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EVALUATION OF WATER NEEDS AND AVAILABILITY IN THE DESIGN OF THE WATER NEEDS MASTERPLAN ON THE IPDN WEST SUMATERA CAMPUS

Fauzi Fauzi[1], Bambang Istijono[2]*, Benny Hidayat[3]
Graduate School, Universitas Andalas, Padang, Indonesia[12]
Civil Engineering Department, Universitas Andalas, Padang, Indonesia[3]
bistijono@eng.unand.ac.id

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**Corresponding Author*

ABSTRACT
The sustainable availability of clean water is crucial for supporting academic, residential, and institutional operational activities in higher education settings. In general, previous research has primarily focused on clean water planning at the city or regional level, without examining the need and availability of water on boarding campuses that have distinct consumption patterns and distribution systems. This research aims to fill the gap by conducting an integrated evaluation of water needs and availability, serving as the basis for preparing a water management master plan at the West Sumatra IPDN Campus. A mixed-methods approach is employed, combining quantitative analysis based on SNI 03-7065-2005 to estimate water needs with qualitative analysis of infrastructure conditions and water quality through field surveys, interviews, and laboratory tests. The results showed that the water demand reached 92,150 liters/day (1.1 liters per second), while the source capacity was 5.03 liters per second, resulting in a surplus of 1,839%. Although the water supply was quantitatively adequate, quality tests revealed turbidity and bacteriological contamination at some distribution points, attributed to the corrosion of galvanized pipes and the absence of secondary filtration. This confirms that sufficient quantity does not guarantee the quality and efficiency of distribution. Therefore, network modernization, the implementation of layered filtration, and periodic monitoring are necessary. This research contributes to the development of a sustainable campus water management model in Indonesia.
Keywords: *Water Needs, Water Availability, Water Quality, Campus Infrastructure, Master Plan, IPDN West Sumatra.*

1. Introduction

Water is a vital environmental component and a fundamental resource for sustaining life on Earth. Humans, animals, and plants depend on the availability of clean water to meet their needs. Humans use water for various household purposes such as drinking, cooking, bathing, washing, and other sanitation activities. Therefore, the provision of adequate and sustainable clean water is a key indicator in achieving public health, environmental sustainability, and sustainable development.

On a global scale, the water crisis has become an increasingly critical environmental and development issue. A report by UN World Water Development (2023) notes that more than 2 billion people worldwide still struggle to access clean water, while water demand is projected to increase by up to 30% by 2050. In Indonesia, similar challenges are also faced. According to data from Central Bureau of Statistics of Indonesia (2024), approximately 11% of households still lack access to clean water suitable for consumption. In West Sumatra Province, the hilly topography and uneven distribution of water sources result in several regions, including Agam Regency, facing a water availability deficit during the dry season. This pressure also has implications for large educational institutions that have high water needs, such as the Institute of Domestic Government (IPDN) West Sumatra Campus in Baso. In addition, water quality is also crucial to pay attention to, as improper water use can lead to health problems, which aligns with the Regulation Ministry of Health of the Republic of Indonesia (2017). Regarding environmental health quality standards and environmental health requirements for water used for sanitation and hygiene purposes, as well as for personal and household hygiene, the water must meet specific physical, chemical, and biological quality parameters. Therefore, the provision of sufficient and clean water is a basic need that must be planned systematically.

The West Sumatra IPDN campus accommodates hundreds of praja, educators, and staff who live in one integrated area. This highlights the high and diverse need for clean water, encompassing consumption, sanitation, and institutional operational activities. However, based on initial observations, the distribution system and clean water infrastructure in the campus environment still face problems, such as pipe leaks, distribution imbalances to user buildings that result in non-optimal meeting of water needs per user building, and suboptimal clean water treatment systems. This condition has the potential to cause inefficiency and disruption of clean water services if it is not comprehensively planned through a water demand master plan approach.

Several previous studies have confirmed the importance of integrated planning in water management within campus environments. Merchán-Sanmartín et al. (2022) prepare a Drinking Water Master Plan for the ESPOL (Ecuador) campus to assess the condition of the distribution system and develop a long-term plan for sustainable water management on the campus. The study demonstrates that the master plan approach can enhance water distribution efficiency and reduce water loss by up to 20%. Meanwhile, a Study by Hidayat & Dewi (2022), analyze water management in the University of Indonesia educational building, and emphasize the importance of integrating technical aspects, user behavior, and institutional policies. On the other hand, (Antão-Geraldes et al., 2024) in his study on two student dormitories in Portugal, he found that water consumption management based on user behavior can save up to 25% of total daily water needs. In the methods, study by Yu et al. (2025) introduced a campus water demand prediction model based on Back Propagation Long Short-Term Memory (BP-LSTM) that is accurate in projecting water demand based on usage patterns.

This type of predictive approach opens up opportunities for educational institutions to conduct empirical, data-driven planning and long-term analysis. However, most of the above studies are still limited to campuses in developed countries or universities with modern infrastructure. Research in the context of developing countries, particularly in Indonesia, remains relatively underdeveloped, especially in official educational institutions with diverse characteristics in terms of activities and management systems.

Most previous research has focused on the city or region scale without examining the integration of water needs plans in institutional campus environments in depth. The available studies generally do not associate national water consumption standards with specific activity patterns in the dormitory campus environment, so they have not been able to describe the characteristics of typical water use in dormitory higher education institutions. In addition, most case studies were conducted outside Indonesia and have not been adapted to local contexts such as spatial data limitations, climatic variations, and applicable national regulations.

Therefore, this study seeks to fill this gap by developing a master plan approach to water needs based on institutional and spatial data at the IPDN West Sumatra Campus, by applying SNI and WHO standards contextually to water use patterns in boarding campus environments that have intensive institutional activities, while considering local water resource conditions and national regulations as the basis for integrated planning that is more applicable and sustainable.

At the IPDN West Sumatra Campus, the need for a Water Needs Master Plan is becoming increasingly urgent. In addition to meeting environmental health standards, this master plan also serves as a basis for investment decision-making, infrastructure development, and water efficiency policies. Considering the geographical conditions of Baso, which face fluctuations in rainfall and limited groundwater availability, a thorough study is needed to balance the need and availability of water in the campus environment.

This research has scientific novelty because it integrates three main approaches: (1) evaluation of actual water needs based on data per building and campus resident activities; (2) analysis of the availability of water sources based on physical conditions and existing infrastructure; and (3) designing a masterplan for long-term clean water needs by considering aspects of efficiency, sustainability, and climate change adaptation. This approach is expected to make an empirical contribution to the literature on water resource management in higher education institutions in Indonesia and serve as a strategic reference for similar institutions in achieving environmentally sound and sustainable campuses.

2. Literature Review

2.1 Planning Water Needs in Institutional Areas

Planning for water needs in an institutional environment requires an integrated approach that combines spatial planning aspects, user projections, and water resource availability. In the context of regional planning, integration is accommodated through Integrated Development Planning (IDP), which serves as the primary instrument for local governments to direct cross-sectoral development. This indicates that integrating water needs with regional development policies is a prerequisite for achieving sustainable water management within the public institutional environment. In line with Mukonavanhu & Nel-Sanders (2024) develop a conceptual framework for integrating water needs planning with regional development strategies, emphasizing the importance of institutional activity-based demand data, such as the number of users, type of facilities, and water use characteristics. In the context of higher education institutions, water demand planning needs to refer to water demand modeling that takes into account the variability of use, seasonal factors, and system efficiency (Deng et al., 2022). Models such as the Water Evaluation and Planning System (WEAP) and AquaStat are often used to simulate projected water needs based on the scenario of campus or educational city development. Thus, an integrated approach not only assesses the current amount of water needed but also projects long-term growth in line with the institution's development plan. This integration is important in developing a Water Demand Master Plan that is adaptive to changes in land use and campus population. Recent developments in integrated water demand assessment highlight the importance of combining scenario-based modeling, spatial analysis, and hydrological variability to support institutional and regional water planning. Study by Bessedik et al. (2023) demonstrate that the application of decision-support tools, such as the Water Evaluation and Planning (WEAP) model, can significantly enhance strategic planning by linking projected water demand with sustainability targets under multiple development scenarios. Similarly, Nahib et al. (2022) show that spatial–temporal modeling of water supply and demand using geospatial methods can improve the accuracy of forecasting, especially in environments experiencing dynamic land-use changes, such as educational campuses or institutional complexes. In addition, a study by Alawsi et al. (2022) emphasizes that accounting for hydrological variability and drought-related uncertainty through hybrid forecasting techniques is essential for ensuring the long-term reliability of water systems. Together, these studies underscore that integrated modeling combining scenario forecasting, spatial analysis, and hydrological risk assessment is fundamental for developing adaptive and data-driven Water Demand Master Plans within institutional settings.

2.2 Water Consumption and Household Use Standards

Understanding water consumption standards is a crucial foundation for estimating water needs at both the household and institutional levels. According to the World Health Organization (2020) guidelines, the minimum water requirement to ensure basic health and hygiene ranges from 50 to 100 liters per person per day, including direct consumption, personal hygiene, and other domestic needs. In the context of educational institutions in Indonesia (National Standards Agency, 2005), the water demand standard for educational institutions ranges from 100 to 200 liters/person/day, serving as the primary reference for planning a clean water supply system in Indonesia. Furthermore, from the aspect of quality and environmental health, the Ministry of Health of the Republic of Indonesia (2017) emphasized that water used for household and institutional purposes must meet physical, chemical, and microbiological requirements to ensure public health. From the technical side of provision, Regulation of the Minister of Public Works and Housing (PWH) number 27/PRT/M/2016 regulates the implementation of a sustainable Drinking Water Supply System (SPAM), covering aspects of quantity, continuity, and quality, and emphasizing the importance of efficient distribution and management of water resources. Meanwhile, a modern water needs modeling approach was developed by Ehteram et al. (2021) through multiple regression analysis and an Artificial Neural Network that takes into account socio-economic variables, population, and climatic conditions to improve the accuracy of long-term water demand estimates. Thus, the integration of international water consumption standards, national policies, as well as technical and predictive approaches, becomes a conceptual and operational foundation in designing an institutional water needs master plan oriented towards the efficiency, health, and sustainability of water resources. Recent advancements in water demand modeling have increasingly relied on statistical and artificial intelligence techniques to enhance the accuracy of institutional and urban water demand forecasting. Uzlu (2024) developed a hybrid Artificial Neural Network (ANN) optimized with the Rao algorithm to predict long-term water demand in Istanbul, demonstrating significantly higher performance compared to traditional linear regression models. This emphasizes the importance of incorporating demographic and economic indicators in demand projections. Similarly, Mekonnen (2023) conducted a comprehensive assessment of current and future water demand scenarios in Addis Kidam, Ethiopia, which revealed that the existing distribution system lacks the hydraulic capacity to meet rising water needs without operational improvements and infrastructure expansion. Complementing the findings of Sattler et al. (2023), a systematic literature review highlighted that agent-based modeling frameworks provide robust tools for analyzing residential water-use patterns and community behavioral responses to climate variability and water management policies, thereby enriching the predictive dimension of integrated water-demand planning.

2.3 Infrastructure Planning and Water Network Design

Infrastructure planning and water network design are the implementation stages of the water demand projection results. Study by Adeoti et al. (2023) analyze the development of water infrastructure in Nigeria in the context of achieving the Sustainable Development Goals, particularly targets 6.1 and 6.4, which focus on universal access to clean water and water use efficiency. The study highlights the significance of substantial investments in pipeline systems, dams, and water treatment facilities in enhancing infrastructure resilience in the post-COVID-19 pandemic era. The use of hydraulic simulation models, such as EPANET, is becoming a common practice on campuses and in institutions, demonstrating that implementing data management systems based on Geographic Information Systems (GIS) and Decision Support Systems (DSS) can enhance network design efficiency and leak detection (Eljamassi & Abeaid, 2013). In the campus context, the system enables integration between underground utility maps, facility locations, and building expansion planning. Therefore, the development of water infrastructure is not only oriented towards capacity, but also towards sustainability principles such as pumping energy efficiency, leakage monitoring, and rainwater harvesting to support sustainable water management. Recent studies have placed a greater emphasis on incorporating resilience, equity, and sustainability principles into the design of water distribution networks. Study by Cassottana et al. (2023) introduced a multidimensional resilience framework that integrates technical, economic, and operational indicators, demonstrating that such an approach enhances system robustness under dynamic environmental and demand conditions. Kwon & Lee (2025) advanced this field by developing an optimized isolation-valve configuration method that incorporates the Water Gini Coefficient to improve equity in water delivery during operational disruptions. Complementing these perspectives, (Cui et al., 2025) showed that integrating socioeconomic projections with spatial network analysis can significantly reduce regional supply–demand imbalances, thereby strengthening the adaptability of water distribution systems to long-term development pressures. Collectively, these studies underscore the importance of adopting holistic, data-driven methodologies in modern water infrastructure planning.

2.4 Evaluation of Water Resources Availability and Capacity

Evaluation of water availability is a crucial aspect in preparing a water master plan to ensure alignment between water demand and supply. assessed the carrying capacity of water resources in Gansu Province, China, using the Improved TOPSIS model with gray relationship analysis that considers environmental, social, and economic variables. Wang et al. (2022) developed the Water Supply–Demand Balance Index (WSDBI) to project the balance of water supply and demand in the higher education region of China. Both models have proven effective in detecting potential water deficits and supporting data-driven water management planning. Similar principles are applied through the Integrated Water Resources Management (IWRM) approach, as recommended by the Global Water Partnership (2022), which serves as an integrated management framework that combines hydrological, social, economic, and institutional aspects of governance. In Indonesia, this approach has been adopted in various studies, such as Adji et al. (2023), which uses the water balance method to analyze the balance of water needs and availability in Padang City, West Sumatra Province and Gunawan et al. (2023) utilize GIS-based hydrological models to calculate the suitability between the availability of water resources and the needs of users in the Yogyakarta campus area. Regulatively, the implementation of IWRM and sustainable water management is supported by Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia No. 06/PRT/M/2015 concerning the Exploitation and Maintenance of Water Sources and Irrigation Structures, 2015 and Regulation of Minister of PWH number 27/PRT/M/2016 about the implementation of SPAM, which emphasizes the principles of quantity, quality, and continuity of sustainable water supply. Thus, the integration of scientific models, local research practices, and national policies provides a conceptual and operational foundation for water management planning at institutional campuses, such as IPDN, to achieve the efficiency, resilience, and sustainability of water resources. Recent international research further underscores the importance of advanced modeling frameworks for assessing water availability and mitigating future supply–demand imbalances under evolving climatic and socioeconomic conditions. Cacal et al. (2024b) applied the Water Evaluation and Planning (WEAP) model within an Integrated Water Resources Management (IWRM) context to assess the impacts of climate change on surface water availability in the Irawan Watershed, Philippines, demonstrating the utility of coupled hydrological-policy models for projecting future water supply under multiple emissions scenarios and informing adaptive water management strategies. Similarly, Deng et al. (2022) developed the IWRAM hybrid modeling framework, which integrates climate projections, bias-correction techniques, and long short-term memory (LSTM) models to forecast irrigation water demand under future climate change scenarios. This reveals significant increases in irrigation needs, underscoring the urgency of proactive water allocation planning. Furthermore, Baran-Gurgul & Rutkowska (2024) emphasize the role of integrated hydrological simulations such as coupled SWAT-MODFLOW systems for evaluating water availability and drought risk in basin-wide planning, which supports sustainable decision-making in water resource management. These studies collectively affirm that integrating hydrological models with climate and demand projections within IWRM frameworks enhances the robustness of water availability assessments and supports resilient planning for institutional and regional water systems.

2.5 Case Study of Water Management in the Campus Area

An implementive approach to sustainable water management in campus areas has been carried out in various countries. Moura et al. (2025) through a case study at the Federal University of the Amazon (Brazil) using the SAPEA-Water system to assess the efficiency of water use and environmental awareness of the academic community. The results showed an increase in efficiency of up to 23% after the implementation of the monitoring system and water conservation education program. Meanwhile, Merchán-Sanmartín et al. (2022) developed a drinking water master plan at the ESPOL (Ecuador) campus to evaluate water distribution, network capacity, and digital data-driven conservation strategies. The master plan was developed using GIS-based hydraulic analysis and water demand modeling, which serves as the primary reference for sustainable campus water management. These studies confirm that the implementation of a water management master plan on campus is not only aimed at providing clean water but also serves as a means of environmental education, promoting resource efficiency, and achieving SDG 6 (Clean Water and Sanitation) and SDG 12 (Responsible Consumption and Production).

3. Research Methods

3.1. Research Design

This study employs a mixed-methods approach that combines qualitative and quantitative methods in a complementary manner to obtain a comprehensive understanding of water management at the West Sumatra IPDN Campus. The qualitative approach is carried out through in-depth interviews, direct observations, and documentation studies to understand water use patterns by the government, staff, and campus operational needs, as well as identify preferences, needs, and challenges in the water management system. Meanwhile, a quantitative approach is employed to collect empirical data through structured questionnaires, field observations, and physical measurements of water needs, availability, and quality. The integration of the two approaches is carried out at the analysis stage, where qualitative findings are used to explain and interpret quantitative results. In contrast, quantitative measurement results are utilized to validate and reinforce qualitative findings. Meanwhile, the selection of this case study is based on the characteristics of a representative and unique campus, serving as an official educational area with an institutional activity system that resembles a mini-city, featuring academic facilities, dormitories, employee housing, and public service facilities that all require an integrated water supply system. Thus, this combination yields a more comprehensive understanding of the relationship between user behavior and the technical conditions of water management systems, providing the scientific basis for designing a sustainable campus water needs master plan.

3.2. Research Location

This research was conducted at the West Sumatra IPDN Campus in Baso District, Agam Regency, West Sumatra Province (coordinates: -0.2815, 100.3810). This location is an educational institution under the auspices of the Ministry of Home Affairs, which has experienced an increase in water needs along with the development of the campus.

3.3. Data Type and Source

This study utilizes two types of data: primary data and secondary data, which are collected through various techniques to provide a comprehensive understanding of the needs and availability of water at the West Sumatra IPDN Campus. Primary data were collected through field observations, interviews, and the distribution of questionnaires. Observations were conducted in a participatory manner to assess the condition of water infrastructure and distribution systems, measure water availability, and determine water use patterns in various campus units. Semi-structured interviews were conducted with praja, staff, water management officers, and campus officials to obtain in-depth information related to water management and perceptions of existing infrastructure conditions. Additionally, a questionnaire was distributed to selected respondents to assess their water consumption patterns, user satisfaction levels, and the effectiveness of clean water management systems. The results of this analysis were analyzed in a quantitative descriptive manner. The informant selection technique employed in this study utilizes Total Selection (Census Sampling), which involves all members of the population as respondents, given that the population is relatively small and easily accessible (Creswell, 2018).

This technique was chosen to guarantee accurate data representation without sample selection bias. The research population consisted of 219 individuals, comprising 110 residents, 102 staff members, three water management officers, and four campus officials involved in water management and policy. Questionnaires were distributed to the entire population, while interviews were conducted with 10% of respondents, randomly selected from each group, to obtain in-depth information.

Secondary data is obtained from official documents such as annual reports, technical records, water management policies, and relevant regulations. This documentation study supports the analysis of water needs, existing conditions, and policy frameworks governing water management on campus. To ensure the reliability of the data, triangulation of sources and methods was carried out by comparing the results of observations, interviews, and supporting documents. The combination of these various techniques enables cross-validation between qualitative and quantitative data, resulting in more accurate and representative research results that inform the formulation of a sustainable water demand masterplan for the West Sumatra IPDN Campus.

3.4. Data Analysis

Data analysis in this study was conducted both quantitatively and qualitatively to obtain a comprehensive understanding of the needs, availability, and management of water at the West Sumatra IPDN Campus. A quantitative approach is used to calculate and compare numerical data, such as projected water needs and water availability. In contrast, a qualitative approach is used to understand the managerial, technical, and behavioral aspects of water users in the campus environment.

1. Analysis of projected water needs
   This analysis aims to determine the amount of water required based on the number of users and the building's function. The calculation was carried out in a descriptive quantitative manner, with reference to National Standards Agency (2005) concerning Piping System Planning Procedures for Buildings (Table 1). Each building on the West Sumatra IPDN Campus is grouped by its use, including dormitories, offices, lecture buildings, public facilities, and official housing.
   The formula for calculating building needs based on SNI 03-7065-2005 is:
   $$Qh = N \times K$$
   Information:
   Qh = Daily clean water requirement (liters/day)
   N = Number of occupants/building users (people)
   K = Per capita water consumption rate (liter/person/day) according to building function
   This analysis technique involves calculating the total water needs per building and the total needs of the campus, and then comparing them with the water production capacity to assess the level of water supply adequacy.
2. Water Availability Analysis was carried out by measuring the direct water discharge at the raw water source that flows to the main reservoir at the IPDN West Sumatra Campus. Water discharge measurement is carried out using the Volumetric method, which calculates water discharge by recording the volume of water flowing in a specified time period. The tools used are containers and stopwatches. The steps in calculating availability with this method are as follows:
   a. Use a 300-liter container.
   b. Use the stopwatch app on your smartphone.
   c. Then fill the container and count the time until the specified container limit.

   The formula for calculating water discharge by the volumetric method is:
   $$Qp = \frac{Volume}{Time}$$
   Information:
   Qp = Water discharge per period
   Volume = Specified volume
   Time = Time required
   While water availability is a comparison between water demand and the amount of water produced, to calculate water availability, a comparison is made between the use of production water and total water needs. This method is commonly used in water resource planning, especially to evaluate whether the water supply meets the needs of the water (Venkatesan & Deo, 2010).

   The formula for calculating water availability is:
   $$WAR\ (\%) = \frac{PW}{TWR} \times 100\%$$
   Information :
   WAR = Water Availability Ratio (%)
   PW = Water Production (liter/detik)
   TWR = Total Water Requirement (liters/second)
   The results of this analysis are used to determine whether the water supply meets the total needs in the campus environment, as well as to formulate recommendations for increasing the capacity of water sources when needed.

Table 1 - Minimum Building Water Utilization Standards Based on SNI 03-7065-2005

No	Building Usage	Water use	Unit
1	Residential	120	Liters/occupant/day
2	Flat shoes	100	Liters/occupant/day
3	Boarding house	120	Liters/occupant/day
4	Hospital	500	Liters/patient/day
5	Primary school	40	Liters/student/day
6	Junior High School	50	Liters/student/day
7	Vocational High School	80	Liters/student/day
8	Shop House	100	Liters/occupant/day
9	Office/Factory	50	Liters/employees/day
10	Department Store	5	Liter/m2
11	Restoran	15	Liters/seat
12	Hotel	250	Liters/beds/day
13	Low-budget accommodation	150	Liter/beds/day
14	Performance Building	10	Liter/seat
15	Multipurpose Building	25	Liter/seat
16	Stations, Terminals	3	Liters/passengers/day
17	Mosque	5	Liters/person

3. This analysis was carried out using a spatial descriptive method, which involved mapping and describing the water flow system from raw water sources to distribution points throughout user buildings. Data was obtained from field observations, pipeline maps, and interviews with campus water managers. This analysis aims to evaluate the efficiency of the distribution system, assess the potential for water loss (non-revenue water), and determine the feasibility of the existing piping system in supporting long-term needs.
4. Water quality analysis is carried out by combining field observation methods and laboratory tests to assess the suitability of water quality to national standards. Direct sensory observation involves evaluating the color, odor, and turbidity of water at its sources and distribution points. Meanwhile, laboratory tests are conducted to measure the physical and chemical parameters of the water, including pH, temperature, dissolved solids (TDS) levels, and heavy metal content. The test results were then compared with clean water quality standards as outlined in Regulation of the Minister of Health Number 32 of 2017 concerning clean water quality standards. This analysis aims to ensure that the water used at the West Sumatra IPDN Campus meets health standards and is suitable for consumption and domestic purposes.
5. Data Analysis Techniques

In general, the data analysis techniques in this study include:

a. Quantitative analysis is used for numerical data such as projected water demand, water discharge, and water availability ratio. Data were analyzed using descriptive statistical methods (mean, comparison, and ratio) to assess the suitability between water demand and supply.
b. Qualitative Analysis is used to examine the results of interviews and field observations related to water management systems, user behavior, and distribution network operational problems. The analysis is conducted through the processes of data reduction, data presentation, and drawing conclusions (Swift, 2022; Taylor et al., 2016).
c. Comparative analysis was carried out by comparing the results of the calculation of water needs and availability to National Standards Agency (2005) as well as the results of previous research to assess the suitability and effectiveness of the water management system on campus.

This combined approach provides a comprehensive understanding of the existing conditions, system efficiency, and the basis for preparing a master plan for water needs and management at the West Sumatra IPDN Campus.

4. Results and Discussion

4.1. Location and Area

This research was conducted at the Institute of Home Affairs Governance (IPDN) West Sumatra Campus, which is located in Bukittinggi City, one of the cities in West Sumatra Province, Indonesia. The campus is located in a hilly area, which is part of the highlands of West Sumatra. Bukittinggi is situated approximately 900 meters above sea level, resulting in a cool climate with average temperatures ranging from 20°C to 27°C.

The IPDN West Sumatra campus spans approximately 25 hectares (IPDN Annual Report 2025). This campus is designed with facilities that support education and training activities for prospective civil servants, especially in the government sector. With a reasonably large area, this campus offers various facilities, including administrative buildings, dormitories, academic buildings, sports halls, sports arena, hall buildings, employee housing, employee dormitories, mosques, libraries, and open spaces that support the learning, physical, and mental development of students.

4.2. Map of Building Grouping in IPDN West Sumatra

The grouping of buildings in IPDN West Sumatra is arranged according to their functions, including administrative buildings, dormitory buildings, academic buildings, sports arena, hall buildings, employee housing, employee dormitories, mosques, and libraries. The building grouping map is as follows:

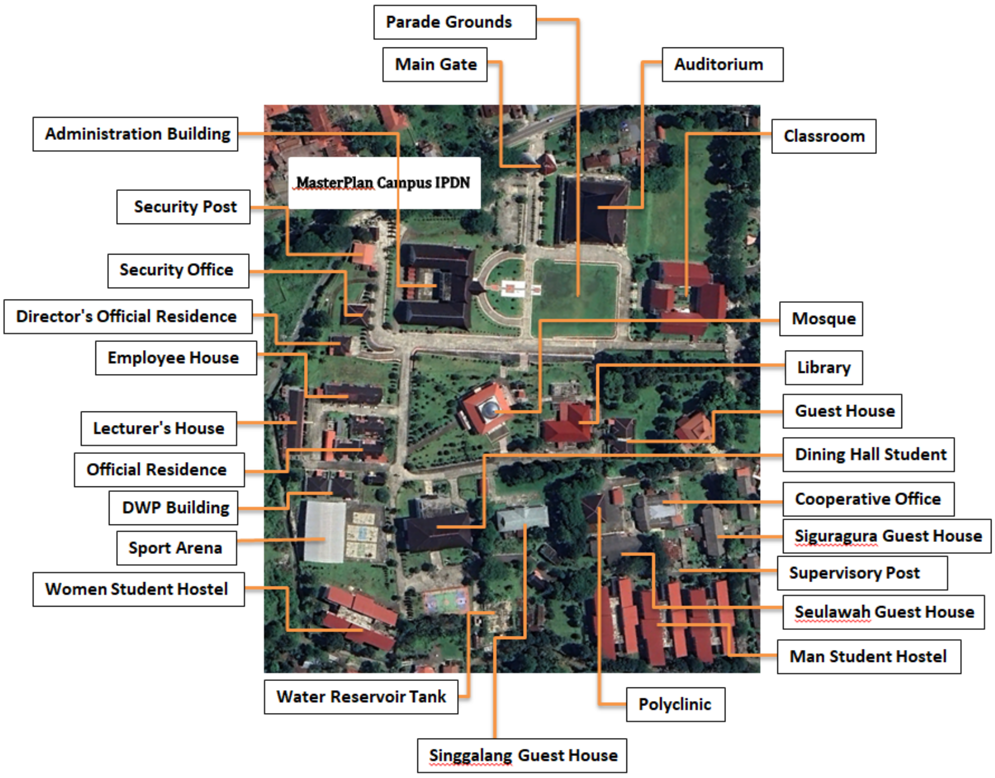

Fig. 1. Building Grouping Map

4.3. Water Needs

Based on data obtained from the 2025 census results and calculations in accordance with SNI 03-7065-2005, the water needs per building at the West Sumatra IPDN Campus in 2025 are presented in Table 2 and Figure 2.

Based on the calculation results presented in the water demand calculation table above, the water demand for the West Sumatra IPDN campus in 2025 will be 92,150 liters/day, or approximately 1.1 liters/second.

The calculation results indicate that the total water demand at the West Sumatra IPDN Campus in 2025 is relatively lower than the water demand standard for dormitory educational institutions, as specified in SNI 03-7065-2005, which ranges from 120 to 150 liters/person/day. This difference indicates the efficiency of water use in IPDN, which the internal water management system can cause, the pattern of strictly scheduled praja activities, and the number of water users in the West Sumatra IPDN campus, which is smaller compared to the amount of water needed in other studies, such as a similar study by Rahmawaty et al. (2022) at the Institut Teknologi Nasional Campus, which had a recorded water requirement of 1.6 liters/second for a similar user capacity, the IPDN figure was more efficient by around 31%.

Table 2 - Water Needs of IPDN West Sumatra Campus

No	Building Name	Number of Users / Capacity	Standard Requirements (SNI 03-7065-2025)	Total Water Requirement (liters/day)
1	Administration building	56 person	50 liters/employee/day	2,800 liters/day
2	Security post	4 person	50 liters/employee/day	200 liters/day
3	Security office	12 person	50 liters/employee/day	600 liters/day
4	Director's official residence	4 person	120 liters/occupant/day	480 liters/day
5	Employee house	47 person	120 liters/occupant/day	5,640 liters/day
6	Official residence	17 person	120 liters/occupant/day	2,040 liters/day
7	Lecturer house	25 person	120 liters/occupant/day	3,000 liters/day
8	DWP building	67 seat	25 liter/seat	1,675 liters/day
9	Sports hall	250 seat	25 liter/seat	6,250 liters/day
10	Man student hostel	75 person	120 liters/occupant/day	9,000 liters/day
11	Women's student hostel	35 person	120 liters/occupant/day	4,200 liters/day
12	Singgalang guest house	40 person	120 liters/occupant/day	4,800 liters/day
13	Seulawah guest house	22 person	120 liters/occupant/day	2,640 liters/day
14	Siguragura guest house	19 person	120 liters/occupant/day	2,280 liters/day
15	Polyclinic (Office)	9 officers	50 liters/employee/day	450 liters/day
	Polyclinic (Patient)	12 patient	500 liters/patient/day	6,000 liters/day
16	Supervisory post	12 person	50 liters/employee/day	600 liters/day
17	Canteen	115 seat	15 liter/seat	1,725 liters/day
	Cooperative office	Wide 168 m²	5 liter/m²	840 liters/day
	Canteen and cooperative office			2,565 liters/day
18	Guest house	12 beds	150 liters/beds/day	1,800 liters/day
19	Canteen for men	350 seat	15 liter/seat	5,250 liters/day
	Canteen for women	110 person	15 liters/person	1,650 liters/day
20	Mosque	500 person	5 liters/person	5,000 liters/day
21	Library for officers	4 officers	50 liters/employee/day	200 liters/day
	Library for students	100 seat	25 liters/seat	2,500 liters/day
	Total library			2,700 liters/day
22	Classroom	121 person	80 liters/student/day	9,680 liters/day
23	Auditorium	500 seat	25 liters/seat	12,500 liters/day
Total daily water requirement				92,150 liters/day

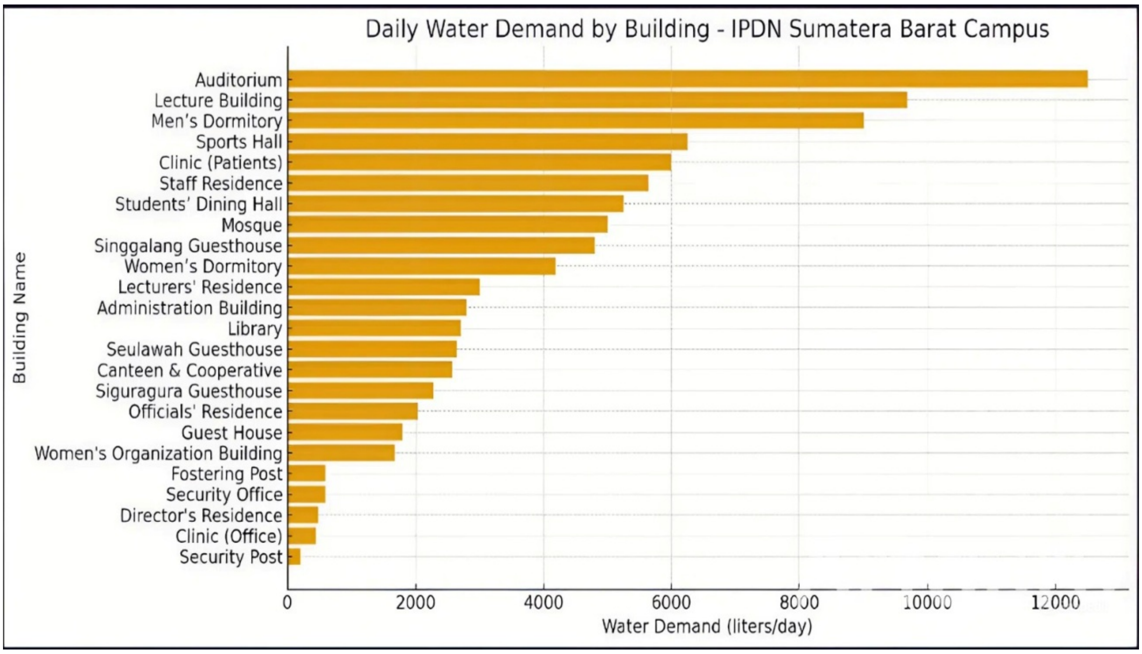

Fig. 2. Water Needs of IPDN West Sumatra Campus

4.4. Water Availability

The manual volumetric method calculates production water discharge based on the volume of water in the tank over a given period. This method involves recording the time it takes for every 300 liters of water that comes out of the reservoir. The tools used are a 300-liter water tank, a stopwatch, a calculator, and a notebook. The water discharge measurement is as follows:

The measurement of the resulting water discharge was conducted on 20 March 2025, at 13:45 WIB. Water discharge measurement is carried out by recording the time needed for every 300 liters of water that comes out of the reservoir. The recording results are shown in the following Table 3:

Table 3 - Volume and time recording results

No	Volume (liters)	Time (seconds)
1	300	61
2	300	58
3	300	60
Average Time		59.6

Source: Measurement results

From the measurement results as in the table above, the resulting water discharge (Qp) can be calculated as follows:

Qp = Volume = 300 liters
Times 59.6 seconds
= 5.03 liters/seconds

So the water discharge produced by the water management system at the West Sumatra IPDN campus is 5.03 liters/second.

Water availability is a comparison between water demand and the water produced. To calculate water availability, a comparison is made between the water production and the total water requirement. This method is commonly used in water resource planning, especially to evaluate whether the water supply is sufficient to meet the needs as per the guidance from Venkatesan & Deo (2010).

$$WAR\ (\%) = \frac{PW}{TWR} \times 100\%$$

$$= \frac{5.03\ \text{liters/seconds}}{1.4\ \text{liters/seconds}} \times 100\%$$

$$= 359\%$$

The calculation results show that the water availability is 359%, or three times the total water needs of the West Sumatra IPDN campus. This indicates that the current water supply system is still able to meet the water needs of all water users in the campus environment well, so it can be concluded that the availability of water on the IPDN West Sumatra campus is greater than the total water needs of all water users in the IPDN West Sumatra campus environment in 2025.

Interpreting this value indicates a significant water surplus condition. This surplus suggests that the water supply system at IPDN still has a substantial reserve of production capacity. However, when compared to the results of the study by Yu et al. (2025) in Gansu Province, China, which has a water availability ratio of around 140–180%, IPDN has a significantly larger margin of availability. This condition can be a potential for the development of a water reserve system, the utilization of rainwater, or the redistribution to a new facility area without adding to the burden on the primary source. This data aligns with the results of interviews with water technicians, who explained that groundwater sources under the campus are still highly productive and have not shown a decrease in discharge throughout the year.

4.5. Water Distribution Infrastructure

Based on the results of surveys and interviews, the water on the IPDN West Sumatra campus comes from groundwater. The mechanism of extracting groundwater is to drill a water source, then suck it up using a water pump to the water source, and then send it to a reservoir. The water is filtered and treated in a storage tank for distribution to buildings and outdoor areas at the West Sumatra IPDN Campus. The components of the water supply system are shown in Figure 3.

The water from the raw water source is sucked up using a submersible pump and then drained into a storage tank. This reservoir is the main tank in the water distribution at the West Sumatra IPDN Campus. Before treatment, the water in this tank will be filtered traditionally to improve its quality and prepare it for distribution. The distribution process is carried out through a network of pipes designed according to the campus layout and user needs, to ensure that the entire area receives a water supply of the appropriate volume and pressure.

The distribution process begins at the primary water source (SA), which is sourced from groundwater and channeled to the water reservoir (BP), serving as the primary storage facility. In these tanks, water is temporarily stored for filtration and treatment, maintaining supply and pressure stability, and providing water reserves in the event of distribution disruptions from the source.

Next, the water from the reservoir flows to the Valve Control (VC) system, utilizing 4-inch-diameter galvanized pipes as the main distribution line. This central flow control system allows operators to control the volume and pressure of water distributed to each campus zone. Valve control also enables the flow of water to be stopped to a specific area when needed, for example, for network maintenance or leak handling. From the valve control, water is delivered to the leading piping network, which utilizes 4-inch-diameter galvanized pipes. These pipes carry water to various secondary distribution points scattered throughout the campus.

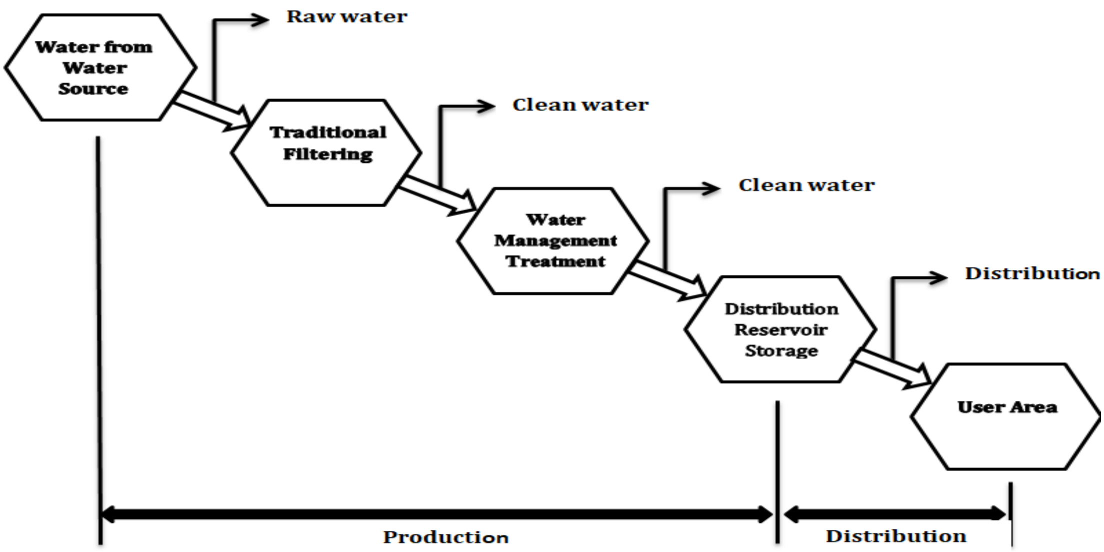

Fig. 3. Water Supply System Components

After reaching the main branch points, the water is distributed using 2- to 2.5-inch diameter PPR pipes, which serve as a secondary network and are directly connected to each user's building. This network comprises various facilities, including administration buildings, lecture buildings, student dormitories, official residences, sports facilities, clinics, libraries, restaurants, and campus mosques. Each building gets its water supply through its own channels, which are sometimes equipped with local valves to maintain continuity of distribution within the building. Clean water distribution pipe of the West Sumatra IPDN Campus, as shown in the following Figure 4:

Fig. 4. Map of the West Sumatra IPDN Clean Water Distribution Pipeline Network.

4.6. Water Quality

1. Quality Based on Sensory Observation.
   Water quality was assessed using human senses at reservoirs, dormitories, sources, and mosques, observing conditions of sight, taste, and smell (Tables 4–6).

Table 4 -Visual Observation (Vision)

Location	Color	Turbidity	Presence of Particles	Visual Conclusion
Dormitory Building	Slightly yellowish	Overcast	Invisible	Early indications of mild contamination
Reservoirs	Somewhat clear, not very clear	Clear	Invisible	Early indications of mild contamination
Water sources	Clear and transparent	Clear	There are fine deposits	The water looks clean and clear
Mosque	Clear and clear	Clear	Invisible	The water looks clean and clear

Table 5 - Smell Observation (Scent)

Location	Odor	Description of Odor	Conclusion
Dormitory Building	None	-	Fresh water with no indication of contamination
Reservoirs	None	-	Still in normal condition
Water sources	A smell	Zinc and Soil Smell	Not too smelly, depending on weather conditions
Mosque	None	-	Fresh water with no indication of contamination

Table 6 - Taste Observation (Tasting)

Location	Dominant taste	Remarks	Conclusion
Dormitory buildings	Neutral	Fresh, tasteless	Safe but needs further lab testing for potability
Reservoirs	Neutral	Fresh has a taste like zinc	Safe but needs further lab testing for potability
Water sources	Feels like zinc	There is a taste like zinc	Safe but needs further lab testing for potability
Mosque	Neutral	Fresh, tasteless	Safe but needs further lab testing for potability

Visual observation of the water showed variations in clarity and possible indications of minor contamination at some points. The water in the Dormitory Building looked yellowish and cloudy, although there were no solid particles visible to the naked eye. These characteristics suggest the potential for initial mild contamination, which may originate from internal piping systems, sediment in reservoirs, or unprotected water sources. The water from the Reservoir Tank appears to be somewhat clear, but not entirely clear. Although no visible particles were found, this condition showed early indications of mild contamination. In contrast, the water from the primary water source and the mosque appears clear and transparent, with no visible particles. Although fine sediments are found in water sources, this water is visually categorized as clean and clear. The clarity of the water from the mosque indicates the best visual quality, which means a more protected or well-maintained distribution and storage system.

Regarding odors, most observation points do not show any suspicious odors. The water from the Dormitories, Reservoirs, and Mosques is odorless, which indicates the absence of biological or chemical contamination based on these parameters. However, this is different from water from the primary water source, which produces metallic odors, such as zinc, and the smell of soil. This can indicate the presence of certain dissolved metals or organic compounds, the appearance of which is influenced by weather factors and the geological characteristics of the surrounding soil. Although this smell is not dominant, its existence requires further attention and confirmation through laboratory tests.

From the observation of the taste of the water, it was found that the water in the Dormitory and Mosque has a neutral and fresh taste, without a foreign taste. This suggests that the water in both locations is relatively safe to consume, at least in terms of sensory taste. However, water from reservoirs and water sources often contains a foreign taste similar to that of zinc metal. This flavor can indicate the presence of small amounts of minerals or heavy metals, which may originate from piping systems, storage tanks, or be inherent to the characteristics of the water source itself. Although this taste does not necessarily indicate unworthiness, its presence is significant enough to warrant laboratory tests as a further verification step.

Overall, these observations show that the water quality in the campus environment is quite good. However, there are early indications of minor contamination at several points that require follow-up with laboratory analysis to ensure the safety of sustainable water use and compliance with applicable regulations, as stipulated in the Regulation of the Minister of Health number 492/Menkes/Per/IV/2010 concerning Drinking Water Quality Requirements.

2. Water Quality Based on Laboratory Tests

Based on the results of water quality laboratory tests at the West Sumatra IPDN Campus, a reasonably comprehensive picture was obtained of the actual condition of clean water used at various distribution points. Sampling was carried out in four representative locations, namely at the raw water source, outside the reservoir, the mosque area, and the farthest location, namely the Student Dormitory, taking into account the physical characteristics of the location and the results of the user questionnaire, which stated that there were indications of cloudy and unclear water at several points. The results of the clean water laboratory test at the four sampling points are presented in Figure 5.

The results of the bacteriological test showed that the raw water source still contained E. coli bacteria (10 CFU/100 ml) and Total Coliform (260 CFU/100 ml), but these values were still within the threshold allowed according to laws and regulations. (Kementerian Kesehatan, 2023), so that it is still considered suitable as raw water. On the other hand, water from outside the reservoir showed excellent bacteriological results, with zero E. coli and total coliform content, indicating the effectiveness of the water storage and treatment process before distribution.

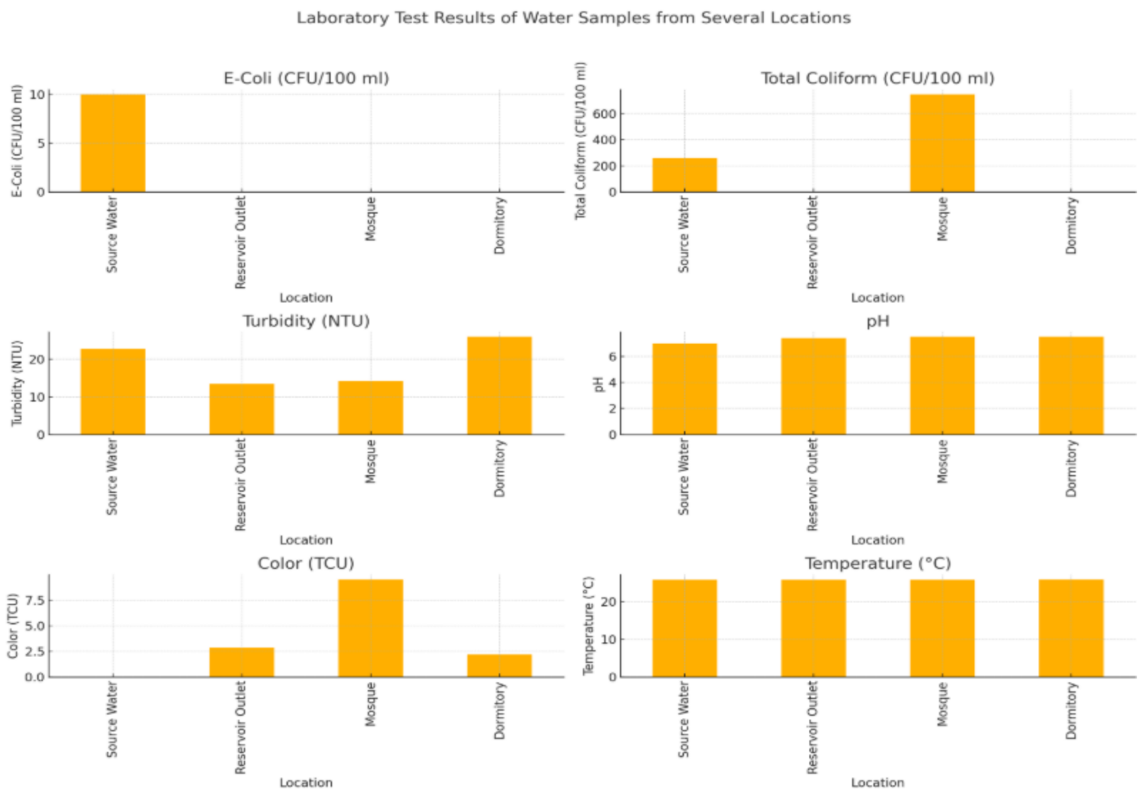

Fig. 5. Diagram of the Results of the Biology, Chemistry, and Physics Examination of Clean Water by IPDN West Sumatra.

However, at the distribution point in the mosque, significant microbiological contamination was found, specifically a total coliform bacteria count of 750 CFU/100 ml, which exceeded the safe limit and rendered the water at that point unsuitable for direct consumption without additional treatment. This suggests the potential for contamination of the local piping system or storage container. On the other hand, the Student Dormitories, which are the furthest distribution points, show good bacteriological results (0 CFU/100 ml for E. coli and Coliform), but with a very high level of turbidity reaching 25.9 NTU, far exceeding the maximum limit of 3 NTU. Similarly, turbidity was also recorded to exceed the standard limit in the mosque and outside the reservoir, at 14.2 NTU and 13.5 NTU, respectively. This indicates that although water can be categorized as safe chemically and microbiologically, aesthetically, and in terms of user comfort, it still needs improvement, particularly in terms of clarity and turbidity.

The physicochemical analysis of all samples showed relatively uniform results. The results are within safe limits, including temperature, pH, color, odor, and the presence of harmful substances such as nitrates, nitrites, chromium, iron, and manganese. All chemical parameters are below the permissible threshold, with water temperatures ranging from 25.7°C to 25.8°C and neutral pH ranging from 7.0 to 7.5. This confirms that the basic quality of water sources in the campus environment remains intact.

However, the main problems faced are more related to the distribution and clarity of the water, which is most likely due to long piping systems, lack of secondary filtration systems, or suboptimal reservoir conditions. These findings were reinforced by interviews with dormitory and mosque staff, who reported a yellowish water color and a metallic taste, especially in the early morning hours of water use.

The correlation between these quantitative and qualitative findings suggests that the decline in water quality does not originate from water sources, but rather from internal distribution networks, particularly in old pipes and storage tanks that are rarely cleaned. Visual observation data also support this conclusion, as locations with high turbidity generally have old galvanized piping systems. The integration of the two data sets yields a more comprehensive understanding: chemically, water remains viable, but aesthetic and distribution aspects require improvement to maintain the perception of quality at the user level.

Thus, it can be concluded that although in general the water used at the West Sumatra IPDN Campus meets the requirements of drinking water quality in terms of chemistry and bacteriology at most points, there are still serious challenges in maintaining the consistency of water quality throughout the distribution network, especially in terms of turbidity and local contamination parameters. This is a crucial basis for water management planning, which involves adding filtration systems, regularly maintaining distribution channels, and enhancing the design of clean water networks in the master plan for campus water needs, ensuring that water quality is guaranteed to the point of final use.

3. Analysis of the Causes of Water Quality Problems

The results of the tests and observations showed that the decline in water quality did not originate from the water source, but rather from the internal distribution chain of the campus. Some of the leading technical causes include:

a. An old (galvanized) piping system that has been corroded so that it releases metal particles (Fe, Zn) into the water stream and increases the turbidity and taste of the water.
b. Sedimentation in reservoirs and reservoirs due to a lack of periodic clean-up causes suspended particles to be carried into the distribution network.
c. Reservoirs or storage tanks without tight lids, which allow the entry of dust, insects, or microorganisms.
d. Fluctuations in water pressure in the pipeline, which can trigger backflow and the entry of microbiological contaminants at leak connection points.
e. The difference in distribution distance, where distant locations such as Dormitories experience decreased pressure and increased water retention time, which increases the chances of microbial settling and growth.

In addition to technical causes, there are also managerial aspects that contribute to water quality degradation, namely:

a. The lack of a regular water quality monitoring system, both at the reservoir level and the final consumption point.
b. There is no standard operating procedure for periodic cleaning of tanks and piping.
c. Lack of coordination between water facilities management units and end users, so that complaint reports (such as yellowish water) are not immediately responded to with technical action.

4. Recommended Technical and Managerial Solutions

Efforts to improve water quality at the West Sumatra IPDN Campus require a combination of integrated technical and managerial approaches. Technically, repairs can be made by replacing old galvanized pipelines with PVC or HDPE pipes that are more corrosion-resistant. This can be achieved by adding secondary filtration systems, such as sand filters or cartridge filters, at reservoirs and final distribution points. Additionally, periodic cleaning and disinfection of reservoirs and distribution pipes can be performed using light chlorination, in accordance with WHO standards. Additionally, installing a sealed cover with filtered ventilation on the storage tank is necessary to prevent air or insect contamination. Meanwhile, a real-time water quality monitoring system (pH, NTU, temperature) at the main point of distribution can improve early detection of water quality degradation. From a managerial perspective, enhancing the quality of water management requires the preparation and implementation of standard operating procedures for water quality management, the establishment of a campus clean water management team, and technical training for management staff on sanitation and network maintenance. All monitoring results and operational activities must be integrated with the water management master plan to ensure that any technical improvements and managerial policies align with the direction of sustainable campus water infrastructure development.

4.7. Analysis of the Water Demand Masterplan

Based on the results of the water needs, availability, and quality analysis, a water management master plan was prepared for the West Sumatra IPDN Campus. The study of water demand revealed that the total consumption was 92,150 liters/day (1.1 liters per second), while the water supply capacity reached 5.03 liters per second, resulting in a surplus of 359%. These findings indicate that the campus has a quantitatively adequate water supply capacity; therefore, the primary focus of planning is not on adding sources but on improving distribution efficiency and enhancing water quality.

The results of the water quality test revealed turbidity and bacteriological contamination at several distribution points, particularly in areas surrounding mosques and dormitories. This problem correlates with field observations that identified old galvanized pipes, sedimentation in storage tanks, and a lack of secondary filtration systems as the leading causes of water quality degradation. Thus, the relationship between the results and the research objectives is clearly depicted. Although the demand and availability of water are balanced, the quality and reliability aspects of the system still do not meet environmental health standards.

The implications of these results for the water management master plan are significant. First, the results of the water needs and availability calculations form the basis for determining the design capacity of the distribution system and allocating development priorities to the network segment experiencing water loss (non-revenue water). Second, the results of the water quality analysis informed investment priorities, focusing on the modernization of the piping network, including the replacement of galvanized pipes with PVC or HDPE, as well as the addition of secondary filtration units at both the reservoir and the final distribution points. Third, field findings suggest the need to strengthen the water quality monitoring system regularly and establish a Campus Water Management Unit to ensure the system's sustainability.

From a long-term planning perspective, the water master plan prepared based on the results of this study serves as a strategic instrument for campus water resource management. The plan will include (1) projection of water demand for the next 20 years as campus capacity grows, (2) redesign of the distribution system to ensure stable pressure and continuity, and (3) integration of water management with conservation strategies such as rainwater harvesting and greywater recycling.

Thus, this discussion emphasizes that the research results are not only descriptive but also provide policy and technical direction for investment decision-making, system improvement priorities, and the preparation of a sustainable and adaptive campus water management master plan that meets future changing needs.

5. Conclusion

This study emphasizes that evaluating water needs and availability at the IPDN West Sumatra Campus is a strategic step in formulating a sustainable water management master plan for the dormitory education environment. The analysis results showed that the total campus water demand exceeded the existing supply capacity, with variations in consumption between buildings influenced by building function, activity intensity, and user characteristics. This finding reinforces the importance of applying the SNI 03-7065-2005 standard not only as a reference for technical calculations but also as a tool for evaluating water use efficiency in official educational settings. In addition, water quality analysis revealed a decline in quality at several distribution points, attributed to the aging of galvanized pipes and the absence of secondary filtration systems, which has the potential to compromise the health standards of drinking water. This result underscores the need to modernize the clean water network system through the replacement of pipe materials, the implementation of layered filtration systems, and the enhancement of water quality control in accordance with WHO standards and the Minister of Health Regulation No. 32 of 2017.

Academically, this research contributes to the enrichment of the literature on water infrastructure planning in integrated educational institutions, utilizing a campus-based water demand modeling approach that is still rarely employed in Indonesia. This study also opens up opportunities for integrating quantitative approaches (calculating needs and availability) with spatial and managerial aspects in the preparation of campus water master plans. In terms of policy, the results of this research provide an empirical basis for local governments and educational institution managers to develop water conservation policies, optimize distribution networks, and enhance the quality of water infrastructure, with a focus on efficiency and sustainability.

The next direction of research should focus on two main areas. First, develop a long-term predictive model to monitor the dynamics of water demand based on campus population growth and changes in activity patterns. Second, a comparative analysis is conducted between official campuses in Indonesia to assess the effectiveness of the policies and design of the water systems implemented, so that best practices can be identified in sustainable campus water planning. Thus, this research not only makes an empirical contribution to water planning practice, but also broadens the academic horizons in water resource management in a boarding education environment.

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