groundwater Potential	Surface Water Potential	Total Water Resources Potential	Percent Groundwater to Total Potential
X Northern Mindanao	2,116	29,000	31,116	6.8
VI Western Visayas	1,144	14,200	15,344	7.45
IX Western Mindanao	1,082	12,100	13,182	8.21
XII Southern Mindanao	1,758	18,700	20,458	8.59
XI Southeastern Mindanao	2,375	11,300	13,675	17.37
III Central Luzon	1,721	7,890	9,611	17.91
IV Southern Tagalog	1,410	6,370	7,780	18.12
VIII Eastern Visayas	2,557	9,350	11,907	21.47
II Cagayan Valley	2,825	8,510	11,335	24.92
V Bicol	1,085	3,060	4,145	26.18
I Ilocos	1,248	3,250	4,498	27.75
VII Central Visayas	879	2,060	2,939	29.91
Total	**20,200**	**125,790**	**145,990**	**13.84**

Source: *Master Plan Study on Water Resources Management in the Republic of the Philippines, 1998*

Considering the uses of groundwater resources, agriculture accounted for about 85 per cent of groundwater demand in 1996, while industry and domestic uses accounted for the remaining 15 per cent. Table 2 shows the groundwater sectorial demand in the Philippines for 1996 and projected for 2025. The estimated average annual groundwater potential was sufficient to supply only 67 per cent of the demand for groundwater in 1996. Due to greater future demand it is projected that the estimated average annual groundwater potential will be able to supply only between 23 to 32 percent of demand for groundwater in the Philippines in 2025.

Table: 2 Groundwater Sectorial Demand in the Philippines for 1996 and projected for 2025 (in MCM per year)

Water Demand	1996	2025		% of Total (1996)
		Low	High	
Municipal	2,178	7,430	8,573	7.27
Industrial	2,233	3,310	4,997	7.46
Agriculture	25,533	51,920	72,973	85.27
Irrigation	18,527	38,769	53,546	61.87
Livestock	107	224	309	0.36
Fishery	6,899	14,437	19,939	23.04
Total Demand	**29,994**	**62,660**	**86,543**	**100.0**
Groundwater (GW) Recharge	20,200	20,200	20,200	
%Potential/Total Demand	67.46	32.24	23.34	

Source: Master Plan Study on Water Resources Management in the Republic of the Philippines, 1998

While the total water resource potential may be adequate to meet current and projected needs of the Philippines, the groundwater resource has been used at a rate greater than the estimated annual supply for many decades. This imbalance in resource potential and extraction poses a serious threat to the sustainability of the Philippine water infrastructure subsector and is critical in meeting the goals of inclusive economic growth of the *Philippine Development Plan 2011-2016*. This is discussed further in the section addressing Water Planning and Management.

4. Water Planning and Management

4.1 Challenges

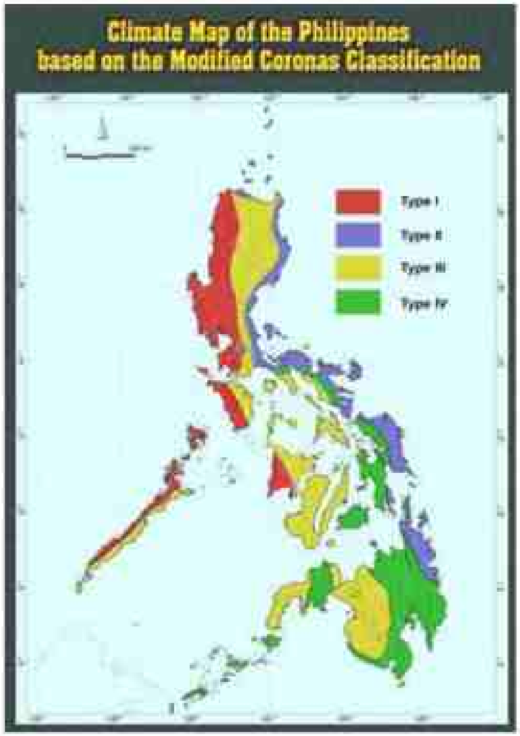
There are a multitude of challenges to water planning and management in the Philippines, all but three stand out. They are the uneven distribution of water resources due to physiography and climate, population growth and internal emigration, and the water supply infrastructure necessary for inclusive economic growth. The ability to address these challenges is anchored in a dynamic and comprehensive national water-resource assessment, that is, one that is continually revised and updated as new hydrological data and information advance the understanding of the resource.

4.1.1 Physiography and Climate

The Philippines has an average annual rainfall of 2,400 mm. However, despite this relatively high amount of rainfall, the archipelagic nature of the country allows for the presence of only small to medium-size watersheds compared to continental lands, thus resulting in relatively small storage capacity of the streams, lakes, and aquifers. Moreover, the high average rainfall value obscures the substantial variability of rainfall both temporally and spatially. Great amounts of rainfall might occur during a single monsoon season that lasts for about four to six months while the rest of the year is almost entirely dry. In many cases much of monsoon rainfall runs off the landscape and flows into the ocean. The monsoon, furthermore, is often unpredictable, causing massive floods in particular year and a seasonal water shortage the next year. This climate and weather variability across the Philippines presents challenges in planning for and managing a dependable water-supply.

In addition to high precipitation, the tropical climate of the Philippines is characterized by high average temperature and high humidity. There are two major seasons: the Rainy Season from June to November, and the Dry Season from December to May. However, the distribution of rainfall in the Philippines is generally dependent on the direction of the moisture-bearing winds relative to the location of the mountain systems. Based on the observed rainfall distribution, four climate types are recognized (Figure 1).

Significant changes in land use and land cover, together with recurring atmospheric-oceanic climatic effects (El Nino and La Nina episodes) and global climate change can have local and regional implications for flow in natural water systems. These factors compound the challenges in meeting demands for water-supply.



Description

Type I - There are two pronounced seasons, dry from November to April, wet from May to October. The maximum rain period is from June to September.

Type II - There is no dry season and with very pronounced rain period from December to February. There is not a single dry month. Minimum monthly rainfall occurs during the period March to May.

Type III - There is no very pronounced maximum rain period with a dry season lasting only from one to three months. It resembles Type I that has a wet and dry season, but the dry season lasts only three months.

Type IV - Rainfall is evenly distributed throughout the year. It resembles Type II because it has no dry season.

Figure 1. Climate map of the Philippines based on the modified Coronas classification (http://kidlat.pagasa.dost.gov.ph/cab/climate-final-2.jpg)

4.1.2 Population Growth and Internal Emigration

The population census of 2007 listed the Philippine population at 88,574,614. At an average annual population increase of 2% (based on 2000-2007 data), the 2010 population is estimated at around 94 million (National Statistics Office, 2010). The most populous region of the country, the National Capital Region (Metropolitan Manila), had a population of 11,553,427 in 2007 (National Statistics Office, 2010). The Manila urban area occupies all or part of six provincial-level jurisdictions and has an estimated population of just over 20 million in 2010 (Figure 2). Population growth affects variables such as the country's economy, its natural environment and natural resources, energy requirements, infrastructure needs and food supply. It places an increasing demand on national water supplies and can negatively impact water quality as well.

Internal emigration to urban centers in the past four decades has resulted in the concentration of populations in three metropolitan regions, namely Metro Manila, Metro Cebu, and Metro Davao. Nearly half of the country's population now resides in urban areas, areas which have an anticipated 2.3 per cent growth rate of urbanization for the period 2010-2015 (Philippine Atmospheric, Geophysical, and Astronomical Services Administration, (PAGASA): Retrieved from (http://kidlat.pagasa.dost.gov.ph/cab/climate.htm)

Metro Manila ranks 15th among the megacities of the world and is the highest density major municipality in the world with a population density of nearly 115,000 per mi^2

(45,000 per km^2). The urban core has a population of approximately 1.7 million in a land area of 15 mi^2 (39 km^2) (Figure 2). The outer suburbs, which are composed of the portions of the urban area outside the National Capital Region, have a population of nearly 8.5 million and a considerably lower density at 28,000 per mi^2 or 11,000 per km^2.(http://www.forbes.com/2006/12/20/worlds-most-congested-cities-biz-energy-cx_rm_1221congested_slide_2.html?thisSpeed=15000)

Similar to nearly all major urban areas of the world, the Manila urban area has experienced substantial suburbanization over recent decades and substantially falling urban centre population densities. In 1950, the core municipality of Manila had a population of fewer than 1 million people, and it represented approximately 60 percent of the urban area population. Over the intervening years, the core of Manila grew by approximately 700,000 people, while the balance of the urban area added nearly 20,000,000 people (Figure 3).

Increasing population density and growth of population centers stress local supplies of water and often results in unsustainable patterns and trends of use. The 2% average annual population increase and the continuing trends of rural to urban migration accentuate the challenges for the water infrastructure subsector presented in the *Philippine Development Plan 2011-2016.* A particular challenge is the planning and management of the water infrastructure in the face of great uncertainty as to the future location and number of people to be served.

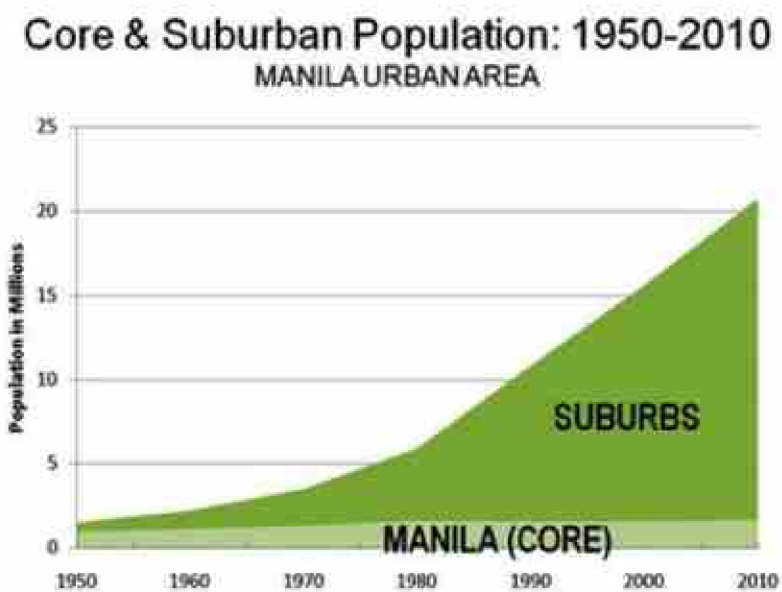


Figure 2. Core and Suburban Population: 1950-2010, Manila urban area (2-Cox, 2011)

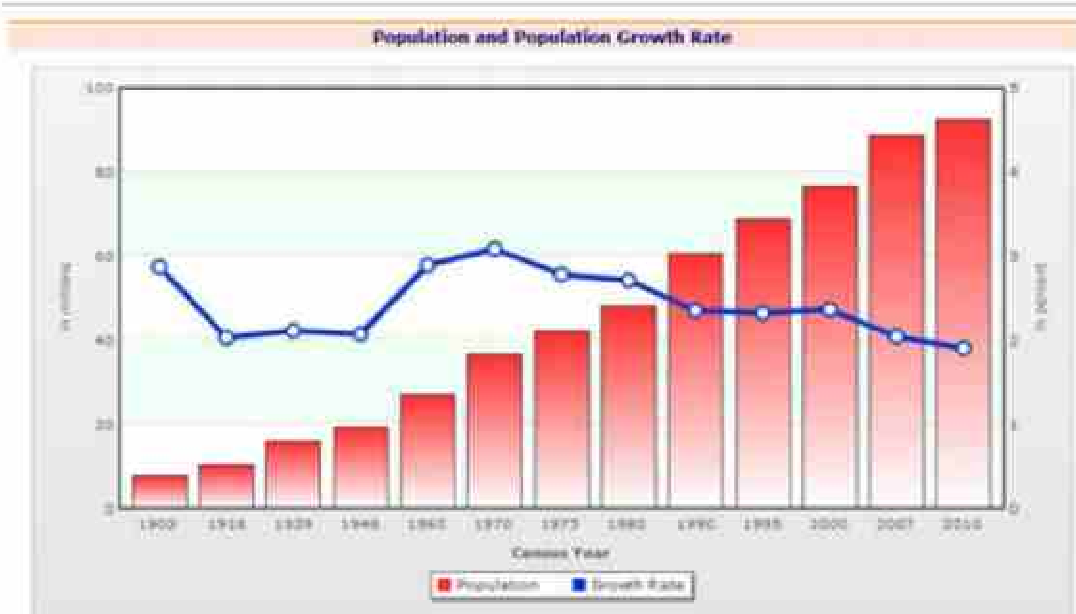


Figure 3. Graphical presentation of Population and Population Growth Rate (as of the 2010 census) is provided in the NSCB website: (http://www.nscb.gov.ph/statmet/default.asp)

4.1.3 Inclusive Economic Growth

The annual growth in Gross Domestic Product (GDP) of the Philippines over the past 11 years as reported by the NEDA has steadily increased from about 3% to about 7% (Figure 4). The exception to this trend was during the global economic crisis of 2008 and 2009. The 7.3 % growth in GDP experienced in 2010 well surpassed the government's target of 5% to 6%. At the same time, the country was experiencing an important transformation in its economic structure, moving away from a mainly agriculture-based economy towards an increasingly service-based economy. The 2010 GDP estimation approximated that more than half of the total GDP came from services, 55.0%, while industry and agriculture contributed 33.3% and 11.7%, respectively (News report).

NEDA has projected that over the next six years there will be a sustained strong economic performance. However, the goal of NEDA as put forward in the *Philippine Development Plan 2011-2016* is for inclusive economic growth, which is defined as a high rate of growth that is sustained, generates mass employment, and reduces poverty.

A high rate of growth has consequences, however. Assuming a high economic growth scenario based on the Master Plan Study on Water Resources Management in the Philippines (JICA, 1998) and without a water resource development program in place, projections are that 17 of the 18 Major River Basins will experience water shortages by 2025; with the river basins in Luzon facing the most serious shortages.

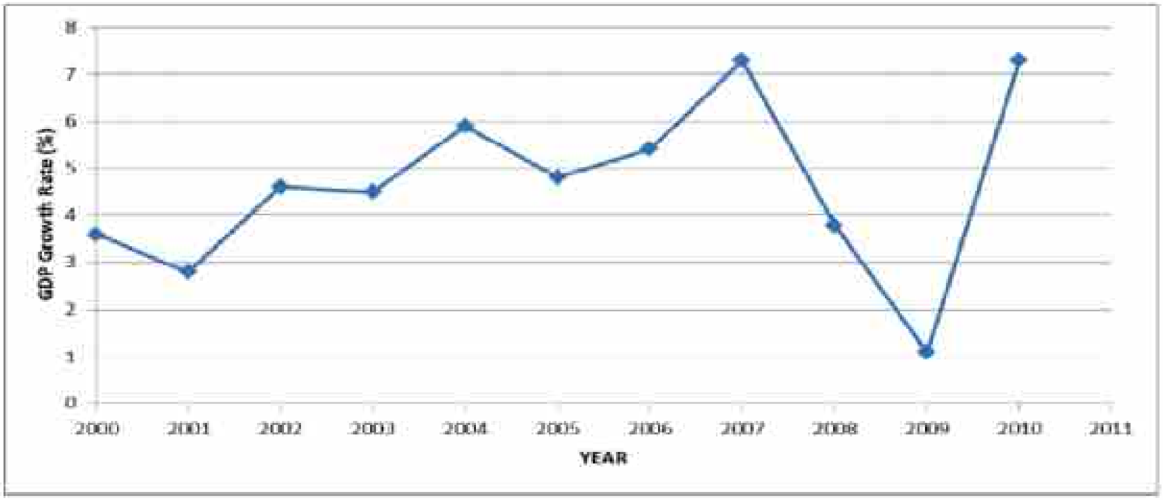


Figure 4. Graph showing Gross Domestic Product growth on an annual basis adjusted for inflation and expressed as per cent.

Growth and economic transformations such as experienced over the last decade, and those that would be associated with inclusive economic growth, will inevitably alter the location, volume, and timing of water demand requiring that the water infrastructure subsector adapt. The challenge for the Philippines is to encourage growth, development, and employment, while protecting and sustaining the water resources that make it all possible. Clearly, comprehensive and accurate assessment of Philippine water resources is essential to enable sustainable economic progress. The social and economic progress of the country is dependent on the proper development and utilization of its water resources, which in turn is dependent on its comprehensive and accurate assessment.

4.1.4 The Need for Comprehensive Water Resource Assessments

The challenges for water planning and management presented individually by physiography and climate, population growth, and inclusive economic growth are magnified when these factors are considered together. Inevitably there is increasing competition among water use sectors - households, agriculture, and power and industry - and the availability of water can be reduced by pollution causing the degradation of water resources. In the latest estimates of water availability, the Philippines ranks only 79th worldwide, with just 6,332 m^3 per capita per year. (NationMaster.com (http://www.nationmaster.com/red/graph/hea_wat_ava-health-water-availability &b_printable=1). This is much lower than the rest of Asia and lower than world averages. This low water availability exists due in part to the inadequate assessment of surface and groundwater resources available to meet current and future needs, and a lack of understanding of the water-quality and water-use characteristics of those resources.

The Philippines has conducted two national water resource assessment programs. The Philippine Water Resources First National Assessment, December 1976 designated 12 Water Resources Regions (WRR) **(**Philippine Water Resources, NWRB, 1976**).** This national assessment was followed by a Framework Plan for 421 river basins in the different WRRs with the objective of establishing land and water resources relationships within each region.

In 1998, a Master Plan Study on Water Resources Management was conducted by the National Water Resources Board in cooperation with JICA. The results of this second assessment were of limited use because hydrological estimates were often based on insufficient data. Moreover, some of the river basin assessments were no longer valid due to changes in land-use characteristics of basins resulting from growing business centers in parts of the country such as Mindanao. With respect to groundwater, estimates of groundwater discharge were based on an assumption that groundwater recharge equals 10% of annual rainfall with no supporting research or analysis.

The acknowledged shortcomings of these previous efforts clearly point to the need for an updated and more comprehensive water-resource assessment for the Philippines. The lack of such a comprehensive and updated water-resource assessment will lead to ineffective planning, management, and policy decisions. The primary objective of the *IWAVE Project* is to strengthen technical capabilities of Member States to fully assess the availability and quality of water resources. The *Development Plan* goal of inclusive economic growth without compromising the sustainability of vital ecosystems will not be effective if not based on the foundation of comprehensive water-resource assessments.

4.2 **Response**

4.2.1 Philippine Water Resource Plans and Policies

An initial response to the challenges of water planning and management in the Philippines is through water resource plans and policies that have been established over the years. These include plans and policies that explicitly express the need for water resource assessments and/or that water is a key national infrastructure. The *Philippine Development Plan 2011-2016* is perhaps the most important active plan and presents in detail the water infrastructure subsector and the need to find new and sustainable sources of water to meet current and future demand. Several of the most important previous plans and policies are:

- Philippine Agenda 21
- Integrated Water Resource Management Plan Framework
- Medium-Term Philippine Development Plan 2004-2010
- The Philippine Water Supply Sector Roadmap
- National Framework Strategy on Climate Change (2010-2022)

These plans and policies are summarized in Appendix 1 with reference to the stated need for hydrogeological data, information, and assessments.

Plans and policies are implemented through the establishment of regulations and laws, water-related laws that impact water resources management are outlined in Appendix 2.

4.2.2 Philippine Water Institutions

Responses to the challenges of water resources management are also found in the missions and mandates of the more than thirty Philippine government institutions having involvement in water resources. Often times however, the missions and mandates of these agencies are found to overlap. The water-related functions of these agencies include:

- water quality and sanitation
- watershed management
- integrated area management
- data collection
- flood management
- irrigation
- hydropower
- water supply
- research

- cloud seeding
- fisheries
- use allocation and regulation

The authority and jurisdiction of these water institutions differ as illustrated in a hierarchy of their coverage (Figure 5). Another way of looking at relevance and completeness of Philippine Water Institutions is to identify the institutions' responsibility and/or state in relation to the different components or aspects of the water cycle (Figure 5a). The decisions and actions on water resources are thus coming from multi-sectorial and multi-level institutes, aside from multi-thematic concerns such as technical, social, economic, and political. Because of the wide range of functions, the water sector is inherently fragmented with some overlaps of responsibility, resulting to conflicts among agencies.

These key institutions in the water sector that collect, interpret, and use hydrological data are led by the National Economic Development Authority and the National Water Resources Board.

The **National Economic Development Authority** (NEDA) is the Philippines' social and economic development planning and policy coordinating body. The Authority is primarily responsible for formulating continuing, coordinated, and fully integrated social and economic policies, plans and programs. NEDA is the lead agency providing policy advice on socioeconomic issues to the country's president and the rest of government.

The **National Water Resources Board** (NWRB) is the lead government agency in the Philippine water sector, conferred with policy-making, regulatory and quasi-judicial functions. The NWRB is responsible for ensuring the optimum exploitation, utilization, development, conservation, and protection of the country's water resource, consistent with the principles of Integrated Water Resource Management. The NWRB's functions and responsibilities are three-fold: formulation and coordination of policies, programs and standards relating to the Philippine Water Sector, management and regulation of all water-related activities, and regulation and monitoring of water utilities. The NWRB Board - composed of five cabinet secretaries, a representative from the academe, and the Executive Director - is chaired by the Secretary of the Department of Environment and Natural Resources. Although independent insofar as its regulatory and quasi-judicial functions are concerned, the NWRB is under the administrative supervision of the Department of Environment and Natural Resources, as an attached agency.

The following Departments and other institutions have an important role in the management of Philippine water resources.

The **Department of Environment and Natural Resources** (DENR) is responsible for watershed management and monitoring, and management of water resources. The Department is also primarily responsible for the implementation and enforcement of the Philippine Clean Water Act; it enforces, reviews, and revises water quality guidelines and standards.

Within the DENR are the following agencies with a role in water:

- Environment Management Bureau (EMB)
- Ecosystem Research Development Bureau (ERDB)
- Forest Management Bureau (FMB)
- Laguna Lake Development Authority (LLDA)
- Mines and Geosciences Bureau (MGB)
- National Mapping and Resource Information Authority (NAMRIA)
- River Basin Control Office (RBCO)

The water-related functions of these agencies are described in Appendix 3A.

The **Department of Interior and Local Government** (DILG) through the PMO WSSP provides technical assistance and capacity building to Local Government Units to help them manage water supply, sewerage, and sanitation services.

Under the DILG are the Local Government Units (LGUs) that provide basic services and facilities for barangays, municipalities, provinces, and cities. The water-related functions of LGUs are described in Appendix 3B.

The **Department of Agriculture** (DA) is the lead agency to boost farmers' income to reduce poverty in the rural sector and to provide sufficient food and sustainable livelihood to the Filipino people.

Within the DA are the following agencies with a role in water:

- Bureau of Fisheries and Aquatic Resources (BFAR)
- Bureau of Soils and Water Management (BSWM)
- National Irrigation Administration (NIA)

The water-related functions of these agencies are described in Appendix 3C.

The **Department of Health** (DOH) is responsible for implementing and enforcing the Sanitation Code of the Philippines. As part of its mandate to protect public health, DOH monitors the quality of drinking water and regulates premises that have sanitation installations. It sets national standards for drinking water quality as well as standards concerning sanitation and sewerage.

Within the DOH are the following agencies with a role in water:

- Environmental Health Service (EHS)
- Bureau of Research Laboratories (BRL)
- Environmental and Occupational Health Office (EOHO)

The water-related functions of these agencies are described in Appendix 3D.

The **Department of Science and Technology** (DOST) is the premiere science and technology body in the country charged with the twin mandates of providing central direction, leadership, and coordination of all scientific and technological activities, and of formulating polices, programs, and projects to support national developments.

Within the DOST are the following agencies with a role in water:

- Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)
- Philippine Council for Agricultural and Aquatic Resources Development (PCAARD)
- Philippine Nuclear Research Institute (PNRI)

The water-related functions of these agencies are described in Appendix 3E.

The **Department of Public Works and Highways** (DPWH) is responsible for flood control and drainage. It provides technical support to LGUs in the development of water supply systems, is tasked to prepare a national program on sewerage and septage management, and is also responsible for flood control.

Within the DPWH are the following agencies with a role in water:

- Bureau of Research and Standards (BRS)
- Metropolitan Waterworks and Sewerage System (MWSS)
- Project Management Office-Rural Water Supply (PMO-RWS)
- Local Water Utilities Administration – Water Districts (LWUA-WD)

The water-related functions of these agencies are described in Appendix 3F.

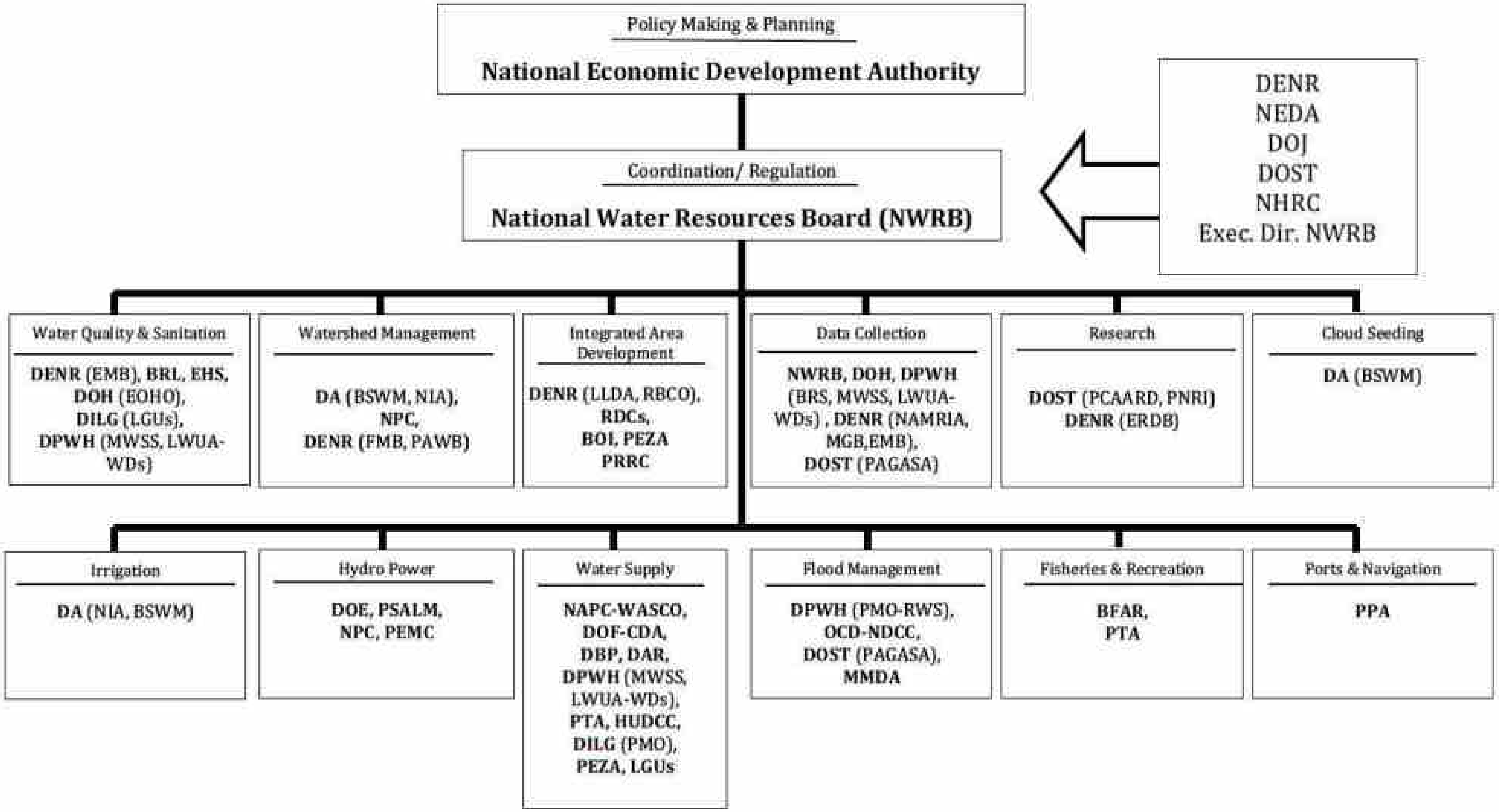
The **National Power Corporation** (NPC) is responsible for the development of power sources including hydro-power so has a vested jurisdiction for watershed areas supporting power generating plants. Under EPIRA LAW (RA 9136, Sec. 34) NPC shall manage and continue to be responsible for watershed rehabilitation. Out of a total watershed area of 620,821 hectares, it is responsible for 481,778 hectares.

Under the Office of the President of the Philippines with a role in water:

The **Pasig River Rehabilitation Commission** (PRRC) was created on January 1999 through Executive Order No. 54 to ensure that the Pasig River is rehabilitated to its historically pristine condition conducive to transport, recreation, and tourism.

Key **state academic and research institutions** provide leadership for research and development on climate change and its impacts in the water sector, for water sector adaptation technologies and tools, and for socioeconomic analysis of adaptation measures, drought and flood resistant crops. These institutions are a critical source of knowledge and information to inform the public, planners, and policy makers.

A summary of the type of data collected by these agencies is provided in Table 3. These agencies make use internally of the hydrological data they collect and interpret, as well as the resulting information and assessments. However, these agencies also provide this information to other Philippine agencies, authorities, and departments for whom this information is of critical importance to their operations and fulfilling their missions.



Source: Modified from Philippine Water Supply Sector Road Map (REF. National Economic Development Authority, 2009. The Philippine Water Supply Sector Roadmap, 94 p.).

Figure 5. Functional Chart of Water Related Agencies in the Philippines

Figure 5a: Philippine Water institutions in relation to Water Cycle

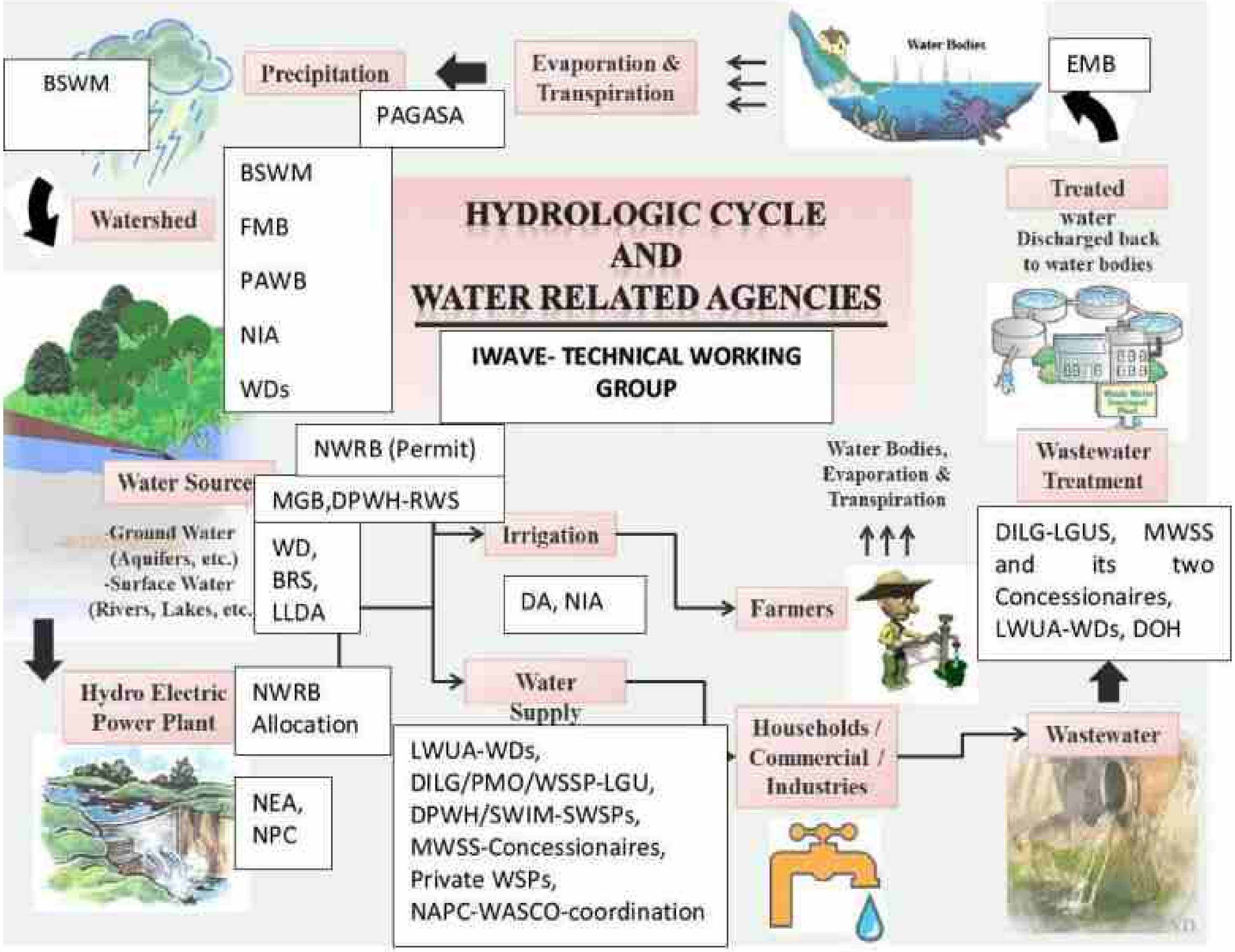


Table 3. Summary of data collected by various government agencies

Agency	Water Quality Data	Well Data	Hydro-geological Data	Climatic Data	Hydrologic Data	Water Usage Data	Dam Reservoir
DENR-EMB	√					√	
DENR-ERDB				√		√	
DENR-FMB				√		√	√
DENR-LLDA	√				√		
DENR-MGB		√	√				
DENR-NAMRIA				√	√		
DENR-RBCO	√	√	√	√	√	√	
DILG-LGU		Collated data user (secondary)				√	
DA-BSWM		√		√	√		
DA-BFAR						√	
DA-NIA		√	√	√	√		√
DPWH-LWUA-	√	√	√			√	
DOH-WDs	√	√	√			√	
DOST-PAGASA				√	√		
DOST-PCAARD	√				√		
DOST-PNRI	√						
DPWH-BRS					√		
DPWH-MWSS	√	√				√	√
DPWH-PMO-RWS		√					
NPC				√	√		√
NWRB	√	√				√	√
PRRC	√						

5. Elements of a Comprehensive Water Resource Assessment

As discussed in Chapter 1, the *Philippine Development Plan 2011-2016* concluded that a critical component of "Accelerating Infrastructure Development" in the water subsector is the identification and development of sustainable new sources of water to meet existing and future demand. In addition, the need for water-resource assessments is confirmed repeatedly in the Philippine national plans and policies, and in the Philippine water agency missions and mandates. The objective of the Philippine *IWAVE Project* has been to identify the gaps in hydrological understanding, data, and information that must be filled in order to strengthen the national capability to accurately assess the resource required to identify the sustainable new sources of water sought by the *Development Plan*. The starting point in identifying these critical national-level gaps is to consider the elements that make up a comprehensive water-resource assessment.

A comprehensive water-resource assessment includes a broad range of physical and hydrologic elements. In this report the elements presented in Table 4 have been organized under the general headings of ***Water Supply***, ***Protection of Water Supply***, and ***Water Production, Development, and Use.***

This organization is similar to that which has been adapted by the Philippine Vulnerability & Adaptation Assessment for the Water Sector under the Millennium Development Goal Fund (MDGF) 1656: *Strengthening the Philippines' Capacity to Adapt to Climate Change.*

Sixteen physical and hydrological elements comprise a typical comprehensive water resource assessment. Table 4 presents the critical hydrological understanding, data and information typically comprising a comprehensive water-resources assessment.

Hydrological understanding and water-resource assessments require such a foundation of spatial and temporal data on the physical, chemical, and biological characteristics of the water resource. Hydrological observations quantify each process in the water cycle, encompassing an extremely wide range of phenomena such as surface water flow and storage, groundwater flow and storage, precipitation, infiltration, runoff, evapotranspiration, and water use and return.

The importance of each element of hydrological understanding to a comprehensive water-resource assessment is determined by the characteristics of the Philippine hydrological setting as well as current and future planning and management needs. Each of these elements is addressed in detail in the following Chapter 6, Gaps in Hydrological Understanding, Data, and Information-Identifying Specific Remedies.

		Hydrological understanding Hydrological data and information
Water supply	Surface water	**Hydrography** Topography, hydrography, storage volume
		Streamflow Discharge, channel geography, rating curves
		Flood and drought risk Recurrence intervals, trends
	Groundwater	**Hydrogeological setting** Surface and subsurface geology, aquifer thickness and extent, resistive layer thickness and extent
		Aquifer characteristics Porosity, hydraulic conductivity, transmissivity, anisotropy, storativity
		Groundwater storage and flow Saturated thickness, water levels, hydraulic gradients
	Water budget	**Precipitation** Point precipitation, areal/regional precipitation, extreme events
		Runoff and recharge to groundwater Runoff coefficients, infiltration and recharge rates
		Evapotranspiration Temperature, point evaporation, meteorological data
		Surface and groundwater interaction Hydraulic gradients, groundwater discharge, seepage to groundwater
Protection of water supply		**Surface water quality** Water chemistry, common and emerging pollutants, trends
		Groundwater quality Water chemistry, common and emerging pollutants, trends
Water production, development, and use		**Withdrawal rate and location** Withdrawal by category, rates, trends
		Consumptive use Consumptive use by category, rates, trends
		Conveyance Rate and Losses Conveyance by category, rates, trends
		Reclaimed wastewater Rates, volumes, trends

Table 4. Critical hydrological understanding, data, and information typically comprising a comprehensive water-resources assessment

6. Gaps in Hydrological Understanding, Data, and Information

The principal gaps in hydrological understanding, data, and information in the Philippines have been identified and profiled through a 2010/2011 inter-agency effort directed by the NWRB. These gaps are considered to be a primary hindrance to the ability of the Philippines to conduct truly accurate and comprehensive assessments of the national water-resource. It is this comprehensive resource assessment that is the principal objective shared by the *Philippine Development Plan 2011-2016* and the *IWAVE Project*. The Development Plan calls for the "identification and development of sustainable new sources of water to meet existing and future demand" as a critical component of "Accelerating Infrastructure Development' in the water subsector. The *IWAVE Project* intends to strengthen the national capability to conduct accurate resource assessment required to identify the sustainable new sources of water sought by the Development Plan. In other words, meeting the principal water infrastructure objective shared by the *Philippine Development Plan 2011-2016* and the *IWAVE Project* - the identification of new fresh water resources ("enhanced availability' in the language of the *IWAVE Project*) – is the mission of the Philippine *IWAVE Project.*

The gaps in hydrological understanding for the Philippines are summarized below, followed by a discussion on details and specific remedies and investments.

6.1 Gaps in hydrological understanding

The gaps in hydrological understanding are introduced below, organized under the 3 general headings of a comprehensive water-resource assessment – ***Water Supply***, ***Protection of Water Supply***, and ***Water Production, Development, and Use*** - presented in Chapter 5. Following each gap are listed a number of specific gaps in hydrological understanding relating to the sub-categories of a comprehensive assessment as presented in Table 4.

6.1.1 Water Supply

- *Insufficient understanding of the quantity and spatial/temporal distribution of surface and groundwater resources*

Surface water

Hydrography

- *the need to understand the national hydrography with sufficient detail and certainty to fully support the Integrated Water Resources Management Framework Plan*
- *the need to understand the limnologic changes occurring to lakes and the vulnerability of lakes to a range of identified and potential stresses.*

Streamflow

- *the need to increase the understanding of streamflow in gauged and ungauged basins*
- *the need to understand surface-water storage and routing on a national scale, and the need to understand the effect of scenarios of extreme weather and climate*

Flood and drought risk

- *the need to quantitatively understand the extent and characteristics of flood- and drought-prone areas in all priority basins, and the need to understand how flood waters might be harnessed to lessen the severity of the impact of droughts*

Groundwater

Hydrogeological setting

- *the need to understand subsurface geology, and aquifer thickness and extent, in sufficient detail and scope to support hydrogeologic investigations and fully assess the groundwater resource of the Philippines*

Aquifer characteristics

- *the need to understand aquifer characteristics in sufficient detail to effectively conduct resource supply assessments and management activities*

Groundwater storage and flow

- *the need to understand the quantity and flow of available groundwater and the effect of extreme weather and climate on groundwater storage and flow*

Water Budget and Global Climate Change

Precipitation

- *the need to have an appropriately advanced level of understanding of the spatial and temporal distribution of precipitation and of extreme events for early warning forecasting and risk assessments*

Runoff and recharge

- *the need to understand runoff and recharge processes, origin of recharge, and residence time of groundwater at national and appropriate local scales*

Evapotranspiration

- *the need to understand evapotranspiration in sufficient detail to support water-resource assessments and management needs*

Surface and groundwater interaction

- *the need to understand the interaction of surface water and groundwater, and to develop a unified understanding of the entire water budget at various scales (spatial and temporal) to support inclusive economic growth and the integrated water-resource management needs of the Philippines*
- *the need to understand with reduced uncertainty the effects on the entire water budget of weather and climate, and global climate change*

6.1.2 Protection of Water Supply

- *Insufficient understanding of the water quality status and trends, and the benefit of sustainable wastewater management*

Surface-water and Groundwater quality

- *the need to understand the baseline and trends of surface-water and groundwater quality and pollution; understand the current and potential vulnerability of surface-water supplies to pollution (natural and anthropogenic)*

6.1.3 Water Production, Development, and Use

- *Insufficient understanding of water use and allocation*

Withdrawal rate and location and Consumptive use

- *the need to understand the withdrawal rates in all use categories across the Philippines, and in particular the magnitude and distribution of consumptive use by both regulated and unregulated water users*

Conveyance rate and loses

- *the need to understand conveyance rates and losses (non-revenue water and agriculture sector losses) in detail sufficient for effective water-resource management*

Reclaimed wastewater

- *the need to understand the potential value of reclaiming wastewater to sustaining water resources, protecting the environment, and ensuring adequate and efficient supply of water*

6.2 Details and specific remedies and investments

The remainder of this Chapter will provide details on the gaps in hydrological understanding listed previously and their underlying gaps in data and information. Specific remedies and investments are suggested as a means to strengthen national expertise and capabilities to fill each gap in hydrological understanding. This discussion is organized by element of the comprehensive assessment presented in Table 4 and will address in sequence the:

GAP IN UNDERSTANDING
CURRENT SITUATION AND GAPS IN DATA AND INFORMATION
SPECIFIC REMEDIES AND INVESTMENTS

6.3 Water Supply

The gap in hydrological understanding in the water supply of the Philippines has been presented earlier in Chapter 6 to be: *Insufficient understanding of the quantity and spatial/temporal distribution of surface and groundwater resources.*

The gaps in hydrological understanding of Water Supply are grouped by their relation to Surface Water, Groundwater, and Water Budget. Figure 6 shows a representative map of Water Supply Study where rainfall, surface water and groundwater were considered.

6.3.1 Surface Water

The discussion of the gaps in hydrological understanding of surface water is grouped by the elements of a comprehensive water-resource assessment as presented in Table 5. These elements are Hydrography, Streamflow, and Flood and Drought Risk.

Water supply	Surface water	**Hydrography** Topography, hydrography, storage volume
		Streamflow Discharge, channel geography, rating curves
		Flood and drought risk Recurrence intervals, trends

Table 5: Elements of a comprehensive water-resource assessment for surface water

6.3.1.1 Hydrography

Hydrography is the science of surveying and mapping watersheds and surface water features such as rivers, lakes, and wetlands. Understanding the hydrography of Philippine surface water depends on data and information on natural topography and watershed configuration, as well as the geometry of lakes, river channels, and floodplains. Also included in this section on Hydrography are some broader physiographic and biographic characteristics of lakes.

6.3.1.1.1 River Basins

A thorough and detailed understanding of the hydrography of river basins in the Philippines is fundamental to the capability to assess the surface-water resource.

GAP IN UNDERSTANDING

Hydrographic features of the Philippines are presented on topographic maps produced by NAMRIA at scales of 1:10,000, 1:50,000 and 1:250,000. Figure 7 shows the map of Philippine Hydrometeorological Monitoring Stations. These maps have been constructed using aerial photographs taken in 1979 and incorporating remotely-sensed and land-based data techniques. The NAMRIA maps are considered current and accurate in accordance with Philippine Reference System of 1992 - PRS92. PRS92 is a homogeneous national network of geodetic control points (GCPs) marked by concrete monuments that has been established using Global Positioning System (GPS) technology.

There are 421 principal river basins in the Philippines; 18 of these basins are greater than 1,400 km^2 in area and are considered Major River Basins. Figure 8 presents the map of major river basins in the Philippines. These Major River Basins cover a total area of about 100,000 km^2, which is about 37% of the total land area of the Philippines (Master Plan Study on Water Resources Management in the Republic of the Philippines: Final Report. (1998). Volume 3 (39), Volume 1-5 (37-40). Philippines).

In addition to the 18 Major River Basins, the University of the Philippines National Institute of Geological Sciences (UP-NIGS) has delineated all sub-basins covering the entire country as well as the division of smaller sub-basins within the major basins based on a digital elevation model (DEM). There is however, a need to validate and clarify with UP-NIGS how the delineation was done. Likewise, as suggested by RBCO, the final delineation of river basin boundaries for the whole country should be harmonized with the delineated number of river basins identified and listed by DPWH (1,434 river basins – data from the National Flood Risk Assessment Study by DPWH).

An Integrated Water Resource Management Plan Framework Plan (IWRMPF) was formulated by the Philippines in 2006. The IWRMPF takes a river basin/watershed approach to water resources management and integrates the management of land resources and water resources - surface water, groundwater, and coastal resources. This initiative will require an advanced level of hydrographic accuracy and utility to support various technical and management elements, and is expected to be a benefit to the entire water sector.

A current critical gap is the need to understand the national hydrography with sufficient detail and certainty to fully support the Integrated Water Resources Management Plan Framework .

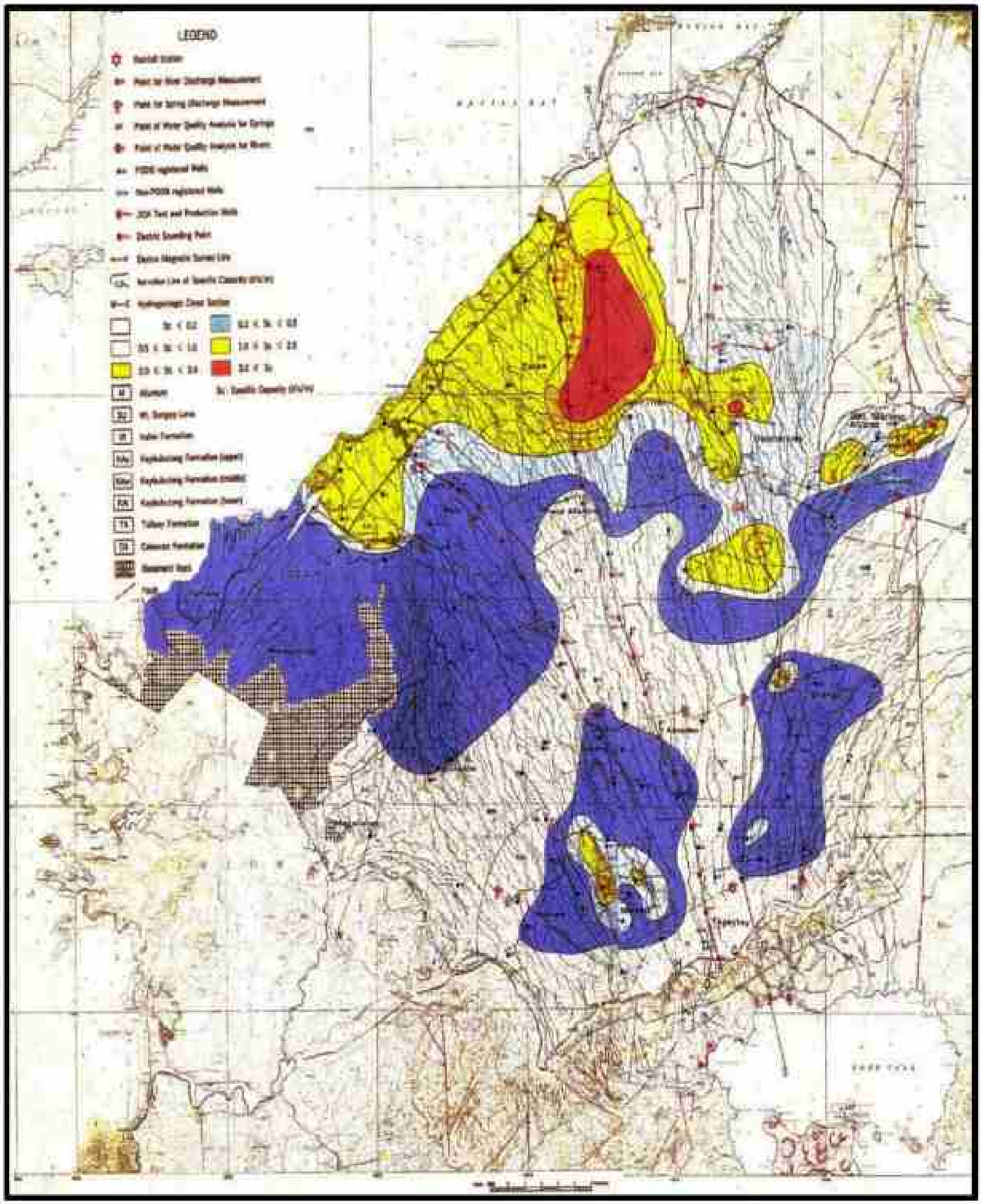


Figure 6. A representative map of Water Supply Study where Rainfall, Surface Water and Ground Water were considered. (Source: *Cavite Water Supply Development Study in the Republic of the Philippines.*)

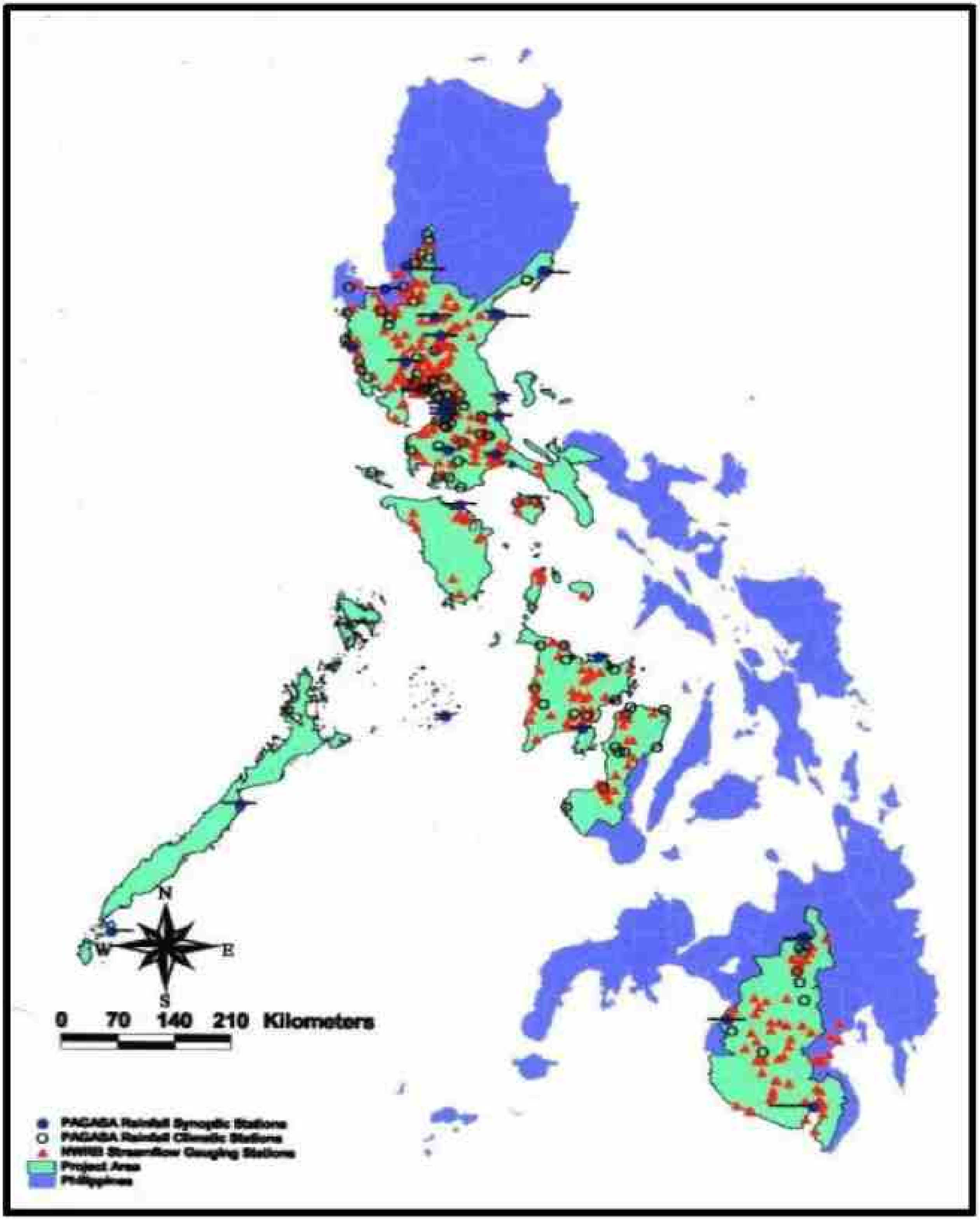


Figure 7. Map of Philippine Hydrometeorologic Monitoring Stations

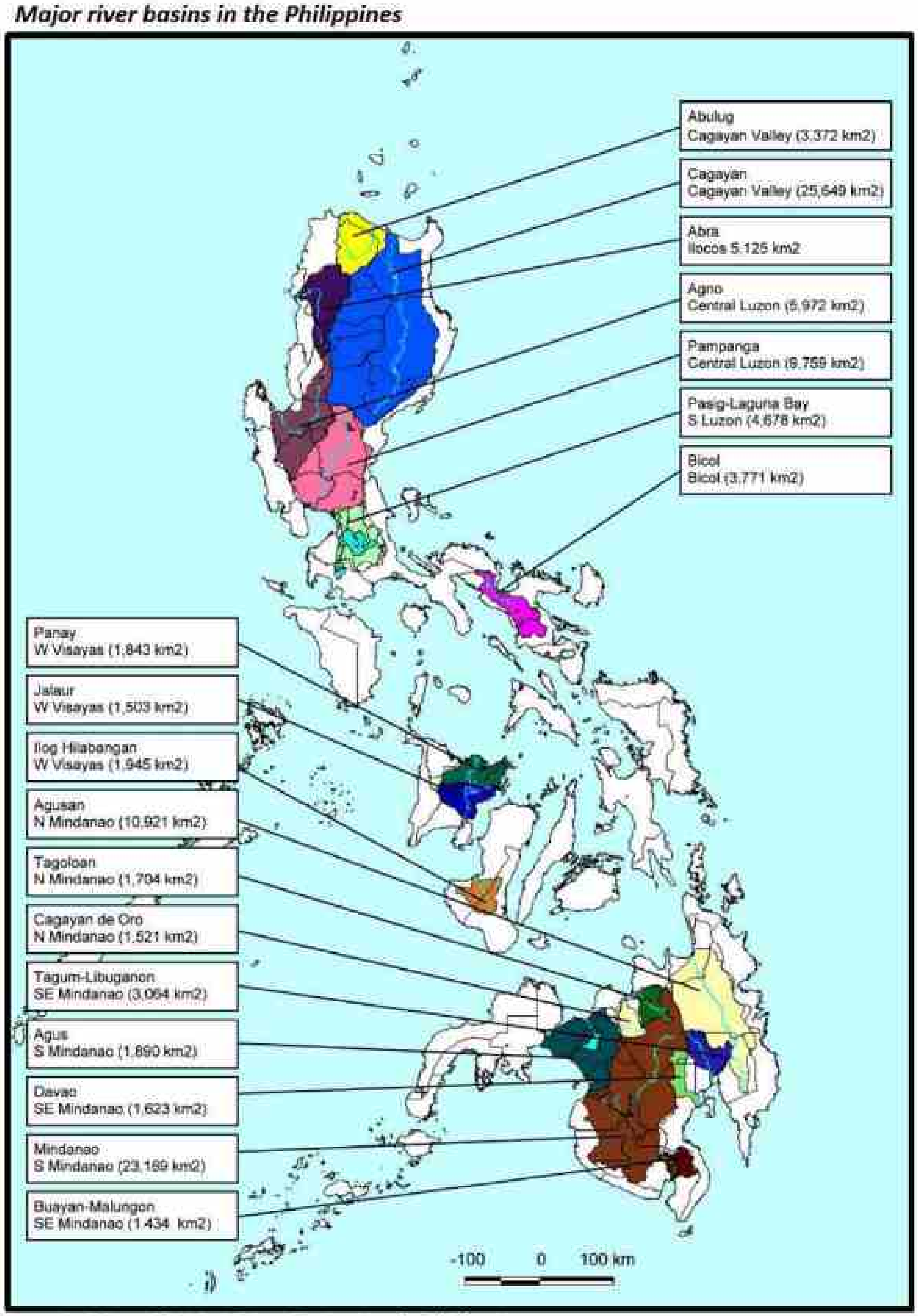


Figure 8. Map of Major River Basins in the Philippines

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

NAMRIA is the national provider for satellite imageries, topographic maps, digital elevation models (DEM), and vector streams. Some products can be downloaded from the NAMRIA web site and some products are available for sale. In addition, regarding data and information for national hydrography of river basins it is noted that:

- NEDA, UP, and NWRB instituted in 2010 ***GIS for Water Resources***, a compilation of water-related information on a municipal scale. It includes a delineation of sub-watersheds or sub-basins based on a medium-resolution digital elevation model (DEM) of the Philippines.
- DENR-NAMRIA, NWRB, DOST-PAGASA, and UP Diliman are shifting to the use of a GIS database in compiling water-related information. They are collaboratively working to solve these persistent problems: coordination in the production of maps at the local level, the tedious process of acquiring maps and map data from multiple sources, the unavailability of GIS software at the local government level, and the lack of human resources and infrastructure to handle Geospatial Information Technologies (GIT) projects. Also identified is the need for data integration and sharing, and the lack of technical standards for data exchange.
- There is no working Philippine spatial data infrastructure (SDI). This in spite of the ***Philippine National Geographic Information Infrastructure Framework Plan (2001-2005)*** of 2000 by the Inter-Agency Task Force on Geographic Information (IATFGI) that formulated standards and plans for the development of a national geographic information infrastructure.
- DENR-NAMRIA is establishing an internal spatial data infrastructure or **NAMRIA SDI** (nSDI) which will help in advancing the national SDI development. The nSDI is an infrastructure that will facilitate the gathering, storage, and distribution of spatial data across NAMRIA. It is an offshoot of the NAMRIA-Geoscience Australia memorandum of understanding signed in August 2009 to strengthen spatial data development and delivery in the Philippines.
- The **One Map, One Philippines** program of the NAMRIA is intended to provide a uniform source of topographic/geographic maps in different scales and formats. However, this program has not yet fully achieved the means for data inter-comparison for the purpose of establishing a national, geo-referenced base map.
- NAMRIA and water agencies are collaborating to address their needs for digital maps, remote sensing images, GIS software, updated topographic and thematic maps, light detection and ranging (LIDAR) technology, and other technologies and software. However, the collaboration has not yet resulted in fully supporting the broad range of requirements of the water agencies.

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand the national hydrography with sufficient detail and certainty to fully support the Integrated Water Resources Management Framework Plan***

*Establish unified geo-referenced base maps for the water sector under **One Map, One Philippines***

Actions – to include:

- ***Fully map political boundaries, catchment boundaries of basins, and hydrogeological setting to support the needs of the water sector –*** through training and capacity building, and upgrading of equipment and software**,** to include appropriate state-of-the-science systems such as developed by:
    - the Hydrology Domain Working Group directed by WMO Commission for Hydrology and the Open Geospatial Consortium
    - WMO South East Asia-HYCOS (in early concept phase)
    - USGS Center for Integrated Data Analytics

National partners – **DENR-NAMRIA**, DENR-MGB, DENR-EMB, NWRB

6.3.1.1.2 Natural lakes and swamps

A thorough and detailed understanding of the hydrography of natural lakes and swamps in the Philippines is important to the capability to assess the local water resource represented by small lakes and swamps and the regional water resource represented by Laguna Lake.

GAP IN UNDERSTANDING

Within the 421 principal river basins of the Philippines are 216 lakes and 22 major marshes, swamps and reservoirs. Of the 216 lakes, seven are currently monitored by the LLDA in addition to its major concern – Laguna Lake. Pictures of the seven monitored lakes (Lakes Bunot, Calibato, Mohicap, Palakpakin, Pandin, Sampaloc, and Yambo) are presented in Figure 9-a. Figure 9-b shows the orthophotograph of Laguna Lake. Plans include adopting a common framework for basin-wide management of Philippine lakes and to explicitly link science with lake management and protection policy. Scientific information, including water-resource assessment and research results, for example, could be integrated into lake basin programs.

Essential to the monitoring and management activity on the lakes in the Philippines is the establishment of morphometric and limnologic baseline information that best describe the lake.

Morphometric data include the following:

- Lake surface area
- Drainage basin area
- Elevation in relation to sea level
- Mean depth
- Maximum depth
- Volume
- Length
- Breadth
- Shoreline length
- Shoreline development
- Other bathymetric information, like the presence of cryptodepressions

The total lake area should be a defined area enclosed within the outline of the particular lake, including any islands, the number of which may affect the surface area and its volume. Likewise, lakes with no outlets are subject to wide and disparate seasonal level fluctuations, e.g. in terms of lake level and chemical concentration.

Limnologic data can be expressed in terms of:

- Water quality, such as water transparency/turbidity, total dissolved solids, alkalinity and pH values, and
- Biological productivity, such as primary productivity (expressed in grams of carbon assimilated per square meter per day, ($gC/m^2/day$) and annual fish-yield expressed as the annual kilogram of normal commercial harvest per hectare per year, (kgm/ha/yr).

The current critical gap is the need to understand the physiographic changes occurring on lakes and the vulnerability of lakes to a range of identified and potential stresses.

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

NAMRIA is the national provider for satellite images, topographic maps, DEM, and vector streams. Some products can be downloaded from the NAMRIA web site and some products are available for sale. In addition, regarding data and information for national hydrography of natural lakes, marshes, and swamps it is noted that:

- The PAWB has responsibility for some lakes within Protected Areas. It is expected that some detailed hydrographic or bathymetric data are held by PAWB.
- The DENR-LLDA has responsibility for Laguna Lake and the lakes within its watershed. It is expected that some detailed hydrographic or bathymetric data are held by LLDA.

- LGU and other concerned agencies may hold some data on lakes outside the Protected Areas of the PAWB.

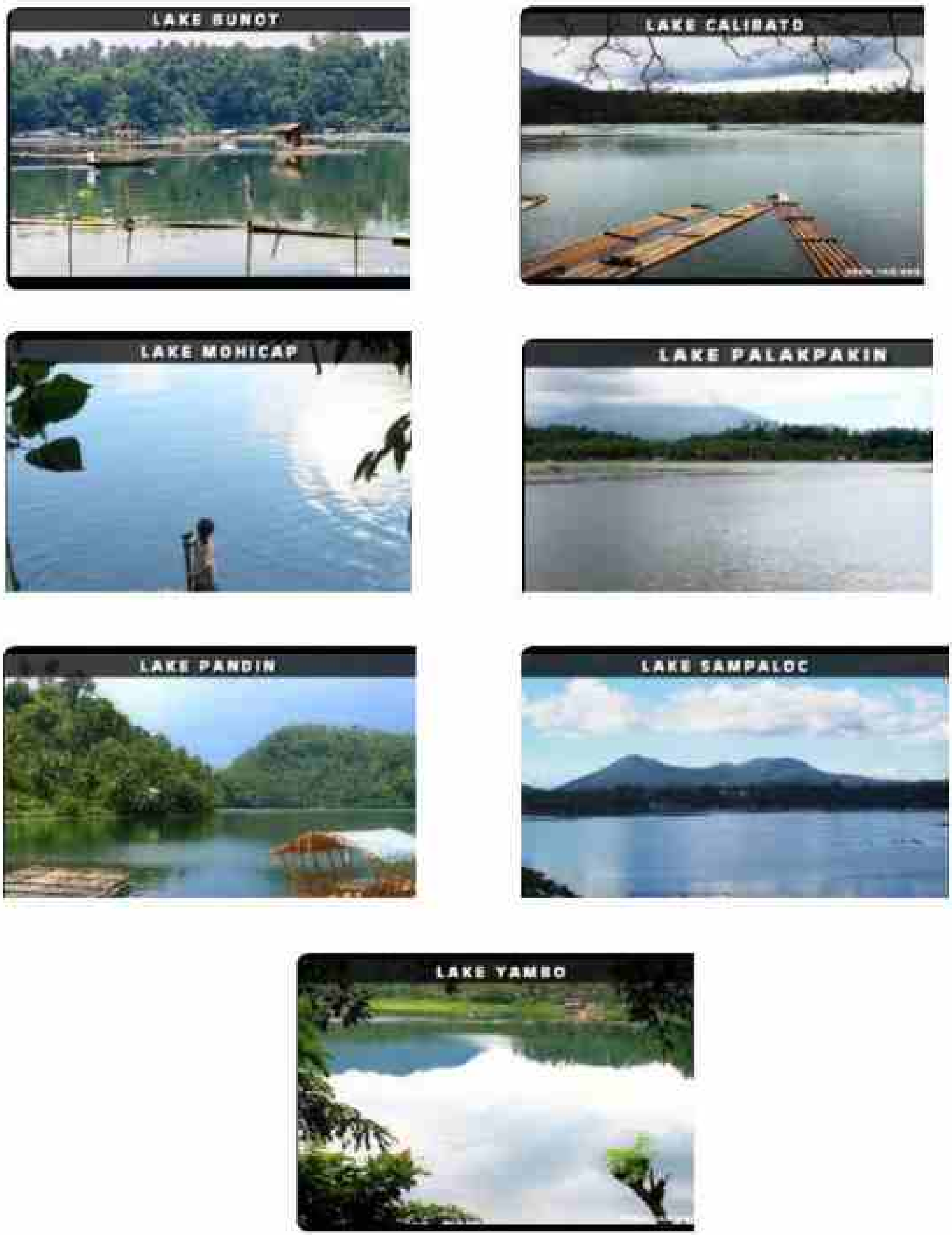


Figure 9-a. Seven lakes monitored by LLDA (Lake Bunot, Calibato, Mohicap, Palakpakin, Pandin, Sampaloc and Yambo). (*Source: Framework planning for basin-level management the Philippine approach by Vicente B. Tuddao Jr.*)

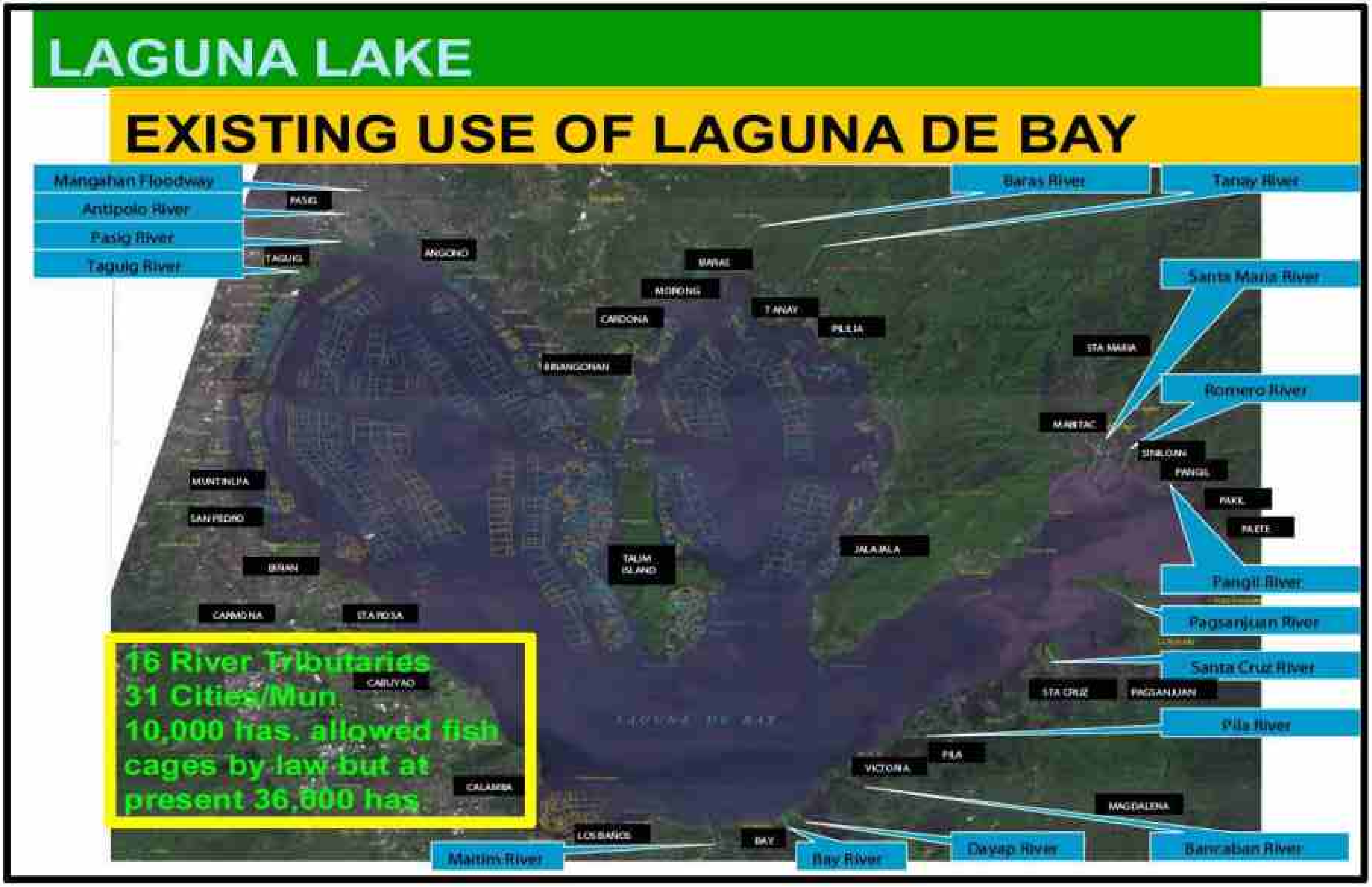


Figure 9-b. Orthophotograph of Laguna Lake. (Source: Laguna Lake Development "Development of a Source of Water for Metro Manila")

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand the limnologic changes occurring to lakes and the vulnerability of lakes to a range of identified and potential stresses.***

Collect appropriate and adequate physical and chemical data from Philippine lakes, marshes, and swamps

Actions

- ***compile and collect sufficient morphometric and limnologic data appropriate for a national inventory of lakes*** - to be conducted by DENR-LLDA for Laguna Lake, PAWB for lakes within Protected Areas, and LGUs/concerned agencies on lakes outside Protected Area.
  - training on data collection methods for national partners provided by DENR-LLDA
- ***develop and implement a Reconnaissance Sampling Program for chemical and isotopic analysis of lake water, sediments, biota and vapors***– *sampling program designed and implemented in collaboration with PNRI and IAEA*; training provided and supported by PNRI and IAEA
- ***measure trophic, ecological integrity, and recreational indicators*** – provide training modelled on the National Aquatic Resource Surveys of the US Environmental Protection Agency or similar
- ***measure indicators of water quality, fish and rice production, biodiversity, carbon storage and climate change mitigation, and recreational use*** – modelled on the Philippine Sub-global Assessment (of the Millennium Ecosystem Assessment) which was focused on Laguna Lake and other priority lakes in the Philippines

National partners - **DENR-LLDA**, DPWH-BRS, DENR-EMB, DOST-PNRI, DENR-NAMRIA, PAWB, LGUs, DA-BFAR

Complete a national inventory of lakes and plan for routine re-assessment

Actions

- ***interpret available data to provide a national inventory of lakes*** - utilize national expertise such as the Philippine Sub-global Assessment and that of international programs such as the National Aquatic Resource Surveys of the US Environmental Protection Agency
- ***establish parameters/indices for periodic re-assessment of Philippine lakes*** – provide training in appropriate established international methods and protocols

National partners - **DENR-LLDA**, DPWH-BRS, DENR-EMB, DENR-NAMRIA, PAWB, LGUs, DA-BFAR

Assess the vulnerability of priority lakes

Actions

- ***use physical, chemical, and isotopic methods to characterize lake interactions with rivers and groundwater*** – also estimate rate of siltation (littoral and benthic zones) and reconstruct paleo-climatic environments.

National partners - **DENR-LLDA**, DPWH-BRS, DENR-EMB, DOST-PNRI, DENR-NAMRIA, PAWB, LGUs, DENR-MGB

6.3.1.2 Streamflow

6.3.1.2.1 Gauged and ungauged basins

GAP IN UNDERSTANDING

Understanding stream discharges and the probability distribution of flows are essential to quantify and manage the resource as water supply and for protection against flood hazard. The DPWH-BRS coordinates all government projects within the river basins through integrated management programs and funding of agency project reports. The current understanding developed for 56 selected and prioritized river basins (derived from DPWH 2011 Year-end report) is presented through resource maps, rating curves, annual reports, and on-line resources. A representative example of a rating curve (Figure 10-a) and rating table (Figure 10-b) is presented for one location.

During the early 1980s the Philippines operated 778 stream gauging stations. The number of stations managed by DPWH-BRS that are currently operating is just 249, a reduction of approximately 68% in the last thirty years. As a direct result of the loss of stations, there has been an increase in the number of ungauged basins and a general decrease in understanding of national streamflow and trends, making it difficult to manage for surface water supply or extreme flows. As a result, the assessment of national surface-water resources might be considered to have a relatively higher uncertainty.

The Integrated Water Resource Management Plan Framework (IWRMPF), a river basin/watershed approach to water resources management, has been adopted requiring the integration of land and water resources, either surface water, groundwater, and coastal resources. The IWRMPF is being implemented by NWRB and piloted in the preparation of IWRM Plan in the Pampanga River Basin. On the other hand, the DENR-RBCO is formulating Master Plans for the other Major River Basins in the country. An initial study has been completed for 2 major river basins - Cagayan River Basin and Mindanao River Basin - and a group of principal river basins in Cebu Province.

At present, RBCO is procuring for the formulation of integrated River Basin Master Plans for 3 Major River Basin (Abra, Davao, and Cagayan de Oro River Basin) for CY 2012 and 2 Priority River Basins (Marikina and Iloilo-Batiano River Basins). A parallel initiative in the preparation of river basin management plans was conducted by other offices such as Agusan River Basin by FASPO and NWRB, Pampanga River Basin by NWRB, Bicol River Basin by FMB and NEDA Region 5, Pasig-Laguna de Bay River Basin by LLDA and PRRC, and Agno River Basin by former Agno River Basin Commission.

All of these initiatives as well as the fundamental understanding of surface-water flow in the Philippines suffer from the loss of structured, routine monitoring of discharge.

The current critical gap is the need to increase the understanding of stream flow in gauged and ungauged basins.

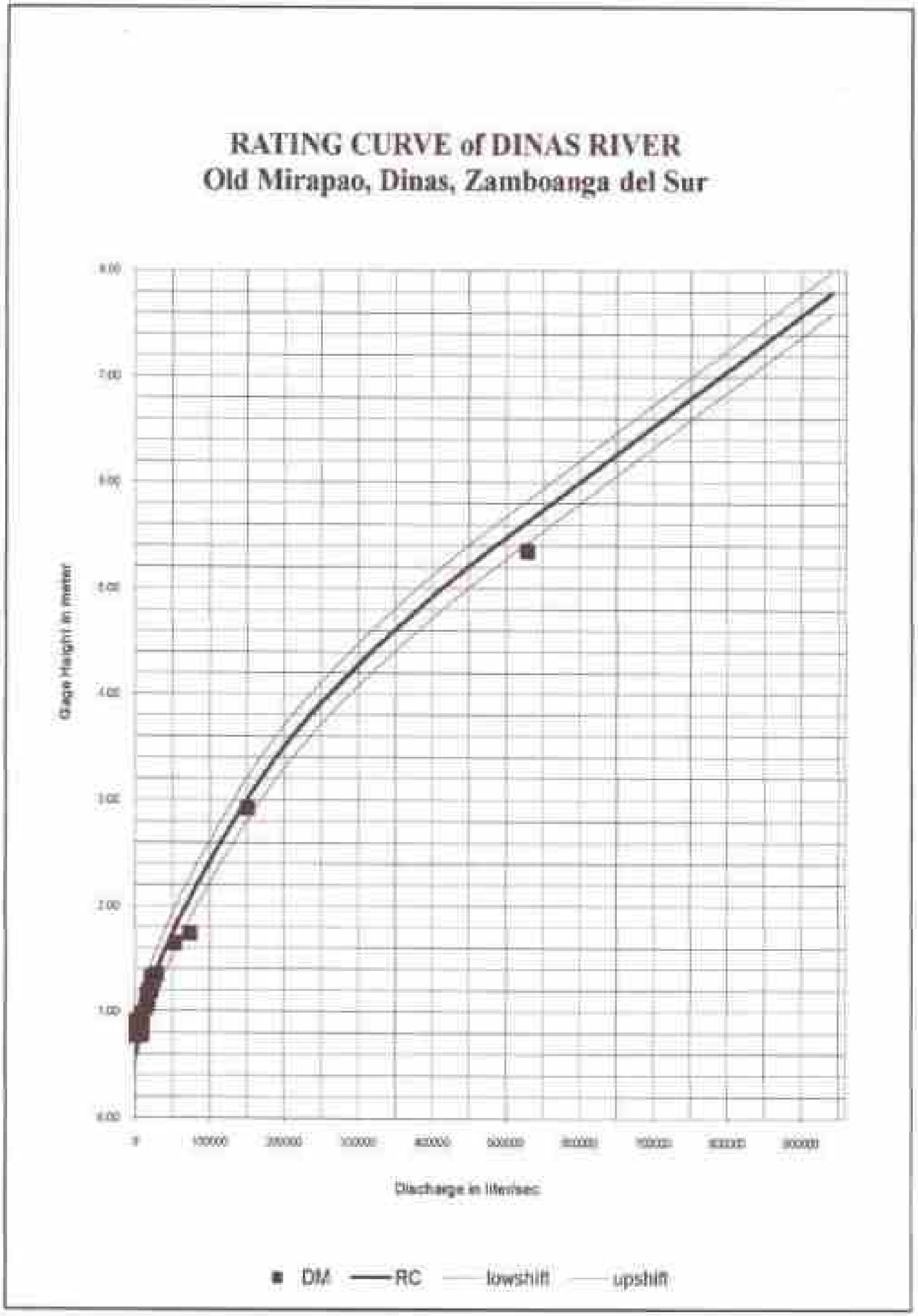


Figure 10-a. Rating Curve for Dinas River, Old Mirapao, Dinas, Zamboanga del Sur

Department of Public Works and Highways BUREAU OF RESEARCH AND STANDARDS EDSA, Diliman, Quezon City	RATING TABLE	Station Code No. Date Prepared: 09/01/08
River Name: DINAS RIVER	@	OLD MIRAPAO, DINAS, ZAMBOANGA DEL SUR

GH (m)	0.00 -0.10	0.01 -0.09	0.02 -0.08	0.03 -0.07	0.04 -0.06	0.05 -0.05	0.06 -0.04	0.07 -0.03	0.08 -0.02	0.09 -0.01	DIFF
0.60	600	1300	1600	1900	2200	2500	3100	3700	4300	4900	100
0.70	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	200
0.80	3600	3900	4200	4500	4800	5100	5400	5700	6000	6300	300
0.90	6600	6950	7300	7650	8000	8350	8700	9050	9400	9750	350
1.00	10100	10500	10900	11300	11700	12100	12500	12900	13300	13700	400
1.10	14100	14550	15000	15450	15900	16350	16800	17250	17700	18150	450
1.20	18600	19100	19600	20100	20600	21100	21600	22100	22600	23100	500
1.30	23600	24150	24700	25250	25800	26350	26900	27450	28000	28550	550
1.40	29100	29700	30300	30900	31500	32100	32700	33300	33900	34500	600
1.50	35100	35720	36340	36960	37580	38200	38820	39440	40060	40680	620
1.60	41300	41940	42580	43220	43860	44500	45140	45780	46420	47060	640
1.70	47700	48360	49020	49680	50340	51000	51660	52320	52980	53640	660
1.80	54300	54980	55660	56340	57020	57700	58380	59060	59740	60420	680
1.90	61100	61800	62500	63200	63900	64600	65300	66000	66700	67400	700
2.00	68100	68820	69540	70260	70980	71700	72420	73140	73860	74580	720
2.10	75300	76040	76780	77520	78260	79000	79740	80480	81220	81960	740
2.20	82700	83460	84220	84980	85740	86500	87260	88020	88780	89540	760
2.30	90300	91080	91860	92640	93420	94200	94980	95760	96540	97320	780
2.40	98100	98900	99700	100500	101300	102100	102900	103700	104500	105300	800
2.50	106100	106920	107740	108560	109380	110200	111020	111840	112660	113480	820
2.60	114300	115140	115980	116820	117660	118500	119340	120180	121020	121860	840
2.70	122700	123560	124420	125280	126140	127000	127860	128720	129580	130440	860
2.80	131300	132180	133060	133940	134820	135700	136580	137460	138340	139220	880
2.90	140100	141000	141900	142800	143700	144600	145500	146400	147300	148200	900
3.00	149100	150040	150980	151920	152860	153800	154740	155680	156620	157560	940
3.10	158500	159480	160460	161440	162420	163400	164380	165360	166340	167320	980
3.20	168300	169320	170340	171360	172380	173400	174420	175440	176460	177480	1020
3.30	178500	179560	180620	181680	182740	183800	184860	185920	186980	188040	1060
3.40	189100	190200	191300	192400	193500	194600	195700	196800	197900	199000	1100
3.50	200100	201240	202380	203520	204660	205800	206940	208080	209220	210360	1140
3.60	211500	212680	213860	215040	216220	217400	218580	219760	220940	222120	1180
3.70	223300	224520	225740	226960	228180	229400	230620	231840	233060	234280	1220
3.80	235500	236780	238020	239280	240540	241800	243060	244320	245580	246840	1260
3.90	248100	249400	250700	252000	253300	254600	255900	257200	258500	259800	1300
4.00	261100	262440	263780	265120	266460	267800	269140	270480	271820	273160	1340
4.10	274500	275880	277260	278640	280020	281400	282780	284160	285540	286920	1380
4.20	288300	289720	291140	292560	293980	295400	296820	298240	299660	301080	1420
4.30	302500	303960	305420	306880	308340	309800	311260	312720	314180	315640	1460
4.40	317100	318600	320100	321600	323100	324600	326100	327600	329100	330600	1500
4.50	332100	333640	335180	336720	338260	339800	341340	342880	344420	345960	1540
4.60	347500	349080	350660	352240	353820	355400	356980	358560	360140	361720	1580
4.70	363300	364920	366540	368160	369780	371400	373020	374640	376260	377880	1620
4.80	379500	381160	382820	384480	386140	387800	389460	391120	392780	394440	1660
4.90	396100	397800	399500	401200	402900	404600	406300	408000	409700	411400	1700
5.00	413100	414840	416580	418320	420060	421800	423540	425280	427020	428760	1740

Figure 10-b: Example of a Rating Table for Dinas River, Old Mirapao, Dinas, Zamboanga del Sur

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

There are a number of agencies that collect streamflow data to meet their individual missions. Primary among these is DPWH-BRS with 249 stations at which the reading of staff gauges provide about 10 years of historical flow data. Over the years DPWH-BRS has coordinated with several agencies in streamflow data-collection activities. In coordination with DA-NIA, the DPWH-BRS stations monitored stream discharge, while with DOST-PAGASA the DPWH-BRS stations determined the amount of precipitation in account for water supply. DOST-PAGASA currently has 4 telemetered streamflow stations in Cagayan, Bicol, Pampanga, and Agno. DOST has plans for adding 40 additional streamflow stations in 2012. Figure 11 shows the location of streamflow gauging stations for the Philippines. Additional details regarding data and information on national streamflow are:

- The NWRB conducts water resource availability analysis for surface water using flow duration curves developed in the 1980s. A critical need is for the collection of current flow data to confirm and augment the historical data and for the development of flow duration curves that reflect the present-day flow.
- The ***National Water Data Collection Network*** (NWDCN) was spearheaded by the NWRB in 2004 to consolidate national data for surface water (DPWH-BRS), groundwater (DENR-MGB), and water quality (DENR-EMB). The surface water flow data that were collected through this effort are currently held by the collecting agencies and were submitted to NWRB. This network is not currently active, but the goal is for these data to be made available through a national data system.
- The ***National Water Information Network*** (NWIN) is an off-shoot of the NWDCN and is also a responsibility of the NWRB. The NWIN is intended to link water-resource databases of all the collecting agencies such as DPWH-LWUA, DPWH-MWSS, DPWH-BRS and other user agencies. The network is intended to provide easy access to data by users and data generating agencies. However, there remains a critical need to update/enhance the NWIN concept taking advantage of new hardware and state of the art software so it can include the range of water data to be incorporated from other agencies. Sustainability of a national system compiling and serving hydrological data is a critical need for the ability of the Philippines to sustainably manage national water resources and utilization of open source software. This need for a national data management framework is stressed by the *Philippine Development Plan 2011-2016*.
- The ***River Basin Integrated Information Management System*** (RBIIMS) of the River Basin Control Office (DENR-RBCO) has been developed, as mandated by Executive Order 816 (2009) to address the gap of inadequate hydrological and hydrogeological data and networks. The RBIIMS is a comprehensive database with user-friendly query system containing technical information used for management, planning and decision-making. The database contains a range of geo-spatial data by river basin such as physiographic data, biological resources, pollution sources, monitoring data, socio-economic data, demography, and institutional data. RBIIMS is localized in the region, allowing flexibility for site specific requirements such as the level of data

encoding, demographic data ranges, retrieval and manipulation/reporting. Each site is an independent node, which can be connected with a network. The development and implementation of the RBIIMS is in collaboration with Partnerships in Environmental Management for the Seas of East Asia.

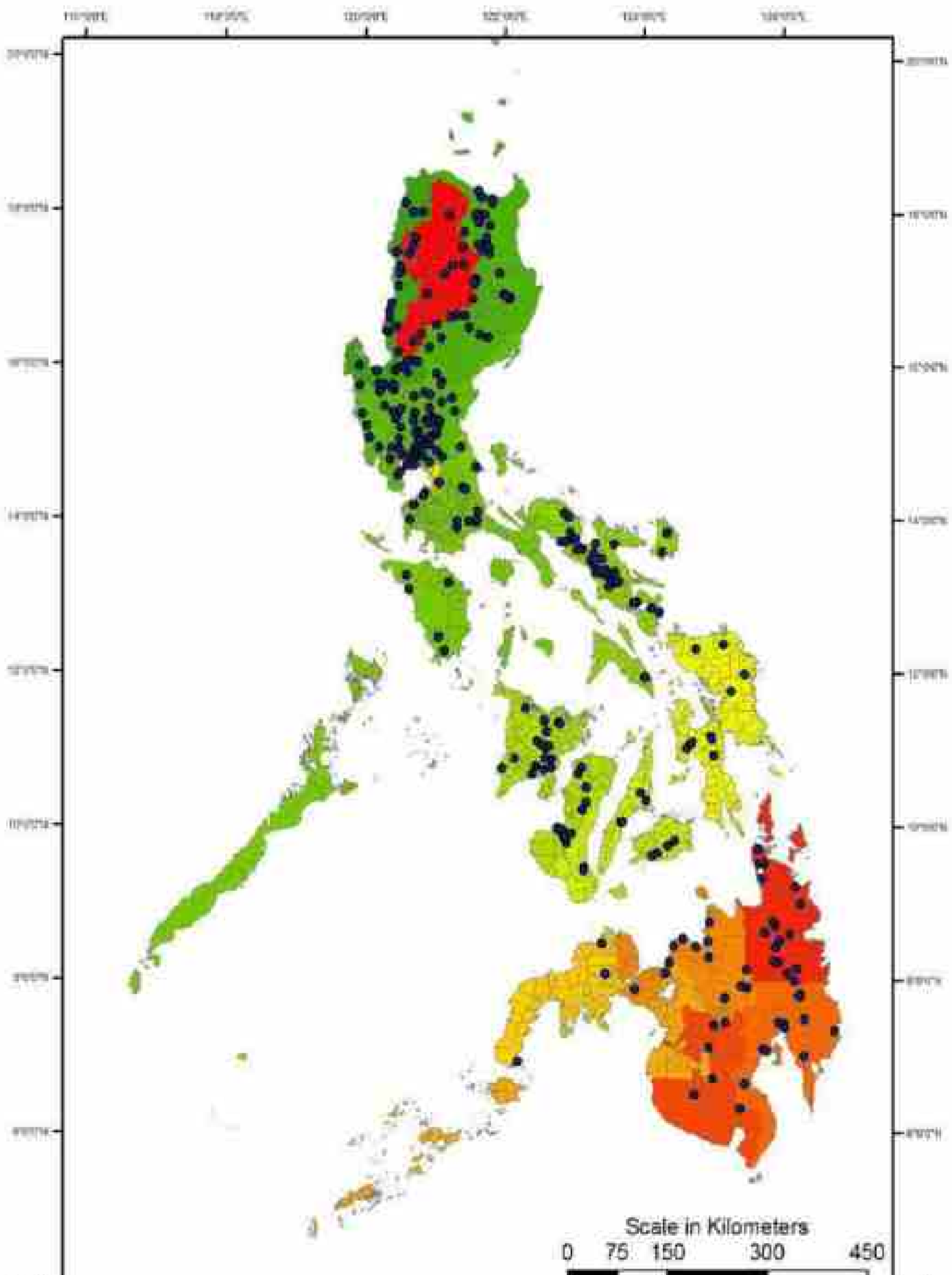


Figure 11. Location of streamflow gauging stations in the Philippines

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to increase the understanding of stream flow in gauged and ungauged basins.***

Strengthen the routine and objective-specific collection of streamflow data

Actions

- ***evaluate and reaffirm the routine collection and collation of streamflow data for gauged rivers*** – responsibility of DPWS-BRS and station partners
- ***establish a national streamflow monitoring network with the active sites routinely monitored by the various agencies as the starting point*** - select sites and attributes using the criteria of the National Water Data Collection Network (NWDCN) for establishing monitoring stations
- ***assess and optimize hydrological networks*** – provide training which augments national expertise with international partners such as USGS Office of Surface Water and WMO HYCOS Program
- ***develop and implement a Reconnaissance Sampling Program for chemical and isotopic analysis of river water*** – sampling program designed and implemented in collaboration with PNRI and IAEA; sample at locations, at time intervals, and for events important to separation of base-flow components; training provided and supported by PNRI and IAEA
- ***harmonize the streamflow data collected by different agencies*** – requires the establishment and support of a data-sharing and data-serving system serving Philippine water agencies

National partners – **DPWH-BRS**, DOST-PNRI, NWRB, DOST-PAGASA, RBCO, DA-NIA, NPC

Interpret streamflow data to develop streamflow statistics for all Philippine river basins – gauged and ungauged

Actions

- ***strengthen national capacity to develop streamflow statistics for basins with a range of historical and current flow measurements*** – provide training in selected state-of-the-science methods, potentially to include:
  - WMO HYCOS Program, perhaps in conjunction with the South East Asia-HYCOS (in early concept phase)
  - USGS Office of Groundwater, National Streamflow Statistics Program
  - IAEA Water Resources Programme
- ***strengthen national capacity to estimate streamflow statistics in ungauged basins*** - provide training in selected state-of-the-science methods, potentially to include:
  - USGS StreamStats Program which applies a regionalization approach using regression analysis of streamflow statistics from gauged sites

  - Global Flood Modelling: Statistical Estimation of Peak-Flow Magnitude - as developed by World Bank Development Research Group and UNEP/GRID-EUROPE
  - Predictions in Ungauged Basins led by the International Association of Hydrological Sciences – goal is to improve the ability of existing hydrological models to generate reliable predictions in ungauged basins
- ***integrate isotopic and flow data to optimize the determination of streamflow statistics*** – under the leadership of PNRI, IAEA, and USGS
- ***establish parameters for maintenance and revision of streamflow estimates*** – through collaboration of national partners

<u>National partners</u> – **DPWH-BRS**, DOST-PNRI, NWRB, DOST-PAGASA, RBCO, DA-NIA, NPC

6.3.1.2.2 *Storage and routing*

GAP IN UNDERSTANDING

Understanding the natural channel storage and hydrological routing of Philippine surface water is the responsibility of DPWH-BRS and DOST-PAGASA (in relation to flood control), LLDA (for Laguna de Bay), NAMRIA (mapping), NIA, NPC, and the River Basin Offices. Maps and models are generated by NAMRIA, PAGASA, NWRB and various river basin projects.

Dams and reservoirs in the Philippines are administered by different departments and agencies for different functions. The total reservoir capacity of the Philippines in the year 2000 was 4.75 km^3, consisting of 6 large dams and about 54 small dams. Figure 12 provides the location of existing and proposed location of storage type dams in Water Resource Region III. The National Power Corporation (NPC) manages dams for power generation, the National Irrigation Administration (NIA) for irrigation, the Metropolitan Waterworks & Sewerage System (MWSS) for domestic water supply for Metro Manila, the Department of Public Works & Highways (DPWH) for flood control, and private mining firms for disposal and control of mine tailings. The Bureau of Soil and Water Management of the DA maintains small water impounding structures (SWIM). Reservoir storage and routing calculations are the responsibility of the individual administering governmental agencies.

In most cases, the NPC and PAGASA have maps and models providing a very good understanding of storage and routing for the reservoirs in Luzon (e.g. Angat, Pampanga, San Roque). Maps and models do not currently exist for other major reservoirs nationwide which are managed by agencies other than NPC and PAGASA; maps and models should be generated for these major dams to provide the same level of understanding to support IWRM and flood-prediction modelling.

Projected future demands for supply and flood control, particularly near urban centers, suggests that surface-water storage needs for urban centers and the need for catchment basins for flood control and irrigation purposes must be reassessed. The recent flooding in Central Luzon brought about by typhoon *Pedring* (international code name Nesat), highlights a current critical gap for the need to understand the effect on surface water storage and routing of scenarios of extreme weather and climate.

Maps and models for reservoir storage and routing must be continually maintained and revised. As stated by PAGASA "Even a well-calibrated model is an ephemeral commodity. Once a river model is developed, changes in watershed characteristics, such as increasing urbanization, drainage improvements, and construction of dams and levees, can make the model obsolete. A continuing cycle of model calibration, collection of river-discharge and rainfall data, and model recalibration is required to provide a current, useful, and accurate flood-forecasting tool."

The current critical gap is the need to understand surface-water storage and routing on a national scale, and to understand the effect of scenarios of extreme weather and climate.

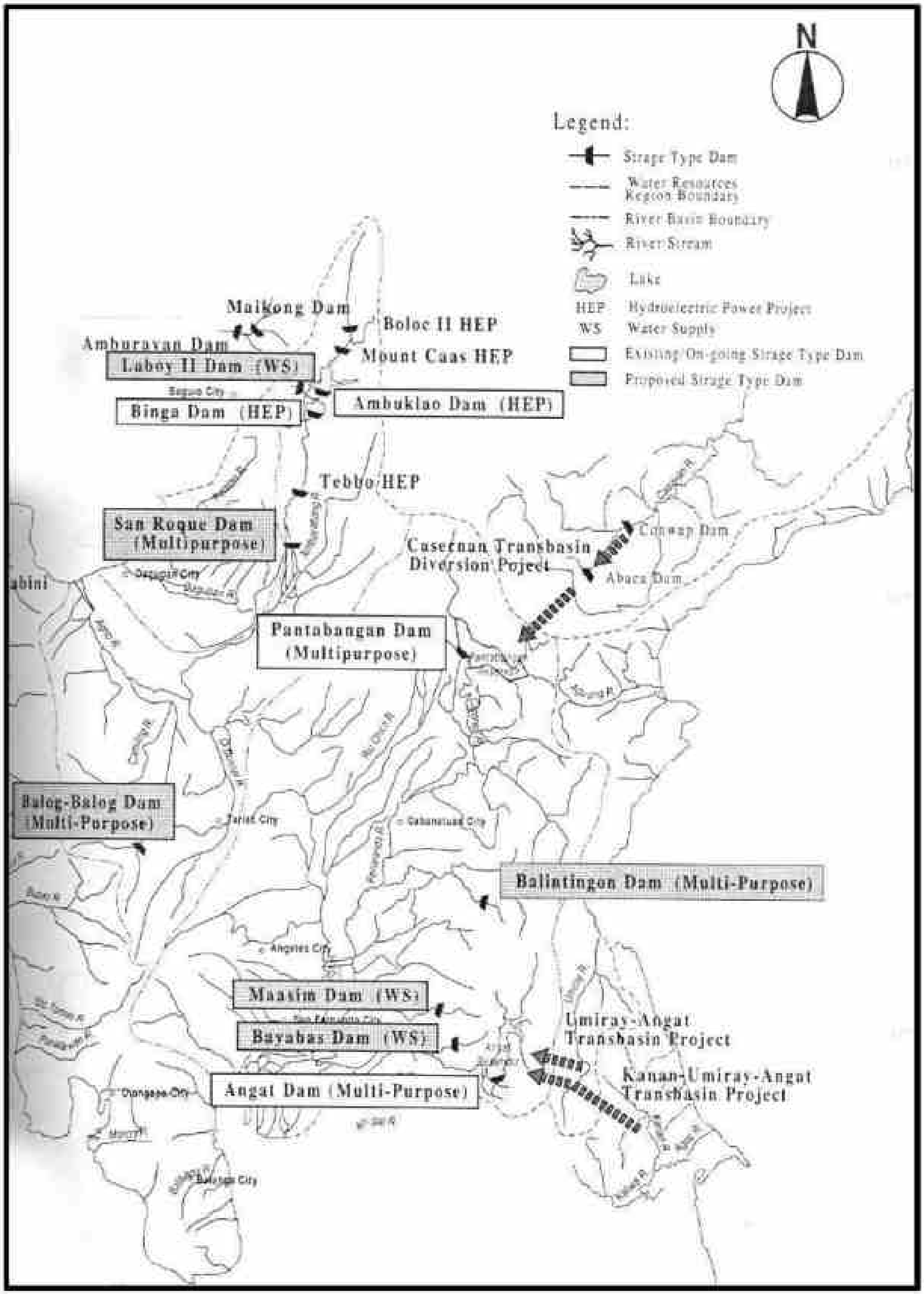


Figure 12: Location of Existing & Proposed Location of Storage Type Dam in Water Resources Region III (Source: Master Plan Study on Water Resources Management in the Republic of the Philippines, 1998)

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

As previously stated, NAMRIA is the national provider for satellite images, topographic maps, DEM, and vector streams. The agencies responsible for understanding how storage and routing of surface water affect their facilities rely to a great extent on NAMRIA to provide current and accurate geospatial and hydrographic data. In addition, the streamflow data discussed in the preceding section are important in understanding storage and routing, so the critical work of DPWH-BRS, DA-NIA, and DOST-PAGASA in providing these data and information is noted. Precipitation data are of course important to the understanding of streamflow in general and will be specifically addressed later this Chapter.

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand surface-water storage and routing on a national scale, and to understand the effect of scenarios of extreme weather and climate***

Ensure the routine collection of streamflow and precipitation data used for surface-water storage and routing analysis

Actions

- ***evaluate and reaffirm the routine collection and collation of streamflow and precipitation data in the analysis of surface-water storage and routing*** – responsibility of DPWS-BRS and station partners along with the agencies responsible for operation of dams
- ***assess and optimize hydrological networks*** – provide training which augments national expertise with international partners such as USGS Office of Surface Water and WMO HYCOS Program

National partners – **DPWH-BRS**, DA-NIA, NPC, DOST-PAGASA, DENR-MGB, NWRB, DPWH-LWUA

Quantify the effect of weather and climate on surface-water storage and routing

Actions

- ***evaluate and simulate surface-water storage and routing under scenarios of weather and climate*** – provide training to strengthen capabilities in standardized methodologies and in using appropriate state-of-the-science modelling approaches
- ***reduce uncertainty in evaluations and simulations*** – optimize hydrological and meteorological networks by adding monitoring stations at statistically-justified locations, particularly adjacent to dams, reservoirs, and critical river reaches
- ***develop numerical models for simulating dry and wet seasonal extremes on surface-water storage, interactions of surface- and groundwater, and***

downstream systems – collaboration of the national partners with international partners to develop this expertise

- ***use isotopic and conventional methods to estimate leakage and evaporation from, and siltation in, surface-water storage*** - training provided and supported by PNRI and IAEA

National partners – **DPWH-BRS**, DA-NIA, NPC, DOST-PAGASA, DOST-PNRI, DENR-MGB, NWRB, DPWH-LWUA

6.3.1.3 Flood and drought risk

GAP IN UNDERSTANDING

Because of the climate and natural setting of the Philippines, flooding is a risk in many areas of the country. Flooding can cause loss of life and livelihood, and often results in substantial costs due to the destruction of infrastructure and private property. Droughts are also a common occurrence in many areas of the Philippines and can result in severe stress on people, agriculture, and water resources.

Flood and drought risks are quantitatively understood only for limited number of Philippine river basins. The most flood-prone areas are located in Eastern Mindanao, Northern Samar, Central Luzon and the Bicol Region (The economic impact of natural disasters in the Philippines, Charlotte Benson, Overseas Development Institute, Working Paper 99, June 1997). Master Plans for flood control projects in 12 out of 18 Major River Basins were formulated in 1982. However, the number of river basins in which flood control works have actually been implemented so far is very limited (Kamoto, M., 2009).

Flood and drought risk management in the Philippines is the responsibility of DPWH, DOST-PAGASA and DA-NIA; these 3 institutions are members of the National Disaster Risk Reduction and Management Council (NDRRMC) which is the highest policy-making, coordinating, and supervising body for disaster management at the national level. The Office of Civil Defense is the executive arm of the NDRRMC, with disaster risk management as its primary responsibility. NDRRMC operations rely on the technical specialization of member agencies, and in the case of floods and droughts it relies on DOST-PAGASA for the understanding of hydro-meteorological phenomena. The meteorological network of DOST-PAGASA is capable of monitoring weather variations, amount and rate of precipitation, percent cloudiness, and typhoon tracks.

Project NOAH (National Operational Assessments of Hazards) is the DOST's response to the call of President Aquino for a more accurate, integrated and responsive disaster prevention and mitigation system, especially in high-risk areas throughout the Philippines. The project harnessed technologies and management services for disaster risk reduction activities offered by the DOST through the PAGASA, PHIVOLCS, and the DOST-ASTI, in partnership with the UP-NIGS and the UP College of Engineering.

Flood hazard is presented on the recent MGB geo-hazard maps at a scale of 1:50,000 (www.mgb.gov.ph), which are available for the entire country. Actual field surveys were undertaken by the agency and the constructed maps are available to the general public for reference.

There is substantial interest in the potential for exploiting to a greater extent the wet season floodwaters for use during the dry season and in some areas to potentially lessen the severity of the impact of droughts. Understanding this potential benefit of floodwaters becomes increasingly important as climate change begins to alter the historical climate patterns.

The current critical gap is the need to quantitatively understand the extent and characteristics of flood- and drought-prone areas in all priority basins, and the need to understand how flood waters might be harnessed to lessen the severity of droughts

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

The assessment of flood and drought risk relies heavily on hydrographic, streamflow, and precipitation data. DENR-NAMRIA is the national provider for satellite images, topographic maps, DEM, and vector streams (www.namria.gov.ph). DENR-NAMRIA and water agencies are collaborating to address their needs for digital maps, remote sensing images, GIS software, updated topographic and thematic maps, LIDAR technology, and other technologies and software. DENR-NAMRIA, NWRB, DOST-PAGASA and UP Diliman, are shifting to the use of GIS database in compiling water-related information.

DPWH-BRS is the primary agency collecting streamflow data with 249 active stations. A number of these stations are operated in coordination with other agencies, for example with DA-NIA, the DPWH-BRS stations monitored stream discharges, while with DOST-PAGASA, the DPWH-BRS stations determines the amount of precipitation in account for water supply. DOST-PAGASA currently has 4 telemetered streamflow stations in Cagayan, Bicol, Pampanga, and Agno. DOST plans to install 400 additional water level monitoring stations by 2013 to provide a better picture of the country's surface water in relation to flood.

DOST-PAGASA is the primary provider of precipitation data with 144 current stations and 600 additional stations to be installed by 2013. Some additional data are collected by DA, MMDA, and perhaps the universities.

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to quantitatively understand the extent and characteristics of flood- and drought-prone areas in all priority basins, and the need to understand how flood waters might be harnessed to lessen the severity of the impact of droughts***

Ensure the routine collection of streamflow and precipitation data used for flood and drought analysis

Actions – to include:

- ***evaluate and reaffirm the routine collection and collation of streamflow and precipitation data used for flood forecasting*** – responsibility of DPWS-BRS, PAGASA, and station partners along with the agencies responsible for operation of dams
- ***assess and optimize hydrological networks with particular emphasis on flood analysis*** – provide training which augments national expertise with international partners such as USGS Office of Surface Water and WMO HYCOS Program

National partners – **DPWH-BRS, DPWH-FCSEC, DOST-PAGASA,** DA-NIA, DENR-MGB, NWRB, DPWH-LWUA

Interpret streamflow and precipitation data to refine understanding and forecasting capabilities for floods and droughts in priority river basins

Actions

- ***conduct advanced analysis of flood and drought risk for resource management***– provide training tailored to the needs of DENR-MGB and other agencies to conduct these analyses at appropriate scales

National partners – **DPWH-BRS, DPWH-FCSEC, DOST-PAGASA**, NWRB, RBCO, DA-NIA, NPC

6.3.2 Groundwater

The discussion of the gaps in hydrological understanding of Groundwater is grouped by the elements of a comprehensive water-resource assessment as presented in Table 6. These elements are Hydrogeological setting, Aquifer characteristics, and Groundwater storage and flow.

Water supply	Groundwater	**Hydrogeological setting** Surface and subsurface geology, aquifer thickness and extent, resistive layer thickness and extent
		Aquifer characteristics Porosity, hydraulic conductivity, transmissivity, anisotropy, storativity
		Groundwater storage and flow Saturated thickness, water levels, hydraulic gradients

Table 6: Groundwater elements of a comprehensive water resource assessment

6.3.2.1 Hydrogeological setting

6.3.2.1.1 Geology

GAP IN UNDERSTANDING

The MGB has published maps of surface geology for the whole country at scales of 1:1,000,000 in 1962 and 1:2,500,000 in 2010. An example of a surface geology map of Metro Manila is provided in Figure 13. In addition, surface geological maps at a scale of 1:50,000 have been produced covering 40% of the country. Published maps cover 213 quadrangles and unpublished maps available in reproducible and digital format cover 188 quadrangles out of the total 970 quadrangles for the entire country. Most of the remaining 60% not covered by published and unpublished geologic maps had been covered by field surveys with reports and maps. The compilation of these reports and maps and field validation/mapping is on-going to cover the entire country. MGB has primary responsibility in the Philippines for preparing and publishing maps of surface geology, but some geologic maps have also been prepared by other government agencies such as the Philippine Institute of Volcanology and Seismology (PHIVOLCS), Department of Energy (DOE), academe, and the private sector for specific purposes.

MGB, through its recently completed 1:50,000 scale Geohazard Mapping and Assessment Project (GMAP), provides a digital version of the geohazard maps that contain various layers of images outlining the Philippines' topographical, geological and coastal features. Figure 14 shows a map of geo-hazards in the Philippines. Of the 1,634 cities/municipalities that had been assessed throughout the country, 1,512 were subjected to an actual field survey, while 106 cities/municipalities were surveyed through remote sensing techniques and 16 were already assessed prior to the formal start of the program in 2006. In 2011 geohazard mapping at a scale of 1:10,000 has begun with a target date of completion by 2014.

In addition to surface geology maps published by MGB, soil maps have been produced beginning in 1980 by BSWM for the entire Philippines at a scale of 1:1,000,000 and for 58 provinces at varying scales of 1:100 000 to 1:500 000. Figure 15 shows a map of soils in the Philippines. However, these maps were prepared using geologic information available at the time and would benefit from revision using more current information.

Within the surface geology maps of MGB are general cross sections of lithology, but these are to present the relationship of rock units and not to provide information of subsurface geology. Even though the understanding of sub-surface geology is generally limited in the Philippines, somewhat greater understanding exists in a few areas where specific studies have been conducted. However, there is a great need to increase the understanding of subsurface geology (stratigraphy, lithology, structural features).

The current critical gap is the need to understand subsurface geology with sufficient detail and scope to support hydrogeological investigations.

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

There are a number of agencies which collect surface and borehole geological data to meet their individual missions. Other agencies collect geological and lithological data during the process of drilling water wells (Table 3). Foremost among these agencies is DPWH-LWUA which holds data on greater than 10,000 water wells. A LWUA web-site provides location information but limited other data (http://122.54.214.222/). Unfortunately, information on lithology and well construction for this extensive data set of wells is available only in paper copy. The DA-NIA holds some well data that includes some georesistivity and lithologic data. The NWRB holds the lithologic logs of water permittees; these logs now number up to 19,743 (NWRB, Summary of water permit grantees, as of December 2011). The DENR-MGB holds lithological and geophysical data coming from exploratory and other project wells. With the exception of the LWUA online database providing primarily location information, all the lithological and geological data are available in hard copy only.

SPECIFIC REMEDIES AND INVESTMENTS – discussed together with the following section on Aquifer Thickness and Extent

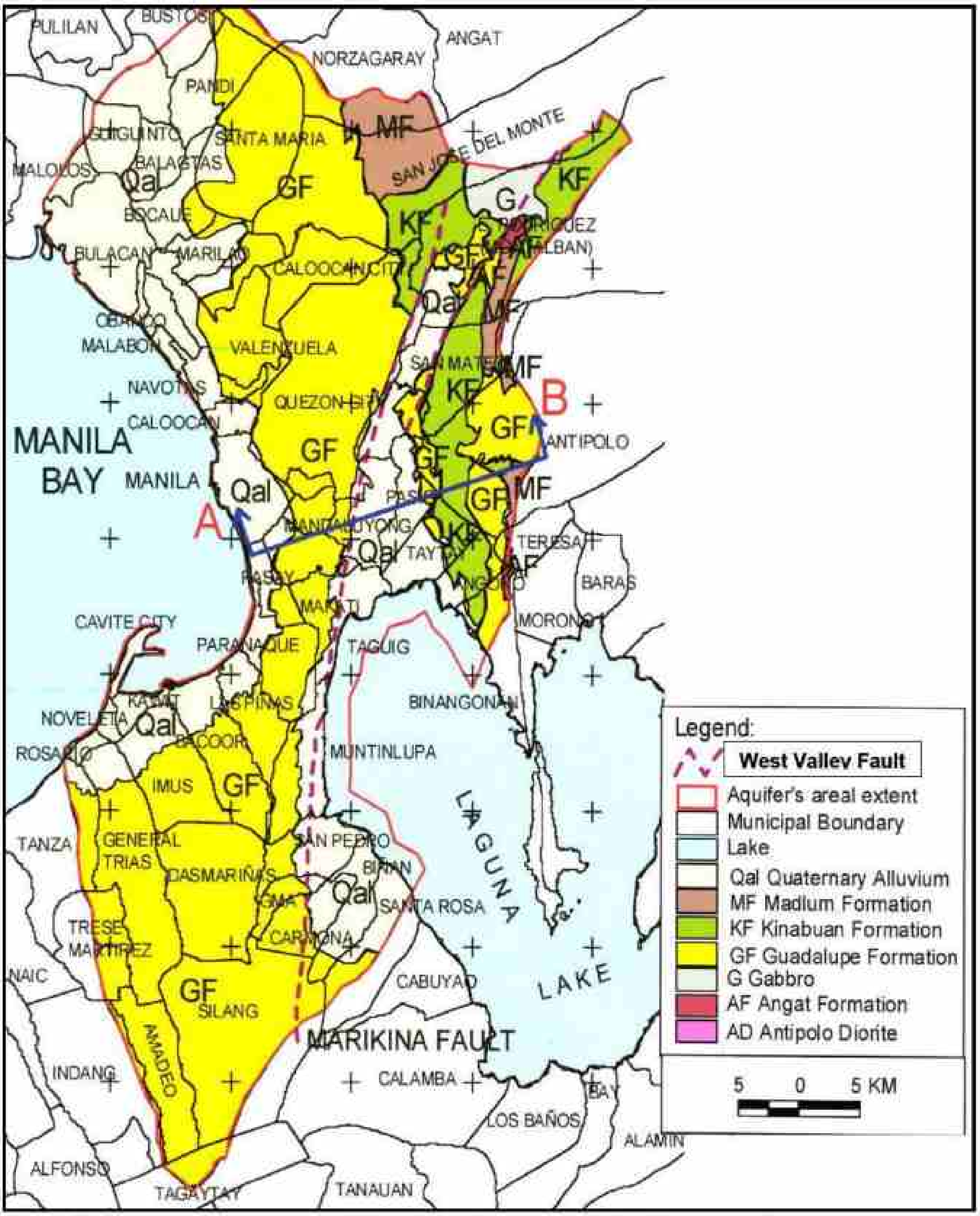


Figure 13: Surface Geology Map of Metro Manila (Source: Water Resources Assessment for Prioritized Critical Areas of Metro Manila, 2004)

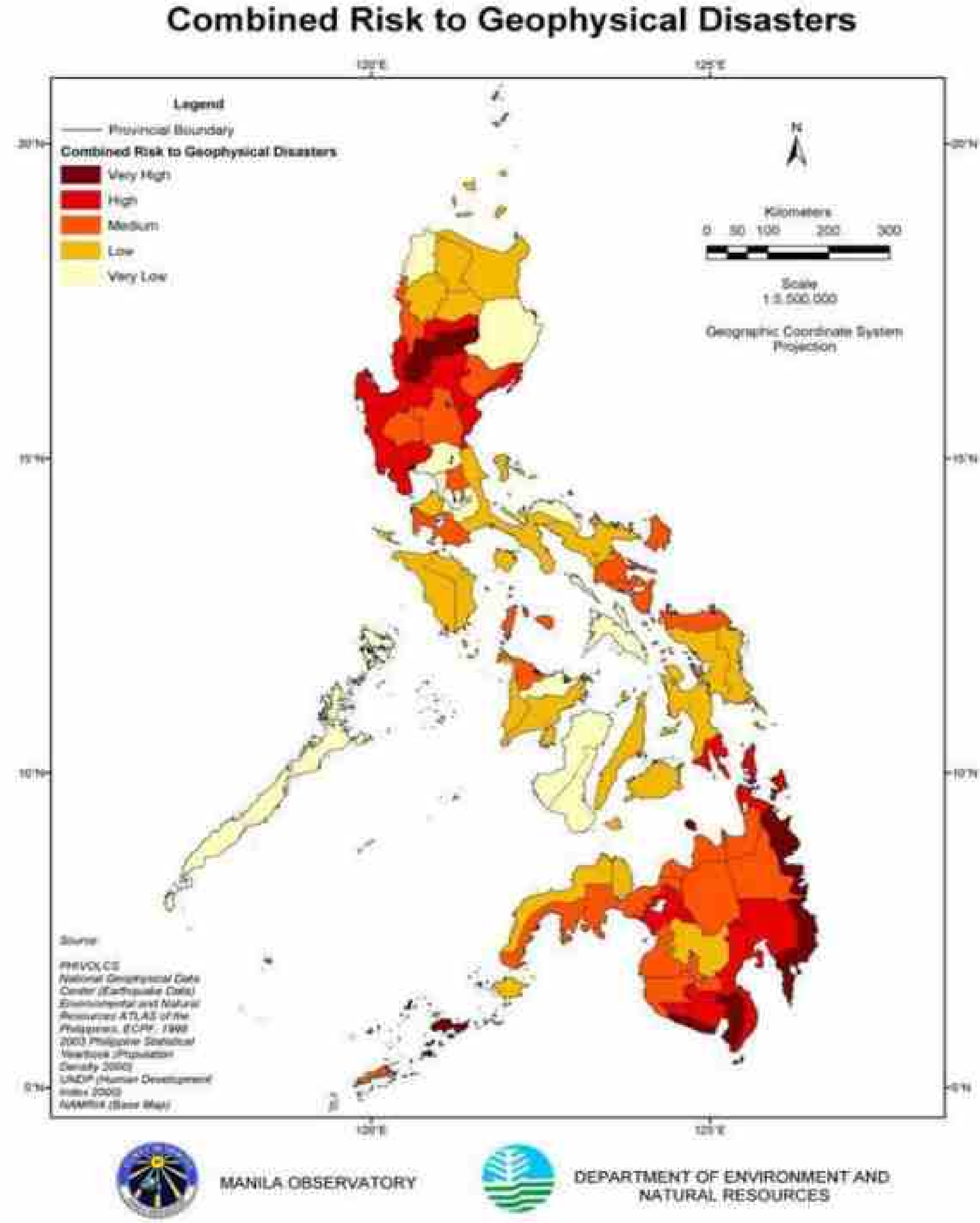


Figure 14. Map of geo-hazards in the Philippines (ref- http://www.maps.nfo.ph/philippines-combined-risk-to-geophysical-disasters/)

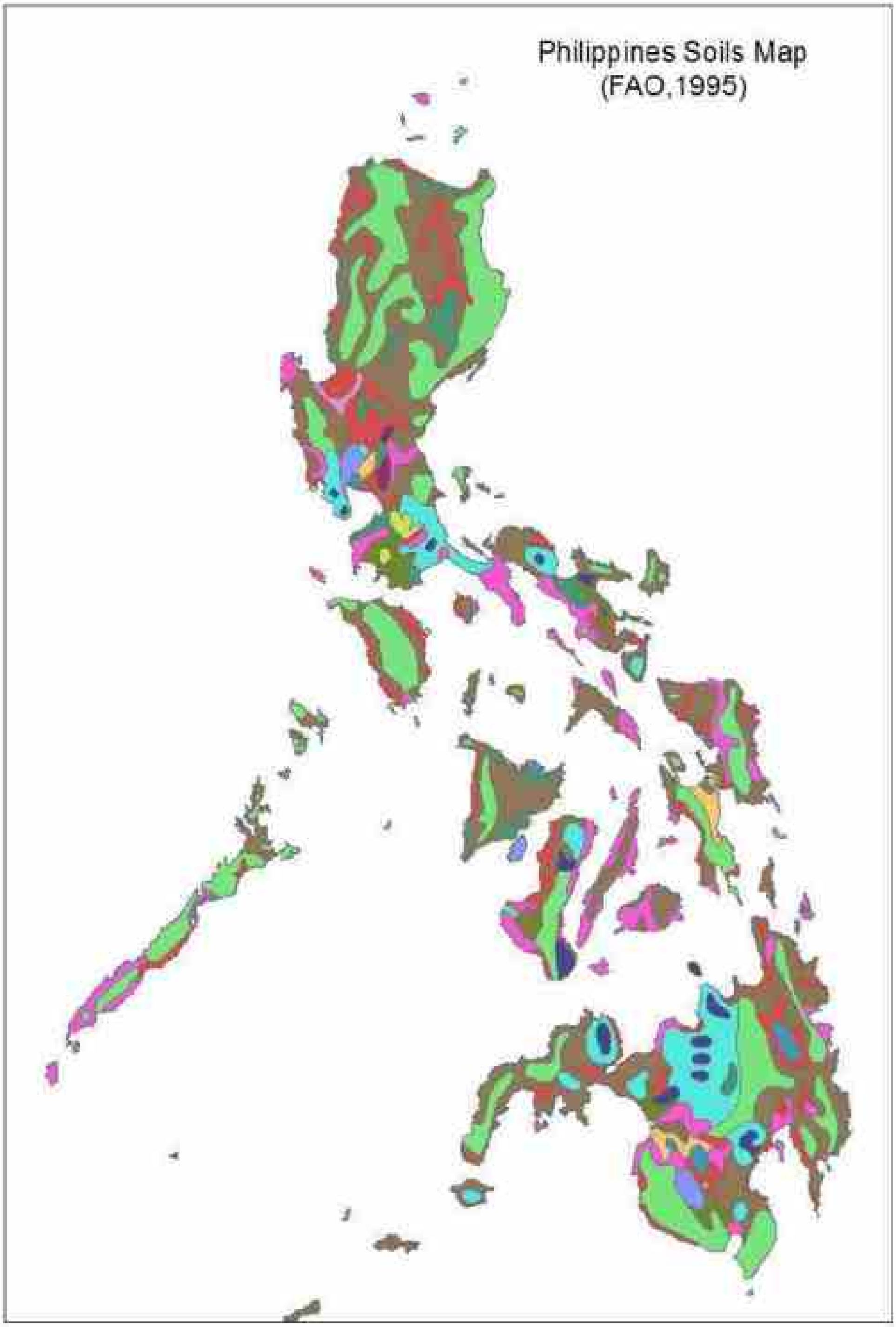


Figure 15. Map of soils of the Philippines

6.3.2.1.2 Aquifer thickness and extent

GAP IN UNDERSTANDING

There is an incomplete understanding of the thickness and extent of Philippines aquifers. Four major groundwater basins are recognized (Cagayan, Central Luzon, Agusan, Cotabato), however their thickness and extent are not known with sufficient detail to meet water-supply management needs and to ensure sustainability. In addition, the many smaller aquifers that are critically important to water supply are not understood in sufficient detail. Maps of Philippine aquifers were completed in 1982 and modified in 1997 by the DENR-MGB. These maps are produced at a scale of 1:2,500,000 and cover the entire country. Figure 16 shows the primary aquifers as shown in the Groundwater Availability Map for Water Resources Region III. The maps are based on the hydrogeological and groundwater assessments surveys, targeted groundwater studies, well and geologic data, and other investigations made in different areas of the Philippines since the early 1960's.

The hydrogeological and groundwater assessment surveys were initiated by DENR-MGB in the 1960's as part of a program to assess groundwater availability in the entire country. The program consists mainly of collection of well and spring data, meteorological and river discharge information, geologic mapping and groundwater sampling. The surveys were conducted covering Batangas and Zambales provinces, Cagayan, Agusan, and Bicol River Basins, and Panay Island. This program did not have the equipment or funds to conduct in-depth studies to better understand regional and local aquifers. By 1990's, the program was no longer a high priority of DENR-MGB and became largely idle.

In 2011 the DENR-MGB began the **Groundwater Resources and Vulnerability Assessment of the Philippines** to address the deficiencies in understanding the nation's aquifers and groundwater resource. Agencies cooperating in the assessment are NWRB, DPWH-LWUA, DPWH-MWSS, and LGU's. This assessment is an ambitious undertaking to compile existing data across agencies and conduct new work to include remote sensing, field surveys, and other data collection, with objectives to:

- Quantify the groundwater resource and provide:
  - National coverage of hydrogeological maps at 1:50,000 and 1:10,000,
  - National coverage of groundwater vulnerability maps at 1:50,000 and 1:10,000,
- Quantify groundwater flow, aquifer drawdown, and saltwater intrusion
- Delineate zones of groundwater vulnerability and recharge zones
- Provide the basis for policy to be used in groundwater regulation
- Develop maps and reports to document the work and interpretations

- Provide means to make data and information available to end users and stakeholders for management and protection of the groundwater resource

The current critical gap is the need to understand aquifer thickness and extent with sufficient detail and scope to fully assess the groundwater resource of the Philippines.

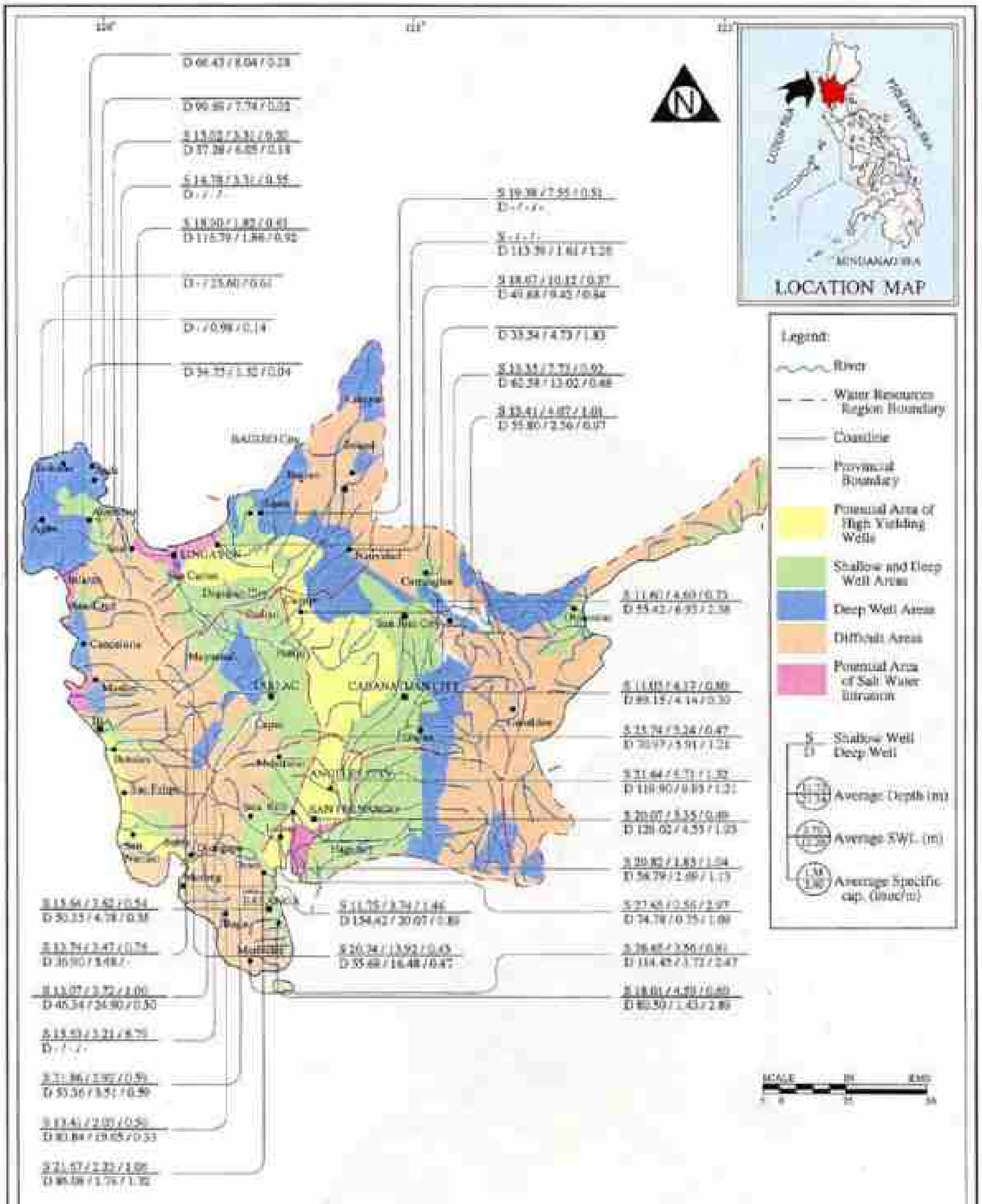


Figure 16: Groundwater Availability Map for Water Resources Region III
Source: Master Plan Study on Water Resources in the Republic of the Philippines

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

The objectives of the DENR-MGB **Groundwater Resources and Vulnerability Assessment** include compilation and synthesis of data across the collaborating agencies (NWRB, DOH-LWUA, DPWH-MWSS, and LGUs). There is a critical need to strengthen the capability of DENR-MGB and collaborating agencies to effectively achieve these data compilation and synthesis objectives, particularly in developing a groundwater resources inventory database which builds on the concept and framework of the National Water Information Network.

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand subsurface geology, and aquifer thickness and extent, in sufficient detail and scope to support hydrogeological investigations and fully assess the groundwater resource of the Philippines***

Collect appropriate and adequate geological and hydrogeological data

Actions

- ***strengthen expertise to successfully implement the* Groundwater Resources and Vulnerability Assessment of the Philippines Project** (DENR-MGB led, started in 2011) – provide training in:
    - broad aspects of hydrogeological data compilation and collection,
    - employing the most efficient and effective field methods and techniques to meet data collection objectives
- ***ensure the collection, compilation, and availability of appropriate data to evaluate water quantity*** – to include conversion of selected historical data to digital data
- ***ensure the interchangeability of data stored at each collecting agency/institution by adopting a uniform data format for storage and retrieval***

National partners – **DENR-MGB**, NWRB, DPWH-MWSS, DENR-EMB, DOH-LWUA/WDs, LGUs

Interpret geological and hydrogeological data for development of detailed national and regional maps of aquifer extent and thickness

Actions

- ***strengthen expertise to successfully implement the* Groundwater Resources and Vulnerability Assessment of the Philippines Project** (DENR-MGB led, started in 2011) – provide training in:
    - enhancing data processing and management systems and databases to support NWIN objectives,
    - interpreting hydrogeological data to evaluate aquifer setting,

- applying appropriate state-of-the-science approaches to meet project output objectives, specifically the groundwater resources maps and inventory database (building on the concept and framework of the NWIN)
- constructing numerical groundwater-flow models to manage data and simulate flow in 3-dimensions.

National partners – **DENR-MGB**, NWRB, DPWH-MWSS, DENR-EMB, DPWH-LWUA/WDs, LGUs

6.3.2.2 Aquifer characteristics

GAP IN UNDERSTANDING

The Philippines has limited understanding of the physical characteristics of regional or local aquifers which is a prerequisite for conducting a comprehensive assessment of water availability. Characteristics critical to this understanding include aquifer porosity, hydraulic conductivity, transmissivity, anisotropy, and storativity; however, most of the aquifers in the Philippines have not been adequately mapped with respect to these physical characteristics. The current understanding of physical characteristics of primary aquifers is generally limited to lumping aquifers into three (3) categories: highly productive, productive, and possible aquifer. A hydrogeology map for Water Resources Region III is presented in Figure 17.

One of the motivations for the **Groundwater Resources and Vulnerability Assessment Program in the Philippines,** initiated in 2011, is the requirement of the Clean Water Act of 2004 for the "the preparation and publication of a national groundwater vulnerability map". The assessment program of DENR-MGB intends to provide the critical understanding of physical characteristics of the Philippines aquifers necessary to create the groundwater vulnerability map. Indeed, the groundwater vulnerability map is a specified product of the assessment program. Additionally, the groundwater resource and vulnerability assessment provides the critical foundation for management and policy decisions. Meeting the ambitious goals of the assessment program is dependent on the support and involvement of the collaborating Philippine agencies and the assistance of hydrogeological experts.

The current critical gap is the need to understand aquifer characteristics in sufficient detail to effectively conduct resource supply assessments and management activities.

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

Data and information on the physical characteristics of aquifer information include lithologic core and drill cuttings, geophysical borehole logs, and aquifer pumping tests. Generally the collection of these data are limited to observations made by DPWH-BRS, DPWH-MWSS, DA-NIA, LWUA-WDs, the Rural Water Supply Office of the DPWH, and private well drillers. The NWRB collects these data from applicants for water rights permits. Various agencies involved in the water sector have their own data archives for these data, including MGB. In general MGB relies on other agencies (public and private) for data and information on aquifer characteristics it uses for its groundwater assessment program.

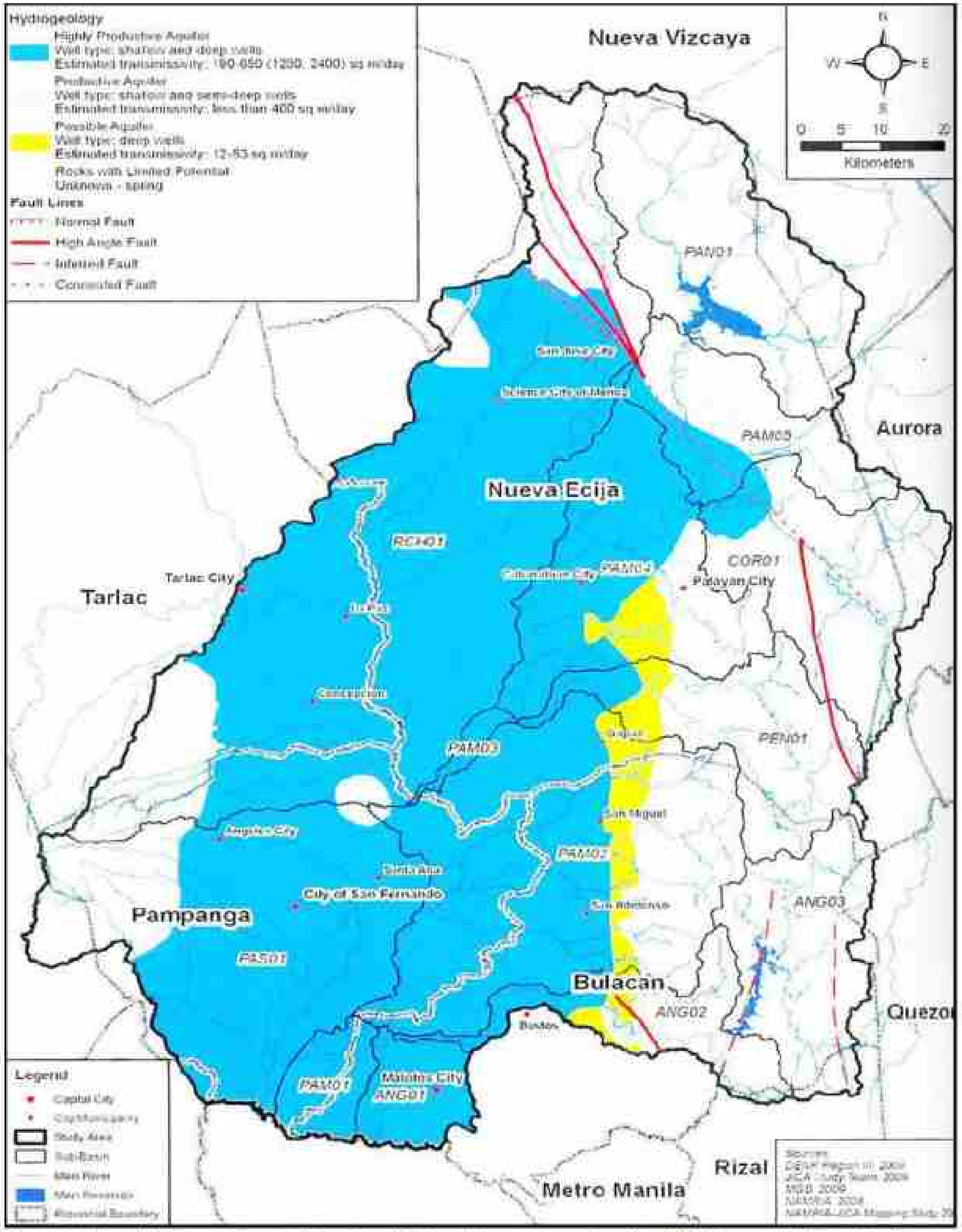


Figure 17: Hydrogeology Map for Water Resources Region III (Source: The Study on Integrated Water Resources Management for Poverty Alleviation and Economic Development in the Pampanga River Basin)

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand aquifer characteristics in sufficient detail to effectively conduct resource supply assessments and management activities.***

Collect appropriate and adequate physical and hydraulic data from aquifers

Actions

- ***strengthen expertise to successfully implement the* Groundwater Resources and Vulnerability Assessment of the Philippines Project** (DENR-MGB led, started in 2011) – provide training in:
  - broad aspects of hydrogeological data compilation and collection,
  - employing the most efficient and effective field methods and techniques to meet data collection objectives

National partners – **DENR-MGB**, NWRB, DPWH-MWSS, DENR-EMB, DOH-LWUA/WDs, LGUs

Interpret geological and hydrogeological data for development of detailed national and regional maps of aquifer characteristics

Actions

- ***strengthen expertise to successfully implement the* Groundwater Resources and Vulnerability Assessment of the Philippines Project** (DENR-MGB led, started in 2011) – provide training in:
  - enhancing data processing and management systems and databases to support NWIN objectives,
  - interpreting hydrogeological data to evaluate aquifer setting and characteristics,
  - applying appropriate state-of-the-science approaches to meet the project output objectives, specifically the groundwater resources maps and inventory database (building on the concept and framework of the NWIN)
  - constructing numerical groundwater-flow models to manage data, and to represent aquifer characteristics in 3-dimensions.
- ***interpret geological and hydrogeological data to develop maps of aquifer characteristics at appropriate national and regional scales***

National partners – **DENR-MGB**, NWRB, DPWH-MWSS, DENR-EMB, DPWH-LWUA/WDs, LGUs

6.3.2.3 Groundwater storage and flow

6.3.2.3.1 Groundwater storage

GAPS IN UNDERSTANDING

The current understanding of storage volume of Philippine groundwater aquifers is very generalized, and is estimated to total about 251 km^3 of water (NWRB, 2001, JICA Master Study on Water Resources Management in the Republic of the Philippines, 1998). The average annual renewable groundwater potential is estimated to be 20.2 km^3/year (refer to Table 1). However, the understanding of groundwater storage and flow must be improved to support national planning and management as well as the inclusive economic development goal of the *Philippine Development Plan 2011-2016.*

The preparation of the Groundwater Availability Map of the Philippines started in the later part of 1970s through a United Nations (UN) and International Association of Hydrogeologists (**IAH**) initiative to standardize the legends in the preparation of the country's hydrogeologic maps. A simplified Groundwater Availability Map was finalized in 1980s using all available geologic and hydrogeologic data (Figure 16). The groundwater basins of the Philippines are relatively small and as a result, information is difficult to represent at the standard 1:2,500,000 map scale. Currently, the topographic sub-basin delineation is used to define groundwater divides in the Philippines, even though surface and groundwater divides can differ substantially. The assumption that surface and groundwater divides are coincident can introduce significant uncertainty in assessing the groundwater resource of a basin, and remains an important gap in current understanding.

The National Water Resources Council (now the NWRB) conducted a rapid assessment of the groundwater resources for the 73 provinces of the country. The primary purpose of the assessment was to come up with a quick assessment of the country's groundwater resources to provide a comprehensive and workable guide for water supply planners/designers and local officials in setting development priorities for water supply projects in rural communities. With this assessment, areas were mapped on a regional scale and were delineated for potential areas of high yielding wells, shallow well areas, deep well areas, difficult areas, or areas with salt water intrusion. The granting of water permits by the NWRB is based on this unpublished groundwater resources assessment report, which included hydrogeological maps specifying safe yield and mining yield based on the geology of the area and the hydrogeologic investigation.

As a follow up to the national safe yield estimates for groundwater conducted in 1980's, the NWRB has conducted detailed groundwater assessments for critical areas like Metro Manila and nearby areas and Metro Cebu (2004). Figure 18 shows the depth to groundwater surface map for Metro Manila. The generated maps (piezometric maps, salinity maps) and other outputs were used by NWRB in formulating policies for groundwater management in the study area. Assessment of other critical areas needs to be conducted, and the resource assessment of all critical areas will benefit greatly from applying appropriate state-of-the-science hydrological techniques. These techniques include numerical modelling and the broader application of isotope techniques. There is a need to build capacity of the NWRB staff in using these methods/techniques.

There are on-going groundwater assessments in local areas that are presently experiencing problems in finding viable water supply particularly in the nine critical areas identified in the Master Plan Study on Water Resources in the Philippines. For example, a groundwater resources assessment for prioritized critical areas of Metro Manila and Metro Cebu had been prepared and the resulting piezometric head and water quality data are currently being used as a tool for regulation (Metro Manila and Metro Cebu Groundwater Assessment, Roberto S. Clemente, R.P. Abracosa, C.C. David, A. B. Inocencio, and G.Q. Tabios, Special Paper Series No. 2001-05, Feb 2001, Philippine Institute for Development Studies). A follow-up study conducted by the NHRC with JICA constructed and calibrated numerical groundwater-flow models and refined the water balance for Metro Manila. This has provided a more accurate assessment of the water resource.

The flow of groundwater in regional and local aquifers is known only in a general sense, based on limited information on saturated thickness, groundwater-level fluctuations, hydraulic gradients, and hydraulic properties. Some projects however have resulted in a high degree of understanding for local areas, such as the assessments made for Metro Manila and Metro Cebu mentioned above In addition, isotope hydrology techniques have been applied by the NEPC and DOST-PNRI through specific projects to better understand aquifer processes in some water-critical areas in the Philippines including, Metro Manila, Bulacan, Pampanga, Cebu, Bacolod City and Davao City. Stable isotope and tritium data generated from these studies formed part of the IAEA Atlas of Isotope Hydrology for Asia and the Pacific

The current critical gap is the need to understand the quantity and flow of available groundwater and the effect of extreme weather and climate on groundwater storage and flow

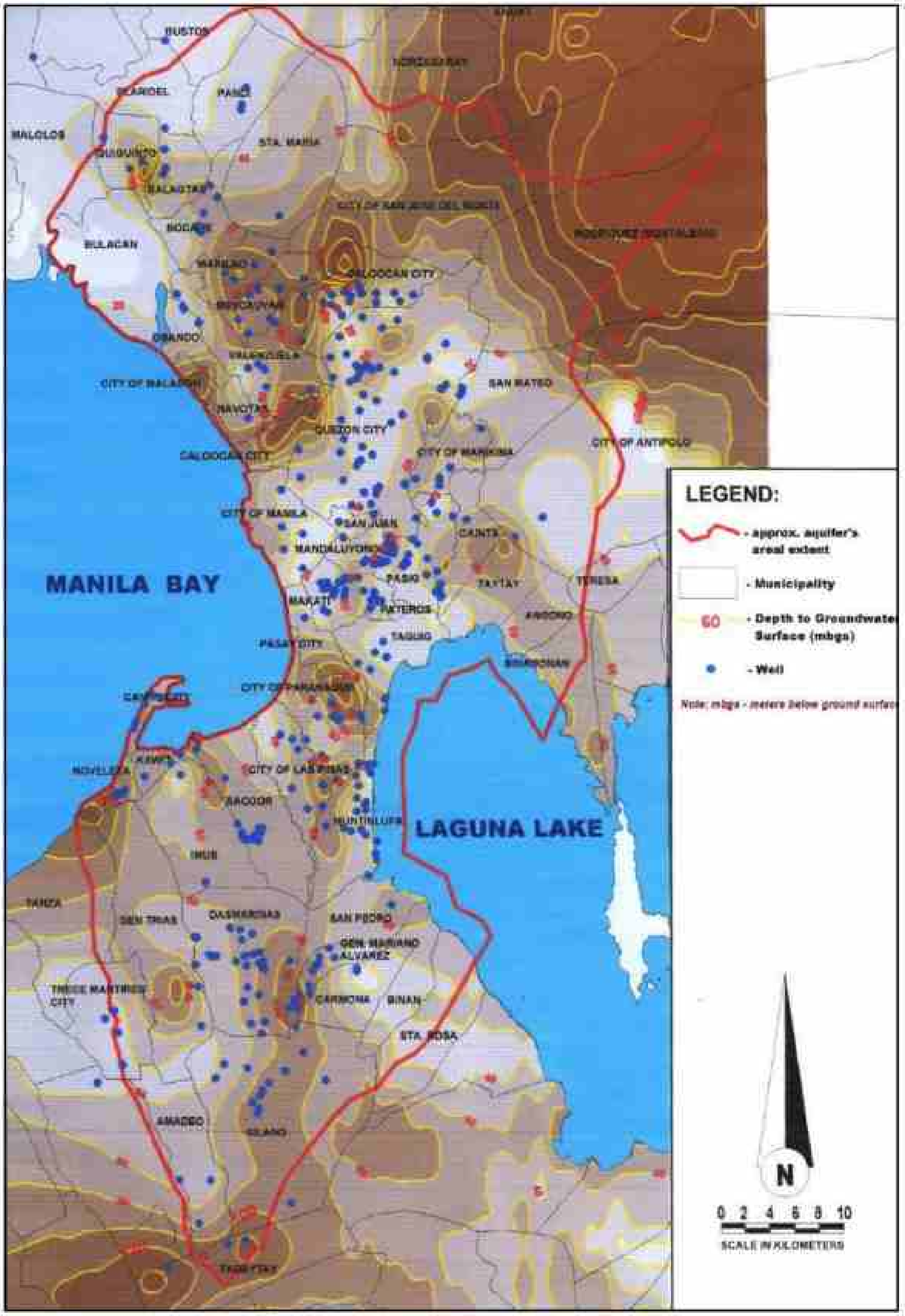


Figure 18: Depth to Groundwater Surface map for Metro Manila

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

There is no national network of monitoring wells in the Philippines dedicated to collecting times-series data for water levels. Individual agencies collect groundwater-level and other data according to their specific mission, but data are usually single measurements or collected over a short-term. Figure 19 presents a map showing locations of groundwater monitoring station at Mt. Pinatubo in Region III. Even though a national network is not currently defined, Water District wells that are under the authority of LWUA, along with wells from other agencies could be identified to form the basis for a monitoring network which could be officially implemented and funded.

The NWRB conducts groundwater resource availability analysis for water rights permits using values for estimated safe yield developed in the 1980s. A critical need is for the collection of present-day data (saturated thickness, groundwater-level fluctuations and trends, hydraulic gradients) to update the historical data, to allow for re-evaluation of the safe yield estimates, and for the application of advanced methods to calculate groundwater flow and availability.

Figure 19. Example of map showing locations of groundwater monitoring stations at Mt. Pinatubo, Region III (*Source: Improvement of National Water Data Collection Network – Groundwater Monitoring*)

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand the quantity and flow of available groundwater and the effect of extreme weather and climate on groundwater storage and flow***

Collect appropriate and adequate hydrogeological data

Actions

- ***strengthen expertise to successfully implement the*** **Groundwater Resources and Vulnerability Assessment of the Philippines Project** (DENR-MGB led, started in 2011) – through training to support:
  - broad aspects of hydrogeological data compilation and collection,
  - employing the most efficient and effective field methods and techniques to meet data collection objectives
- ***develop and implement a Reconnaissance Sampling Program for chemical and isotopic analysis of groundwater*** – sampling program designed and implemented in collaboration with PNRI and IAEA; training provided and supported by PNRI and IAEA
- ***assess and optimize the groundwater monitoring network*** - provide training which augments national expertise with international partners such as USGS Office of Groundwater and WMO HYCOS Program; implement a national groundwater monitoring scheme to observe groundwater fluctuations and trends

National partners – **DENR-MGB**, NWRB, DPWH-MWSS, DOST-PNRI, DENR-EMB, DPWH-LWUA/WDs, LGUs

Interpret geological and hydrogeological data for development of detailed national and regional maps of groundwater resource availability

Actions

- ***strengthen expertise to successfully implement the*** **Groundwater Resources and Vulnerability Assessment of the Philippines Project** (DENR-MGB led, started in 2011) – through training to:
  - enhance data processing and management systems and databases to support NWIN concepts and objectives,
  - interpret hydrogeological, chemical, and isotopic data to evaluate groundwater resource availability,
  - apply state-of-the-science approaches to meet the project output objectives, specifically the groundwater resources maps and inventory database (building on the concept and framework of the NWIN),
  - construct numerical groundwater-flow models to manage data and simulate aquifer storage and flow in 3-dimensions.

National partners – **DENR-MGB**, NWRB, DPWH-MWSS, DOST-PNRI, DENR-EMB, DOH-LWUA/WDs, LGUs

6.3.3 Water Budget

Water budget describes the movement of water between the atmosphere, the land surface, and aquifers. Quantifiably understanding the water budget is essential for the effective management of national water resources. The discussion of gaps in hydrological understanding of the Water Budget is grouped by the elements of a comprehensive water-resources assessment as presented in Table 7.

Water supply	Water budget	**Precipitation** Point precipitation, areal/regional precipitation, extreme events
		Runoff and recharge to groundwater Runoff coefficients, infiltration and recharge rates
		Evapotranspiration Temperature, point evaporation, meteorological data
		Surface and groundwater interaction Hydraulic gradients, groundwater discharge, seepage to groundwater

Table 7. Water Budget elements of a comprehensive water resource assessment

6.3.3.1 Precipitation

GAP IN UNDERSTANDING

The Philippines has a good understanding of the climate and weather affecting the islands. Climate and weather, of course, provide the precipitation that is the origin of the surface and groundwater resource. PAGASA has the primary responsibility for developing the national understanding in precipitation and models and through the study of extreme events. Figure 20 presents a map showing the distribution of precipitation in Water Resources Region II. However, the agency lacks enough modern equipment and sufficient number of strategically located stations to adequately understand the temporal and spatial variability of weather and climate, as well as developing systems models and analyses for weather prediction and risk assessments. PAGASA could be an important provider of specialized assistance at specific locations or in instances where water-resource supply or management questions arise, especially if adequate resources and logistics are supplied. Currently the temporal and spatial understanding of precipitation and storm events is inadequate considering the size and variability of the Philippine landscapes and climates, and this significantly hampers the ability to provide meaningful predictions of extreme events and risk assessment.

The current critical gap is the need to have an appropriately advanced level of understanding of the spatial and temporal distribution of precipitation and of extreme events for early warning forecasting and risk assessments

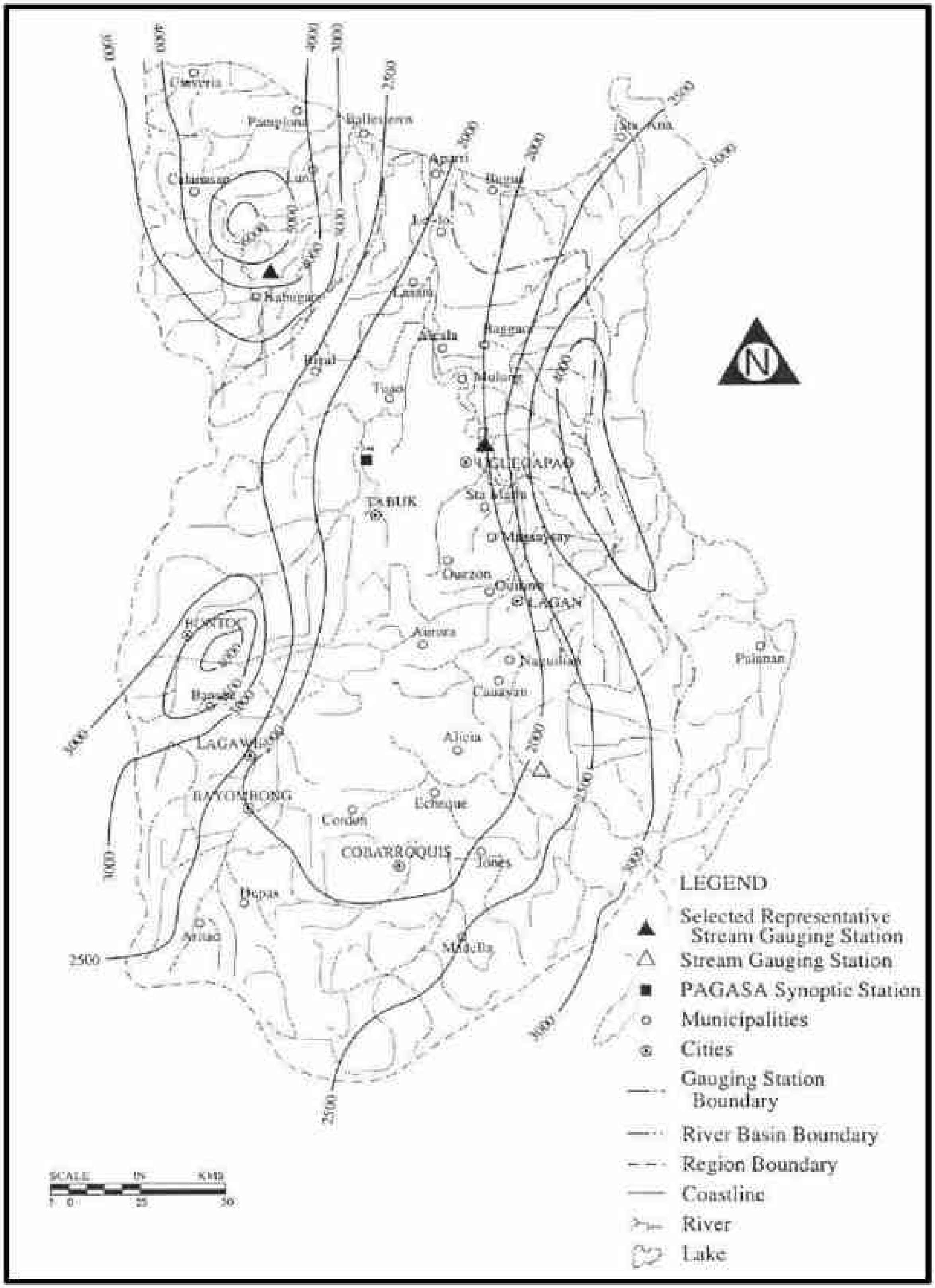


Figure 20: Map showing the distribution of precipitation for Water Resources Region III. (Source : Master Plan Study on Water Resources in the Republic of the Philippines)

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

The 600 precipitation monitoring stations that are expected to be installed in 2012 by DOST are expected to substantially improve the density of data that can be used to refine the understanding of the precipitation component of the water budget. There are 69 automatic weather stations from PAGASA and 76 ASTI automatic weather stations. Figure 21 shows the locations of synoptic stations in the Philippines.

Figure 21: Philippine Synoptic Stations (Source: PAGASA)

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to have an appropriately advanced level of understanding of the spatial and temporal distriution of precipitation and of extreme events for early warning forecasting and risk assessments***

Collect appropriate and adequate precipitation and other meteorological data

Actions

- ***evaluate and reaffirm the routine collection and collation of precipitation and other meteorological data*** – responsibility of PAGASA and other with stations
- ***develop and implement a Reconnaissance Sampling Program for chemical and isotopic analysis of precipitation***– sampling program designed and implemented in collaboration with PNRI and IAEA; training provided and supported by PNRI and IAEA
- ***establish a national precipitation monitoring network incorporating active sites of the various agencies*** - select sites and attributes using the criteria of the National Water Data Collection Network (NWDCN) for establishing monitoring stations
- ***assess and optimize hydrological networks*** – provide training which augments national expertise with international partners such as WMO and CRCSI Australia
- ***harmonize the precipitation data collected by different agencies*** – will require the establishment and support of a data-sharing and data serving system serving Philippine water agencies

National partners – **DOST-PAGASA**, DPWH-BRS, DOST-PNRI, NWRB, RBCO, DA-NIA, NPC

Reduce the uncertainty in estimates of precipitation for early-warning forecasting and risk assessments

Actions

- ***strengthen national capacity to develop precipitation statistics at national and appropriate local scales*** - provide training in appropriate state-of-the-science methods, potentially to include:
  - WMO HYCOS Program, perhaps in conjunction with the South East Asia-HYCOS (in early concept phase)
- ***establish parameters for maintenance and revision of precipitation statistics*** – through collaboration of national partners

National partners -**DOST-PAGASA**, RBCO, DA-NIA, NPC, NWRB

6.3.3.2 Runoff and recharge to groundwater

GAP IN UNDERSTANDING

The Philippines has only a general understanding of precipitation runoff and recharge to groundwater. Runoff and groundwater recharge in particular are very difficult to measure directly, which results in large uncertainties in these water budget components.

The MGB has the primary responsibility for developing the national understanding of groundwater recharge and to present this understanding in maps of recharge potential and average annual recharge. The current understanding of recharge at a national scale is reflected in the interpretation of groundwater availability as presented in the Groundwater Availability for Water Resources Region III (Figure 16). In order to fully support the national need to assess and manage the groundwater resource the Philippines must increase the understanding of runoff and recharge at appropriate scales.

Isotope hydrology techniques have been applied by the NEPC and DOST-PNRI to better understand recharge to groundwater, aquifer processes, and surface water-groundwater interaction. These techniques have been applied in some water-critical areas in the Philippines including Metro Manila, Bulacan, Pampanga, Cebu, Bacolod City and Davao City. Stable isotope and tritium data generated from these studies are included in the IAEA Atlas of Isotope Hydrology - Asia and the Pacific. These isotope hydrology techniques should be better utilized in assessing national groundwater resources through more fully understanding of the origin of recharge and residence time of groundwater

The critical current gap is the need to understand runoff and recharge processes, origin of recharge, and residence time of groundwater at national and appropriate local scales

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

The Philippines has no active programs or studies that are providing insight into runoff and recharge to groundwater. The extent of data holdings is not well known, and data that may exist are not compiled in a way useful for estimating runoff and recharge. Data and expertise that has been developed in local studies could be usefully applied in a national evaluation, but no efforts are currently being made for national studies.

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand runoff and recharge processes, origin of recharge and residence time of groundwater at national and appropriate local scales***

Collect appropriate and adequate data underlying estimates of runoff, groundwater recharge, and residence time

Actions

- ***evaluate and reaffirm the routine collection and updating of data used to estimate runoff, groundwater recharge, evapotranspiration, residence time including precipitation, streamflow, surface runoff, meteorological data, infiltration rates, groundwater levels***
- ***integrate and harmonize these data*** - will require the establishment and support of a data-sharing and data-serving system for water agencies
- ***evaluate and improve quality of data used to estimate runoff, groundwater recharge, and evapotranspiration*** – provide training on developing and implementing a Quality Assurance Plan for collection of these data
- ***develop and implement a Reconnaissance Sampling Program for chemical and isotopic analysis of precipitation, surface and groundwater*** – sampling program designed and implemented in collaboration with PNRI and IAEA; training provided and supported by PNRI and IAEA

National partners – **DENR-MGB**, NWRB, DOST-PNRI, DPWH-LWUA, DOST-PAGASA, and DA-BSWM

Reduce uncertainty in estimates of runoff, groundwater recharge, and residence time

Actions

- ***strengthen national capacity to reduce uncertainty in estimates of runoff, groundwater recharge, and residence time*** – provide training on standardized methodologies and numerical modelling approaches

National partners – **DENR-MGB**, NWRB, DOST-PNRI, DPWH-LWUA, DOST-PAGASA, and DA-BSWM

6.3.3.3 Evapotranspiration

GAP IN UNDERSTANDING

The Philippines has a generally good understanding of evapotranspiration (ET) from the land surface. ET is one of the largest components of the water budget and is generally difficult to measure directly. However ET can be estimated using meteorological, remotely sensed, and land-cover data.

The DA has primary responsibility to develop the national understanding of ET and models of ET from different land use and vegetation cover. Figure 22 shows the Philippine mean annual potential evapotranspiration. ET maps are available for different crops (e.g. rice and corn) and farming practices for most agricultural areas. Understanding of ET from non-agricultural areas is somewhat less developed because the need has been less critical. The size and variability of the Philippine landscapes and climates suggest that the use of remotely sensed data and advanced approaches will be critical to developing this national understanding of ET.

The critical current gap is the need to understand evapotranspiration in sufficient detail to support water-resource assessments and management needs

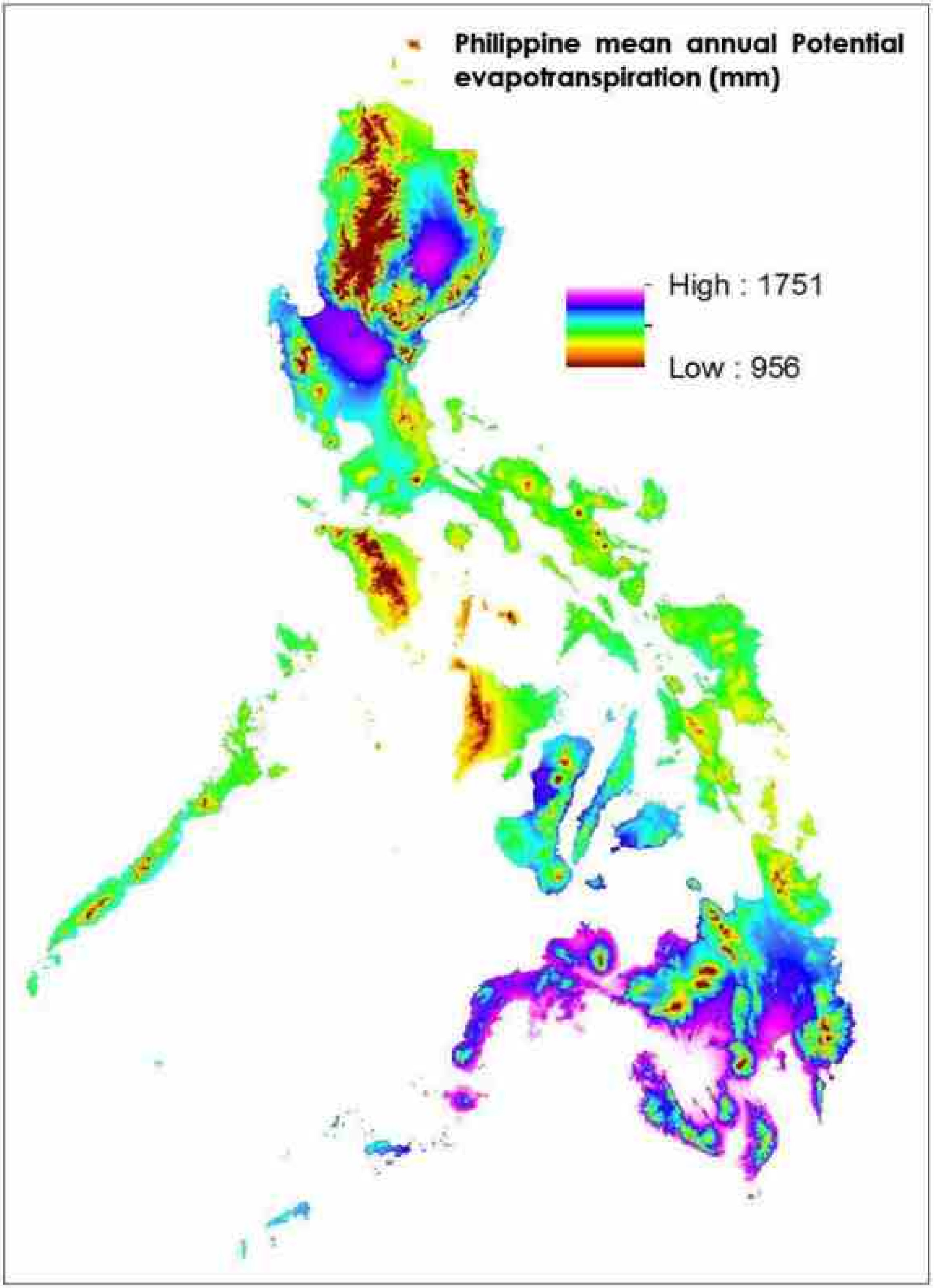


Figure 22: Philippine Mean Annual Potential Evapotranspiration (Source: www.worldclim.org)

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

The 600 precipitation monitoring stations that are expected to be installed in 2012 by DOST are expected to substantially improve the density of data that can be used to refine the understanding of water budget components affecting ET. Map showing the current and planned meteorological sites that contribute to the determination of evapotranspiration in the Philippines is presented in Figure 23.

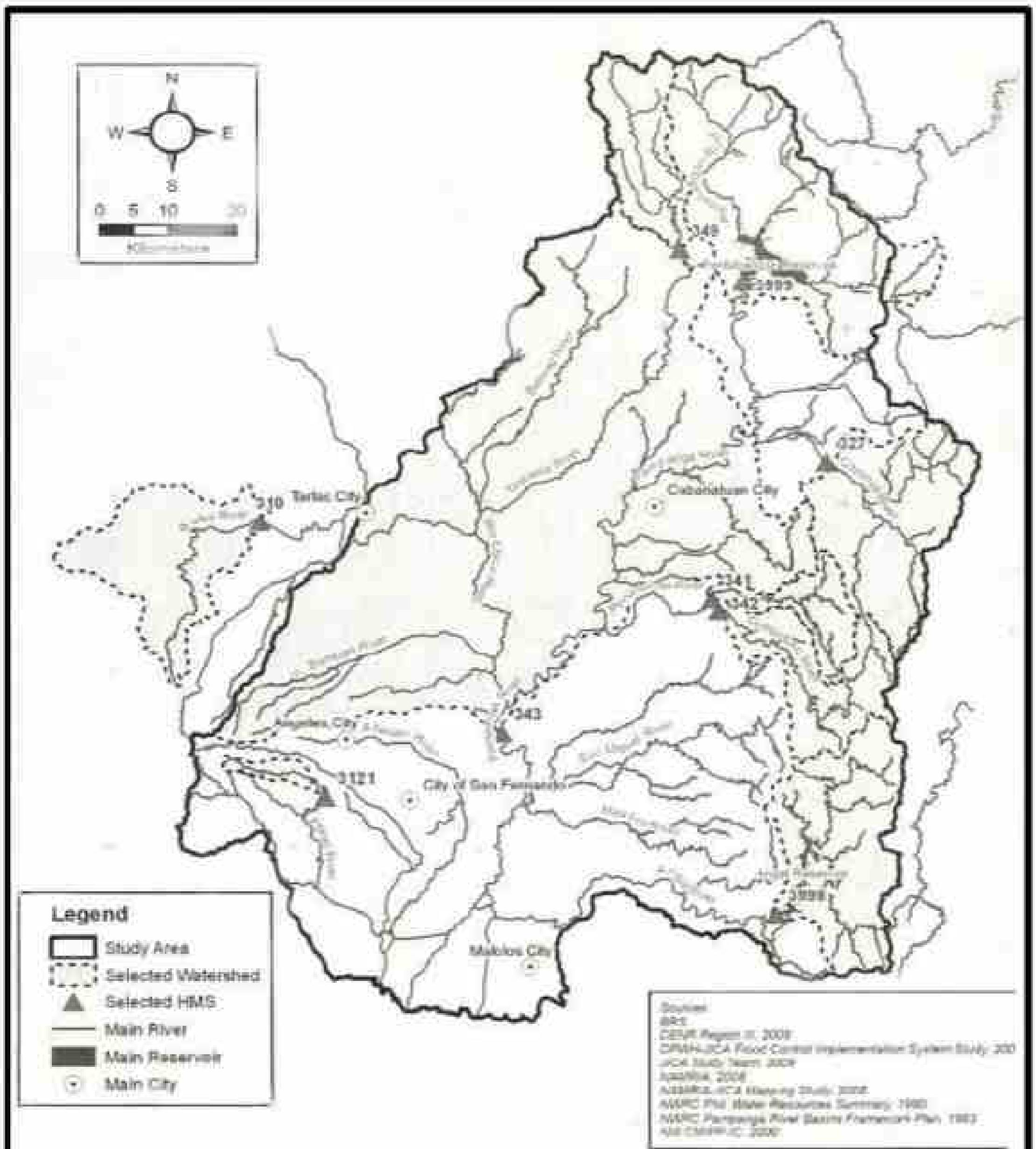


Figure 23: Map showing the current and planned meteorological sites that contribute to the determination of Evapotranspiration in the Philippines. (Source: The Study on the IWRM for Poverty Alleviation and Economic Development for the Pampanga River Basin)

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand evapotranspiration in sufficient detail to support water-resource assessments and management needs***

Collect appropriate and adequate data underlying estimates of evapotranspiration

Actions

- ***evaluate and reaffirm the routine collection and updating of data used to estimate evapotranspiration*** - including precipitation and related meteorological data
- ***integrate and harmonize these data*** - will require the establishment of data-sharing and data-serving for Philippine water agencies
- ***evaluate and improve quality of data used to estimate evapotranspiration*** – provide training on developing and implementing a Quality Assurance Plan for collection of these data

National partners – **DOST-PAGASA**, DENR-MGB, NWRB, DPWH-LWUA, and DA-BSWM

Reduce uncertainty in estimates of evapotranspiration

Actions

- ***reduce uncertainty in estimates of runoff, groundwater recharge, and evapotranspiration*** – provide training on standardized methodologies and numerical modelling approaches on estimation of evaporation

National partners – **DOST-PAGASA**, DENR-MGB, NWRB, DPWH-LWUA, and DA-BSWM

6.3.3.4 Surface and groundwater interaction

GAP IN UNDERSTANDING

All sources of water in reality constitute a single resource, however, the Philippines has limited understanding of surface and groundwater interactions and a broader integrated water budget. This lack of understanding has important consequences for the sustainability and protection of water resources and ecosystems, and is particularly critical in areas of shallow aquifers that are vulnerable to over-exploitation and pollution.

Some understanding of surface and groundwater interactions comes from general studies and site investigations conducted by various institutions or academic departments, such as the catchment level study on water balance in Pampanga River Basin. Figure 24 presents the water balance catchments for the Pampanga River Basin. However, it is the composite understanding of how surface and groundwater interact as a single resource that is at the heart of understanding the national water budget and is the foundation for effective water management and resource sustainability. The need for this composite understanding and use of available modelling techniques is extremely well recognized by the leading water institutions as they advocate for integrated water resource management. In particular the *Philippine Development Plan 2011-2016* recognizes the importance of recognizing the single resource nature of the water infrastructure subsector.

The critical current gap is the need to understand the interaction of surface water and groundwater, and to develop a unified understanding of the entire water budget at various scales (spatial and temporal) to support the integrated water-resource management needs of the Philippines.

An additional critical gap is the need to understand with reduced uncertainty the effects on the entire water budget of weather and climate (and Global Climate Change).

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

While quantifying water budgets is a relatively new effort on the part of the Philippine water sector, its importance is well understood and the filling of other gaps in data and information provide an essential foundation for focusing more broadly on national budgets and water balances as a management approach (IWRM).

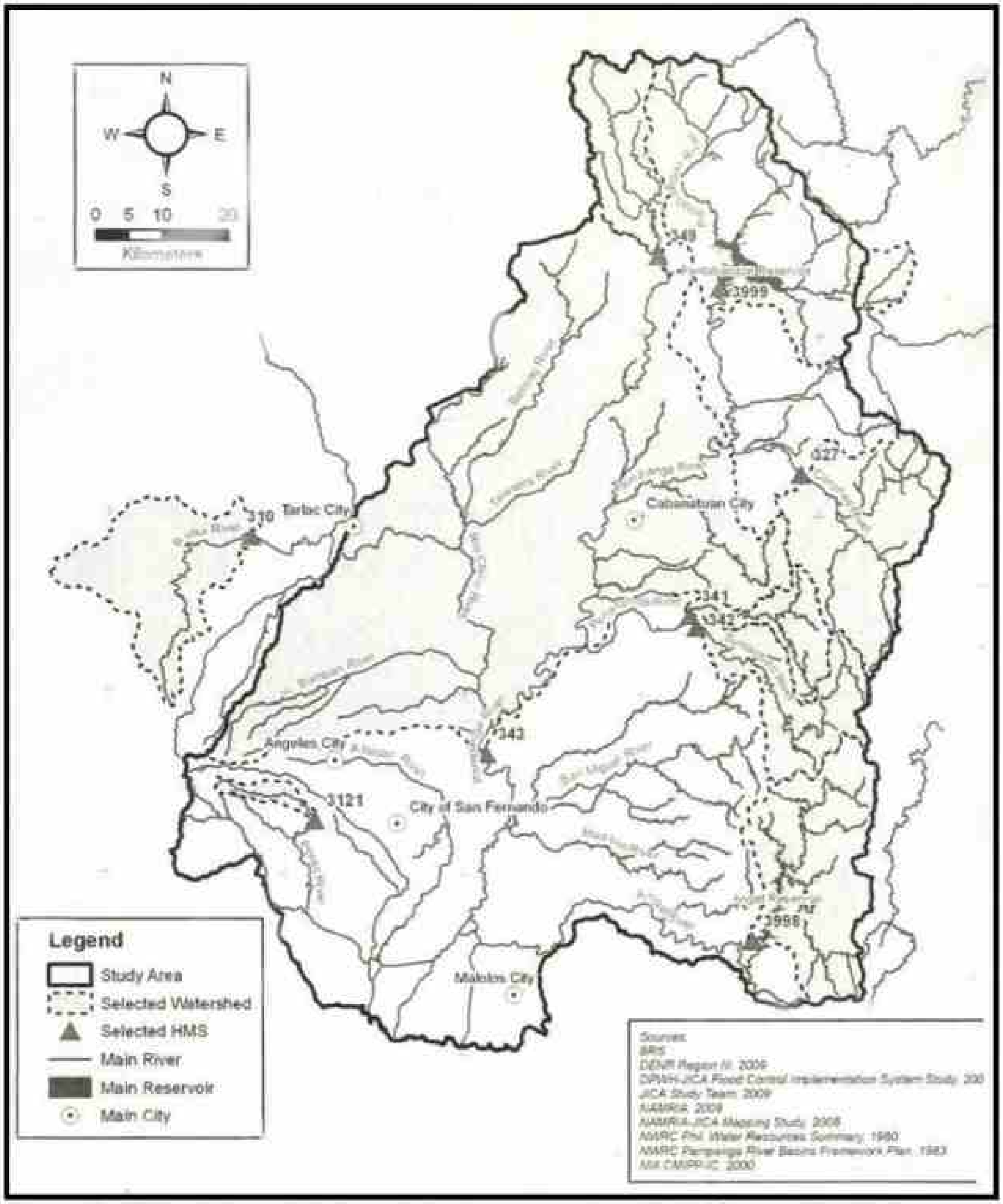


Figure 24: Water Balance Catchments for Pampanga River Basin (Source: The Study on IWRM for Poverty Alleviation and Economic Development for the Pampanga River Basin, 2010)

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand the interaction of surface water and groundwater, and to develop a unified understanding of the entire water budget at various scales (spatial and temporal) to support the integrated water-resource management needs of the Philippines.***

An additional critical gap is the need to understand with reduced uncertainty the effects on the entire water budget of weather and climate and Global Climate Change.

Conduct simulations of surface- and groundwater-flow at national and regional scales

Actions

- ***investigate regional and basin hydrogeological framework and the recharge of surface water to groundwater*** - provide training in appropriate state-of-the-science numerical modelling to characterize surface water and groundwater flow and interaction
- ***Apply chemical and isotopic techniques to investigate groundwater and surface water interaction and to constrain/verify results of basin-scale water-balance models*** - training provided and supported by PNRI and IAEA and other partners

National partners – **NWRB**, DPWH-LWUA, DOST-PNRI, and universities

Establish the necessary data framework and technical capacity to simulate the Philippine water budget at different scales

Actions

- ***accurately downscale climate data input from global climate models*** – provide training on different methods and techniques
- ***generate updated data on climate change scenarios and inputs***
- ***integrate climate change scenarios and forecasts of water budget*** – provide training in tools/methods for calculating temporal and spatial distribution of water resources in different geographic areas
- ***fully utilize the capability of the Climate Change Impact Modelling (CCIM) software of NEDA and NWRB*** – provide the modelling output for appropriate use by other Philippine agencies

National partners – **NWRB**, DPWH-LWUA, DOST-PAGASA, NEDA, DENR-MGB

Establish the necessary data framework and technical capacity for science-based collaboration on water availability in Philippine river basins

Actions

- ***compile and collect hydrological data in river basins using most effective field methods and techniques*** – through training on data collection and management, and building on the concept and framework of the NWIN

National partners – **DPWH-BRS**, DOST-PAGASA, NWRB, DENR-NAMRIA, DENR-RBCO, DENR-MGB

Optimize the Climate Change Impact Modelling effort to simulate the influence of Global Climate Change on the Philippine water budget at different scales

Actions

- ***simulate the impacts of different scenarios of Philippine climate change to surface and groundwater system, including sea level rise in coastal areas***
- ***integrate climate change scenarios and forecasts of water budget*** – provide training in tools/methods for calculating temporal and spatial distribution of water resources in different geographic areas
- ***fully utilize the capability of the Climate Change Impact Modelling (CCIM) software of NEDA and NWRB*** – provide the modelling output for appropriate use by other Philippine agencies

National partners – **NEDA** and NWRB

6.4 Protection of the Water Supply

The Gap in Hydrological Understanding in protecting the water resource of the Philippines has been presented earlier in Chapter VI to be: Insufficient understanding of the water quality status and trends, and the benefit of sustainable wastewater management. *The discussion of gaps in hydrological understanding of Protection of the Water Supply is grouped by the elements of a comprehensive water-resources assessment as presented in Table 8.*

Protection of the water resource of the Philippines requires a sufficient science-based understanding of the baseline status of water chemistry and quality for surface and groundwater. The baseline understanding is the foundation upon which the presence and effect of common and emerging pollutants are evaluated. Primary threats to the quality of national water resources are industrial discharges, chemical residuals from agricultural operations, and domestic wastewater. Adequate understanding of the baseline water chemistry is critical in documenting trends in water quality, both in the case of worsening quality and in the case of improvements due to regulatory or mitigation efforts. Improvement in water quality, and hence availability, can be expected from increasing sustainable wastewater management in the Philippines but that benefit is difficult to quantify and is poorly understood at present.

Protection of water supply	**Surface water quality** Water chemistry, common and emerging pollutants, trends
	Groundwater quality Water chemistry, common and emerging pollutants, trends

Table 8. Protection of Water Supply elements of a comprehensive water resource assessment

6.4.1 Surface-water quality

GAP IN UNDERSTANDING – SURFACE WATER

The baseline water chemistry and quality of Philippine surface water is understood in only the most general sense. In many areas, pollution of surface-water resources has been at crisis level for many years. As an example of a national problem, more than half of the organic pollution that reaches streams in Metro Manila can be attributed to domestic wastewater. Unfortunately, in-depth understanding of the origin, transport, and impact of this organic pollution is not possible because of lack of data and information. As a consequence, the most cost-effective and efficient approaches to this human health and water-resource problem cannot currently be defined. In addition to coliform and organic-rich domestic waste, the varied causes of surface-water contamination include heavy metals and organic compounds from industrial effluents and waste disposal facilities, and nutrients from agricultural activities.

Philippine water quality is assessed based on the set of "Beneficial Uses" defined in the DENR Administrative Order (DAO) 34, Series of 1990. Under this DAO, there are 33 parameters that define the desired water quality per water body classification. Accordingly, a water body must meet all the criteria of each applicable parameter 100 per cent of the time to maintain its designated classification. Using the provisions of DAO No. 34 (1990) and No. 23 (1997), the EMB, as of 2009, has classified 632 water bodies in terms of best usage. These include 283 Principal Rivers (drainage areas of not less than 40 sq. km.) accounting for 67% of the country's 421 Principal Rivers identified by the NWRB. Figures 25-a, -b, and -c present a summary of classified water bodies in the Philippines, number of classified water bodies and distribution of classified water bodies per region respectively.

The LLDA produces water-quality reports for seven lakes in the Laguna Lake watershed - specifically Lakes Bunot, Calibato, Mohicap, Palakpakin, Pandin, Sampaloc, and Yambo. In addition, numerous short-term water-quality studies have been undertaken in the past by various agencies for targeted understanding of water-quality conditions. However, there is a great need to establish water-quality criteria at a national scale.

Surface water chemistry of various river bodies has not been translated into maps that are regularly updated.

A current critical gap is the need to understand the baseline and trends of surface-water quality and pollution, and to understand the current and potential vulnerability of surface-water supplies to pollution (natural and anthropogenic)

6.4.2 Groundwater Quality

GAP IN UNDERSTANDING - GROUNDWATER

The baseline water chemistry and quality of Philippine groundwater is understood in only the most general sense. That understanding comes largely from information from water supply wells operated by Water Districts under LWUA or from wells in specific project areas. Often, only limited water-quality parameters are measured when these wells are sampled.

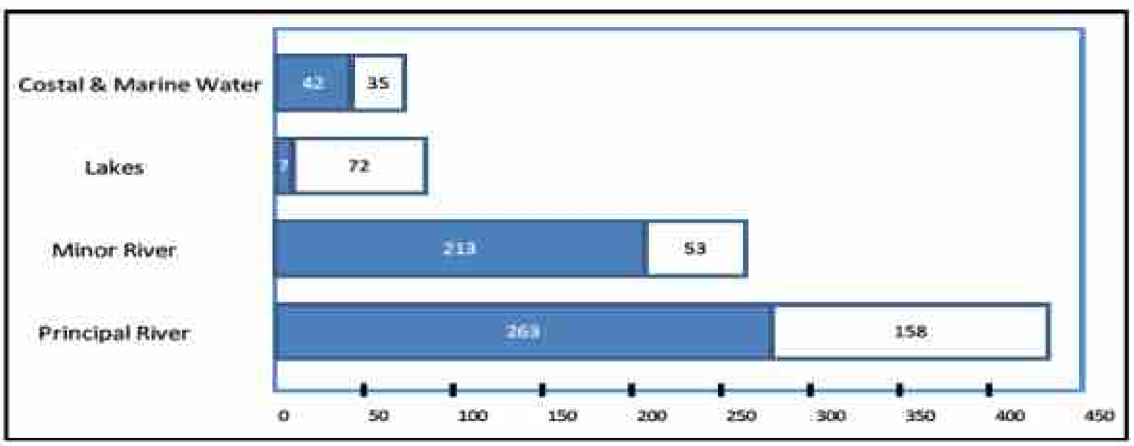
Common causes of groundwater contamination are varied but include coliform and organic-rich domestic waste, saltwater intrusion, heavy metals and organic compounds from industrial effluents and waste disposal facilities, and nutrients from agricultural activities. In many areas of the Philippines, pollution of groundwater resources has reduced the available supply. In-depth understanding of the origin, transport, and impact on groundwater resources of organic pollution by waste water is not possible because of lack of data and information. As a consequence, the most cost-effective and efficient approaches to this human health and water-resource problem cannot currently be defined.

Salt water intrusion is a special category of pollution that threatens coastal groundwater resources due to over-extraction of groundwater, and has been specifically studied in several sites within Metro Manila and immediate vicinities and in other coastal areas in the country. Figure 26 presents the salinity map for Metro Manila. There is a need to understand the vulnerability to saltwater intrusion of other coastal areas in the country.

Under the Tapwatch Program of DENR-EMB selected wells were sampled and analyzed for potability. In 2005, 88 shallow wells from local communities from marginalized barangays were monitored and tested, and 41% were found to be not potable. In 2008, 59 sites were monitored and tested, and 39% were found to be not potable.

Philippine groundwater quality can be assessed based on the set of "Beneficial Uses" defined DAO 34 in the same way surface water is. However, to this point no effort has been made to establish groundwater classification. This would be an important contribution to the distribution of groundwater chemistry and quality in the Philippines.

A current critical gap is the need to understand the baseline and trends of groundwater quality and pollution and to understand the current and potential vulnerability of groundwater supplies to pollution (natural and anthropogenic)



	Principal River	Minor River	Lakes	Costal & Marine Water
Classified	263	213	7	42
Unclassified	158	53	72	35
TOTAL	421	266	79	77

Source: emb.gov.ph/wqms/2001-2005

Figure 25-a. Summary of Classified Water Bodies in the Philippines (Source: www.emb.gov.ph)

Classification	Number
INLAND SURFACE WATERS	
Class AA **Water intended as public water supply requiring only approved disinfection to meet the PNSDW**	5
Class A **Water suitable as water supply requiring conventional treatment to meet the PNSDW**	203
Class B **Water intended for primary contact recreation(e.g. bathing, swimming, skin diving, etc.)**	149
Class C **Water for fishery, recreation, boating, and supply for manufacturing process aftrer treatment**	231
Class D **Water inteded for agriculture, irigation, livestock water, etc.**	23
COASTAL AND MARINE WATERS	
Class SA **Water suitable for fishery production, tourism, marine parks, coral reef parks, and reserves**	4
Class SB **Waters inteded for recreation such as bathing, swimming, skin diving, etc., and as spawning areas for Bangus and similar species.**	20
Class SC **Water intended for recreation/boating, fishery and as mangrove areas for fish and wildlife sactuaries**	27
Class SD **Water intended for industrial purposes such as cooling**	3

Figure 25-b. Number of classified water bodies. (Source : *emb.gov.ph*)

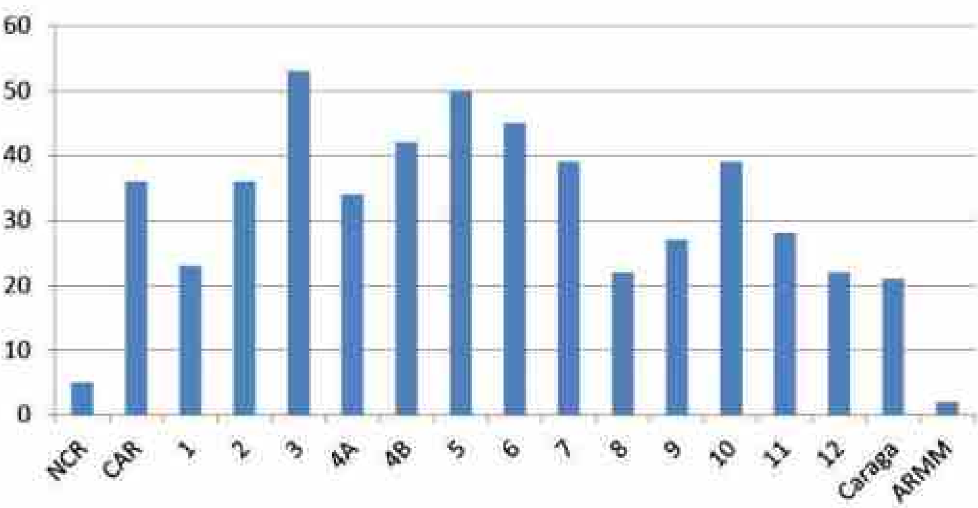


Figure 25-c. Distribution of Classified Water Bodies per Region. (Source: *emb.gov.ph*)

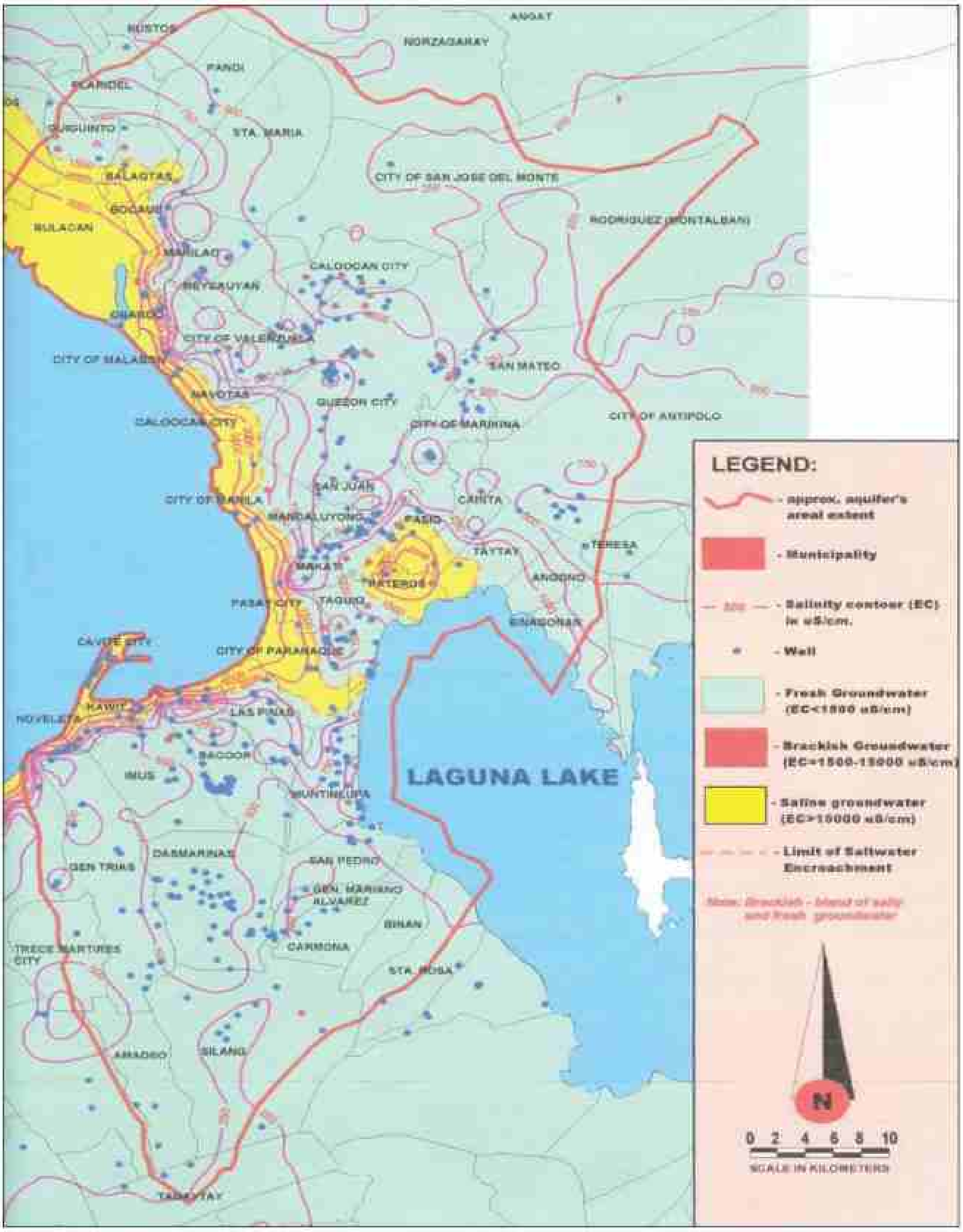


Figure 26: Salinity Map for Metro Manila (Source: Water Resources Assessment for Prioritized Critical Areas of Metro Manila, 2004)

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

National Standards

National standards for drinking-water quality as well as standards concerning sanitation and sewerage collection are set by the DOH. Implementation of these standards is delegated to LGUs and Water Districts.

The Philippine Clean Water Act of 2004 (RA 9275) aims to comprehensively address water pollution issues. The Clean Water Act not only aims to protect the bodies of water from pollution but also mandates urban communities to be connected to a sewerage system within 5 years. The Act establishes Water Quality Management Areas (WQMA) such as watersheds, river basins, and other water-resource areas. The Act also establishes the Area Water Quality Management Fund for the maintenance and upkeep of the water bodies in the WQMA. To date, five WQMAs have been proclaimed (the jurisdiction of the Laguna Lake Development Authority is considered as a special WQMA) but the Area Water Quality Management Fund has yet to be operationalized.

Water-Quality Monitoring – surface water

Several institutions are mandated to carry out water-quality monitoring programs, however due to budget limitations the data collected by these institutions are not sufficient to provide a comprehensive understanding of the current quality of surface-water resources.

The EMB monitors quality of critical surface-water resources. From 2001 to 2005 EMB, through its Regional Offices, has monitored water quality in 196 inland surface waters which included 192 rivers and 4 lakes. Monitoring at priority stations is done on a monthly or quarterly basis depending on budget.

The PRRC monitors surface-water quality for Pasig and San Juan Rivers and the LLDA monitors surface-water quality for Laguna de Bay and incoming tributaries. The LLDA has established water quality criteria/water usage and classification for freshwater in the Laguna Lake basin. The LLDA collects water-quality data for the seven lakes in the Laguna Lake watershed - specifically Lakes Bunot, Calibato, Mohicap, Palakpakin, Pandin, Sampaloc, and Yambo. DOH monitors water quality for water-borne diseases and potability of water. The MGB also conducts water-quality monitoring of mining sites across the Philippines.

Numerous short-term water-quality studies undertaken by various agencies in the past have provided important data for assessing water-quality conditions. However, there is a great need to establish water-quality criteria at a national scale.

Water-Quality Monitoring – groundwater

DENR-MGB and the DOH Regional Offices and Water Districts are the primary collectors for physical and chemical data for groundwater quality (Table 3). DOH-LWUA-WDs conduct measurement of water-quality parameters on their wells following Philippine National Standard for Drinking Water. The DOH also collects some bacteriological data for groundwater.

Several other agencies also collect groundwater samples for analysis:

- MWSS conducts measurement of water-quality parameters on their wells following the Philippine National Standard for Drinking Water
- NWRB collects in situ water-quality data (EC, CL, PH, TDS,) from groundwater wells and physical, chemical, and bacteriological analysis submitted by permittees.
- Under the Tapwatch Program of DENR-EMB selected wells are sampled and analyzed for potability. In 2005, 88 shallow wells from local communities from marginalized barangays were monitored and tested, and in 2008, 59 sites were monitored and tested.

While there is not a formal monitoring network for groundwater quality the distribution of sites at which routine groundwater sampling takes place. Figure 27 shows map of water quality monitoring for Region V.

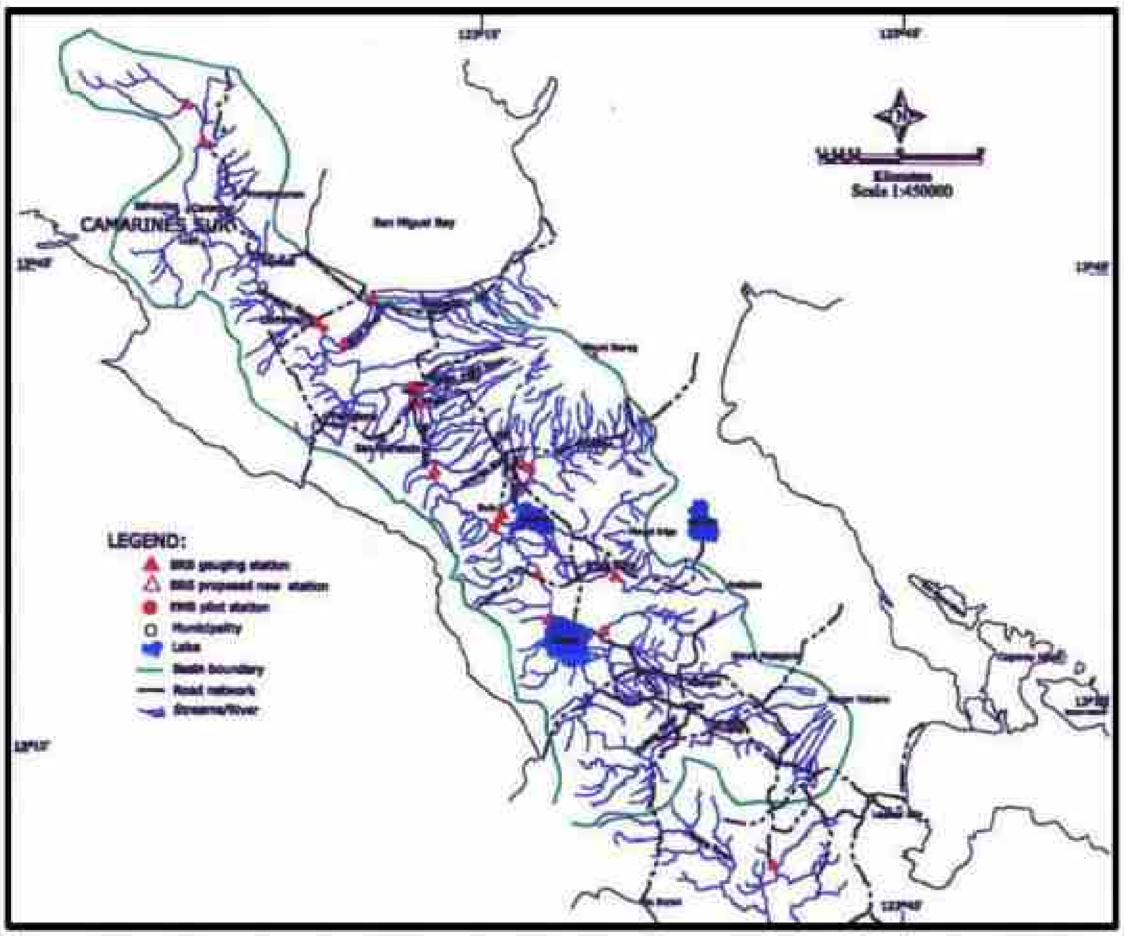


Figure 27 : Map showing Water Quality Monitoring Stations in Region V. (Source: National Water Data Collection Network for Water Quality, 2001)

Isotope Hydrology

PNRI conducts project–based investigations of isotopes in groundwater to determine sources, transport, and residence time. PNRI also conducts radiological measurements on drinking water for quality assessments.

Sanitation

Because of the high cost of capital investment, operation, and maintenance of centralized sewage treatment plants, many populations will continue to depend on private domestic wastewater treatment. Assessing and monitoring the performance of many individual septic tanks which typically flow to the storm drainage network (combined system) is very challenging.

The enactment of the Clean Water Act is a significant development in the sanitation sector. The responsibility for the planning and implementation of sanitation programs and the monitoring of local sector performance belongs to the LGUs, through the Provincial/Municipal Water and Sanitation (WATSAN) Development Councils. Evidence suggests that these local level managers are not often able to perform satisfactorily as they do not have the capacity to undertake the functions that are expected of them. As a result, the local utilities are not able to sustain the operation and maintenance of the sanitation system, expand service coverage, or collect the data necessary to assess and monitor performance. Achieving sustainable wastewater management is a goal that depends on accurate, sufficient, and timely data for all aspects of water supply and sanitation.

Major projects and initiatives

- The current administration of President Benigno S. Aquino III has put forward through the NEDA the *Philippine Development Plan 2011-2016* which includes the goal of improved environmental quality for a cleaner and healthier environment through reducing pollution. It plans to:
    - Operationalize the Area Water Quality Management Fund – *to allow the WQMAs to build their funds in order to implement identified water-quality improvement projects in their area.*
    - Revive the National Water Information Network (NWIN)
    - Develop a pollution load-based discharge allocation for industries – *an improvement over relying on the concentration-based guidelines in DAO 35*
    - Conduct water-quality modelling and other data analysis – *one example is The Partnerships in Environmental Management for the Seas of East Asia (PEMSEA)* which has embarked on a program to compute pollution loads per sub-basin in Metro Manila
    - Implement the Information Systems Strategic Plan (ISSP) – *ISSP aims to develop information systems that will address the integration, collaboration and consolidation of data/information to deliver quality and timely statistics in spatial and digital form.*
- The *Philippine Water Supply Sector Roadmap (PWSSR)* (NEDA, 2010) calls for the development of capacities of key LGUs, WSPs and NGAs for the sustainable

management of the water supply and wastewater management sector. The MDGF 1919 is a result of the *PWSSR* that is being implemented by NEDA, DILG, and NWRB. Help will be provided to local communities to establish, manage, and sustain their own water system. Three major projects related to sanitation and aligned with the PWSSR targets 95-are on-going nationwide:

- *Philippine Water Supply and Sanitation Sector Assessment and Monitoring Project* spearheaded by DILG and DOH. The assessment process will rely on information generated on a regular basis by a sector monitoring and evaluation system that will be established based on key indicators identified and the survey form that will be implemented. This will be linked to the LGUs management information systems and linked either to the PhilWATSAN Portal of the NWRB or to the DILG website.
- DOH collaboration with NWRB to compile/manage baseline information on water supply and sanitation
- Development of the *Capacity Building Framework for Water and Sanitation* spearheaded by DILG and DOH

- The *Philippine Portal for the Water Supply & Sanitation Sector* (http://philwatsan.org.ph) was created in 2008 and funded by GTZ containing the policies, projects/programs, research/publications and statistics on WATSAN. It is maintained and operated by the NWRB.
- The *National Environmental Health Action Plan (NEHAP)* is advocating to facilitate, support, and harmonize the establishment of LGU MIS integrating the water supply and waste-water management sector and linking them to the Phil WATSAN Portal
- The *Sustainable Sanitation in East Asia (SuSEA) Philippines Program*, local sustainable sanitation plans are being developed for 6 municipalities in the country. The project deals with information, education and communication plans and materials.
- The *Manila Third Sewerage Project* funded by the World Bank and implemented by the Manila Waters is an USD 85 million initiative for the improvement of sewerage and sanitation conditions in the eastern part of metro Manila. It aims to enhance the septage management program, pilot the combined sewer-drainage system approach, and promote advocacies and education campaigns to increase awareness on the negative environmental impacts of wastewater.

<u>Data-Quality Assurance</u>

Routine and project-specific collection of water-quality data in the Philippines most often does not include a quality control/quality assurance plan to ensure adequate methods of data collection, presentation, and evaluation. Metadata in national databases are usually not traceable due to poor data management systems; a national system wherein a dataset can be traced through an indexing protocol is not in place.

The NWRB has several initiatives underway relating to data-quality assurance:

- formulate national policy guidelines that define and establish data-quality assurance as a national objective

- collaborate with data-collecting agencies to incorporate or strengthen their existing Quality Assurance Plans as appropriate
- establish a Quality Assurance/Quality Control Plan for Philippine meteorological, hydrological, and supporting data, and provide oversight for its implementation and review.

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand the baseline and trends of surface- and groundwater quality and pollution, and to understand the current and potential vulnerability of water supplies to pollution (natural and anthropogenic)***

Collaborate with NEDA for the successful implementation of the Philippine Development Plan for 2011-2016 in all aspects relating to water-quality and sanitation

Actions:

- ***develop project proposals for consideration by NEDA***
- ***conduct project monitoring and evaluation***

National partners – **NEDA and NWRB**, all water data collecting agencies

Apply isotope hydrology techniques to water-resources management and protection

Actions:

- ***conduct isotopic data analysis and interpretation*** - training provided and supported by PNRI and IAEA
- ***integrate isotope techniques with surface- and groundwater studies*** – particularly with respect to determining contaminant source, transport mechanism, and fate; training provided and supported by PNRI and IAEA

National partners – **DOST-PNRI**, NWRB, EMB, and MGB

Strengthen expertise to conduct water-quality modelling and other data analysis nationwide

Actions:

- ***provide training in appropriate state-of-the-science systems***, such as those developed or supported by USEPA Watershed and Water-Quality Modelling Technical Support Center, with expertise in modelling applications for the development of Total Maximum Daily Loads (TMDL), waste load allocations, and watershed protection plans.
- ***provide training in appropriate state-of-the-science conjunctive groundwater/surface-water modelling*** - to assess water-quality implications for integrated water resources management nationwide; to utilize chemical and isotopic data to calibrate or constrain numerical models
- ***provide training in developing a range of technical and educational products*** - such as report cards, atlas maps, charts, time-series data, graphs

National partners – **RBCO**, DOST-PNRI, EMB, LLDA, NWRB, and PEMSEA

6.5 Water Production, Development, and Use

The Gap in Hydrological Understanding regarding water production, development, and use in the Philippines has been presented earlier in Chapter VI to be: Insufficient understanding of water use and allocation. *The discussion of gaps in hydrological understanding of the Water Production, Development, and Use is grouped by the elements of a comprehensive water-resources assessment as presented in Table 9.*

The four related elements of a comprehensive water-resource assessment are withdrawal rate and location; conveyance rate and losses; consumptive use; and reclaimed wastewater. A quantitative understanding of these elements is fundamental to the management and sustainability of water resources of the Philippines. Without the basic data required for this understanding, it is inevitable that resource planning and management, as well as the goal of inclusive economic growth, will fall short.

Water production, development, and use	**Withdrawal rate and location** Withdrawal by category, rates, trends
	Consumptive use Consumptive use by category, rates, trends
	Conveyance Rate and Losses Conveyance by category, rates, trends
	Reclaimed wastewater Rates, volumes, trends

Table 9. Water Production, Development, and Use elements of a comprehensive water resources assessment

6.5.1 Withdrawal rate and location

Quantifiably understanding the rate and location of surface- and groundwater withdrawals is a fundamental and critical part of assessing the entire water budget and is essential for effective resource planning and management.

6.5.2 Consumptive use

Quantifying consumptive use is essential for accurately gauging the effect on sustainability of the water resource. Collecting adequate data and estimating water use is a challenging prospect under the best of conditions; in the case that adequate data are not available, the uncertainty associated with the interpretation of water-use increases proportionally.

GAP IN UNDERSTANDING

The Philippines has a general yet insufficient understanding of the magnitude and distribution of water use. Although the regulatory framework is in place, the allocation of water resources for various purposes (municipal, industrial, hydro-power and agriculture) lacks a sound scientific basis. This is compounded by the lack of a system of data collection to account for all water withdrawals in the country. The data that are collected across watersheds and by the different water agencies are not generally integrated, limiting the ability to make effective, efficient, and equitable water management and policy decisions.

Operational water scarcity results from the lack or insufficient supply of water due to problems in source development, distribution infrastructure, or a high rate of user demand. Knowledge gaps in operational water scarcity include limited data for analysis of water-use patterns, cost, efficiencies and sustainability, limited data for issues of water infrastructure, conservation and re-use strategies, and limited data for pricing and water allocation schemes. These knowledge gaps result in potential conflict among the different water users, most notably in rapidly urbanizing centers in the country. This problem is further compounded by weaknesses in the management of water distribution systems and inefficiencies in the use of water.

The NWRB has the primary responsibility for developing the understanding of Philippine water use, and uses the issuance of water rights as a primary means for estimating water use volumes and distribution. The total water withdrawal in 2010 amounted to 193 BCM/yr estimated on the basis of the permits for water rights issued by the NWRB (NWRB, 2010 data). The number of permits or water rights issued by category in 2010 in the country is shown in Figure 28. The water allocated for surface and groundwater withdrawals by category based on the permits or water rights issued as of December 2011 is shown in Figure 29-a; and the water allocated for groundwater withdrawals by category based on permits or water rights issued as of December 2011 is shown in Figure 29-b. The location sites of surface and groundwater extraction as of December 2010 is shown in Figure 30.

Of the 193 BCM/yr withdrawn in 2010, 57% is allocated for hydropower and 43% is allocated for other non-consumptive uses. Estimating water use solely based on permitted water rights as opposed to reported pumpage or through statistical approaches, results in a greater uncertainty in the understanding of spatial and temporal distribution of water use. In addition, it is believed that a significant amount of water withdrawal is unregulated and undocumented. This unaccounted-for water withdrawal might be used for any of the use categories, such as domestic, municipal purposes, industries, irrigation, or fisheries and livestock. NWRB estimates that 60% of total groundwater withdrawal for all uses is without any permits for water rights.

A current critical gap is the need to understand the withdrawal rates in all use categories across the Philippines and in particular the magnitude and distribution of consumptive use for both regulated and unregulated water users

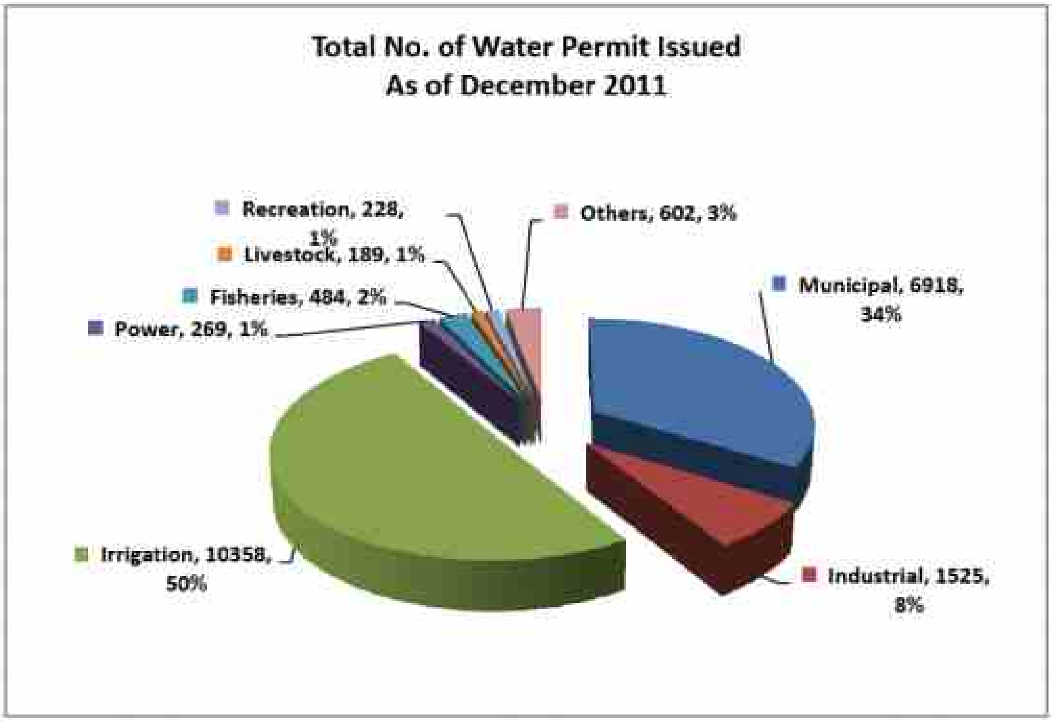


Figure 28: Number of permits or water rights issued by category in 2011.

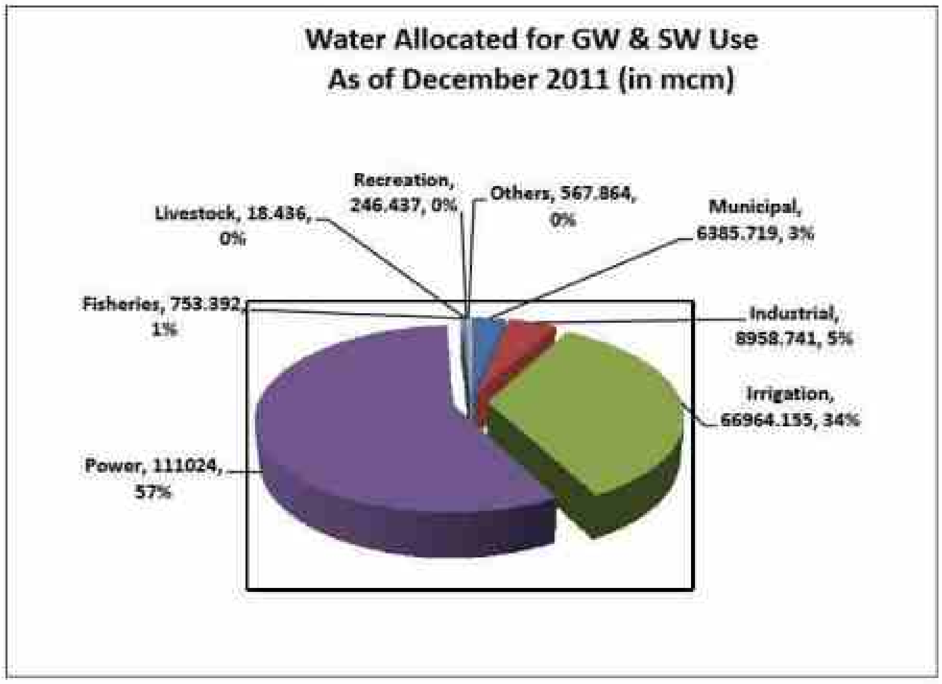


Figure 29-a: Water allocated for surface and groundwater withdrawals by category

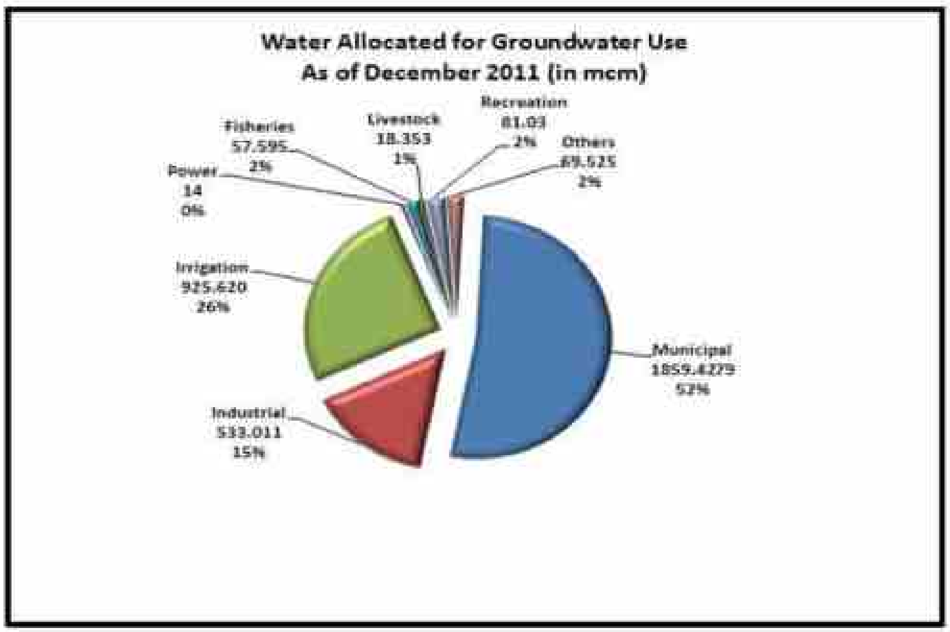


Figure 29-b: Water allocated for groundwater withdrawals by category

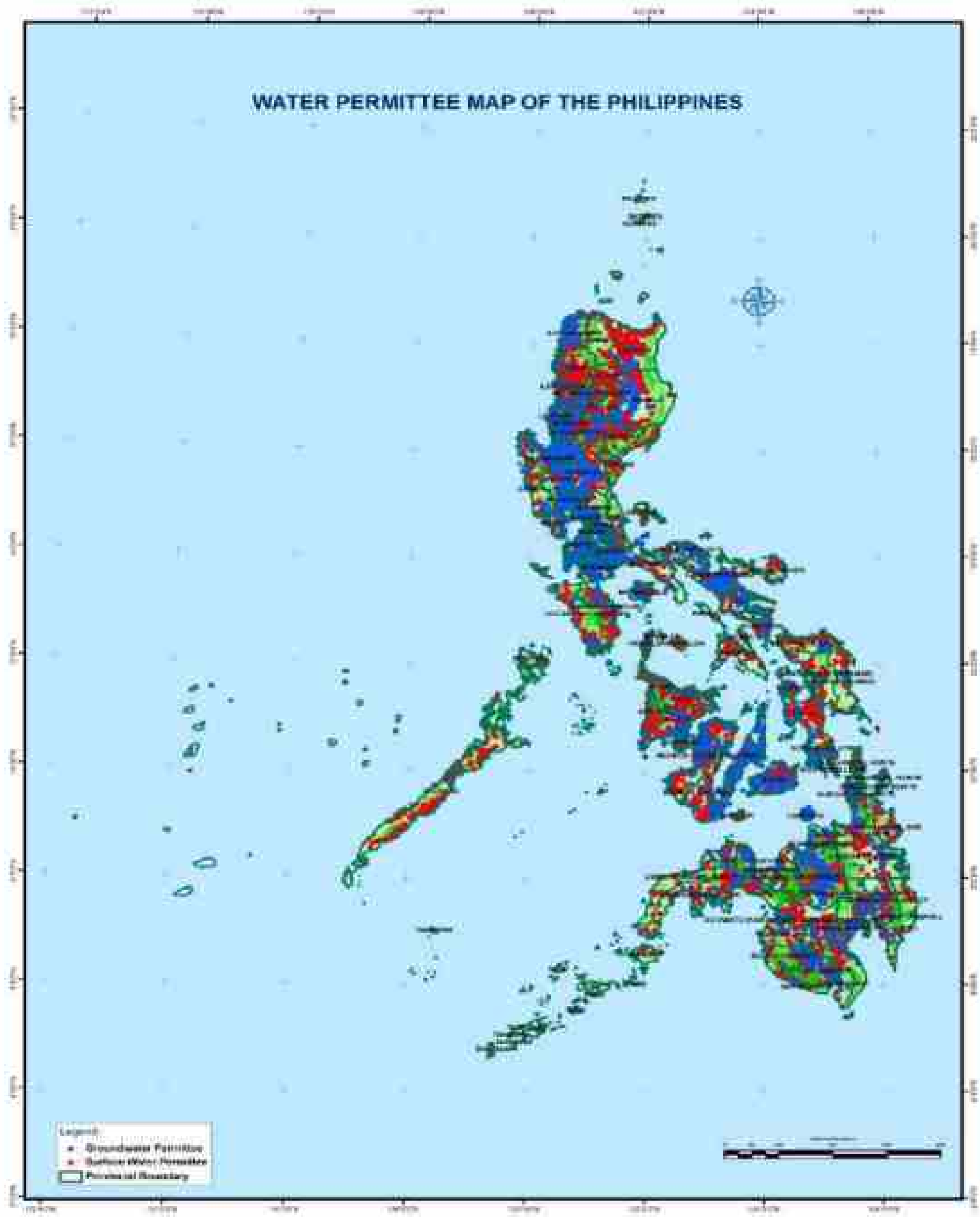


Figure 30. Map showing the location sites of surface and groundwater extraction as of December 2010 (Source : *NWRB)*

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

National databases of water-use information are largely incomplete, fragmented, and not updated. The NWRB initiated the development of the Water Permit Knowledge database as part of the NWIN project. The Water Permit Knowledge database is envisioned as a centralized system for collecting uniform water-use information, which will also track individual water rights permit applications and speed up the granting of the permits. Streamlining the process may encourage users to register and acquire permits, thus improving the accuracy of the reported water withdrawal values for each user type. The Water Permit Knowledge database of the NWIN can be an important part of a comprehensive approach that must be taken for a national information management system to integrate data across the water sector.

The currently reported volume and distribution of water withdrawal is based on the water rights issued by the NWRB. The NWRB estimates that issued water rights represent only about a third of water users because the majority have not registered their water extraction activities properly. Moreover, bulk water users with water permits are not properly monitored for actual extraction rates and volumes. This includes water for municipal purposes (water districts), commercial and industrial activities, power generation and various agriculture-related purposes.

Because it is believed that there are about twice as many unregistered water users as there are registered users, estimating water use on the basis of water rights issued by NWRB is believed to greatly underestimate true water use. A commonly used coefficient is that 60% of water use in the Philippines is unregistered and unregulated. This magnitude of unaccounted water use increases the uncertainty associated with any local or national assessment of water resource. A national inventory that quantifies or estimates legal and illegal uses will improve the accuracy and usefulness of a comprehensive water-resource assessment. Such data are important in the sustainable development and management of new water sources.

The basis for water rights permits is based on the calculated water availability, that is, the allowable water extraction per permitee is based on an evaluation of local water resources and the submitted requirements of the applicants on a first come first serve. For withdrawals from river systems an environmental flow of 10% of the mean flow is deducted.

Growth targets and forecasted water usage for cities and municipalities cannot be calculated with sufficient accuracy due to lack of data. Annual water withdrawals for the major water-use categories (agriculture, industry, domestic) are not projected into the future to identify areas of potential conflict between supply and demand. In addition, it is important that uncertainties due to climate and land-use changes and other socioeconomic factors should be noted in making this projection. Having this capability will require the development of mathematical models and decision-support tools which address water allocation and supply management needs. Such models and tools are currently not available within the Philippine water sector.

There is no formally established process for water-related agencies to meet with stakeholders in industry and the public sector to discuss and determine future water requirements. This inevitably results in inefficiencies in the delivery and use of the resource.

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand the withdrawal rates in all use categories across the Philippines and in particular the magnitude and distribution of consumptive use for both regulated and unregulated water users***

Conduct a comprehensive inventory of all water uses (legal and illegal, surface water and groundwater, consumptive and non-consumptive, all use categories)

Actions:

- ***provide training in appropriate state-of-the-science water-use reporting and estimation programs***, such as those of:
  - the USGS National Water-Use Information Program which analyses the source, use, and disposition of water resources at local, state, and national levels, and develops water-use databases
  - the Australia Water Resources Program which compiles water use information and determines water-access entitlements, allocations and water trading at national and water-management-area scale
- ***implement the most cost-effective and efficient approaches to reduce the uncertainly in water-use data and estimates***
- ***develop appropriate data-sharing and reporting requirements and systems***
- ***integrate water-use data into a revamped NWIN or alternate national data system for water-use data management, and to support resource assessment and sustainable use***

National partners – **NWRB**, LGUs and deputized agencies

Evaluate the validity of the often-used 60% coefficient for determining total water use

Actions:

- ***Update the Rapid Assessment for Water Source done in the 1980s and the Unpublished Groundwater Investigations nationwide***, incorporating appropriate new techniques and approaches
- ***Support revamped NWIN and use the expanded data holdings to evaluate the validity of the 60% coefficient***
- ***provide training in data processing, management, and interpretation***
- ***provide training on the use of groundwater modelling for water allocation and determining potential interference of proposed wells***

National partners – **NWRB** and deputized agencies

Develop refined water-use projections for future scenarios of economic development, land-use change, socioeconomic variables, and climate change

Actions:

- ***provide training in appropriate state-of-the-science modelling approaches for water-use projections and scenarios, and for allocation of water resources***
- ***develop maps, charts, and other interpretation of the simulations***
- ***establish rules for water allocation plans to ensure adequate provision of water for environmental, social and cultural purposes whilst fostering sustainable water use and development.***
- ***conduct an Information and Education Campaign targeting appropriate audiences***

National partners – **NWRB**, NEDA, LGUs, PAGASA and other concerned agencies

Determine in-stream non-consumptive environmental water needs and integrate the knowledge into water planning efforts

Actions:

- ***provide training on the estimation of environmental flow***

National partners – **NWRB** and other concerned agencies

Simulate water-supply management incorporating demand-side management, quality of available water resource, ecosystem preservation and protection, and future water-use projections

Actions:

- ***provide training in the construction of and use of water-supply models,***
- ***develop maps, charts, and other interpretation of the simulations***
- ***develop and adopt a Water Resources Information System to include a water infrastructure allocation system for current and proposed scenarios***
- ***develop water demand management strategies to promote sustainable water use and deliberately reduce the demand for water***

National partners – **NWRB**, EMB, PAWB, DA and other concerned agencies

6.5.3 Conveyance rate and losses

GAP IN UNDERSTANDING

The Philippines has a general understanding of the rate of conveyance through water supply and waste systems and the associated losses. The LWUA, the MWSS, and other water service providers have the responsibility for understanding and quantifying the operation of their systems and providing data, maps, and models to the overseeing authorities or institutions. Those systems which are continually monitored have a proportionally greater understanding of conveyance rate and losses, than those systems with less monitoring.

A critical current gap is the need to understand conveyance rates and losses (non-revenue water and irrigation losses) in detail sufficient for effective water-resource management.

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

Loss of water in a distribution system is determined as the difference between the volume supplied to the system and the volume metered at delivery. The lost water is called "non-revenue water" because the cost is not recovered. The water is lost due to leaks in the system or due to illegal tapping or withdrawals. The Manila Water Company Inc. has been successful in substantially decreasing conveyance losses over recent years however there is a need to achieve a similar level of understanding on conveyance rates and losses for water supply on a national scale. There is also a need to measure, estimate, or otherwise account for losses due to conveyance for irrigation.

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand conveyance rates and losses (non-revenue water and agriculture sector losses) in detail sufficient for effective water-resource management.***

Employ appropriate advanced techniques to quantify conveyance rates in municipal and agricultural delivery systems

Actions:

- ***provide training in the measurement and estimation of conveyance rates***

National partners – **LWUA**, WDs, MWSS and its two concessionaires, DA-NIA and other concerned agencies

Identify and replicate best-management practices regarding conveyance-loss detection and monitoring

Actions:

- ***provide training in best management practices regarding conveyance loss detection and monitoring***

National partners – **LWUA**, WDs, MWSS and its two concessionaires, DA-NIA and other concerned agencies

6.5.4 Reclaimed wastewater

GAP IN UNDERSTANDING

Water recycling and reuse is the planned and deliberate use of treated wastewater for beneficial purposes such as irrigation, recreation, industry, recharging of underground aquifers, and drinking water. The Philippines currently has very limited reclaimed wastewater being used for water supply or aquifer recharge. Of the few systems operating, there is very limited understanding of the rates, losses, and water quality of the water involved. However, reclamation of wastewater is an approach advocated in the *Philippine Development Plan 2011-2016* advancing the water infrastructure subsector in support of the goal of inclusive economic growth. Quantifying the benefit of reclaiming wastewater will be an important contribution to the success of the Development Plan as well as more broadly sustaining the water resources of the Philippines

A current critical gap is the need to understand the value of reclaiming wastewater in sustaining water resources, protecting the environment, and ensuring adequate and efficient supply of water.

CURRENT SITUATION AND GAPS IN DATA AND INFORMATION

In 2007, the DA-BSWM has issued guidelines on wastewater re-use for agricultural purposes and DA Regional Offices are responsible for issuing the certification for this particular purpose in relation to the implementation of RA 9275 Sections 13 and 14 (Wastewater Charge and Discharge Permitting Systems) which is being implemented by DENR-EMB. DA-BSWM can shed light on the aspect of wastewater re-use for agricultural purposes.

Some institutions have started to install systems for reclaiming wastewater, such as Shoe Mart's Skygarden in Quezon City, which uses recycled wastewater for the maintenance of its elevated garden, and Xavier School in San Juan for watering its football field. However, the practice is not yet institutionalized and has not been used for aquifer recharge. Wastewater reclamation should be established as a routine water conservation measure throughout the country. In addition, water quality standards for wastewater need to be established for different uses in the Philippines.

SPECIFIC REMEDIES AND INVESTMENTS

To address: ***the need to understand the potential value of reclaiming wastewater to sustaining water resources, protecting the environment, and ensuring adequate and efficient supply of water.***

Collaborate with NEDA for the successful implementation of the Philippine Development Plan for 2011-2016 in all aspects relating to reclamation of waste water

Actions:

- ***provide training in appropriate state-of-the-science approaches to wastewater reclamation,*** building on current initiatives and successes
- ***develop national inventory of demonstration sites for wastewater reclamation,*** building on current examples and successes such as:
    - Shoe Mart's Skygarden in Quezon City
    - Xavier School in San Juan

National partners – **NEDA**, NWRB, DA and other interested agencies

7. Key Results and Key Findings

The Philippine *IWAVE Project* has identified the gaps in hydrological understanding, data, and information that are currently hindering a comprehensive assessment of the water resources of the Philippines. The gaps in hydrological understanding are organized by categories of ***Water Supply***, ***Protection of Water Supply***, and ***Water Production, Development, and Use***. Each gap in hydrological understanding is the result of one or several specific gaps which are organized by relevant sub-categories. To address or fill each specific gap, one or several specific remedies or investments have been identified.

7.1 Water Supply

- *Insufficient understanding of the quantity and spatial/temporal distribution of surface and groundwater resources*

Surface water

Hydrography

- *the need to understand the national hydrography with sufficient detail and certainty to fully support the Integrated Water Resources Management Framework Plan*
- *the need to understand the limnologic changes occurring to lakes and the vulnerability of lakes to a range of identified and potential stresses.*

Streamflow

- *the need to increase the understanding of streamflow in gauged and ungauged basins*
- *the need to understand surface-water storage and routing on a national scale, and the need to understand the effect of scenarios of extreme weather and climate*

Flood and drought risk

- *the need to quantitatively understand the extent and characteristics of flood- and drought-prone areas in all priority basins, and the need to understand how flood waters might be harnessed to lessen the severity of the impact of droughts*

Groundwater

Hydrogeological setting

- *the need to understand subsurface geology, and aquifer thickness and extent, in sufficient detail and scope to support hydrogeologic investigations and fully assess the groundwater resource of the Philippines*

Aquifer characteristics

- *the need to understand aquifer characteristics in sufficient detail to effectively conduct resource supply assessments and management activities*

Groundwater storage and flow

- *the need to understand the quantity and flow of available groundwater and the effect of extreme weather and climate on groundwater storage and flow*

Water Budget and Global Climate Change

Precipitation

- *the need to have an appropriately advanced level of understanding of the spatial and temporal distribution of precipitation and of extreme events for early warning forecasting and risk assessments*

Runoff and recharge

- *the need to understand runoff and recharge processes, origin of recharge, and residence time of groundwater at national and appropriate local scales*

Evapotranspiration

- *the need to understand evapotranspiration in sufficient detail to support water-resource assessments and management needs*

Surface and groundwater interaction

- *the need to understand the interaction of surface water and groundwater, and to develop a unified understanding of the entire water budget at various scales (spatial and temporal) to support inclusive economic growth and the integrated water-resource management needs of the Philippines*
- *the need to understand with reduced uncertainty the effects on the entire water budget of weather and climate, and global climate change*

7.2 Protection of Water Supply

- *Insufficient understanding of the water quality status and trends, and the benefit of sustainable wastewater management*

Surface-water and Groundwater quality

- *the need to understand the baseline and trends of surface-water and groundwater quality and pollution; understand the current and potential vulnerability of surface-water supplies to pollution (natural and anthropogenic)*

7.3 Water Production, Development, and Use

- *Insufficient understanding of water use and allocation*

Withdrawal rate and location and Consumptive use

- *the need to understand the withdrawal rates in all use categories across the Philippines, and in particular the magnitude and distribution of consumptive use by both regulated and unregulated water users*

Conveyance rate and loses

- *the need to understand conveyance rates and losses (non-revenue water and agriculture sector losses) in detail sufficient for effective water-resource management*

Reclaimed wastewater

- *the need to understand the potential value of reclaiming wastewater to sustaining water resources, protecting the environment, and ensuring adequate and efficient supply of water*

The recommendations of this report can be used by NEDA and NWRB to plan for specific investments in people and resources to fill the identified gaps. Filling these gaps will lead to greatly strengthened national capability to conduct comprehensive water-resource assessments and to the identification of new and sustainable sources of water. These are necessary and critical steps in the "massive investment" in the Water Infrastructure Subsector called for in the *Philippine Development Plan 2011-2016* in supporting the national goal of inclusive growth. Equally important is that the strengthened national capability will enable more effective and efficient planning and management of the Water Infrastructure Subsector into the future.

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9. Appendices

APPENDIX 1. Philippine Water Resource Plans and Policies

The responses to the challenges of water management in the Philippines are to be found in water resource plans and policies that have been undertaken over the years. Several of the most important plans and policies are listed here with reference to the stated need for hydrogeological data, information, and assessments.

Philippine Agenda 21

Philippine Agenda 21 was adopted in September, 1996 with the issuance of Memorandum Order No. 399 which identified the roles of the Philippine Council for Sustainable Development (PCSD). Philippine Agenda 21 is the nation's blueprint for sustainable development and it is part of the country's response to fulfill its commitments in the historic Earth Summit in 1992.

The Philippine Agenda 21 describes an action plan for each ecosystem - coastal/marine, freshwater, upland, lowland, and urban. The need for water-resource assessment is one of the five freshwater-ecosystem issues and concerns identified in Philippine Agenda 21.

Integrated Water Resource Management Plan Framework

An Integrated Water Resource Management Framework Plan was formulated by the Philippines in 2006. One of the principal elements of this IWRM Plan framework is Supply Optimization, which is embedded in Outcome 1 (relating to water quality) and in Outcome 2 (relating to water quantity). The IWRM Plan Framework endorses assessments of surface and groundwater supplies, water balances, wastewater reuse, and environment impacts of distribution and use options.

Medium-Term Philippine Development Plan 2004-2010 and Philippine Development Plan 2011-2016

The Medium-Term Philippine Development Plan (MTPDP) (2004-2010) of the National Economic and Development Authority (NEDA) underscores the need to translate the Millennium Development Goals (MDG) commitments to action.

The present Aquino administration recognizes the role of water resources in contributing to inclusive growth and poverty reduction. It supports the performance of the country's economic sectors and ensures equitable access to infrastructure services, especially as these affect the people's health, education, and housing. Water is one of the key infrastructures.

Regional Development Plans (RDPs) are developed for each of the 17 administrative regions consistent with the general policies and strategies espoused in the MTPDP to fight poverty by building prosperity for the greatest number of Filipinos. Each RDP contains Water Supply and Sanitation Sector (WSSS) policies and strategies that are focused on the specific region's priorities.

The Provincial Water Supply, Sewerage and Sanitation Sector Plans (PW4SPs) aim to formulate a long-term provincial development plan for the WSSS sector up to the year 2015 including a 5-year medium-term sector investment plan based on the long-term development plan.

The Philippine Water Supply Sector Roadmap

The Philippine Water Supply Sector Roadmap (PWSSR), second edition, undertaken with NEDA and NWRB in the lead, was completed in 2010. The Roadmap provides the direction to be followed to achieve the long-term vision of access to safe, adequate and sustainable water supply for all by 2025.

One of the programs of the PWSSR is water-resource assessments in critical areas. This program covers the systematic assessment, development, and sustainable management of water resources in identified critical areas and priority major river basins in the country. It includes the conduct of technical studies on selected river basins, adoption of the river basin integrated management and development framework plan, development of integrated river basin master plan, organization and strengthening of river basin organizations, and the supervision of the implementation of river basin development projects. However, these plans have not been fully implemented due to lack of comprehensive water resources assessments to provide the necessary benchmark information.

The National Framework Strategy on Climate Change (2010-2022)

Climate change is the most serious and most pervasive threat facing humanity today. The Intergovernmental Panel on Climate Change (IPCC) affirmed in its Fourth Assessment Report (2007) that the "warming of the earth's climate system is unequivocal" and that this warming is attributed to the dramatic rise in human-induced greenhouse gas emissions since the mid-20th century.

The Philippines, being an archipelago, now faces threats from more intense tropical cyclones, drastic changes in rainfall patterns, sea level rise, and increasing temperatures. All these factors contribute to serious impacts on the natural ecosystems – on the river basins, coastal and marine systems, and their biodiversity – cascading to impacts on food security, water resources, human health, public infrastructure, energy, and human settlements.

Section 11 of Republic Act No. 9729 mandates the Climate Change Commission (CCC) to formulate the Framework Strategy and Program on Climate Change based on the country's vulnerabilities, adaptation needs and mitigation potential, all in accordance with international agreements. The Framework is committed towards ensuring and strengthening the adaptation of natural ecosystems and human communities of the Philippines to climate change. The aim is to build a roadmap that will serve as the basis for a national program on climate change and establish an agenda upon which the country would pursue a dynamic process of determining actions through the National Climate Change Action Plan process.

APPENDIX 2. Philippine Water Related Laws and Regulations

A. Water Related Laws

Other relevant issuances and policies on water resources management embodied in a number of enabling laws include the following:

The **Sanitation Code of the Philippines (PD 856 of 1975**) delineates the functions of the Department of Health in terms of promotion and preservation of the health of the people and raise the health standards of individuals and communities.

The **Philippine Water Code 1976** establishes the basic principles and framework for the revision and consolidation of all the laws governing the ownership, appropriation, utilization, exploitation, development, conservation, and protection of water resources. The review and amendment of this code has been recommended to ensure that it is integrated into the adaptation strategies and disaster risk reduction and management of the *Philippine Strategy on Climate Change Adaptation*.

The **Local Government Code of 1991** provides empowerment of local executives in the delivery of services which include water supply and sanitation services.

The **Environmental Code of 1997** prescribes the management guidelines aimed to protect and improve the quality of water resources through classification of surface waters and establishment of water quality.

Executive Order No. 123 of September 2002 (Reconstructing the NWRB) – Straightening the NWRB including the assumption of LWUA's WD tariff approving authority.

Executive Order (EO) 279 (February 2, 2004) "Instituting Reforms in the Financing Policies for the Water Supply and Sewerage Sector and Water Service Providers and Providing for the Rationalization or LWUA's Organizational Structure and Operations in Support Thereof"- seeks to gain substantial reforms in the financing policies for water supply and sanitation service providers.

The **Philippine Clean Water Act (March 22, 2004**) provides comprehensive water-quality management for all the water bodies of the Philippines. It also provides the framework for sustainable development to achieve a policy of economic growth in a manner consistent with the protection, preservation, and revival of the quality of fresh, brackish, and marine waters. The passage of this law is also the first attempt to consolidate different fragmented laws of the Philippines on water resources management.

Executive Order No. 387 of November 2004, transferred LWUA from the Office of the President to DPWH.

Executive Order No. 510 of March 2006 created the River Basin Control Office (RBCO) in DENR. The RBCO has the power and function, together with the DPWH, to rationalize the various existing river basin projects such as Mt. Pinatubo Hazard Urgent Mitigation, Iloilo Flood Control, Lower Agusan Flood Control, Bicol River Basin and Watershed Management, etc., to develop a national master plan for flood control together with the DPWH and the National Disaster Coordinating Council; to rationalize and prioritize reforestation in watersheds; and to perform other functions as the President or the DENR Secretary may direct.

The enactment of the **Philippine Climate Change Act (Republic Act 9729 of July 27, 2009)** provides the opportunity for a more cohesive and coordinated effort towards climate change adaptation and mitigation. The institutional mechanism in implementing the Philippine Strategy on Climate Change Adaptation lies with the creation of the Climate Change Commission, headed by the President, under RA 9729, which will lead in the implementation of the national level strategies and plans of action.

B. Water Related Regulations

EMB - LAWS AND POLICIES : Water Quality Management

EMB MC 2012-001
CLARIFICATION ON THE APPLICABILITY OF EFFLUENT REGULATIONS

DAO 2011-14
DESIGNATION OF THE SINOCALAN-DAGUPAN RIVER SYSTEM AS WATER QUALITY MANAGEMENT AREA AND CREATION OF ITS GOVERNING BOARD

MC 2009-15
PROCEDURAL MANUAL FOR THE DESIGNATION OF WATER QUALITY MANAGEMENT AREAS

MC 2009-14
STRICT IMPLEMENTATION OF THE 50 METERS BUFFER ZONE

DAO 2009-12
DESIGNATION OF THE SARANGANI BAY WATER QUALITY MANAGEMENT AREA AND CREATION OF ITS GOVERNING BOARD

DAO 2009-11
DESIGNATION OF ILOILO-BATIANO RIVER SYSTEMS WATER QUALITY MANAGEMENT AREA AND CREATION OF ITS GOVERNING BOARD

JMC 2009-01
CREATION OF THE LA MESA WATERSHED MULTI-SECTORAL MANAGEMENT COUNCIL AND DEFINING ITS FUNCTIONS

DMC 2009-01

ADDITIONAL LIST OF CLASSIFIED WATER BODIES

EMB MC 2009-002

AMENDING REVISED PROCEDURAL MANUAL FOR DAO 03-30 DATED 30 JUNE 2003 ON THE CLASSIFICATION OF THE FAST-FOOD STORES, RESTAURANTSAND SIMILAR QUICK-SERVICE ESTABLISHMENTS

EMB MC 2008-008

ISSUANCE OF THE AMBIENT WATER AND EFFLUENT QUALITY MONITORING MANUALS

DAO 2008-07

DESIGNATION OF MARILAO-MEYCAUAYAN-OBANDO RIVER SYSTEM WATER QUALITY MANAGEMENT AREA AND CREATION OF ITS GOVERNING BOARD

Volume II Manual

MANUAL ON EFFLUENT QUALITY MONITORING

Volume I Manual

MANUAL ON AMBIENT WATER QUALITY MONITORING

DAO 2007-28

INSTITUTIONALIZING THE MANILA BAY ENVIRONMENTAL PROJECT WITHIN THE DENR THROUGH THE IMPLEMENTATION OF THE OPERATIONAL PLAN FOR THE MANILA BAY COASTAL STRATEGY (OPMBCS)

DMC 2007-10

LIST OF CLASSIFIED WATER BODIES IN 2006

DMC 2005-006

LIST OF CLASSIFIED WATER BODIES OF 2004

DAO 2005-10

IMPLEMENTING RULES AND REGULATIONS OF THE PHILIPPINE CLEAN WATER ACT OF 2004 (REPUBLIC ACT NO. 9275).

DMC 2004-13

LIST OF CLASSIFIED / RE-CLASSIFIED WATER BODIES IN 2003

DMC 2004-11

COMPLIANCE OF ALL WASTEWATER DISCHARGERS TO UPGRADED AND RECLASSIFIED WATERBODIES

DMC 2004-10

CLARIFICATION ON THE FORM OF CYANIDE REFERRED TO IN THE DENR ADMINISTRATIVE ORDER (DAO) NO. 34: REVISED WATER USAGE AND CLASSIFICATION/WATER QUALITY CRITERIA AND THE DENR ADMINISTRATIVE ORDER NO. 35: REVISED EFFLUENT STANDARDS OF 1990

DAO 2004-25

AMENDING CHAPTER V, ARTICLE I OF THE IMPLEMENTING RULES AND REGULATION OF PD 984 BY DELETING THE AUTHORITY TO CONSTRUCT AND CONVERSION OF PERMIT TO

OPERATE TO DISCHARGE PERMIT FOR WATER POLLUTION SOURCE/CONTROL FACILITIES

EMB MC 2003-008

PROCEDURAL AND REFERENCE MANUAL FOR DAO 2003-27

DAO 2003-39

IMPLEMENTING RULES AND REGULATIONS OF DAO 16, SERIES OF 2002 ENTITLED "THE DENR-EMB NATIONAL ENVIRONMENTAL USER'S FEE OF 2002."

RA 9275

AN ACT PROVIDING FOR A COMPREHENSIVE WATER QUALITY MANAGEMENT FOR OTHER PURPOSES.

DAO 2003-27

AMENDING DAO 26, DAO 29 AND DAO 2001-81 AMONG OTHERS ON THE PREPARATION AND SUBMISSION OF SELF-MONITORING REPORTS (SMR).

DAO 2003-26

REVISED INDUSTRIAL ECOWATCH SYSTEM AMENDING IMPLEMENTING GUIDELINES OF DAO 98-51 SERIES OF 1998

EMB MC 2003-006

IMPLEMENTATION SCHEME FOR INDUSTRIAL ECOWACTH SYSTEM 2003

EMB MC 2003-007

PROCEDURAL MANUAL FOR DAO 2003-26

DAO 1990-35

REVISED EFFLUENT REGULATIONS OF 1990, REVISING AND AMENDING THE EFFLUENT REGULATIONS OF 1982

DAO 1994-26A

PHILIPPINE STANDARDS FOR DRINKING WATER 1993 UNDER THE PROVISION OF CHAPTER II, SECTION 9 OF PD 856, OTHERWISE KNOWN AS THE CODE ON SANITATION OF THE PHILIPPINES.

DAO 1990-34

REVISED WATER USAGE AND CLASSIFICATION/WATER QUALITY CRITERIA AMENDING SECTION NOS. 68 AND 69, CHAPTER III OF THE 1978 NPCC RULES AND REGULATIONS

PD 1067-IRR

WATER CODE OF THE PHILIPPINES - IMPLEMENTING RULES AND REGULATIONS

PD 1067

THE WATER CODE OF THE PHILIPPINES

APPENDIX 3. Agencies under various Departments and their functions

A. Department of Environment and Natural Resources (DENR)

Under the DENR:

The **Environment Management Bureau** (DENR-EMB) is the lead agency under DENR that handles the implementation of the Philippine Clean Water Act. It develops and reviews water quality management policies, rules and regulations such as ambient water quality guidelines and effluent standards. It also implements some of the Act's critical provisions such as the commercial and industrial wastewater charge and discharge permitting system and the designation of Water Quality Management Areas. It also conducts ambient water quality monitoring and classification activities for the country's surface water bodies and acts as the Secretariat for the Pollution Adjudication Board. EMB also formulates environment quality standards for water, air, land, noise and radiation; approves environmental impact statements and issues Environmental Compliance Certificates (ECC).

The **Ecosystem Research Development Bureau** (DENR-ERDB) is the principal research and development unit of the DENR. Its research, development, and extension activities are focused on the five major ecosystems of the Philippines specifically forests, upland farms, grasslands and degraded areas, coastal zone and freshwater, and urban areas.

The Forest Management Bureau (DENR-FMB) formulates and recommends policies and programs for the effective protection, development, occupancy management, and conservation of forest lands and watersheds.

The **Laguna Lake Development Authority** (DENR-LLDA) is a quasi-government agency that by virtue of RA 4850, leads, promotes, and accelerates sustainable development in the Laguna de Bay region. Regulatory and law-enforcement functions are carried out with provisions on environmental management, particularly on water quality monitoring, conservation of natural resources, and community-based natural resource management. Patterned after the LLDA are (five other [?]) Water Quality Management Areas (WQMAs) which are designated to coordinate efforts related to the improvement of water quality within their jurisdiction.

The **Mines and Geosciences Bureau** (DENR-MGB) is responsible for the administration and disposition, conservation, management, development, and proper use of the country's mineral lands and mineral resources including those in reservations and lands of public domains. One of its programs is the conduct of groundwater resource and vulnerability assessments of various areas in the country with the goal of developing a groundwater availability map. This map is intended to be used as a tool by decision makers in the management of available water resources for future development, particularly by NWRB in permitting rights for water withdrawals.

The **National Mapping and Resource Information Authority** (DENR-NAMRIA) surveys and maps the land and water resources of the Philippines. The authority is mandated to provide map-making services to the public and private sector and to act as the central mapping agency. In addition, the Authority is the depository and distribution facility for natural resources data in the form of maps, charts, texts, and statistics.

The **River Basin Control Office** (DENR-RBCO) was created through EO No. 510 on March 5, 2006 and is the coordinating agency to: 1) rationalize the various existing river basin projects; 2) develop a national master plan for flood control by integrating the various existing river basin projects and developing additional plan components as needed; 3) rationalize and prioritize reforestation in watersheds; 4) develop a master plan on integrated river basin management and development; 5) act as water body that shall coordinate all government projects within the river basins; and 6) implement water-related projects such as river rehabilitation, lake management, and other water resources management and development.

The subsequent EO No. 816 declared the RBCO under the DENR as the lead agency for the integrated planning, management, rehabilitation and development of the country's river basins. The RBCO is tasked to rationalize and integrate plans, projects, and programs related to the country's river basins. The RBCO serves as the oversight office of all government agencies and corporations pursuing relevant river basin initiatives such as river basin infrastructure development, flood control, environmental protection, and integrated water resources management. Other RBCO mandates include river basin integrated planning, river basin organization creation and mobilization, a river basin integrated information system, and river basin focused areas of intervention.

B. Department of Interior and Local Government (DILG)

Under the DILG:

The **Local Government Units** (DILG-LGUs) provide water supply and sanitation services for the local areas. Water Districts (WDs) are usually organized in provincial centers or urban areas where financial viability is better. At the barangay level, especially in non-viable areas, Barangay Water Services Associations (BWSAs), Rural Water Supply Associations (RWSAs) and Cooperatives act as water service providers in lieu of water districts.

The basic services and facilities vested in the LGUs are listed for Barangay, Municipality, Province and City respectively in Sec. 17, Chapter I of the Local Government Code (LGC) of 1991.

a) Basic Services and Facilities vested in LGUs

For a Barangay – Services and facilities related to general hygiene and sanitation and maintenance of water supply systems;

For a Municipality – Extension and on-site research and facilities related to agriculture and fishery activities; inter-barangay irrigation systems; water and soil resources utilization and conservation projects, and enforcement of fishery laws in municipal waters including conservation of mangroves; implementation of community-based forestry projects subject to supervision, control and review of DENR, and management and control of communal forests; services and facilities related to general hygiene and sanitation; communal irrigation, small water impounding projects, artesian wells, spring development, rain-water collections and water supply systems, sea walls, dikes, drainage and sewerage, and flood control.

For a Province – Assistance in organization of farmers and fishermen's cooperatives and other collective organizations, and transfer of appropriate technology; and inter-municipal water works, drainage and sewerage, flood control, irrigation systems, and reclamation projects; and

For a City – All the services and facilities of the municipalities and the provinces.

C. Department of Agriculture (DA)

Under the DA:

The **Bureau of Fisheries and Aquatic Resources** (DA-BFAR) formulates plans for the proper management, accelerated development, and proper utilization of fisheries and aquatic resources.

The **Bureau of Soils and Water Management** (DA-BSWM) is the mapping arm of the Department of Agriculture and is mandated to advise and render assistance on the utilization of soils and water as vital agricultural resources. The BSWM is responsible for formulating measures and guidelines for effective soil, land, and water resource utilization. The BSWM is also mandated to coordinate the implementation of Small Scale Irrigation Projects which have been proven effective to mitigate the impacts of El Nino events in the country.

The **National Irrigation Administration** (DA-NIA) undertakes program-oriented and comprehensive water resources projects for irrigation purposes as well as concomitant activities such as flood control, drainage, land reclamation, hydropower development, watershed management and etc.

D. Department of Health (DOH)

Under the DOH:

The **Local Water Utilities Administration** (DOH-LWUA) was established in 1973 to promote the development of provincial water supply in the Philippines. LWUA, as a specialized lending institution, is a one-stop-shop from which the Water Districts (WDs) receive financial assistance, engineering/technical services, and institutional development and regulatory services. The LWUA regulates the operation of Water Districts in municipalities and cities outside Metro Manila. The agency also provides technical and financial assistance for the development of those WDs, and reviews rates or changes established by these local water utilities. The review and approval of WD water tariffs as well as the general performance rating of WDs are mandated functions of LWUA.

LWUA, through its Water Resources Research and Training Department (WRRTD), manages and maintains a computerized groundwater data bank of groundwater quality and locations and undertakes groundwater assessments and research studies for various water districts.

The Water Districts (DOH-WDs) were created by the same 1973 decree that created LWUA, paving the way for the water district concept in the provision of water supply, sewerage, and sanitation outside of Metro Manila. The WDs are administered by the Metropolitan Waterworks and Sewerage Services of the Department of Public Works and Highways.

The **Environmental Health Service (EHS)** is responsible for water supply and sanitation programs and strategies to forestall environment-related diseases.

The **Bureau of Research Laboratories (BRL)** monitors quality drinking water.

E. Department of Science and Technology (DOST)

Under the DOST:

The **Philippine Atmospheric, Geophysical and Astronomical Services Administration** (DOST-PAGASA) provides meteorological forecasts and information through its network of weather stations and other sources of weather data. It is engaged in the collection and assessment of selected hydrological data in river basins, particularly those with operating hydroelectric dams.

The **Philippine Council for Agricultural and Aquatic Resources Development** (DOST-PCAARD) formulates national agriculture, forestry and natural resources research and development program on multi-disciplinary inter- agency approach for the various commodities including water resources.

The **Philippine Nuclear Research Institute** (DOST-PNRI) conducts research and development on the application of isotope and nuclear techniques in water resources management and protection.

F. Department of Public Works and Highways (DPWH)

Under the DPWH:

The **Bureau of Research and Standards** (DPWH-BRS) is engaged in monitoring and studies of water resources as well as conducting water research and setting water-quality standards. The BRS collects, processes, stores, and disseminates streamflow, water quality, and sediment data of rivers and lakes.

By virtue of E.O. # 124 dated January 30, 1987, the function of coordinating and supervising the collection of surface water; including their processing, publication, storage and dissemination was transferred to the Bureau of Research and Standards (BRS) of the DPWH.

The BRS is mandated to:

- Review, develop criteria and standards for the design, establishment, operation of national network of surface water observation stations;
- Review, develop criteria and standards for the design, establishment, operation of national network of groundwater observation wells;
- Initiate, develop and recommend specification standards of hydrologic equipment.

The **Metropolitan Waterworks and Sewerage System** (DPWH-MWSS) assumes jurisdiction, supervision, and control over all waterworks and sewerage system in Metro Manila, in the province of Rizal, and in some municipalities in the neighboring provinces of Bulacan and Cavite. In 1997, it entered into a public-private partnership agreement with two companies that were given the concession to provide water supply, sewerage and sanitation in Metro Manila.

Project Management Office-Rural Water Supply (DPWH-PMO-RWS) manages the planning, design, construction, operation and maintenance of foreign assisted rural water supply projects.