Engineering and Applied Sciences
2026, Vol. 11, No. 5, pp. 155–163
https://doi.org/10.11648/j.eas.20261105.11

Research Article

Adaptive Infrastructure Management of the Angat Dam: Evaluating Water Supply Reliability Amidst Urbanization and Climate Extremes in Metropolitan Manila

Ma. Teresa Villena Villacorta*, Joseph Raniel Bianes

Open University System, Polytechnic University of the Philippines, Manila, Philippines

Abstract

Metropolitan Manila depends heavily on the Angat Dam system, while urban demand and hydroclimatic variability place increasing pressure on reservoir operations. This study evaluates monthly reservoir elevation and billed water-demand records from January 2019 to December 2025 using descriptive and inferential trend analysis, an operationally grounded analytical stress threshold of 180 m, threshold sensitivity testing, and reliability-resilience-vulnerability (RRV) indicators. Institutional and project documents were also reviewed to interpret adaptive infrastructure-management responses. Mean billed demand increased from 2,826.58 million liters per day (MLD) in 2019 to 2,946.37 MLD in 2025, peaking at 3,069.50 MLD in May 2024. The estimated annual demand slope was 23.72 MLD per year, but it narrowly missed statistical significance at the 5% level ($p = 0.054$). At 180 m, ten of 84 monthly observations were failures; the minimum was 160.97 m in July 2019. The system achieved 88.10% reliability, 40.00% resilience, and mean vulnerability of 5.86 m. Sensitivity testing at 175, 180, and 185 m produced reliability values of 96.43%, 88.10%, and 84.52%, respectively, while resilience remained between 33.33% and 40.00%. Results show that high overall reliability can coexist with slow recovery and concentrated seasonal risk. The evidence supports anticipatory reservoir operation, climate-informed monitoring, demand management and non-revenue-water reduction, transmission redundancy, source diversification, and institutionalized RRV monitoring. The study demonstrates a transparent, replicable screening approach for climate-sensitive urban water infrastructure where detailed hydraulic models are unavailable.

Keywords

Adaptive Infrastructure Management, Angat Dam, Climate Variability, Metropolitan Manila, Reservoir Reliability, RRV, Urban Water Security

1. Introduction

Urban water systems must maintain service while demand, climate, infrastructure condition, and operating constraints change simultaneously. Climate change is intensifying hydrological uncertainty and increasing the importance of adaptation in water-resource planning [1]. Rapid urbanization adds pressure to already constrained systems [6, 7]. This challenge is acute in Metropolitan Manila because its bulk-water system depends heavily on the Angat-Ipo-La Mesa cascade. A prolonged decline in Angat storage can therefore propagate through raw-water conveyance, treatment, and distribution

*Correspondence: Ma. Teresa Villena Villacorta (ma.villacorta@mwss.gov.ph)

Received: 21 July 2026; **Accepted:** 5 August 2026; **Published:** 11 September 2026

operations. A recent critical review further identifies water shortage, flooding, temperature rise, aging assets, and inadequate climate adaptation as interconnected threats to urban water infrastructure performance [16].

Conventional performance reporting often emphasizes average supply or isolated shortage events. Such measures can obscure three distinct questions: how often the system remains satisfactory, how quickly it returns to a satisfactory state after stress, and how severe the deficit becomes. Hashimoto et al. formalized these dimensions as reliability, resilience, and vulnerability (RRV) [2]. Adaptive water management complements RRV by treating monitoring, evaluation, and operational adjustment as a continuing learning process rather than a one-time design decision [3].

Existing studies provide strong technical and governance foundations for resilient urban water management. Recent Angat-focused work demonstrates the value of data-driven reservoir-level forecasting and climate-scenario assessment [10, 11], while contemporary resilience frameworks emphasize monitoring, recovery capacity, flexibility, and learning [12, 13]. However, applications that combine monthly threshold behavior, demand trends, RRV performance, threshold sensitivity, and documented infrastructure responses remain limited for the Angat-dependent system. This study addresses that gap by integrating performance screening with adaptive infrastructure-management interpretation for 2019-2025. Recent evidence also shows that resilience depends on selecting an appropriate mix of centralized and decentralized system scales and on evaluating robustness, autonomy, flexibility, preparedness, and recovery together [17, 18]. A recent critical review further identifies water shortage, flooding, temperature rise, aging assets, and inadequate climate adaptation as interconnected threats to urban water infrastructure performance [16].

2. Materials and Methods

2.1. Study System and Research Design

The study covers the Angat Dam system in Norzagaray, Bulacan, and its role as the principal raw-water source for Metropolitan Manila [8]. Angat is a multipurpose reservoir supporting municipal water supply, irrigation, hydropower, and flood management. A retrospective mixed-method design.

Combined quantitative analysis of monthly operational records with qualitative review of institutional and infrastructure documents. The unit of quantitative analysis was one calendar month.

2.2. Data Sources and Preparation

***Table 1**. Data sources and analytical roles.*

Dataset	Period and resolution	Primary use	Source
Reservoir elevation	Jan 2019-Dec 2025; monthly	Trend, threshold and RRV analysis	MWSS/NPC operational records
Billed water demand	Jan 2019-Dec 2025; monthly	Demand trend and seasonal comparison	MWSS reports
Climate-event classification	2019-2025; annual/contextual	Interpretation of hydroclimatic conditions	PAGASA bulletins
Infrastructure and policy documents	2019-2025	Adaptive-management interpretation	MWSS, NWRB and project reports

Records were arranged chronologically, checked for unit consistency, and compared across annual and monthly summaries. The analysis uses billed demand as an observable pressure indicator; it is not treated as a complete water-balance measure. The 2025 record is included as supplied in the thesis dataset. Because the study relies on secondary records, conclusions concern system-level screening rather than causal attribution or hydraulic performance at individual facilities.

2.3. Threshold and RRV Definitions

A month was classified as satisfactory when reservoir elevation E_t was at least 180 m and as a failure month when E_t was below 180 m. The base threshold was selected because 180 m is identified in Angat operating specifications as the reservoir's low or minimum operating level [9] and is therefore an operationally meaningful screening boundary rather than an arbitrary statistical cut-off. It does not represent structural dam failure or the complete loss of municipal supply; instead, it marks a condition in which operating flexibility and allocations to competing uses may become constrained. Because reservoir response also depends on storage volume, inflow, releases, seasonal rule curves, and conveyance capacity, the threshold is treated as an analytical stress indicator rather than a universal engineering failure level.

Reliability:

$$Rel = (\text{number of satisfactory months}) / (\text{total months})$$

Resilience:

$$Res = (\text{failure months followed by a satisfactory month}) / (\text{failure months})$$

Vulnerability:

$$V = \Sigma \max(0, 180 - E_t) / (\text{number of failure months})$$

Normalized vulnerability was calculated as 100V/180, enabling the metric to be expressed as a percentage of the threshold. These definitions follow the conceptual distinction introduced by Hashimoto et al. [2], while retaining a simple form appropriate to the available monthly dataset.

Statistical trend and threshold-sensitivity analysis

To assess statistical significance, we fitted ordinary least-squares regressions to the seven annual mean values for billed demand and reservoir elevation, with calendar year as the predictor. Two-sided tests used $\alpha = 0.05$, and slopes are reported with 95% confidence intervals. The non-parametric Mann-Kendall test was used as a robustness check because the annual series is short and need not be normally distributed. Threshold sensitivity was evaluated by recalculating failure count, reliability, resilience, mean vulnerability, and normalized vulnerability at 175, 180, and 185 m. These values represent a ±5 m band around the documented 180 m low operating level and test whether the substantive interpretation depends on the selected cut-off.

2.4. Documentary Analysis

Institutional reports and project documents were reviewed using a structured matrix covering monitoring and forecasting, drought operations, demand management, asset maintenance, transmission capacity and redundancy, source diversification, and interagency coordination. Documentary evidence was used to explain observed system behavior and identify management implications; it was not converted into a causal effectiveness score.

2.5. Ethics and Reproducibility

The study involved no human participants and used secondary operational and documentary data. RRV equations, threshold alternatives, and statistical procedures are specified above. The complete 84-month reservoir-elevation matrix is provided as Supplementary Material to support independent reproduction of the threshold, sensitivity, and trend calculations.

3. Results

3.1. Reservoir Elevation and Seasonal Stress

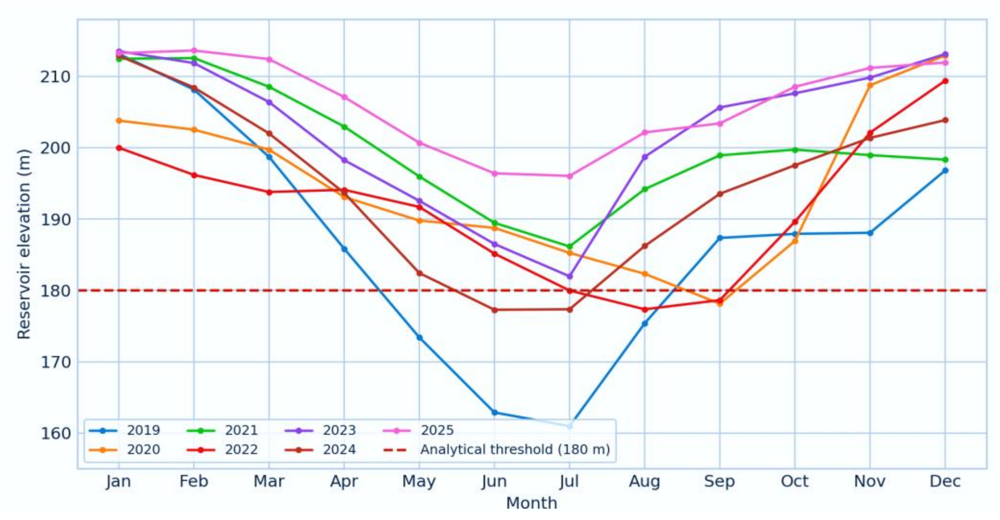

Figure 1. *Monthly Angat Reservoir elevations, 2019-2025. The dashed line is the study's analytical stress threshold.*

Reservoir elevation displayed a consistent seasonal decline from approximately March to July, followed by recovery during the wetter months. The minimum, 160.97 m in July 2019, was 19.03 m below the analytical threshold. Additional failure months occurred in 2020, 2022, and 2024, demonstrating that critical conditions were episodic but recurrent rather than confined to the 2019 shortage.

Table 2. *Monthly observations below the 180 m analytical threshold.*

Year	Month	Elevation (m)	Deficit (m)
2019	May	173.41	6.59
2019	Jun	162.89	17.11
2019	Jul	160.87	19.03
2019	Aug	175.38	4.62
2020	Sep	178.13	1.87
2022	Jul	179.98	0.02
2022	Aug	177.35	2.65
2022	Sep	178.63	1.37
2024	Jun	177.28	2.72
2024	Jul	177.35	2.65

3.2. Demand Trend

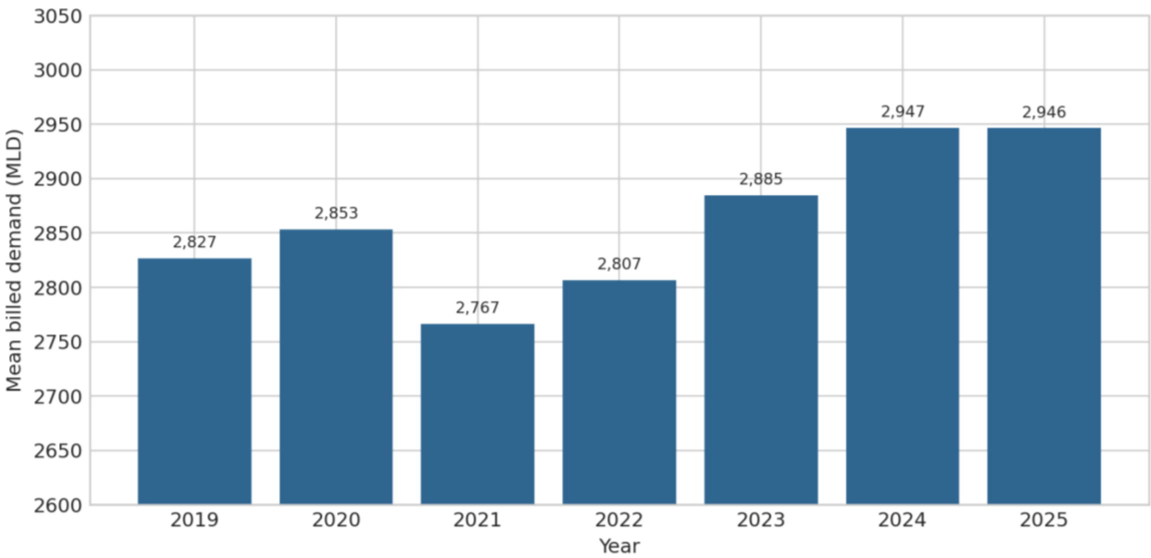

Figure 2. *Mean billed water demand, 2019-2025 (MLD).*

Mean billed demand increased by 119.79 MLD between 2019 and 2025, a net rise of 4.24%. The series declined in 2021 before recovering and reaching its highest annual mean in 2024 (2,946.74 MLD). The highest monthly value in the source dataset was 3,069.50 MLD in May 2024. High-demand months overlapped with the seasonal reservoir decline, concentrating operational pressure between May and July.

The annual-mean regression estimated an increase of 23.72 MLD per year (95% CI: -0.62 to 48.06 MLD/year; $R^2 = 0.557$), but the result did not reach the pre-specified 5% significance level ($p = 0.054$). The Mann-Kendall test likewise did not identify a statistically significant monotonic trend ($\tau = 0.524$, $p = 0.136$). Annual mean reservoir elevation increased by an estimated 2.23 m per year, but this trend was also not statistically significant (95% CI: -0.27 to 4.74 m/year; $p = 0.070$; Mann-Kendall $\tau = 0.619$, $p = 0.069$). Accordingly, the observed increases should be interpreted as descriptive changes over a short seven-year record rather than definitive long-term trends.

Table 3. Descriptive statistics for billed demand.

Year	Mean (MLD)	Minimum (MLD)	Maximum (MLD)
2019	2,826.58	2,757.00	2,888.00
2020	2,853.43	2,750.20	2,957.60
2021	2,766.63	2,688.96	2,901.14
2022	2,806.69	2,648.81	2,863.60
2023	2,884.78	2,775.35	2,952.66
2024	2,946.74	2,879.59	3,069.50
2025	2,946.37	2,852.89	3,010.07

3.3. RRV Performance

Of 84 monthly observations, 74 were satisfactory, and 10 were failures, yielding reliability of 88.10%. Four failure months were followed immediately by recovery above the threshold, producing resilience of 40.00%. Total deficit across failure months was 58.63 m; mean vulnerability was therefore 5.86 m, equivalent to 3.26% when normalized by 180 m.

Table 4. Reliability-resilience-vulnerability results.

Indicator	Calculation	Result	Interpretation
Reliability	74/84	88.10%	High frequency of satisfactory months
Resilience	4/10	40.00%	Moderate month-to-month recovery
Vulnerability	58.63/10	5.86 m	Mean deficit during failures
Normalized vulnerability	(5.86/180)×100	3.26%	Deficit relative to threshold

The combined metrics show why reliability alone is insufficient. The system was satisfactory in most months, yet recovery after a failure month was not consistently rapid, and the 2019 event featured several consecutive, deep deficits.

Threshold sensitivity

Sensitivity analysis shows that the number of classified failure months changes with the analytical threshold, but the management interpretation remains consistent. Across the three thresholds, reliability remained above 84%, whereas immediate post-failure recovery remained at or below 40%.

Table 5. Sensitivity of RRV indicators to alternative analytical thresholds.

Threshold (m)	Failure months	Reliability (%)	Resilience (%)	Mean vulnerability (m)	Normalized vulnerability (%)
175	3	96.43	33.33	9.24	5.28
180	10	88.10	40.00	5.86	3.26

Threshold (m)	Failure months	Reliability (%)	Resilience (%)	Mean vulnerability (m)	Normalized vulnerability (%)
185	13	84.52	38.46	8.99	4.86

At 175 m, only the three deepest 2019 observations were classified as failures, producing higher reliability but greater mean deficit severity among failures. At 185 m, 13 months were classified as failures and reliability declined to 84.52%. Because resilience remained low to moderate under every specification, the conclusion that recovery capacity warrants management attention is not an artifact of the 180 m threshold. Operational adoption should nevertheless be preceded by validation against daily inflow, storage volume, release, allocation, and service-continuity records, followed by hydrological or reservoir-operation modeling.

3.4. Adaptive Infrastructure-Management Evidence

Table 6. Adaptive management interpretation from institutional and project documents.

Manage Domain	Observed contribution	Remaining need
Monitoring and forecasting	Support earlier recognition of the declining storage and rainfall shifts	Integrate trigger-based forecast with operating decisions
Drought operations and demand management	Enables allocation control and conservation during stress	Strengthen NRW reduction and seasonal demand measures
Asset and transmission management	Maintenance and upgrades support continuity	Increase redundancy and address aging conveyance assets
Governance coordination	Aligns reservoir, allocation and service decisions	Formalize shared indicators, triggers and post-event learning
Source diversification	Reduces systemic dependence on a single	

Documentary evidence indicates that monitoring, operational adjustment, infrastructure maintenance, and interagency coordination contribute to supply continuity. However, the analysis does not isolate the effect of any single intervention. The persistent seasonal overlap between high demand and low elevation points to the need for coordinated portfolios rather than a single-project response.

4. Discussion

4.1. High Reliability Does Not Eliminate Concentrated Risk

An 88.10% reliability value can appear reassuring, but the resilience and vulnerability results reveal material weaknesses. Consecutive failures in 2019 and 2022 show that stress can persist once the threshold is crossed. This is consistent with the purpose of RRV analysis: systems with similar success frequencies may differ substantially in recovery speed and failure severity [2]. For management, monthly RRV indicators should therefore be reported together and disaggregated by season and event.

4.2. Urban Demand and Hydroclimatic Variability Interact

The study does not claim that demand growth caused individual low-elevation events; reservoir behavior also reflects rainfall, inflow, releases, allocation rules, and antecedent storage. Nevertheless, rising billed demand reduces operating margin when dry-season storage is already declining. The IPCC's assessment of increasing climate-related water risks reinforces the need to plan for non-stationary conditions rather than relying solely on historical averages [1, 4].

4.3. Comparison with International Experience

The Angat results are consistent with international evidence showing that acceptable average performance can conceal concentrated drought and recovery risk. In the Kabul River Basin, RRV assessment under climate scenarios demonstrated that reliability, resilience, and vulnerability respond differently to hydrologic stress and should be interpreted jointly

[12]. Cape Town's 2015-2018 drought showed that reservoir drawdown can escalate into an urban supply emergency when climatic stress interacts with demand, governance, and social inequality; its response combined strong demand restrictions, communication, operational control, and subsequent diversification [14]. Indonesian utility assessments similarly emphasize risk screening, emergency preparedness, alternative sources, asset protection, and institutional coordination where climate and disaster information is incomplete [15]. Compared with these cases, Metropolitan Manila shares exposure to source concentration and seasonal hydrologic stress, but the present Angat screening indicates relatively high monthly reliability alongside limited immediate recovery. The comparison supports a portfolio response rather than reliance on a single infrastructure project. International guidance for rapidly growing cities likewise treats source-water protection and diversification as complementary measures for reducing dependence on a single supply source [19].

4.4. Implications for Adaptive Infrastructure Management

First, a threshold dashboard should link reservoir elevation, storage, inflow, forecast rainfall, demand, and conveyance condition to predefined actions. Data-driven Angat forecasting research demonstrates the practical value of converting monitored water levels into short- and long-horizon decision support [10]. Second, demand management—including conservation and NRW reduction—should intensify before the seasonal minimum rather than after shortages emerge. Third, transmission redundancy and condition-based asset management can reduce the probability that hydrological stress is compounded by infrastructure failure. Fourth, source diversification should be assessed as a portfolio decision, considering reliability contribution, lifecycle cost, environmental impacts, climate robustness, and distributional effects. Finally, governance arrangements should include joint review of each stress episode and periodic recalibration of thresholds. These measures reflect adaptive management as an iterative cycle of monitoring, evaluation, adjustment, and learning [3, 5, 13]. These recommendations are consistent with recent resilience literature advocating climate-informed infrastructure adaptation, balanced centralized-decentralized configurations, multi-dimensional performance metrics, source-water protection, leakage reduction, treated-water reuse, scenario planning, target setting, and shared data across institutions [16-20].

4.5. Limitations

Although sensitivity testing was conducted across 175-185 m, the analysis remains elevation-based and does not model storage volume, inflow, release, treatment capacity, network hydraulics, water quality, or competing sectoral allocations. The annual trend tests contain only seven observations and therefore have limited statistical power; non-significance should not be interpreted as proof that no long-term trend exists. Billed demand is an imperfect proxy for total demand and may be affected by service conditions, non-revenue water, and reporting practices. Climate events are used contextually, and causal relationships were not estimated. Documentary analysis may not capture undocumented real-time decisions. The results should therefore be interpreted as system-level performance screening. Future work should validate the operating threshold using daily observations, storage-elevation curves, allocation and service data, and hydrological or reservoir-operation models; extend the time series; evaluate autocorrelation and change points; and compare alternative infrastructure portfolios through simulation and multi-criteria analysis. Future assessments should also extend beyond RRV to include infrastructure robustness, autonomy, flexibility, preparedness, service recovery, and source-scale interactions, as recommended in recent drinking-water resilience frameworks [17, 18].

5. Conclusions

At the 180 m base threshold, the Angat Dam system maintained satisfactory elevation in 74 of 84 months from 2019 to 2025, corresponding to 88.10% reliability. Yet ten failure months, 40.00% resilience, and mean vulnerability of 5.86 m demonstrate that satisfactory average performance coexists with slow recovery and episodically severe stress. Sensitivity testing at 175 and 185 m changed the number of failures and reliability estimates but preserved the central finding of limited immediate recovery. The most critical episode occurred in mid-2019, while further threshold breaches in 2020, 2022, and 2024 show recurring exposure. Annual demand and elevation slopes were positive but did not meet the 5% significance criterion, so they should be treated as short-record descriptive signals rather than confirmed long-term trends.

For Metropolitan Manila, reliability planning should combine climate-informed reservoir operation, anticipatory demand and NRW management, monitoring and forecasting, resilient conveyance assets, diversified sources, and coordinated institutional triggers. RRV indicators provide a concise monitoring layer, but they should complement—not replace—hydraulic, hydrological, economic, and environmental analysis. The study’s principal contribution is an integrated and transparent screening framework that connects observed performance with adaptive infrastructure-management decisions.

Abbreviations

ADB	Asian Development Bank
AWTIP	Angat Water Transmission Improvement Project
ENSO	El Niño-Southern Oscillation
IPCC	Intergovernmental Panel on Climate Change
MLD	Million Liters Per Day
MWSS	Metropolitan Waterworks and Sewerage System

NPC	National Power Corporation
NRW	Non-Revenue Water
NWRB	National Water Resources Board
PAGA	Philippine Atmospheric, Geophysical and
SA	Astronomical Services Administration
RRV	Reliability-Resilience-Vulnerability
WTP	Water Treatment Plant

Supplementary Material

The supplementary material can be accessed at https://doi.org/10.11648/j.eas.20261105.11

Acknowledgments

Ma. Teresa Villacorta: Conceptualization, Formal Analysis, Methodology, Writing – original draft

Joseph Raniel Bianes: Writing – review & editing

Data Availability Statement

The monthly reservoir-elevation observations used for threshold, sensitivity, and RRV calculations are provided in Supplementary Material. Annual billed-demand summaries are reported in Table 3. Additional institutional and operational records are available from the originating agencies subject to their access and disclosure requirements.

Conflicts of Interest

The author declares no conflict of interest.

References

[1] Intergovernmental Panel on Climate Change. (2022). Climate change 2022: Impacts, adaptation and vulnerability. Cambridge University Press. https://doi.org/10.1017/9781009325844

[2] Hashimoto, T., Stedinger, J. R., & Loucks, D. P. (1982). Reliability, resiliency, and vulnerability criteria for water resource system performance evaluation. Water Resources Research, 18(1), 14-20. https://doi.org/10.1029/WR018i001p00014

[3] Pahl-Wostl, C. (2007). Transitions towards adaptive management of water facing climate and global change. Water Resources Management, 21(1), 49-62. https://doi.org/10.1007/s11269-006-9040-4

[4] Intergovernmental Panel on Climate Change. (2023). Climate change 2023: Synthesis report. IPCC. https://doi.org/10.59327/IPCC/AR6-9789291691647

[5] Organisation for Economic Co-operation and Development. (2015). OECD principles on water governance. OECD Publishing. https://www.oecd.org/cfe/regionaldevelopment/OECD-Principles-on-Water-Governance-en.pdf

[6] United Nations Department of Economic and Social Affairs, Population Division. (2019). World urbanization prospects: The 2018 revision. United Nations. https://doi.org/10.18356/b9e995fe-en

[7] Asian Development Bank. (2020). Asian water development outlook 2020: Advancing water security across Asia and the Pacific. Asian Development Bank. https://doi.org/10.22617/SGP200296-2

[8] National Irrigation Administration. (n.d.). Angat Dam. https://opfais.nia.gov.ph/Viewer/Angat

[9] Jaranilla-Sanchez, P. A., Shibuo, Y., & Koike, T. (2013). Optimization of dam operation for maximizing water use and flood prevention: A case of Angat Dam, Philippines. Proceedings of the International Symposium on Management Systems for Disaster Prevention.

[10] Ibañez, S. C., Dajac, C. V. G., Liponhay, M. P., Legara, E. F. T., Esteban, J. M. H., & Monterola, C. P. (2022). Forecasting reservoir water levels using deep neural networks: A case study of Angat Dam in the Philippines. Water, 14(1), 34. https://doi.org/10.3390/w14010034

[11] Robles, K. P. V., & Monjardin, C. E. F. (2025). Assessing future water availability under climate change scenarios: A case study of Angat Dam in the Philippines. Water, 17(14), 2085. https://doi.org/10.3390/w17142085

[12] Sediqi, M. N., & Komori, D. (2024). Assessing water resource sustainability in the Kabul River Basin: A standardized runoff index and reliability, resilience, and vulnerability framework approach. Sustainability, 16(1), 246. https://doi.org/10.3390/su16010246

[13] Crozier, A., Lence, B. J., & Weijs, S. V. (2024). Resilience framework for urban water supply systems planning. Sustainable and Resilient Infrastructure, 9(4), 386-406. https://doi.org/10.1080/23789689.2024.2340378

[14] Calverley, C. M., & Walther, S. C. (2022). Drought, water management, and social equity: Analyzing Cape Town, South Africa's water crisis. Frontiers in Water, 4, 910149. https://doi.org/10.3389/frwa.2022.910149

[15] World Bank. (2021). Planning for an uncertain future: Strengthening the resilience of Indonesian water utilities. World Bank. https://openknowledge.worldbank.org/handle/10986/35136

[16] Ferdowsi, A., Piadeh, F., Behzadian, K., Mousavi, S.-F., & Ehteram, M. (2024). Urban water infrastructure: A critical review on climate change impacts and adaptation strategies. Urban Climate, 58, 102132. https://doi.org/10.1016/j.uclim.2024.102132

[17] Arnaud, N., Poch, M., Popartan, L. A., Corominas, L., & Verdaguer, M. (2024). How scale influences the resilience of urban water systems: A literature review of trade-offs and recommendations. Water, 16(11), 1571. https://doi.org/10.3390/w16111571

[18] Carneiro, J., Loureiro, D., Cabral, M., & Covas, D. (2024). Comprehensive resilience assessment framework for water distribution networks. Water, 16(18), 2611. https://doi.org/10.3390/w16182611

[19] USAID Urban Resilience by Building and Applying New Evidence in Water, Sanitation, and Hygiene. (2022). Desk review on the enabling factors for resilient urban water supply using source water protection and diversification. United States Agency for International Development.

[20] World Health Organization Regional Office for Europe. (2024). Strengthening climate resilience in the drinking-water and sanitation sector through the Protocol on Water and Health. World Health Organization. https://iris.who.int/handle/10665/379287

Biography

Ma. Teresa Villena Villacorta is a Filipino civil engineer specializing in water infrastructure development, engineering management, and sustainable water resource planning. A graduate of Catanduanes State University and a licensed Civil Engineer, she has more than two decades of experience in both the public and private sectors, holding key roles in project planning, construction management, cost engineering, and infrastructure development. She currently serves as a Technology and Design Researcher at Metropolitan Waterworks and Sewerage System-Corporate Office, where she leads research, policy development, and innovation initiatives focused on enhancing water supply reliability, infrastructure resilience, and sustainable water management. Through her work, she advances evidence-based solutions that support long-term water security and the development of resilient infrastructure in the Philippines.