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Analysis of Irrigation Networks and Actual Operation and Maintenance Needs (AKNOP) in the Paniis Lebak Main Canal

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Abstract

Irrigation network maintenance plays a strategic role in ensuring efficient and sustainable water distribution to support agricultural productivity. This study aims to evaluate the condition of the irrigation network and calculate the Actual Operation and Maintenance Needs Index (AKNOP) for the Paniis Lebak Main Canal in Kuningan Regency, West Java, Indonesia. A mixed quantitative and qualitative approach was employed through field observations, water discharge measurements, assessments of irrigation canals and hydraulic structures, and maintenance cost calculations based on the technical guidelines of the Indonesian Ministry of Public Works and Housing (PUPR). The results indicate that the irrigation canal remains generally functional; however, minor to moderate damage was identified, reducing the efficiency of water distribution. Irrigation infrastructure plays a strategic role in sustaining agricultural productivity by ensuring a reliable and well-regulated water supply to paddy fields. Optimizing the performance of the irrigation network depends largely on the effective implementation of Operation and Maintenance (O&M) activities, which must be carried out systematically and accurately. From a financial planning perspective, the Actual Operation and Maintenance Needs Index (AKNOP) serves as a critical instrument for estimating maintenance requirements. Accurate AKNOP estimation requires a comprehensive network walkthrough to identify and inventory the actual physical condition and damage of irrigation infrastructure, thereby providing a reliable basis for maintenance planning and budget allocation.

INTRODUCTION

Irrigation networks play a vital role in supporting agricultural productivity by ensuring the efficient distribution of water to farmland. One of the primary components of an irrigation system is the weir, which regulates water flow and diverts it into irrigation canals. However, irrigation infrastructure is often affected by problems such as sediment accumulation, uncontrolled vegetation growth, and inadequate maintenance, all of which reduce the efficiency of water distribution (Asfaw & Seyyid, 2026; Bhatti et al., 2021; Ikundabayo et al., 2026; Kassa, 2017).

The management of agricultural water resources depends heavily on the proper maintenance of irrigation networks. A well-maintained irrigation system facilitates the distribution of water to agricultural land, improves crop productivity, and ensures the long-term sustainability of the irrigation system. Since the weir serves as the main structure for regulating and diverting water into irrigation canals, its maintenance, together with that of the entire irrigation network, has a significant influence on the overall performance of the irrigation system (Ertiro et al., 2017; Mohammadi et al., 2019).

Irrigation maintenance includes activities such as removing sediment deposits and invasive vegetation from irrigation canals, repairing canal structures and hydraulic facilities, and restoring damaged sluice gates and other supporting infrastructure. If these activities are not carried out regularly and effectively, irrigation networks may deteriorate, disrupting water distribution and reducing agricultural productivity. For example, a study conducted on the Pacal Irrigation Network identified that 18.11% of the canals and hydraulic structures experienced minor damage, highlighting the importance of periodic maintenance to ensure the efficiency and sustainability of irrigation systems (Nanda et al. 2024). Similarly, Rahmadani et al. (2024) reported that inefficient water distribution may result from damage to irrigation infrastructure, further emphasizing the need for regular maintenance to maintain system performance and sustainability.

An important aspect of irrigation management involves not only physical maintenance but also the evaluation of the Actual Operation and Maintenance Needs Index (AKNOP). By assessing the current condition of irrigation infrastructure, AKNOP determines the operational and maintenance requirements necessary to maintain effective system performance. Accurate AKNOP calculations are essential for budget planning and resource allocation, ensuring that maintenance activities can be implemented efficiently and effectively.

The urgency of this research is underscored by the critical role of irrigation in supporting agricultural productivity in Indonesia, particularly in regions like Kuningan Regency where rice cultivation is a primary economic activity. According to the Directorate General of Water Resources (2023), many irrigation networks in Indonesia are experiencing degradation due to inadequate maintenance, threatening agricultural productivity and food security. The Paniis Lebak Main Canal serves a significant irrigation area, and its performance directly affects the livelihoods of local farmers.

The novelty of this research lies in its comprehensive approach that integrates physical network condition assessment, water discharge measurements, institutional analysis, and AKNOP calculations to provide a holistic evaluation of irrigation network performance. This study specifically examines the Paniis Lebak Main Canal in Kuningan Regency, an area that has not been extensively studied in previous irrigation research. By combining quantitative measurements with qualitative observations and financial analysis, this research provides practical recommendations for improving irrigation management.

Therefore, this study aims to evaluate the condition of irrigation infrastructure and determine the Actual Operation and Maintenance Needs Index (AKNOP) to support effective maintenance planning, improve water distribution efficiency, and enhance the sustainability of irrigation systems.

Irrigation Management Challenges in Asia

Based (Molle et al., 2009) The challenges of irrigation management in Asia are not only related to the technical aspects of water distribution, but also closely related to the hydraulic bureaucratic structure that manages the irrigation system. This hydraulic bureaucracy refers to government institutions and apparatus that control the flow of water centrally and top-down, with the main goal of optimizing agricultural production on a large scale. The main challenges are as follows:

1. Concentration of Power and Control

Water management is often centralized in government agencies that have full control over water resources, thereby reducing the participation of local communities and farmers in decision-making.

2. Complex and Rigid Bureaucracy

Complex organizational structures and rigid administrative procedures often lead to slow responses to local needs and changing field conditions.

3. Conflict of Interest and Inequality

Bureaucracy-controlled water distribution can create inequitable access between different groups of farmers, especially those who are more socially and economically weak.

4. Reliance on Large Infrastructure

The focus on the construction of dams, major canals, and massive infrastructure projects sometimes ignores adaptive and participatory water management at the local level.

5. Impacts of Climate Change

Changing rainfall patterns and water supply uncertainty exacerbate already complex irrigation management challenges.

The hydraulic bureaucracy often ignores the social and institutional dimensions in irrigation management. This hinders the development of more flexible, participatory, and sustainable irrigation systems, thus impacting the effectiveness and equity in water distribution.

Irrigation Network Concept

Pipelines and other structures used to drain water from underground reservoirs to farmland are called irrigation networks. The irrigation network consists mainly of:

a. The main channel is the main channel through which water flows into the secondary channel.
b. Secondary channels are channels that flow into tertiary channels after receiving water in the main channels.
c. Tertiary Channel: This is the stream that carries water to agricultural land.
d. Quaternary Channel: A small channel that regulates the distribution of water at the level of farmers or groups of farmers.

To increase agricultural yields, irrigation networks are essential because they provide a consistent and reliable water supply, allow farmers to manage planting times, and reduce the risk of crop failure due to drought.

Technical standards for irrigation networks in Indonesia are regulated in (Regulation of the Minister of Public Works and Public Housing Number 14/PRT/M/2015 of 2015 concerning Criteria and Determination of the Status of Irrigation Areas, 2015). This regulation establishes technical criteria for the planning, implementation, and management of irrigation networks to ensure the efficiency and sustainability of irrigation systems.

Irrigation Network

The term "irrigation network" refers to a complex system of pipes and other infrastructure installed to systematically drain water to farmland. Dams, sluices, tapping structures, and drainage channels are additional components of this network that also include primary, secondary, and tertiary channels.

Irrigation system

Rural irrigation and government irrigation are two categories of Indonesian irrigation systems that use river water to irrigate rice crops. Its management is the basis of this difference. There is no funding for communal irrigation systems in villages from the federal government. The community is solely responsible for creating and supervising irrigation networks. Researchers Prof. Drs Erman Mawardi and Ir. Moch. Memed classifies government-funded irrigation schemes as semi-technical or simple technical (H.E., 2015).

Technical Irrigation

The isolated water network of the drainage system allows for proper measurement, regulation and control of the water supply in various places. Everything that is built will remain. Nearly 500 hectares of land are under irrigation. Some examples of irrigation systems are Jatiluhur, Rangtang, Pemali, Comal, and Sampean.

Simple Irrigation

Usually they get funding from the government to build or improve the system. Nonetheless, local officials are responsible for running it. Due to the absence of a flow measurement and control system and the presence of a semi-permanent structure, the water flow is uncontrollable. In 1971, the total area of simple irrigation was 0.96 million hectares, semi-technical irrigation was 1.14 million hectares, and technical irrigation was 2.10 million hectares, according to Division I, Directorate General of Water Resources. At the same time, 1.04 million hectares are irrigated by the village system.

Simple irrigation projects

Aiming to increase national rice production through the implementation of several small-scale initiatives with simple technical needs, the Simple Irrigation Project—the aforementioned simple irrigation system was implemented. The area of irrigation area for this project is less than or equal to 2,000 hectares. There is a balance between simplicity and reliability in technical design, implementation, exploitation, and maintenance. Deliver results efficiently and affordably. The implementation cost was only 250,000 Indonesian Rupiah per hectare of irrigated land in 1980.

Network Conditions

Regulation on Network Conditions (Resolution No. 12 of 2015 concerning Irrigation Management, issued by the Minister of Public Works and Public Housing). (Jakarta: Ministry of Public Works and Public Housing Indonesia, 2015) on the exploitation and maintenance of irrigation networks. The performance of the main irrigation structure can be evaluated in accordance with the standards set out in this regulation. Here are the different types of structural conditions:

a. Excellent condition 99%+
b. Condition 80 to 90%
c. Condition: 60-<80%
d. Defective condition: less than 60%

This assessment is used as a basis for developing a follow-up program, both rehabilitation and routine and periodic maintenance.

METHOD

Research methodology was a fundamental element in a scientific activity because it is the basis in the process of collecting, processing, and testing data to obtain conclusions that can be accounted for. Conceptually, the research methodology includes a set of steps and procedures that are systematically arranged to obtain relevant information and analyze it objectively. Data collection, especially primary data, is essential because it serves as a basis for analysis and conclusion formation.

This study uses a descriptive-inductive qualitative methodology. The descriptive approach aims to describe in detail the conditions and phenomena studied based on data obtained in the field. The inductive approach is used to draw conclusions that depart from empirical facts and direct observation results, then developed into a more comprehensive generalization or understanding based on the research context.

Analysis Method

The research methodology used includes several stages of technical and non-technical studies to obtain a comprehensive picture of the performance of the irrigation system.

1. Potential Discharge Analysis

a. Potential Discharge

Watershed Area (watershed) area and rainfall data for a given period are used to calculate potential discharge, which is an estimate of surface water availability. This calculation generally uses a simple water balance approach that converts rainfall into water volume by considering the area of the catchment area (Asdak, 2018).

In this study, semi-monthly rainfall data for 20 years (1999–2018) was used as the basis for the analysis. Mathematically, the potential discharge can be calculated by the equation:

Description:

CH = Rainfall (mm)

DTA area = Water catchment area (km^2)

b. Flagship Debit

Dependable flow is the minimum discharge that can still be expected to be available with a certain level of reliability, generally 80% for irrigation planning (KP-01, 2013; FAO, 1996). This means that the discharge has a chance of being fulfilled by 80% in the observation period.

The calculation is done by sorting the annual average discharge data from the largest to the smallest value. The flagship discharge position is determined using the Weibull formula:

$R80 = (0.8 \times n) + 1$

Description:

R80 = nth flagship discharge sequence value

n = number of years of observation (e.g.: 20 years → R80 = 17)

The main discharge is the value at the fifth position from the bottom if n = 20.

2. Analysis of Physical Conditions of Networks

All parts of the irrigation system, including the main building, distribution and tapping structures, main channels, sewers, and any additional structures, are physically inspected to ensure they are in compliance, as well as other complementary buildings. Assessment of physical condition is an initial indicator in determining the level of performance of the irrigation system (Directorate General of Natural Resources, 2016).

In general, the network condition index is formulated as:

KONjar = KONbujar + KONbsjar + KONsaljar + KONbpgjar + KONbpgjar

Description:

KONjar = Percentage of total condition of irrigation network

KONbujar = Condition of the main building of the network

KONbbsjar = Condition of the building for the subdivision and tapping building

KONsaljar = Condition of irrigation canals

KONspgjar = Drain condition

KONbpgjar = Building condition on the sewer line

3. Water Demand Analysis

To find out how much water should be used for irrigation to meet the needs of plants, an analysis of water needs is carried out. Considerations include irrigation system efficiency, plant evapotranspiration (ETc), and water loss due to percolation and seepage. In addition, the contribution of effective rainfall is also included in the calculation (FAO, 1998).

The calculation of reference evapotranspiration (ETo) can use the Penman-Monteith method recommended by FAO as an international standard (Allen et al., 1998).

4. Institutional and Human Resources Analysis

The institutional review aims to evaluate the role of irrigation management organizations, showcasing the involvement of P3A, the Water User Farmers Association, in running and maintaining the system. Aspects of human resource capacity, organizational structure, and coordination patterns between institutions were analyzed to determine the effectiveness of irrigation governance (Uphoff, 1986; PUPR Ministerial Regulation No. 12/PRT/M/2015).

5. AKNOP Analysis (Operational and Maintenance Real Needs Figures)

The AKNOP analysis was carried out to calculate the real cost of operation and maintenance of the irrigation network based on actual conditions in the field. The calculation takes into account the degree of network damage, the unit price of materials and labor wages, and the volume of work required.

According to the Directorate General of Natural Resources (2023), AKNOP must be updated regularly to match the dynamics of network conditions and changes in market prices, so that budget planning can be carried out realistically and sustainably.

RESULT AND DISCUSSION

Analysis of Factors Affecting Operational and Maintenance Effectiveness (O&P)

4 Technical Factors (Design, damage, water availability)

Technical factors are one of the crucial aspects in the implementation of O&P. at DI Paniis Lebak, some of the technical problems found include:

1. Light to moderate damage to some tapping buildings and sluices.
2. Channel leakage at some point that causes water loss.
3. Sedimentation and narrowing of channels, which inhibit the optimal flow of water.
4. The design of the channel has not been adapted to the current topography and dynamic planting patterns.
5. Fluctuations in water discharge, especially in the dry season, affect the stability of water distribution.

Institutional Factors (OP Officers, P3A/GP3A)

Irrigation management institutions play an important role in ensuring the smooth running of O&P. At the research site, the institutions consist of:

1. Supervision of the irrigation network is handed over to the Regional Technical Implementation Unit (UPTD).
2. Discharge arrangements and maintenance implementation are the responsibility of the Dam Operations Officer (POB), including Mantri and PPA.

3. P3A and G3A, the Water User Farmers Association, as implementers in the field.

Socio-Economic Factors (farmer participation, contribution costs)

Community participation, especially farmers as the main users of irrigation water, is still relatively low. Problems identified include:

1. Lack of cost and labor contribution from farmers in O&P activities.
2. Lack of awareness of the importance of regular maintenance for irrigation sustainability.
3. Dependence on the government in terms of financing and technical management.

This factor has an impact on the weak strengthening of farmer institutions, as well as hindering the sustainability of irrigation network management.

Environmental Factors (sedimentation, wild vegetation, weather)

Environmental conditions have a major influence on the operation of irrigation systems, with the following findings:

1. High sedimentation due to erosion from the upstream area causes siltation of the channel.
2. The growth of wild vegetation in the channel slows down the rate of water flow.
3. Climate change and rainfall patterns cause water supply irregularities, especially in long dry seasons or flash floods.
4. These environmental factors require special attention in the form of long-term preventive and adaptive measures.

Irrigation Network OP Condition Index

Tabel 1 Kondisi OP

No.	Components	Which exists (%)	Maks (%)	Min (%)	Optimum (%)
1.	Physical Infrastructure	23,23	45	25	35
2.	Plant Productivity	12,01	15	10	12,5
3.	Supporting Facilities	7,33	10	5	7,5
4.	Personnel Organization	10,17	15	7,5	10
5.	Documentation	4,23	5	2,5	5
6.	P3A	3,35	10	5	7,5
	TOTAL	**60,32**	**100**	**55**	**77,5**

Source: Office data

Analysis of Operation and Maintenance Real Needs (AKNOP)

Based on the module Basic Knowledge of Aknop The calculation of the AKNOP is carried out through several stages, including:

1. AKNOP Bendung: Determine the needs of operational costs and maintenance of weirs based on applicable regulations, including the operation of sluices, minor repairs, garbage removal, and labor wages.
2. AKNOP of Canals and Buildings: Calculated based on inventory data of the physical condition of irrigation canals and buildings, taking into account the scale of priority of activities and the division of work areas of irrigation engineers.
3. Motion Weir KNOB: Included in a separate stage with special technical calculations adapted to the characteristics of the motion building.

Irrigation Management Real Needs Figures (AKNPI)

The performance index, or the physical condition of the irrigation network, is a major factor in determining the AKNOP (Actual Operation and Maintenance Needs Figure) budget, which cannot be calculated with just one number. However, based on the latest technical standards and research averages in Indonesia (such as from PUPR modules and case studies of various regions),

Table 2 The Main Components of the budget are usually divided into several main headings:

Activity Components	Estimated Percentages	Provisions
Operating Costs	40–45%	Salary of operations and maintenance officers (PPA/Pekarya), meeting fees of the Water Users Farmers Association (P3A), and procurement of office stationery (ATK).
Routine Maintenance	20–30%	Weed cleaning, garbage removal on channels, and regular lubrication and inspection of sluices.
Periodic Maintenance	30–40%	Sediment (mud) dredging, minor repairs to rock pairs, and light rehabilitation of irrigation buildings.

Factors That Can Increase the Budget

For the budget can swell if:

a. Channel Length: The longer the primary and secondary channels are compared to the area area, the cost of grass tripe and dredging will increase.
b. Damage Rate: If the performance index is below 70%, it usually requires periodic maintenance that is repair, not just maintenance.
c. Regional Minimum Wage (UMR): Local labor costs greatly affect the "Operating Costs" post.

Simulation of the details of the AKNOP budget for the Irrigation Area (DI) covering an area of 375 Ha. This simulation assumes the condition of the network in the "Sufficient/Medium" category with a total budget of around IDR 215,000,000 per year (average IDR 573,000/Ha).

Table 3 Factors That Can Increase the Budget

No.	Activity Components	Job Description	Estimated Cost (Rp)
I	**Operating Costs**		**85.000.000**
1	Officers' Wages (PPA and Workers)	Salary of irrigation observer and sluice gate guard (3–4 people).	70.000.000
2	Official Travel and ATK	Coordination activities with related agencies, preparation of reports, and procurement of office stationery.	10.000.000
3	Operating Work Tools	Procurement of flashlights, boots, simple discharge measuring instruments, and other work supplies.	5.000.000
II	**Routine Maintenance**		**55.000.000**
1	Drain Cleaning	Weeds and garbage cleaning in irrigation canals is carried out about three times a year.	30.000.000
2	Sluice Gate Maintenance	Lubrication (greasing), light painting, and inspection of the condition of the sluice.	15.000.000
3	Patching Light Damage	Repair of minor cracks in the rock pair and the slightly damaged parts of the channel.	10.000.000
III	**Periodic Maintenance**		**75.000.000**

1	Sediment Dredging	Removal of sludge or sedimentation manually or using tools.	45.000.000
2	Building Repair	Small-scale repairs to concrete floors, building wings, and other complementary components.	30.000.000
	Total Budget		**215.000.000**

This allocation reflects a comprehensive approach in managing and maintaining the function of irrigation services in DI Paniis Lebak in a sustainable manner, paying attention to the operational aspects, maintenance, rehabilitation, as well as community empowerment and disaster preparedness.

Solutions Based on AKNOP Results

1. Prepare a budget plan that is right on target for each component of the irrigation network, based on the results of the calculation of real needs in the field.
2. Adjust operational and maintenance activities to prioritize the physical condition of the lines and buildings that have been inventoried.
3. Empowering field officers (POB/juru) according to their duty area so that the implementation of water discharge and maintenance arrangements runs optimally.
4. Integrate the results of AKNOP into the annual planning to make irrigation network management more efficient and sustainable.

CONCLUSION

The results of the study show that the operational conditions and maintenance of irrigation networks in the Paniis Lebak Irrigation Area (DI) have a direct impact on the efficiency of water distribution and agricultural land productivity. The findings of the study show that the main problems affecting network performance include high sedimentation in channels, uncontrolled growth of wild vegetation, and suboptimal routine maintenance activities. These conditions cause a decrease in flow capacity and irregularities in water distribution to rice fields. The results of the evaluation of the Operation and Maintenance Real Needs Index (AKNOP) show that the largest proportion of the budget is absorbed for rehabilitation activities or repair of infrastructure damage. This indicates that the preventive maintenance approach has not been running optimally. Theoretically, planned routine maintenance can reduce large rehabilitation costs and extend the service life of irrigation infrastructure (Directorate General of Natural Resources, 2016; FAO, 1996). Thus, optimizing operation and maintenance activities is a key factor in maintaining the sustainability of the irrigation system. Based on the results of research and literature review, some strategic recommendations that can be applied to improve the performance of the irrigation network in Paniis Lebak include: Increasing the allocation of routine maintenance budgets, so that sedimentation cleaning activities, vegetation control, and minor repairs can be carried out periodically before heavy damage occurs. Optimization of operational personnel and increasing human resource capacity, through technical training related to sluice gate operations, discharge measurement, and network inspection. Supporting the mission of the Water User Farmers Association (P3A) to improve irrigation management through community involvement in operation and maintenance (Uphoff, 1986; Regulation of the Minister of PUPR No. 12/PRT/M/2015). Identification of Physical Degradation: The determinant factors that degrade the performance of the Paniis Lebak irrigation network are the high rate of sedimentation which causes siltation of the channel, as well as the invasion of wild vegetation (weeds) that inhibits the flow rate. This physical damage is exacerbated by the lack of preventive measures on tapping buildings and sluices. Evaluation of AKNOP Financing: The current structure of the Operation and Maintenance Real Needs (AKNOP) figure shows an imbalance in allocation. Most of the budget is absorbed for rehabilitation costs (heavy repairs) due to damage that is already severe. This indicates that maintenance management is still reactive (waiting for damage to be repaired), not preventive (maintaining regularly). The implementation of the strategy is expected to be able to increase the effectiveness of water distribution, maintain the sustainability of water resources, and support the sustainable increase of agricultural productivity in the DI Paniis Lebak service area.

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