Rural Water Supply

Volume I

Design Manual

WATER
PARTNERSHIP
PROGRAM

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MALACAÑAN PALACE
MANILA

MESSAGE

I congratulate the institutions, agencies, and individuals of the water sector for your collaborative publication of the **Rural Water Supply Manual**.

This Manual is the latest of many multi-sectoral efforts to extend the availability of safe water to our countrymen. Water security is a critical issue that we must address, for it is essential to maintaining the well-being and dignity of human life. Thus, I am heartened by our steady progress in this regard—significantly decreasing the number of families without access to water from over 27 million in the 1990s to less than 16 million at present. These accomplishments are in no small part due to the cooperation among agencies and institutions and the support given by their leadership, who have established the necessary programs and administrative mechanisms to enable a dynamic exchange of skills and expertise.

To sustain the gains that we have achieved in securing the safety and accessibility of our water resources, our government is set on formulating and implementing a unifying framework that will harmonize the work of all engaged stakeholders in the water sector, in order to enhance support and ensure that the provision of safe water becomes a universal, self-sustaining aspect of our total development as a nation.

With your continued enthusiasm, I am confident that we can meet and perhaps even surpass our Millenium Development Goal for safe water. Equitable growth can only be accomplished by integrating social justice as the central component of our development agenda, applying a fair and equal treatment of every individual under the law and by our institutions. Let us work together to realize our shared aspiration of a sustainable Philippines.

BENIGNO S. AQUINO III

MANILA
February 2012

Foreword

Purpose of this Manual

This **RURAL WATER SUPPLY DESIGN MANUAL** is the first of three related volumes prepared for the use of prospective and actual owners, operators, managements, technical staff, consultants, government planners and contractors of small Level III and Level II water supply systems in the Philippines.

Its purpose is to introduce the key concepts and considerations involved in the design of small waterworks facilities for Level II and III systems.[1] For the technical persons, hopefully it will facilitate their work by providing them with a ready resource reference for their everyday use. For the non-technical readers, such as the many who are involved in the management and operation of small water supply systems, hopefully it will be an aid in understanding the design process, giving them a basis for participating in decisions that would enable them to avail more usefully of the services of the technical consultants and contractors they must deal with.

Overall, the local and international partners who cooperated in making these Manuals possible hope that they will help the participants in the rural water supply sector to understand better the nature of the water supply business, its responsibilities to the stakeholders, and the role of the government agencies and regulatory bodies that seek to help them operate sustainably while protecting the consumers.

On the Use of the Manual

This **RURAL WATER SUPPLY DESIGN MANUAL** and the companion volumes in the series can at best serve as a general reference and guide. As they refer to the information, recommendations, and guidelines contained in them, readers are urged to consider them always in relation to their own specific requirements, adapting and applying them within the context of their actual situation.

Even as they refer to this Manual for information, its users are advised to consult with qualified professionals – whether in the private sector, in the local governments, or in the regulatory and developmental agencies concerned with the water sector – who have had actual experience in the construction, management, operation, maintenance, and servicing of water supply systems and utilities – including those other professionals who can help them in the financial, legal and other aspects of their small water supply business.

[1] A few of the topics covered may also be relevant to Level I systems, which consist of a single well or pump serving a limited number of beneficiaries at source. However, it was felt unnecessary to focus on Level I systems requirements in this work, as the design, engineering, operational and maintenance of requirements of Level I systems – as well as the organizational and training support – are adequately provided by the relevant government agencies and supported by non-government agencies.

Manual Organization

The three volumes in this series of RURAL WATER SUPPLY MANUALS are as follows:

Volume I: DESIGN MANUAL. – Its purpose is to introduce and give the reader the key design concepts in the design of waterworks facilities. For non-technical readers who are involved in the management and operation of small water supply systems, rather than in their actual design and construction, the text of Volume I will be useful in understanding and in making decisions that would enable them to avail more usefully of the services of the technical consultants and contractors they must deal with.

Volume II: CONSTRUCTION SUPERVISION MANUAL. – This volume presents the considerations, requirements, and procedures involved in supervising a waterworks project. How these are implemented should be clear to one who supervises, inspects, or manages such a project. For this reason, the details of implementation are covered in the chapters on Pipeline and Pumping Facilities Installation, Concrete and Reservoir Construction, Water Sources, Metal Works, and Painting.

Volume III: OPERATION AND MAINTENANCE MANUAL. – This volume focuses on the small water system as a public utility, and answers the question "What are the requirements to effectively manage and sustainably operate a small utility?" It covers the institutional and legal requirements of setting up a water supply business, the demands of ensuring water safety through proper treatment, the nature and requirements of operating and maintaining the water distribution system, and its administration, commercial, financial, and social aspects.

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Acronyms & Abbreviations

Government and Other Organizations

ASTM	American Standard for Testing Materials
AWS	American Welding Society
AWWA	American Water Works Association
BIR	Bureau of Internal Revenue
CDA	Cooperative Development Authority
DAR (ARISP)	Department of Agrarian Reform, Agrarian Reform Infrastructure Support Program
DILG	Department of Interior & Local Government
DOH	Department of Health
DPWH	Department of Public Works & Highways
LWUA	Local Water Utilities Administration
NIOSH	National Institute for Occupational Safety and Health (United States)
NSO	National Statistics Office
NWRB	National Water Resources Board
SEC	Securities & Exchange Commission
WHO	World Health Organization

Technical & Operational Terms, Units of Measure

AC	alternating current
ADD	average daily demand
AL	allowable leakage
BOD	Bio-oxygen Demand
CAPEX	capital expenditure
CBO	Community-Based Organization
cc	cubic centimeter
CIP	cast iron pipe
cm	centimeter
COD	chemical oxygen demand
CPC	Certificate of Public Conveyance
CT	Contact Time
cumecs	cubic meter per second
Dia	diameter
dam	dekameter
Dep	depreciation expenses
dm	decimeter
Elev	elevation
EV	equivalent volume
F/A	Force/Area
g	grams
GPM	gallons per minute
gpm	gallons per minute
HGL	hydraulic grade line
hm	hectometer
HP	horsepower
HTH	High-Test Hypochlorite

IDHL	Immediately Dangerous to Life and Health
kg	kilograms
kgf	kilogram force
km	kilometer
kpa	kilopascals
KPIs	key performance indicators
LGUs	Local Government Units
lm	linear meter
lpcd	liters per capita per day
lps	liters per second
m	meter
m2	square meter
m3	cubic meter
m3/d	cubic meter per day
MaxNI	maximum allowable net income
MDD	maximum day demand
mg/l	milligrams per liter
mg/l	milligrams per liter
mm	millimeter
mld	million liters per day
mm/hr	millimeters per hour
MOA	Memorandum of Agreement
N/m2	Newtons per square meter
NGO	Non-Government Organization
NPSH	net positive suction head
NRW	non-revenue water
NTU	Nephelometric turbidity unit
O&M	operation and maintenance
OD	outside diameter
Opex	operational expenses
Pa	Pascal
PE	polyethylene pipe
PEER	property and equipment entitled to return
PNS	Philippine National Standards
PNSDW	Philippine National Standards for Drinking Water
psi	pounds per square inch
PVC	polyvinyl chloride pipe
PWL	pumping water level
ROI	return on investment
RR	revenue requirements
RWSA	Rural Water & Sanitation Association
SCBA	self-contained breathing apparatus
SMAW	shielded metal arc welding
SSWP	Small-Scale Water Provider
SWL	static water level
TDH	total dynamic head
TDS	total dissolved solids
VC	volume container
VIM	variation in mass
Wc	container
Wcm	container + material
WHP	water horsepower
WL	water level

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Chapter 1
Introduction

This Chapter presents the major considerations in the design of successful small water supply systems such as are appropriate to serve the populations in rural areas and small towns in the Philippines.

A. THE PHILIPPINE WATER SECTOR EXPERIENCE

Starting in the 1970s, the Philippine Government introduced certain developmental practices and concepts to strengthen the water sector and expand its coverage of the population. These led to the improved overall sustainability of water utilities, the establishment of more small water systems, the institutionalization of support for all water service levels, and the increase in commitments of development funds to maintain the positive impetus that had been created.

While these practices and concepts were applied initially to advance sector-wide objectives, the lessons learned are relevant today in the conceptualization, planning, strategy-setting, operation and expansion of the individual small utility. They can be summarized as follows:

1. Phased Design

In designing systems, the concept of having a master plan for each utility (with a design horizon of 10-20 years) was adopted but implemented in phases. The initial phase was designed to address only the service demand projected for the initial years, but provided for eventual expansion. The implementation of subsequent phases was made contingent on increases of the revenue base and service demand, and on the creditworthiness of the utility. This realistic, conservative approach prevented the overdesign of the system and introduced the concept of cost recovery tariffs.

2. Use of Updated Technology

The new technologies introduced, like geo-resistivity surveys to determine the sites and design of wells, computerization, new drilling methodologies, and hydraulic networking models – were an important boon for the effective planning and operation of water utilities.

3. Operational Autonomy

Water districts (WDs), water cooperatives and rural water & sanitation associations (RWSAs) were operated by boards chosen from the community. They retained all their water revenues, which were used for defraying operational costs, debt service and as reserves for the utility business. These organizations also had to source their own funds either from internally generated cash or loans. The financial autonomy and discipline that had to be adopted by these utilities helped greatly to improve their management and operation.

4. Tariff Design and Public Consultation

The tariff mandated by government policies is designed as a full-recovery tariff which all utilities must adopt. The law also requires all utilities to present in a public hearing or in a general membership assembly all petitions for tariff adjustments.

5. Institutional Development Practices

Water districts (WDs) had to adhere to standard commercial practices and organizational structure guidelines developed by LWUA. The Billing and Collection System and the preparation of formal Financial Statements are examples of these commercial practices. Training programs were also developed for all staff levels within the WD, from the Board down to the operators.

6. Monitoring System

Key Performance Indicators and operating standards were introduced and all WDs, water cooperatives, and grantees of Certificates of Public Conveyance (CPC)[1] of the National Water Resources Board (NWRB)[2] were required to submit monitoring reports at least on an annual basis. The monitoring system pinpointed the poor performing utilities and helped the regulators institute immediate remedial measures.

B. CONSIDERATIONS FOR A SUSTAINABLE SYSTEM

From the experience of the water sector, the considerations that determine a sustainable system fall into four major areas:

1. **Technical Considerations** – From the outset, the design and construction of the system should be done right, using the appropriate technology, equipment and materials. It is clear that if a newly built system experiences high NRW or unaccounted-for water at the start of its operational life, the correction of the likely systemic deficiencies would be very expensive, disruptive of operations and revenue streams, and almost futile.

2. **Financial Considerations** – Financial considerations have to do with building and operating the system at the least possible cost but in a way that meets all standards and the customers' requirements. These considerations must strike a balance between the acceptance and affordability levels of customers, on the one hand, and the appropriate cost recovery tariff structure, on the other, as the latter constitutes

[1] A formal authority to operate a water utility
[2] NWRB is the Philippines' national economic regulatory body for private water systems.

the primary source of funds needed to support the operational, maintenance and repair, and future requirements of the utility.

3. **Social Considerations** – This means engaging the population and gaining the broad community support that is needed to initiate and carry out the public utility project. The interests and concerns of the various stakeholders, including the local officials, businesses, community leaders, and the homeowners as groups and individuals have to be considered and their views given the proper respect. A small town water business needs to operate with a strong social base to support its role as a public utility.

4. **Environmental Considerations** – This means that the system should be built and operated in relation to its environment. It must be sure that its sources of water have not been, and will not be compromised by surrounding developments. At the same time it has to preserve the viability of its water sources, and to ensure that extractions are well within the limits of safe yields. During the construction and operational period, care must be taken to ensure that it does not cause pollution of the environment or degradation of adjacent aquifers waterways and bodies of water.

C. THE WATER SYSTEM DESIGN PROCESS

The design of small water supply systems has to consider key decision areas related both to the facilities and to the operation and maintenance issues that the utility needs to address. The details of these decision areas, which are summarized below, are discussed in several chapters and an annex in this volume (referred below by Chapter and Annex) and in Chapter 8 of Volume III.

1. **Service Level** – The decision on service level or levels that the utility would provide should be based on a consultation process among the stakeholders. Service levels are discussed in Chapter 3.

2. **Water Demand Projections** – It is necessary to determine the design horizon for which the facilities will be designed, and project the population to be served annually over this horizon, the unit consumptions, and expected non-revenue water. These projections are based on the historical data on population growth and levels, as well as on analyses of current and future developments in the area to be served, their effects on income levels, and other information relevant to the drivers of water consumption. This will lead to a determination of how much water demand the system needs to support. These are discussed in Chapter 3.

3. **Facilities Designs** – The considerations, guidelines, and parameters of the different design elements for the components of small water systems are presented in the Chapters from 6 to 14.

4. **Capital Investment and O&M Costs** – Estimated Investment Costs are presented in Appendix C. The planner/designer will have to estimate the O&M costs based on the details of the proposed system, its water source, and facilities.

5. **Tariff Design** – Tariff design is discussed in Chapter 8: Financial Aspects in the companion "OPERATION AND MANAGEMENT MANUAL" (Volume III in this series on Rural Water Supply).

6. **Design Iteration** – Before plans are finalized, there is need to confirm if the facility, as proposed, meets the social criteria of affordability and acceptance. If the expected tariffs are too high or the unit investment cost is more than ₱ 15,000/connection (Level III), the proposed project should probably be redesigned starting from the reduction in service level objectives, lowering the standard for unit water consumption, and other measures to match the financial capabilities of the proposed users..

7. **Plans and Design Specifications** – Once all the agreements, design parameters, and assumptions are established, the detailed plans have to be prepared by professional engineers to ensure a well-balanced system that will fulfill its objectives, and to provide a detailed guide for the construction of the facilities.

Annex A gives additional details of the design steps, including a flowchart of the design process.

D. DESIGN OUTPUTS

The Detailed Engineering Design outputs are the following:

1. **Engineer's Report** – This report contains special design provisions as well as a summary of the design standards used. (Refer to Annex C for Design Standards). Design provisions include: demand requirements, justification of any treatment process adopted, soil conditions as a basis for foundation design, distribution system analysis, and source description and justification.

2. **General Layout** – This is usually the first page of the detailed plans showing the name of the barangay/town covered, the CBO or agency in charge of the WS facilities, the location of major facilities (sources, reservoirs) and coverage of the pipe network.

3. **Detailed Plans** – These are also called the blueprints or working drawings. The designs of these facilities are explained in the chapters in this Manual covering the particular component of the facilities. Plans will include the locations, elevations, schematics, dimensions and elevations of all facilities.

4. **Specifications** – Specifications always accompany a set of working drawings. Specifications refer the type of material to be used, installation and disinfection procedures, and the quality of workmanship. There are in general two types of material specifications that can be adopted…material or performance. Specifications can be found in the different chapters of this Design Manual.

   Among the different agencies, it is only the LWUA that has a complete set of specifications for water systems. It is suggested that the LGUs or CBOs concerned secure a copy of these specifications for reference or use it to the maximum extent possible.

   Table 1.1 shows some examples of specifications.

Table 1.1: Sample Specifications

Plastic pipe materials	All materials including pipe, fittings, valves and fire hydrants shall conform to the latest standards issued by the PNS 14:2004 or PNS-ISO 4427:2002 and be acceptable to the approving authority. In the absence of such standards, materials meeting applicable Product Standards and acceptable to the approving authority may be selected.
Pavement concrete subject to heavy loads	Unless otherwise indicated on the plans, the minimum concrete compressive strength for slabs on fill subjected to pneumatic tired traffic will be 4,000 pounds per square inch @ 21 days. Portland cement shall meet specifications of PNS 14:2004
Drain pipe for ground reservoir	The overflow for a ground-level storage reservoir shall open downward and be screened with twenty-four mesh non-corrodible screen. The screen shall be installed within the overflow pipe at a location least susceptible to damage by vandalism. The overflow pipe shall be of sufficient diameter to permit waste of water in excess of the filling rate
Steel bars	Rolled bars used for concrete reinforcement shall conform with PNS 49: 2002 requirements.
Submersible pump	The pump to be used shall have an operating characteristic of xxx m TDH and yyy lps at a minimum efficiency of 60% as indicated in its operating curve.
Disinfection procedure	All wells, pipes, tanks, and equipment which can convey or store potable water shall be disinfected in accordance with current AWWA procedures. Plans or specifications shall outline the procedure and include the disinfectant dosage, contact time, and method of testing the results of the procedure.

5. **Bill of Quantities and Cost Estimates** – The bill of quantities prepared during the detailed engineering phase will be used as the bill of quantities in the bid documents, and the cost estimates will be used as a basis of the agency estimate for the bid.

Chapter 2

The Nature and Importance of Water

This Chapter discusses the nature of water, the hydrologic cycle and climate change effects as they relate to the operation of a small public water utility business designed to supply the potable water needs of Philippine communities.

A. THE PHYSICAL AND CHEMICAL NATURE OF WATER

Water is one of the most abundant substances on Earth without which life, it is said, cannot exist. It covers more than 70 per cent (70%) of the earth's surface and exists as vapor in the earth's atmosphere. It is considered as the universal solvent because of its ability to dissolve almost all organic and inorganic solids and gases it comes in contact with. For this reason, pure water is never found in nature. Even rainwater, the purest natural water, contains chemicals dissolved from the air. Pure water is obtained only by special methods of distillation and by chemical action in laboratories.

Pure water is a tasteless, odorless and colorless liquid. Water in liquid form is most dense at 4° C, (39.2° F). The density of water at this temperature is used as a standard of comparison for expressing the density of other liquids and solids. At 4° C, one liter of water weighs 1 kilogram (a density of 1 gram/cc). In its gas form as a vapor, water is lighter than air, thus, it rises in the atmosphere.

Other important properties of water are the following:

- At 4°C pure water has a specific gravity of 1. (Some reference the s.g. base temperature as 60F.)
- The density of pure water is a constant at a particular temperature, and does not depend on the size of the sample (intensive property). Its density however, varies with temperature and impurities.
- Water is the only substance on Earth that exists in nature in all three physical states of matter: solid, liquid and gas.
- When water freezes it expands rapidly adding about 9 % by volume. Fresh water has a maximum density at around 4° C. Water is the only substance whose maximum density does not occur when solidified. As ice is lighter than liquid water, it floats.
- The specific heat of water in the metric system is 1 calorie – the amount of heat required to raise the temperature of one gram one degree Celsius. Water has a higher specific heat than almost any other substance. The high specific heat of water protects living things from rapid temperature change.

B. USES AND IMPORTANCE OF WATER

Uses of fresh water can be categorized as consumptive and non-consumptive. Consumptive water use is water removed from available supplies without return to a water resource system (e.g., water used in manufacturing, agriculture, and food preparation that is not returned to a stream, river, or water treatment plant). Non-consumptive water use refers to a water use that can be treated and returned as surface water. A great deal of water use is non-consumptive, which means that the water is returned to the earth as surface runoff.

1. Domestic Uses

Small water utilities are primarily concerned with water for potable use, which is basically for the home. Aside from drinking, other domestic uses include washing, bathing, cooking and cleaning. Other household needs might include tending and watering of home gardens and the upkeep of domestic animals. Basic household water requirements have been estimated to average around 40 liters per person per day. The standard used for drinking water supplied by Level II and Level III utilities is potability, or water that can be consumed directly by drinking without risk of immediate or long-term harmful effects.

2. Other Uses

Other use categories for water supplied by water utilities include Municipal, Irrigation, Power Generation, Fisheries, Livestock Raising, Industrial and Recreational uses.

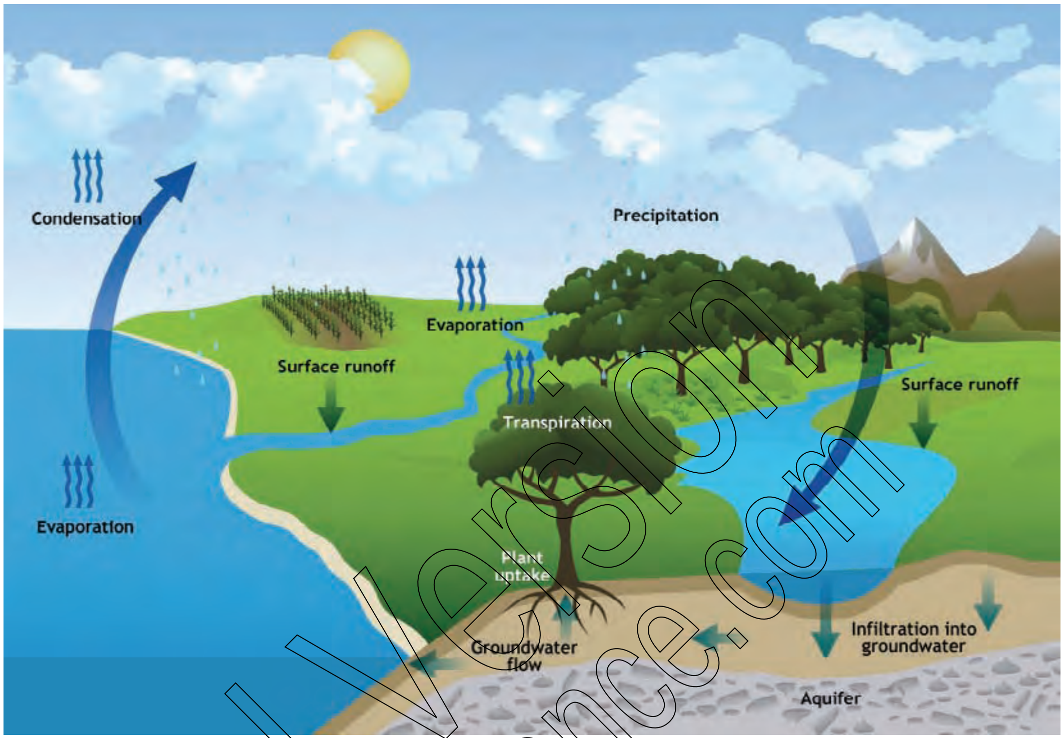
C. THE HYDROLOGIC CYCLE

The hydrologic or water cycle (Figure 2.1) is a conceptual model published on the internet that describes the storage and movement of water on, above and below the surface of the Earth. Since the water cycle is truly a "cycle," there is no beginning or end. Water occurs in one of its three forms (solid, liquid and vapor) as it moves through this cycle. The water cycle consists primarily of precipitation, vapor transport, evaporation, evapo-transpiration, infiltration, groundwater flow, and runoff.

1. Water in the Atmosphere

The sun, which drives the water cycle, heats water in oceans and seas. Water evaporates as water vapor into the air. Ice and snow may melt into liquid or sublimate directly into water vapor. Evapo-transpiration is water transpired from plants and evaporated from the soil. The water vapor rises in the atmosphere where cooler temperatures cause it to condense into clouds. As the air currents pick up and move the water vapor, cloud particles collide, grow, and fall out of the sky as precipitation. Where the precipitation falls as snow or hail, it can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snow packs can thaw and melt, and the melted water flows over land as snowmelt.

Figure 2.1: Hydrologic or Water Cycle



Landscape for Life website (http://landscapeforlife.org/give_back/3b.php)

2. The Bodies of Water

Most water falls back as rain into the oceans or onto land, where it flows over the ground as surface runoff. A portion of runoff enters rivers in valleys, where the stream flow moves the water towards the oceans. Some of the runoff and groundwater is sequestered and stored as freshwater in lakes. But not all the runoff flows into rivers or lakes; much of it soaks into the ground as infiltration.

3. Water in the Earth

Some of the water infiltrates deep into the ground and replenishes aquifers, which store freshwater underground for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies as groundwater discharge. Some groundwater finds pathways that eventually lead to openings in the land surface, where it comes out as springs. Over time, the water returns to the ocean, where the water cycle started.

4. The Phenomena in the Water Cycle

The various phenomena that characterize the water cycle are as follows:

- **Evaporation** – Evaporation is the process by which liquid water is converted into a gaseous state. It takes place when the humidity of the atmosphere is less than the evaporating surface (at 100% relative humidity there is no more evaporation).
- **Condensation** – Condensation is the change in state of water from vapor to liquid when it cools. This process releases latent heat energy to the environment.
- **Precipitation** – Precipitation is any aqueous deposit (in liquid or solid form) that develops in a saturated atmosphere (relative humidity equals 100%) and falls to the ground. Most precipitation occurs as rain, but it also includes snow, hail, fog drip, and sleet.
- **Infiltration** – Infiltration is the absorption and downward movement of water into the soil layer. Once infiltrated, the water becomes soil moisture or groundwater.
- **Runoff** – This is the topographic flow of water from the area on which it precipitates towards stream channels located at lower elevations. Runoff occurs when the capacity of an area's soil to absorb infiltration has been exceeded. It also refers to the water leaving a drainage area.
- **Evapo-transpiration** – This covers the release of water vapor from plants into the air.
- **Melting** – Melting is the physical process of a solid becoming a liquid. For water, this process requires approximately 80 calories of heat energy for each gram converted.
- **Groundwater Flow** – This refers to the underground topographic flow of groundwater because of gravity.
- **Advection** – This is the movement of water in any form through the atmosphere. Without advection, water evaporated over the oceans could not precipitate over land.

D. FACTORS ALTERING THE WATER CYCLE

Many factors have an impact on the normal workings of the water cycle. Some of these are either man–made, such as extent of agricultural and industry activities, deforestation and forestation, the construction of dams, the amount of water abstracted from surface and groundwater, and the effects of urbanization in terms of consumption and obstruction of the topographic flow of groundwater.

The other factors are those that influence climate change, which is basically manifested as a perceptible distortion of climate patterns. A large degree of uncertainty governs the understanding on how precipitation and temperature change leads to changes in runoff and river flows, flooding and drought patterns. The earth's climate has always changed, but it is the fast rate of change that is causing concern. As an example, there has been an increase of 0.61° C in the measured temperature in the Philippines from the 1950s to 2005.

About 86% of the global evaporation occurs from the oceans, which reduces their temperature by evaporative cooling. Without the cooling effect of evaporation, the earth would experience a much higher surface temperature. The rising temperatures will increase evaporation and result in increased rainfall. This situation may cause more frequent droughts and floods in different regions due to their variations in rainfall.

The Philippines suffered a severe drought in 1999 and two milder dry spells in 2004 and 2007. Droughts in the Philippines have destroyed millions of pesos worth of crops, reduced the country's water supply, and threaten widespread blackouts as power companies contend with low water levels in hydroelectric dams.

1. Responsibilities of Utilities in Relation to Climate Change

For their part, utilities must do whatever is necessary to promote water conservation measures and reduce non-revenue water. The Philippines is highly vulnerable to the impacts of typhoons, flooding, high winds, storm surges and landslides. It is therefore incumbent on the water system designer to consider, on one hand, the location and features of the utility's facilities, so as to protect them from negative effects of the climate and environmental changes that are being felt; and, on the other hand, ensure that the operation of the utility will not harm the ecology and that its design and plans incorporate measures to avoid adding to risk factors that contribute to climate changes.

2. Climate Change Effects to Consider

Climate changes have significant effects on the available sources of water, as well as on the competing demands on its use. Small water utilities have to be alert to these effects as they pose threats on their long-term viability and sustainability.

a. Climate Change Effects:

1. Rising Sea Levels
2. Increased saline intrusion into groundwater aquifers
3. Water treatment challenges: increased bromide; need for desalination
4. Increased risk of direct storm and flood damage to water utility facilities

b. Effects of Warmer Climate:

1. Changes in discharge characteristics of major rivers due to upstream changes
2. Changes in recharge characteristics of major groundwater aquifers due to upstream changes
3. Increased water temperature leading to increased evaporation and eutrophication in surface sources
4. Water treatment and distribution challenges
5. Increased competing demands for domestic and irrigation
6. Increased urban demand with more heat waves and dry spells
7. Increased drawdown of local groundwater resources to meet the increasing water demands

c. Effects of More Intense Rainfall Events:

1. Increased turbidity and sedimentation
2. Loss of reservoir storage
3. Water filtration or filtration/avoidance treatment challenges
4. Increased risk of direct flood damage to water utility facilities

3. Suggested Strategies to Mitigate Risks from Climate Change

Within the capabilities of small water utilities are some strategies that they can implement either as part of their day-to-day operations, or as special measures in response to external developments.

a. Water Conservation Measures:

1. Meter all production and connections
2. Reduce NRW
3. Demand Management through tariff design
4. Dissemination of water conservation tips to consumers

b. Design of Facilities

1. If possible have at least 2 sources of supply at different locations.
2. Build superstructures above high flood line level.
3. Adopt energy-efficiency programs and, where possible, select facilities which require less power consumption.

4. Monitor wells near coastlines to prevent salinization. If climate change causes sea levels to rise dramatically, even aquifers that have been sustainability utilized can suffer salinization.
5. Utilization of renewable energy sources

c. Reforestation of Watersheds:

1. Join or initiate community programs for watershed reforestation. Enlist assistance from NGOs and the LGU units.
2. Enlist the support of the community in protecting the watersheds.

d. Mitigation of Disaster Effects

1. Formation of a Disaster Response Committee
2. Networking with multi-sectoral organizations

Chapter 3

Water Demand

This Chapter describes the method of determining the water volumes needed by a new small water utility project to supply the population it intends to cover.

A. GENERAL

The first step in designing a Level II or small Level III water system is to determine how much water is needed by the population to be covered. The water to be supplied should be sufficient to cover both the existing and future consumers. It must include provisions for domestic and other types of service connections. In addition to the projected consumptions, an allowance for non-revenue water (NRW) that may be caused by leakages and other losses should be included.

Water demands are influenced by the following factors:

1. Service levels to be implemented
2. Size of the community
3. Standard of living of the populace
4. Quantity and quality of water available in the area
5. Water tariffs that need to be shouldered by the consumers
6. Climatological conditions
7. Habits and manners of water usage by the people

Once the consumption demands are defined, the next step is to determine the service level as part of the demand analysis.

B. SERVICE LEVEL DEFINITIONS

Water service levels are classified in the Philippines under three types[3], depending on the method by which the water is made available to the consumers:

- **Level I (Point Source)** – This level provides a protected well or a developed spring with an outlet, but *without a distribution system*. The users go to the source to fetch the water. This is generally adaptable for rural areas where affordability is low and the houses in the intended service area are not crowded. A Level I facility normally serves an average of 15 households within a radius of 250 meters.

[3] NEDA Resolution No.5, Series 1998

- **Level II (Communal Faucet System or Stand Posts)** – This type of system is composed of a source, a reservoir, a piped distribution network, and communal faucets. Usually, one faucet serves four to six households within a radius of 25 meters. It is generally suited for rural and urban fringe areas where houses are clustered in sufficient density to justify a simple piped system. The consumers still go to the supply point (communal faucet) to fetch the water.

- **Level III (Waterworks System or Individual House Connections)** – This system includes a source, a reservoir, a piped distribution network, and individual household taps. It is generally suited for densely populated urban areas where the population can afford individual connections.

C. DESIGN PERIOD

In commercial utility models, the design period normally spans long periods involving decades within which the initial capital outlay and succeeding outlays for expansion and rehabilitation can be rationally recovered. For small water utilities, including those owned by the local governments, such large outlays are not available and cannot be matched by the rural population's capacity to pay. For these reasons, the design period or horizon in this Manual is set at 5 or 10 years. In fact, these are the design periods frequently decided by agreements among the funder, the implementing agency, and the community or the LGU. In setting the design period, the designer should take into account the terms of the financing package and the potential consumers' capability and willingness to pay the amounts needed to support repayment.

The advantages and disadvantages for the 5- and 10-year options are:

1. Five-year design period

- **Advantages** – Low initial capital cost. If the project is to be financed through a loan, the loan amortizations are lower due to the lower investment cost.

- **Disadvantages** – Need for new capital outlays after five (5) years to upgrade system capacity. Most waterworks facilities, like reservoirs and pipelines are more viable to plan for a one stage 10-year period than to plan in two stages of 5-year period each.

2. Ten-year design period

- **Advantages** – The water system facilities are capable of meeting the demand over a longer period. No major investment cost is expected during the 10-year design period.

- **Disadvantages** – The higher initial capital cost will require initial tariffs to be set higher.

D. DESIGN POPULATION

The design population is the targeted number of people that the project will serve. Examples in this section on population and water demand projections are based on the assumption that the design period is 10 years and the design year (or base year) is 2020.

There are 2 ways of projecting the design population.

1. Estimate the population that can be served by the sources. In this case, the supply becomes the limiting factor in the service level, unless a good abundant and proximate source is available in the locality.
2. Project the community or barangay population, and determine the potential service area[4] and the served population.

For purposes of illustration, the latter method is used throughout this Chapter. (The challenge is to discover and develop sources for populations in need of potable water supply. It is relatively simple to correlate the projected population to be served with the limitations of supply that may be determined using the first method.)

The historical population growth rates of the municipality/city/barangays are needed as the basis for population projections. The population is enumerated every 5 years (beginning on 1960, except in 2005 where it was moved to 2007 due to budgetary constraints). The latest national census was conducted for year 2010 but no official results have as yet been released by the NSO. These data can be obtained from the local governments themselves or from the National Statistics Office (NSO).[5]

Steps 1-3 below are used to determine the design population.

1. Projecting Annual Municipal and Barangay Growth Rates

The basic equations to be used to determine the average annual growth rate within the last censual period (in this case from 2000 to 2007):

$$\boldsymbol{P_{2007} = P_{2000}(1 + GR)^n}$$

or

$$\boldsymbol{GR = \left(\frac{P_{2007}}{P_{2000}}\right)^{\frac{1}{n}} - 1}$$

Where:

$\boldsymbol{P_{2007}}$ = population in 2007
$\boldsymbol{P_{2000}}$ = population in 2000
$\boldsymbol{GR}$ = annual growth rate (multiply by 100 to get percent growth rate)
$\boldsymbol{n}$ = number of years between the two census, in this case $\boldsymbol{n = 7}$

[4] Areas with pipes
[5] As of Oct 2010, the available census data are for years 2000 and 2007.

Using the above equations, the latest average annual growth rate GR for the municipality and its barangays (potential service area) can be determined. If a new census report is released by NSO, say for the year 2010, the above formula should be adjusted accordingly.

The latest historical GR of each covered barangay could then be projected every five years (2010, 2015, 2020). If no projections of population or growth rates are available for the municipality, the following assumptions can be used:

1. The maximum annual GR by year 2010 will be 2.5% (unless there is a planned development in the barangay that will boost immigration). It is assumed that the Government's population program and the public awareness of the issue will eventually temper high population growth. This is applicable to historical annual GRs that are more than 2.5%. Interpolation of the GR2007 and GR2010 will be done to get the GRs for the in-between years.
2. The minimum annual GR by year 2010 will be 1.0%. An annual GR of less than 1.0% for any barangay to be served is deemed unreasonably low considering that with the provision of accessible water supply, the barangay very likely will attract migrants. This is particularly applicable to historical annual GRs that are less than 1.0%. The GR_{2007} and GR_{2010} could then be interpolated to get the GRs for the in-between years.
3. For the reasons stated, the GRs within 1.0% to 2.5% will decrease by a modest 0.5% per year.

Table 3.1 shows a sample GR projection using the above method.

Table 3.1: Sample Growth Rate Projections

Barangay	Population		Growth Rate (%)	Projected Annual Growth Rate (%)		
	2000	2007	2000 – 2007	2000 – 2010	2010 – 2015	2015 – 2020
Bgy 1	1,000	1,300	3.82	3.51	3.01	2.50
Bgy 2	2,000	2,300	2.02	1.99	1.94	1.89
Bgy 3	1,800	1,900	0.78	0.83	0.91	1.00

The projected growth rates are preliminary and should be examined if reasonable and realistic. These should be compared with projections, if any, from the Provincial and Municipal Planning and Development Offices. Adjustments on the computed GRs should be made as considered necessary.

2. Projecting Municipal and Barangay Populations

Having projected the annual growth rates, the year-by-year population projections for the municipality and barangays could then be computed by applying the basic equation

$$P_n = P_0(1 + GR)^n$$

Where:

$\boldsymbol{P_n}$ = the projected population after nth year from initial year
$\boldsymbol{P_0}$ = the population in the intial year of the period concerned
$\boldsymbol{GR}$ = the average growth rate between the 2 periods
$\boldsymbol{n}$ = number of years between $\boldsymbol{P_0}$ and $\boldsymbol{P_n}$

To project, for example, the population for the years 2010, 2015 and 2020, the equation is substituted as follows:

$$\boldsymbol{Pop_{2010} = actual\ Pop_{2007}(1 + projected\ GR_{2007-2010})^3}$$
$$\boldsymbol{Pop_{2015} = Pop_{2010}(1 + projected\ GR_{2010-2015})^5}$$
$$\boldsymbol{Pop_{2020} = Pop_{2015}(1 + projected\ GR_{2015-2020})^5}$$

The population for the years in-between are projected by using the same basic equation and applying the respective growth rates for the periods.

3. Projecting the Population Served

After determining the projected population for each of the barangays, the next step is to determine the actual population to be served. Some of the residents may not ask for the service, and some will be too far from the distribution system. Determining the actual potential users involves but is not limited to the following activities:

1. Preparation of base maps.
2. Ocular inspection gain familiarity with the physical and socio-economic conditions of the potential service area. Note that population densities must be estimated.
3. Delineation of the proposed service area (where the pipes are to be laid).
4. Determination and assessment of the level of acceptance by the residents of the planned water system. A market survey is recommended, in which one of the questions to be asked is if the respondent is willing to avail of the service, and how much is the respondent willing to pay per month for a Level II or a Level III service.
5. Assessment of the availability and abundance/scarcity of alternative water sources, such as private shallow wells, dug wells, surface waters, etc.

The percentage of those willing to avail of the planned water service could be adopted in the plan for the initial year of operation. The annual increase from the initial year up to the end of the design period will have to be assumed by the planner. For this he/she will have to consider the general economic capacity of the families and other pertinent information. For every year, the served population is estimated by applying the percentage of willingness to the projected population, per barangay, for the year.

E. WATER CONSUMPTIONS

Water consumptions served by small water utilities are commonly classified into Domestic Use, Commercial Use, Institutional Use, or Industrial Use. In rural areas, water consumption is generally limited to domestic uses, i.e., drinking, cooking, cleaning, washing and bathing. Domestic consumption is further classified as either Level II consumption (public faucets) or Level III consumption (house connections).

1. Unit Consumptions

Unit consumption for domestic water demand is expressed in per capita consumption per day. The commonly used unit is liters per capita per day (lpcd). If no definitive data are available, the unit consumption assumptions recommended for Level II and Level III domestic usages in rural areas are as follows:.

- Level II Public Faucets: 50 - 60 lpcd

  (Each public faucet should serve 4 - 6 households)

- Level III House Connections: 80 - 100 lpcd

If there are public schools and health centers in the area, they will be supplied from the start of systems operation and be classified as institutional connections.

Commercial establishments can also be assumed to be served, after consultation with the stakeholders, within the 5-year period. The unit consumptions of institutional and commercial connections are, in terms of daily consumption per connection, usually expressed in cubic meters per day (m^3/d). Unless specific information is available on the consumptions of these types of connections, the following unit consumptions for commercial and institutional connections can be used.

- Institutional Connections: 1.0 m^3/d
- Commercial Connections: 0.8 m^3/d

This unit consumption can be assumed to be constant during the design period under consideration, *unless available information indicates otherwise*.

2. Total Consumption

The total consumption is the sum of the domestic, institutional and commercial consumptions expressed in m^3/d.

a. Domestic Consumption:

The year-by-year total domestic consumption is projected by applying the projected unit consumption to the projected population to be served for each year. The served population is estimated by employing the market survey results and the planner's judgment of the potential of the area.

Based on experience, most water systems originally constructed as Level II have upgraded either to Level III or to a combined Level II and Level III system.

In anticipation of the trend towards upgrading to Level III in the future, the Level II system planner should assume that within 5 years, 90% of the households served would opt for individual house connections.

This estimate, however, should be tempered by the planner's direct first-hand information about the area and its population.

b. Institutional and Commercial Consumption:

After having considered the possible timing and number of institutional and commercial connections, the projected yearly consumptions for each category are estimated by applying the corresponding projected unit consumptions as presented in the preceding section.

F. NON-REVENUE WATER (NRW)

Non-revenue water is the amount of water that is produced but not billed as a result of leaks, pilferages, free water, utility usages, etc. An allowance should be made for this category; otherwise, the designed source capacity would not be sufficient to supply the required consumption of paying customers.

In actual operation, the NRW should be a cause of concern and should be subject to measures to keep it as low as possible. For planning purposes, however, a conservative approach should be adopted. The water demand projection should assume that the NRW of the new system will be fifteen percent (15%) of the estimated consumptions. The plan's figure can be increased up to a total of 20% at the end of 10 years. . These assumed NRW figures require good maintenance of utilities, pro-active leakage prevention, and no illegal connections for 100% recovery of supplied water.

G. WATER DEMAND

The water demand is a summation of all the consumptions given in the preceding sections and will determine the capacity needed from the source/s. The average daily water demand, also known as the average day demand, is calculated (in m^3/day or lps) from the estimated water consumptions and the allowance for the NRW (expressed as a percentage).

A system with consumption of 2 lps with a 15% NRW will have an average day demand equal to

$$\frac{\mathbf{2\ lps}}{(\mathbf{1}-\boldsymbol{NRW})} = \mathbf{2.4\ lps}$$

1. Demand Variations and Demand Factors

Water demand varies within the day and also within the year. This demand variation is dependent on the consumption pattern of the locality and is measured by four demand conditions which are:

- **Minimum day demand**: The minimum amount of water required in a single day over a year.
- **Average day demand**: The average of the daily water requirement spread in a year.
- **Maximum day demand**: The maximum amount of water required in a single day over a year.
- **Peak hour demand**: The highest hourly demand in a day.

Each of the above demand conditions is designated a demand factor to define its value based on the average day demand. For a Level II/III system, the following demand factors are recommended:

Demand Parameter	Demand Factor
Minimum day demand	0.3 of average day demand
Average day demand (ADD)	1.0
Maximum day demand	1.3 of average day demand
Peak hour demand	2.5 of ADD (>1,000 connections) 3.0 of ADD (<1,000 connections)

The average day demand is first estimated, and the estimates for the other demands follow by directly applying the respective demand factors to the projected average day demand.

2. Uses of the Demand Variations

- **Minimum day demand**: The pipe network system is analyzed under a minimum demand condition to check on possible occurrence of excessive static pressures that the system might not be able to withstand. No point in the transmission and distribution system should be subjected to pressure more than 70 m.
- **Average day demand**: Annual estimates and projections on production, revenues, non-revenue water, power costs, and other O&M costs are based on the average day demand.
- **Maximum day demand**: The total capacity of all existing and future water sources should be capable of supplying at least the projected maximum day

demand at any year during the design period. The design of treatment plants, pump capacity and pipelines considers the maximum day demand supply rate as an option in the optimization analysis.

- **Peak hour demand**: The pipeline network should be designed to operate with no point in the system having pressure below 3 meters during peak hour conditions. If there is no reservoir, the power ratings of pumping stations should be sufficient for the operation of the facilities during peak hour demands.

SAMPLE COMPUTATIONS

Given data:

$$P_0 = 2000$$
$$P_{10} = 3000$$
$$\text{Persons per HH} = 5$$

Determine: Required source capacity for a well operating 18 hr/day

Analysis:

The number of standpipes would be, at present,

$$2000 \text{ persons}/5 \text{ persons per HH}/6 \text{ HH} = 67 \text{ standpipes}$$

Each standpipe should be able to supply 50 lpcd x 6 HH x 5 = 1500 lpd.

Domestic consumption for the 67 standpipes: 67 x 1500 lpd = 100,500 lpd

Assuming 15% NRW, source capacity should be

$$\left(\frac{\mathbf{100,500\ lpd}}{\mathbf{0.85}}\right) \times \left(\frac{\mathbf{1\ day}}{\mathbf{18\ hrs}}\right) \times \left(\frac{\mathbf{1\ hr}}{\mathbf{3600\ sec}}\right) = \mathbf{1.82\ lps \ldots say\ 2\ lps}$$

However, a source capacity of 2 lps now will not be sufficient for future demand of P_{10}

Even if the source capacity required now is only for a Level II system, the proper approach is to determine the source capacity requirement for a Level III system.

For a system that started as a Level II system, we can assume that 90% of the HHs will have Level III connections at Year 10.

No. of Level III connections in P10 = 3000/5 x 90% = 540 connections

For this community size, additional 2 commercial and one institutional connection can be assumed.

Since only 90% will have Level III connections, the remaining population (300 persons or 60 HH) will still rely on standpipes. At 6 HH per standpipe, 10 standpipes will still be needed by Year 10.

(See continuation of Sample Computations next page)

(Continuation of Sample Computations)

Total connections 10 years from now:

Standpipes: $10 \text{ standpipes} \times 6 \text{ HH} \times 5 \frac{\text{persons}}{\text{HH}} \times 50 \text{ lpcd} = 15 \text{ m}^3\text{d}$

House connections: $540 \text{ conn} \times 5 \frac{\text{persons}}{\text{HH}} \times 90 \text{ lpcd} = 43 \text{ m}^3\text{d}$

	Standpipes	Domestic	Commercial	Institutional	TOTAL
Connections	10	540	2	1	543
Average Day Consumption (m^3/d)	15	243	1.6	1.0	**261**

Assuming a NRW of 15% the ADD will be:

$$261/0.85 = 307 \text{ m}^3/\text{d}$$

Since the source capacity must be able to satisfy the maximum day demand (1.3 of ADD), the source capacity must be equal to:

$$307 \times 1.3 = 400 \text{ m}^3/\text{d}$$

If the source will operate for only 18 hr/day, then capacity should be capable of producing:

$$\left(\frac{400 \text{ m}^3}{\text{d}}\right) \times \left(\frac{1 \text{ Dd}}{18 \text{ hr}}\right) \times \left(\frac{1 \text{ hr}}{3600 \text{ sec}}\right) \times \left(\frac{1000 \text{ l}}{\text{m}^3}\right) = 6.17 \text{ lps}$$

Chapter 4

Water Sources

After the demand has been estimated, the next step is to look for a source that passes both the quantity and quality requirements. This Chapter presents an overview of the possible water supply sources that can be utilized for rural and other small water supply systems.

A. WATER RESOURCES

In the selection of a source or sources of water supply, adequacy and reliability of the available supply could be considered the overriding criteria. Without these, the water supply system cannot be considered viable. These, together with the other factors that should be considered (and which are interdependent), are as follows:

- Adequacy and Reliability
- Quality
- Cost
- Legality
- Politics.

Adequacy of supply requires that the source be large enough to meet the water demand. Frequently, total dependence on a single source is undesirable, and in some cases, diversification is essential for reliability.

From the standpoint of reliability, the most desirable supplies are, in descending order:

1. An inexhaustible supply, whether from surface or groundwater, which flows by gravity through the distribution system
2. A gravity source supplemented by storage reservoirs
3. An inexhaustible source that requires pumping
4. A source or sources that require both storage and pumping.

The capacity or flow rates and water quality of each type of source should be evaluated through actual flow measurements, water quality sampling and testing – or, if available, recent data that can be relied upon to be accurate. In addition, information on potential sources of contamination and pollution should be determined.

B. BASIC CLIMATOLOGY OF THE PHILIPPINES

The Philippines has annual rainfall varying throughout the country from 965 mm (38 in) to 4,064 mm (160 in). The monsoon rains are pulled in by hurricanes or typhoons. The actual distribution of rainfall varies widely with time and location due to the archipelagic nature of the country's geography and regional climatic conditions.

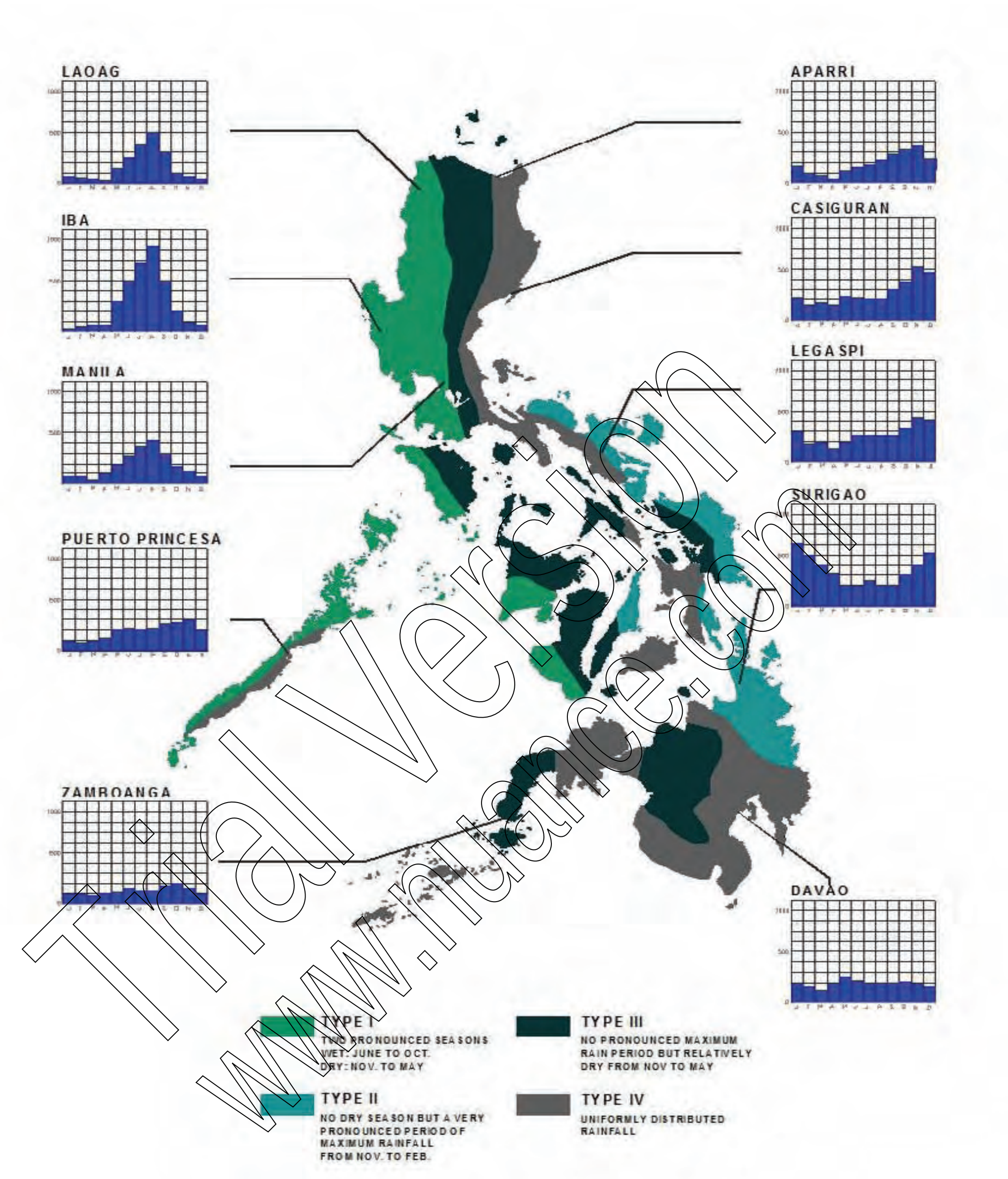
The tropical climate of the Philippines is marked by comparatively high temperature, high humidity and plenty of rainfall. The mean annual temperature is 27.7° C. January is the coolest month with a mean temperature of 22° C, while the warmest month is May with a mean temperature of 34° C.

Based on temperature and rainfall, the climate of Philippines can be categorized generally into two predominant seasons: the rainy season, from June to November; and the dry season, from December to May. Different sectors of the country, however, are characterized by important variants of these general classifications. For purposes of understanding the available water sources for a distribution system, these are better characterized, based on the prevalent distribution of rainfall, in classifications or types of climate shown in Figure 4.1, and summarized as follows:

- **Type I**: Two pronounced seasons: dry from November to April and wet during the rest of the year. The western parts of Luzon, Mindoro, Negros and Palawan experience this climate. These areas are shielded by mountain ranges but are open to rains brought in by southwest monsoons (Habagat) and tropical cyclones.
- **Type II**: Characterized by the absence of a dry season but with a very pronounced maximum rain period from November to January. Regions with this climate are located along or very near the eastern coast. They include Catanduanes, Sorsogon, eastern part of Albay, eastern and northern parts of Camarines Norte and Sur, eastern part of Samar, and large portions of Eastern Mindanao.
- **Type III**: Seasons are not very pronounced but are relatively dry from November to April and wet during the rest of the year. Areas under this type include the western part of Cagayan, Isabela, parts of Northern Mindanao and most of Eastern Palawan. These areas are partly sheltered from the trade winds but are open to Habagat and are frequented by tropical cyclones.
- **Type IV**: Characterized by a more or less even distribution of rainfall throughout the year. Areas with this climate include Batanes, Northeastern Luzon, Southwest Camarines Norte, Western Camarines Sur, Albay, Northern Cebu, Bohol and most of Central, Eastern and Southern Mindanao.

The climate types and the rainfall data can be used in assessing the average volume of rain for a given area to determine the feasibility of rain harvesting or capacity of certain surface sources to supply projected demands.

Figure 4.1: Climate Types of the Philippines



Generally, the east and west coasts of the country receive the heavier rainfall. The northeast monsoon or "Amihan" brings frequent rains to the east coast of the islands, while the southwest monsoon or "Habagat" brings rainy season in Manila and the western coast, as well as the to the northern parts of the archipelago.

The central parts of the country, particularly Cebu, Bohol and a part of Cotabato receive the smallest amount of rainfall. As indicated in Figure 4.1, the annual rainfall ranges from less than 1,000 mm in Southern Mindanao to more than 4,000 mm in the eastern portion of the country. In places where rainfall is uniformly distributed throughout the year and where groundwater and surface water are not available, rainwater might have to be used as a source of water supply through the use of simple rain harvesting methods.

C. CLASSIFICATION OF WATER SOURCES

Water sources are generally classified according to their relative location on the surface of the earth. These are characterized as follows:

1. Rainwater

Rainwater, or atmospheric water, is a product of water vapor that has risen due to evaporation and accumulated in the atmosphere, which condenses and falls on the Earth's surface. As the water vapor that has accumulated in cloud formations condenses, it forms drops of rain that fall to the Earth.

2. Surface Water

Surface water is exposed to the atmosphere and subject to surface runoff. It comes from rains, surface runoff and groundwater, and includes rivers, lakes, streams, ponds, impounding reservoirs, seas, and oceans.

The quantity of surface runoff depends on a large number of factors; the most important of which are the amount and intensity of rainfall, the climate and vegetation, and the geological, geographical, and topographical features of the catchment area.

The quality of surface water is determined by the amount of pollutants and contaminants picked up by the water in the course of its travel. While flowing over the ground, surface water collects silt, decaying organic matter, bacteria and other microorganisms from the soil. Thus, all surface water sources should be presumed to be unsafe for human consumption without some form of treatment.

For rural water supply systems, surface water sources should be chosen as the last priority because of the high cost of treatment and the general lack of expertise for the maintenance and operation of the appropriate treatment facilities.

3. Groundwater

Groundwater is that portion of rainwater which has percolated beneath the ground surface to form underground deposits called aquifers. The upper surface of groundwater is the water table. Groundwater is often clear, free from organic matter and bacteria due to the filtering effect of soil on water percolating through it. However, groundwater almost always contains minerals dissolved from the soil. Groundwater is often better in quality than surface waters, less expensive to develop for use, and usually provides more adequate supply in many areas in the country.

For rural water supply systems, groundwater is generally preferred as a water source. The types and extraction methods are as follows:

- **Spring** – is a point where groundwater flows out of the ground, and is thus where the aquifer surface meets the ground surface. A spring may be ephemeral (intermittent) or perennial (continuous). Springs can be developed by enlarging the water outlet and constructing an intake structure for water catchment and storage. The methodology is discussed in detail in Chapter 6.
- **Well** – is a hole constructed by any method such as digging, driving, boring, or drilling for the purpose of withdrawing water from underground aquifers. Wells can vary greatly in depth, water volume and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water by removing minerals such as arsenic, iron and manganese.

  Well water may be drawn by pumping from a source below the surface of the earth. Alternatively, it could be drawn up using containers, such as buckets that are raised mechanically or by hand. Wells are discussed in detail in Chapter 7.
- **Infiltration Galleries/Wells** – Infiltration galleries are horizontal wells, constructed by digging a trench into the water-bearing sand and installing perforated pipes in it. Water collected in these pipes converges into a "well" from which it is pumped out. Infiltration galleries are discussed more in Chapter 7.

Chapter 5
Water Quality

This Chapter describes the parameters and limits which define potable water.

A. WATER QUALITY

"Water quality" is a measure of how good the water is, in terms of supporting beneficial uses or meeting its environmental values. Potable water is water suitable for drinking and cooking purposes. Potability considers both the safety of water in terms of health, and its acceptability to the consumer – usually in terms of taste, odor, color, and other sensible qualities.

B. WATER QUALITY TESTS

Before deciding on the source/s of surface or groundwater, it is important to conduct water quality tests through representative samples. These tests ideally should be performed on site and through samples taken to the laboratory for definitive analysis.

1. Water Quality Parameters

Samples from the potential surface and groundwater sources should be collected and analyzed for several quality parameters. During sampling, some parameters may be observed and tested on site with the use of portable equipment; while others have to be analyzed formally by an accredited testing laboratory.

Weather conditions, time of sampling, flow rate (when possible) and the physical appearance (color) of the water at the sampling point should be included in the assessment report. A prescribed volume and number of samples for laboratory analyses will have to be collected, stored in appropriate containers, protected to preserve the original quality , and transported to the testing laboratory in the soonest time possible.

All naturally occurring chemicals that are of health significance and found in the drinking-water supply as a result of the geological characteristics in the locality should be in the priority list tabulated in Table 5.1. The list of priority physical and chemical parameters to be monitored may be changed based on the results of previous water examinations. Parameters that are less likely to occur in water may be less frequently tested.

These tests are important in the selection of a potential source of supply. They also become necessary when major developments or environmental changes occur in the vicinity that might affect the quality of water of an existing source, or if important changes are found in the quality of the water originating from a previously tested source.

Table 5.1: Water Quality Parameters to Be Tested		
High Priority (critical) Parameters:		
1. Microbiological : (Total Coliform, Fecal Coliform) 2. Arsenic 3. Cadmium 4. Lead 5. Nitrate	6. Benzene 7. Color 8. Turbidity 9. Iron 10. pH	11. Manganese 12. Chloride 13. Sulfate 14.Total Dissolved Solids (TDS)
Other Parameters:		
1.Temperature 2. Biological Oxygen Demand 3. Ammonia as NH_3-N	4.Total Hardness 5. Chromium 6. Sulfide	7. Dissolved Silica 8. Total Mercury 9. Pesticides

2. Frequency of Sampling

The NWRB and the Department of Health (DOH) prescribe certain protocols for the testing of water at the supply source and through the distribution system. These are different for the microbiological concerns and the physical and chemical characteristics of the product.

a. Microbiological Tests:

The minimum number of samples, which are to be collected periodically by existing water utilities and delivered to the DOH or its authorized laboratory for examination, is based on the mode and source of the water supply (Table 5.2). Samples are to be taken from the distribution network.

Table 5.2: Minimum Frequency of Sampling for Drinking-Water Supply Systems for Microbiological Examination

Source/Supply Mode	Population Served (no. of persons)	Minimum Frequency of Sampling
Level I	90 -150	Once in three (3) months
Level II	600	Once in two (2) months
Level III	Less than 5,000	1 sample monthly
	5,000 - 100,000	1 sample per 5,000 population per month
	More than 100,000	20 samples and additional one (1) sample per 10,000 population per month
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b. Physical/Chemical Tests:

The minimum frequency of physical and chemical sampling for drinking water supply is once a year regardless of service levels. Samples are to be taken from the source itself.

C. COMPONENTS OF WATER QUALITY

In accordance with the Philippines National Standards for Drinking Water, three aspects of water quality need to be considered. These are the Chemical, Physical and Microbiological aspects.

1. Chemical Aspects

Chemical contamination of water sources may be due natural sources or certain industries and agricultural practices. When toxic chemicals are present in drinking water, there is the risk that they may cause either acute or chronic health effects. Chronic health effects are more common than acute effects because the levels of chemicals in drinking water are seldom high enough to cause acute health effects.

1. **Hardness** – hardness is due primarily to calcium and magnesium carbonates and bicarbonates (which can be removed by boiling) and calcium and magnesium sulfate and chloride (which can be removed by chemical precipitation using lime and sodium carbonate). Hardness in water is objectionable for the following reasons:
   - Calcium and magnesium sulfate have a laxative effect.
   - Hard water makes lathering more difficult, and so it increases soap consumption.
   - In boilers, pots and kettles, hardness causes scaling, resulting in the reduction of the thermal efficiency and restriction of flow.
2. **Alkalinity and Acidity** – the presence of acid substances is indicated by pH below 7.0 and alkaline substances by pH greater than 7.0. Acidic water is corrosive to metallic pipes.
3. **Carbon Dioxide** – the presence of appreciable quantities of carbon dioxide makes water corrosive due to carbonic acid formation and the presence of free CO_2.
4. **Dissolved Oxygen** – aside from a flat taste, water devoid of oxygen may indicate an appreciable level of oxygen-consuming organic substances.
5. **Chemical Oxygen Demand (COD)** – COD is a measure of the amount of organic content of water. As bacteria utilize oxygen in the oxidation of organic matter, the COD increases and the dissolved oxygen in the water decreases.
6. **Organic Nitrogen** – organic nitrogen is a constituent of all waste protein products from sewage, kitchen wastes and all dead organic matter. Freshly produced waste normally contains pathogenic bacteria. All water high in organic nitrogen should therefore be suspected for possible contaminants.

7. **Iron and Manganese** – groundwater usually contains more of these two minerals than surface water. Iron and manganese are nuisances that must be removed if the quantity is greater than 0.3 mg/l and 0.1 mg/l respectively, as they cause staining of clothing and plumbing fixtures. Also, the growth of iron bacteria causes the clogging of strainers and screens and the rusting of metallic conduits. The appearance of a reddish brown or black precipitate in a water sample after shaking indicates, respectively, the presence of iron or manganese.
8. **Toxic Substances** – a number of chemical substances, if present in appreciable concentration in drinking water, may constitute a danger to health. These toxic substances include arsenic, barium, cadmium, hexavalent chromium, cyanide, lead, selenium and silver.
9. **Phenolic Compounds** – these cause undesirable taste in water whenever present.

2. Physical Aspects

The turbidity, color, taste, and odor of water should be monitored. Turbidity should always be low, especially where disinfection is practiced. High turbidity can inhibit the effects of disinfection against microorganisms and enable bacterial growth.

Drinking water coloration may be due to the presence of colored organic matter. Organic substances can also cause water odor, though odors may result from many factors, including biological activity and industrial pollution.

Taste problems relating to water could be indicators of changes in the water source or in the treatment process. Inorganic compounds such as magnesium, calcium, sodium, copper, iron, and zinc are generally detected by the taste of water.

1. **Turbidity** – is a measure of the degree of cloudiness or muddiness of water. It is caused by suspended matter in water like silt, clay, organic matter or microorganisms. Even when caused by factors that do not pose a health risk, turbidity is objectionable because of its adverse aesthetic and psychological effects on the consumers.
2. **Color** – is due to the presence of colored substances in solution, such as vegetable matter and iron salt. It does not necessarily have detrimental effects on health. Color intensity could be measured through visual comparison of the sample to distilled water.
3. **Odor** – odor should be absent or very faint for water to be acceptable for drinking. Pure water is odorless; hence, the presence of undesirable odor in water is indicative of the existence of contaminants.
4. **Taste** – pure water is tasteless, hence, the presence of undesirable taste in water indicates the presence of contaminants. Algae, decomposing organic matter, dissolved gases, and phenolic substance may cause tastes.

3. Microbiological Aspects

Drinking water should exclude microorganisms that are known to be pathogenic. It should not contain bacteria that indicate fecal pollution, of which coliform bacteria are the primary indicator as it is found in the feces of warm-blooded organisms.

Parasitic protozoa and helminths are also indicators of water quality. Species of protozoa can be introduced into water supply through human or animal fecal contamination. Most common among the pathogenic protozoans are Entamoeba and Giardia. Where possible, only water sources that are not likely to be contaminated by fecal matter should be used.

Pathogens in water can be removed by filtration or by disinfection. Chlorine, which is readily available and inexpensive, is the usual disinfectant. However, it is not fully effective against all organisms.

The two basic methods used for the enumeration of coliform organisms in water are multiple-tube fermentation method and the membrane filtration method. Estimates of the numbers of coliform organisms are given in terms of Most Probable Numbers (MPN) per 100 ml, when using the multiple-tube fermentation method, and colonies per 100 ml. when determined by the membrane filtration method. These tests must be conducted by DOH-accredited laboratories only[6].

4. Philippine Standards for Water Quality

The Philippines National Standards for Drinking Water 2007 (PNSDW-2007) provide the minimum standards for quality of potable water. As per PNSDW, drinking water must be clear, colorless and free from objectionable taste and odor. Table 5.3 on the following pages presents the PNSDW standards for physical and chemical quality. All other standard values are contained in the PNSDW Administrative Order No. 2007-0012 or any other standards more recently issued by the Department of Health.

[6] List of these is available at the DOH website

Table 5.3: Standard Values for Physical and Chemical Qualities for Acceptability

Constituent	Maximum level(mg/l) or Characteristic	Remarks	Method of analysis
Taste	No objectionable Taste	The cause of taste must be determined.	Sensory Evaluation
Odor	No objectionable Odor	The cause of odor must be determined.	Sensory Evaluation
Color – True: Apparent:	5 NTU 10 NTU	Decomposition of organic materials such as leaves or woods usually yield coloring substances to water	Visual Comparison; Colorimetry Method
pH	6.5-8.5 (5-7 for product water that has undergone reverse osmosis or distillation)	The acceptable range may be broader in the absence of a distribution system.	Electrometric method
Turbidity	5 NTU	Turbidity increases with the quantity of suspended matters in water	Turbidimetry
Aluminum	0.2 mg/l	Aluminum sulphate is used in water treatment as a coagulant.	FAAS, EAAS. ICP, Colorimetry Method
Chloride	250 mg/l	Chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff, and seawater intrusion	Argentometric Method, 1C
Hardness	300 as $CaCO_3$	Hardness is due to the presence of naturally occurring divalent cations, resulting from contact of acidic groundwater with limestone and dolomites.	FAAS, EAAS. ICP, Colorimetry Method
Hydrogen Sulfide	0.05 mg/l	Hydrogen sulfide is a common nuisance contaminant. Although not hazardous to health, the offensive odor and corrosiveness of water containing hydrogen sulfide make treatment necessary.	Methylene Blue Method, Iodometric Method
Iron	1.0 mg/l	Iron is found in natural fresh waters. It may be present in drinking water as a result of the use or iron coagulants or the corrosion of steel and cast iron pipes during water distribution.	Phenanthroline, AAS, ICP, Colorimetric Method

Constituent	Maximum level(mg/l) or Characteristic	Remarks	Method of analysis
Manganese	0.4 mg/l	Manganese occurs naturally in many surface and groundwater sources, particularly in anaerobic or low oxidation conditions.	Persulfate Method, AAS, ICP, ICP/MS
Sodium	200 mg/l	Sodium is usually associated with chloride; thus, it may have the same sources in drinking water as chloride.	AAS (Flame absorption mode), ICP/MS, Flame
Sulfate	250 mg/l	High levels of sulfate occur naturally in groundwater	Turbidimetric Method, Ion Chromatography, Gravimetric Method
Total Dissolved Solids (TDS)	500 (but < 10 for water product that has undergone reverse osmosis or distillation process)	TDS in drinking water originate from natural sources, sewage, urban runoff and industrial wastewater	Gravimetric, dried at 180° C
Zinc	5.0	Zinc may occur naturally in groundwater. Concentration in tap water can be much higher as a result of dissolution of zinc from pipes.	FAAS, ICP, ICP/MS

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