

## Analysis of Actual Operation and Maintenance Cost Requirements (AKNOP) for the Cikahuripan Irrigation Network in Sukabumi Regency

Cece Suhendi<sup>1\*</sup>, Ardin Rozandi<sup>2</sup>

<sup>1,2</sup>Department of Civil Engineering, Universitas Nusa Putra, Sukabumi, West Java, Indonesia

\*Corresponding author, e-mail: [cecesuhen@nusaputra.ac.id](mailto:cecesuhen@nusaputra.ac.id)

**Abstract**— The Cikahuripan Irrigation Area in Sukabumi Regency plays an important role in supporting agricultural productivity, particularly rice cultivation. However, the irrigation network has experienced functional degradation due to sediment accumulation, erosion, and malfunctioning water control structures, resulting in suboptimal water distribution. This study aims to determine the Actual Operation and Maintenance Cost Requirement (AKNOP) and identify priority maintenance activities needed to restore irrigation performance. The research employed an observational method through field inspections, inventory surveys, and analysis of irrigation infrastructure conditions. Primary and secondary data were collected from relevant agencies and direct observations. The AKNOP calculation was carried out by identifying operation and maintenance activities, determining work volumes, and estimating costs based on applicable unit price analyses. The results showed that the total AKNOP for the Cikahuripan Irrigation Network was Rp. 493,240,000, consisting of operation costs of Rp. 132,302,800 (30%), routine maintenance costs of Rp. 293,306,813 (65%), and periodic maintenance costs of Rp. 22,731,003 (5%). The study concludes that routine maintenance activities constitute the largest expenditure due to the extensive deterioration of irrigation facilities. It is recommended that responsible agencies prioritize sediment removal, vegetation control, and repair of damaged structures. The findings provide a practical basis for budgeting and improving irrigation management to support sustainable agricultural productivity.

*Keywords: Irrigation Network; Operation and Maintenance; AKNOP; Irrigation Management.*

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### 1. Introduction

Irrigation systems are essential infrastructures that support agricultural productivity, food security, and regional economic development. The sustainability of irrigation services depends heavily on effective operation and maintenance (O&M) activities to ensure that water distribution networks continue to function efficiently and reliably. Inadequate maintenance often results in structural deterioration, sediment accumulation, hydraulic inefficiencies, and reduced service performance, which ultimately affect agricultural production and farmers' livelihoods.

Recent developments in infrastructure management have emphasized the importance of systematic maintenance planning and cost estimation as key components of sustainable asset management. Accurate cost estimation enables infrastructure managers to allocate limited resources effectively while maintaining service quality and operational performance. Comprehensive cost estimation provides a

fundamental basis for infrastructure planning and budgeting [1], while cost accounting and financial analysis support effective resource allocation and long-term infrastructure management [2], [3]. Furthermore, life-cycle cost considerations have become increasingly important to ensure that maintenance expenditures contribute to sustainable asset performance throughout the service life of infrastructure assets [4].

Operation and maintenance management has evolved from traditional corrective approaches toward more systematic and data-driven strategies. Optimization of O&M expenditures has been shown to improve infrastructure efficiency and reduce long-term operational costs [5]. Similarly, maintenance planning models support more effective decision-making and enhance the reliability of infrastructure systems [6]. The adoption of predictive maintenance approaches has also gained considerable attention because it enables managers to identify potential failures before significant deterioration occurs, thereby minimizing maintenance costs and service interruptions [7].

Advances in digital technologies have further transformed maintenance management practices. Big data analytics and predictive maintenance frameworks have demonstrated significant potential for improving infrastructure monitoring and maintenance planning [8]. The implementation of digital twin technology has emerged as an innovative solution for infrastructure management by enabling continuous monitoring and performance evaluation of physical assets [9]. Furthermore, digital twin-based anomaly detection techniques can facilitate the early identification of operational deficiencies and asset deterioration, thereby improving maintenance effectiveness [10]. Intelligent sensing technologies also play an important role in monitoring infrastructure conditions and supporting maintenance decision-making processes [11]. In addition, advanced monitoring systems integrated with artificial intelligence and data analytics have been reported to improve asset management effectiveness, operational reliability, and maintenance efficiency [12].

From a systems engineering perspective, infrastructure management requires the integration of technical, operational, and financial considerations into a unified decision-making framework. Engineering systems should be managed through structured approaches that consider system performance, operational requirements, resource availability, and long-term sustainability objectives [13]. These principles are highly relevant to irrigation infrastructure, where operational effectiveness depends on the coordinated performance of canals, hydraulic structures, personnel, equipment, and maintenance resources.

In Indonesia, irrigation networks play a strategic role in supporting national food security, particularly in rice-producing regions. However, many irrigation systems experience declining performance due to aging infrastructure, sedimentation, erosion, damaged hydraulic structures, and limited maintenance funding. These challenges often reduce water delivery efficiency and hinder agricultural productivity. The Cikahuripan Irrigation Network in Sukabumi Regency is one example of an irrigation system facing such conditions. Field observations indicate the presence of sediment accumulation, erosion along canal sections, and malfunctioning sluice gates that reduce the effectiveness of water distribution to agricultural lands.

Although previous studies have discussed irrigation performance and maintenance management, limited research has focused on determining Actual Operation and Maintenance Cost Requirements (AKNOP) through comprehensive field-based assessments. Most studies emphasize technical performance evaluation without integrating infrastructure condition assessment, personnel requirements, operational facilities, maintenance priorities, and budgeting considerations into a single framework. Therefore, this study aims to analyze the Actual Operation and Maintenance Cost Requirements (AKNOP) of the Cikahuripan Irrigation Network in Sukabumi Regency. The study evaluates existing irrigation conditions, identifies operation and maintenance needs, estimates the required budget for routine and periodic maintenance activities, and determines priority actions for improving irrigation network performance. The

findings are expected to provide practical recommendations for irrigation managers and government agencies in optimizing maintenance resource allocation while supporting sustainable agricultural productivity and long-term irrigation asset management.

## 2. Method

This study employed an observational research approach to evaluate the condition of the Cikahuripan Irrigation Network and determine the Actual Operation and Maintenance Cost Requirement (AKNOP). The research was conducted in the Cikahuripan Irrigation Area, Sukabumi Regency, West Java, Indonesia. The observational method was selected because it enables direct assessment of irrigation infrastructure conditions and provides accurate information regarding operational and maintenance requirements. Through field observations, researchers were able to identify existing problems, assess the functionality of irrigation structures, and estimate the resources required to maintain the network's performance.

The overall research procedure is presented in Figure 1. The study began with a preliminary survey and problem identification to understand the current condition of the irrigation system. Subsequently, primary and secondary data were collected from field observations and relevant institutions. The collected data were then analyzed to evaluate the condition of irrigation structures and canals, identify operation and maintenance requirements, and estimate the associated costs. Finally, the Actual Operation and Maintenance Cost Requirement (AKNOP) was calculated based on the identified activities and the applicable unit price analysis.

Data collection was carried out using both primary and secondary sources. Primary data were obtained through direct field inspections of irrigation structures, canals, gates, and supporting facilities to assess their physical condition and operational status. Secondary data were obtained from the local water resources agency and irrigation management offices, including irrigation area maps, network schemes, infrastructure inventory records, damage assessment reports, and regional unit price analysis documents. The types of data utilized in this study are presented in Table 1.

Field observations were conducted throughout the irrigation network to identify damaged structures, sediment accumulation, erosion, malfunctioning gates, and other factors affecting system performance. Each structure and canal section was evaluated to determine its functionality and maintenance priority. Based on the inventory and condition assessment results, the required operation and maintenance activities were identified. These activities included routine maintenance, such as vegetation clearing, sediment removal, cleaning of structures, lubrication of gates, and repainting of operational equipment, as well as periodic maintenance involving repair or replacement of damaged components.

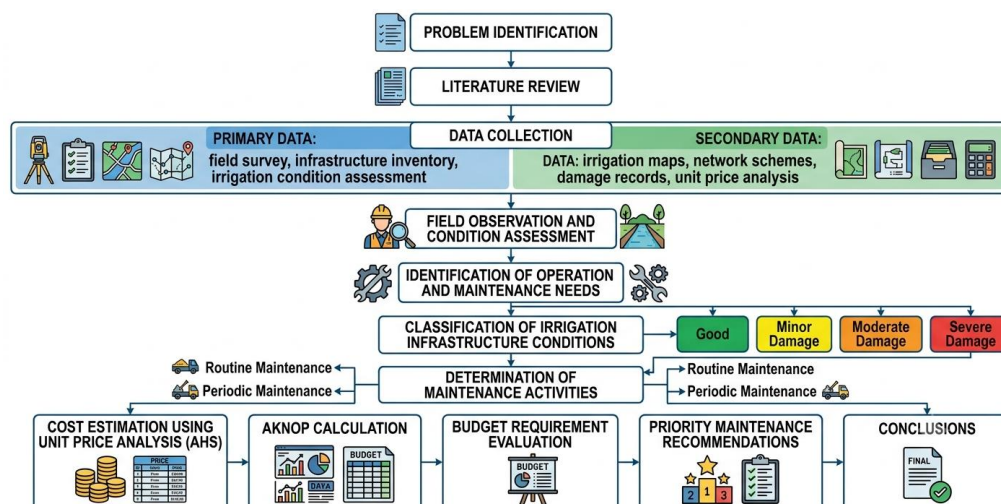


Figure 1. Research flowchart

Table 1. Data requirements and sources

| No | Data Type                         | Description   | Source                          |
|----|-----------------------------------|---|---------------------------------|
| 1  | Irrigation area map               | Administrative and service area information               | Water Resources Agency          |
| 2  | Irrigation network scheme         | Layout of canals and hydraulic structures                 | Water Resources Agency          |
| 3  | Infrastructure inventory data     | Condition and functionality of irrigation assets          | Agency records and field survey |
| 4  | Damage assessment data            | Information on damaged canals and structures              | Field survey                    |
| 5  | Unit price analysis (AHS)         | Cost estimation reference                                 | Sukabumi Regency Government     |
| 6  | Operation and maintenance records | Existing operational activities and maintenance practices | Irrigation management office    |

The AKNOP assessment was subsequently performed by estimating the costs associated with operational activities, routine maintenance, and periodic maintenance. Cost estimation was based on the volume of work required and the applicable regional unit prices. The final AKNOP value represented the total budget necessary to ensure the continued functionality and sustainability of the Cikahuripan Irrigation Network. The results of this analysis were used to identify priority maintenance actions and provide recommendations for improving irrigation management and budget allocation in the study area.

### 3. Results and Discussion

Following the field inventory and condition assessment of irrigation infrastructure, an analysis of the Actual Operation and Maintenance Cost Requirement (AKNOP) was conducted for the Cikahuripan Irrigation Network. The analysis aimed to estimate the budget required to ensure the sustainable operation and maintenance of the irrigation system during the following fiscal year. The assessment considered personnel requirements, operational facilities, maintenance equipment, and rehabilitation needs based on the observed condition of canals and hydraulic structures.

The personnel requirements identified for the irrigation management system are presented in Table 2. The staffing needs were determined according to the operational area, number of hydraulic structures, and length of irrigation canals. The analysis indicates that the irrigation area requires one head observer, one irrigation supervisor, one dam operator, three water distribution officers, and one maintenance worker to support effective operation and maintenance activities.

Table 2. Proposed Personnel Requirements for the Cikahuripan Irrigation Network

| No | Personnel                        | Standard Requirement                            | Existing Condition   | Required Personnel |
|----|----------------------------------|---|----------------------|--------------------|
| 1  | Head Observer (UPTD)             | 1 person + 5 staff per 5,000–7,500 ha           | 512 ha               | 1                  |
| 2  | Irrigation Supervisor            | 1 person per 750–1,500 ha                       | 512 ha               | 1                  |
| 3  | Dam Operator (POB)               | 1 person per dam                                | 1 dam                | 1                  |
| 4  | Water Distribution Officer (PPA) | 1 person per 3–5 intake/distribution structures | 11 intake structures | 3                  |
| 5  | Maintenance Worker               | 1 person per 2–3 km of canal length             | 3.6 km               | 1                  |

In addition to human resources, communication and transportation facilities are essential to support operational activities and coordination among field personnel. The required communication equipment for each operational staff member is summarized in Table 3. The results indicate that handheld

communication devices are necessary to improve coordination and response during irrigation operation and maintenance activities.

Table 3. Analysis of Transportation and Communication Equipment Requirements

| No | Personnel                        | Standard Requirement                            | Facility Required         | Quantity       |
|----|----------------------------------|---|---------------------------|----------------|
| 1  | Head Observer (UPTD)             | 1 person + 5 staff per 5,000–7,500 ha           | Communication device (HT) | 1              |
| 2  | Irrigation Supervisor            | 1 person per 750–1,500 ha                       | Communication device (HT) | 1              |
| 3  | Dam Operator (POB)               | 1 person per dam                                | Communication device (HT) | 1              |
| 4  | Water Distribution Officer (PPA) | 1 person per 3–5 intake/distribution structures | Communication device (HT) | 2              |
| 5  | Maintenance Worker               | 1 person per 2–3 km canal length                | HT and maintenance tools  | 1 HT + 5 tools |

The evaluation also identified deficiencies in operational support equipment. As shown in Table 4, several facilities require upgrading, including routine maintenance equipment, office facilities, and irrigation documentation systems. The replacement of damaged office equipment and updating of irrigation inventory records are necessary to improve administrative efficiency and asset management.

Table 4. Analysis of Operational Equipment Requirements

| No | Component                     | Existing Condition                                   | Required Improvement  |
|----|-------------------------------|--|---|
| 1  | Routine maintenance equipment | 1 grass-cutting machine                              | Additional operation and maintenance equipment                                |
| 2  | Office equipment              | Printer damaged                                      | Procurement of computer and printer   |
| 3  | Documentation system          | No irrigation database book, 1 network scheme, 1 map | Preparation of irrigation database book and updating maps and network schemes |

Field inspections further revealed various levels of deterioration among irrigation structures and canal facilities. The proposed maintenance and rehabilitation activities based on the observed conditions are presented in Table 5. Most structures were classified as experiencing minor damage, while several intake and distribution structures exhibited moderate damage requiring more intensive interventions. Sediment accumulation, erosion, damaged gates, and deterioration of operational components were identified as the dominant issues affecting system performance.

Table 5. Proposed AKNOP Maintenance Activities for Irrigation Structures

| Condition Category | Number of Structures | Percentage (%) | Proposed Action   |
|--------------------|----------------------|----------------|---|
| Good               | 3                    | 10             | Routine inspection and sediment removal                           |
| Minor Damage       | 24                   | 80             | Routine maintenance, gate painting, lubrication, sediment removal |
| Moderate Damage    | 3                    | 10             | Gate replacement, structural repair, sediment removal             |
| Severe Damage      | 0                    | 0              | -   |
| Total              | 30                   | 100            | -   |

The findings indicate that sediment deposition is one of the most critical problems affecting the hydraulic performance of the irrigation network. Excessive sediment reduces flow capacity, limits water delivery

efficiency, and increases the risk of overflow during high-flow periods. Similar findings have been reported in previous irrigation management studies, where sedimentation and gate malfunction significantly reduced irrigation service performance. Therefore, routine sediment removal and rehabilitation of hydraulic structures should be prioritized to maintain the functionality of the irrigation system.

Based on the identified operational requirements, the annual operation cost was estimated. Before presenting the cost components, the detailed operation budget is summarized in Table 6. The operational expenditure includes personnel salaries, office supplies, printing and documentation, meeting expenses, fuel consumption, work equipment, and miscellaneous administrative costs.

Table 6. Final Operation Cost Requirement

| No                   | Cost Component             | Amount (IDR) |
|----------------------|----------------------------|--------------|
| 1                    | Salaries/Wages/Honorarium  | 102,000,000  |
| 2                    | Office Supplies            | 4,440,000    |
| 3                    | Printing and Documentation | 15,199,600   |
| 4                    | Meeting Expenses           | 675,000      |
| 5                    | Fuel Cost                  | 2,317,200    |
| 6                    | Work Equipment             | 3,831,000    |
| 7                    | Miscellaneous Expenses     | 3,840,000    |
| Total Operation Cost |                            | 132,302,800  |

The analysis shows that the total annual operation cost requirement reaches IDR 132,302,800. Personnel salaries constitute the largest expenditure component, accounting for approximately 77% of total operation costs. This result highlights the importance of human resources in ensuring effective irrigation management and water distribution services. Routine maintenance activities are essential for preserving irrigation infrastructure functionality and preventing further deterioration. The estimated routine maintenance costs are presented in Table 7.

Table 7. Final Routine Maintenance Cost Requirement

| No                             | Maintenance Activity              | Amount (IDR) |
|--------------------------------|-----------------------------------|--------------|
| 1                              | Routine Maintenance Activities    | 272,491,113  |
| 2                              | Supporting Maintenance Activities | 20,815,700   |
| Total Routine Maintenance Cost |                                   | 293,306,813  |

The total routine maintenance cost was estimated at IDR 293,306,813. This expenditure covers canal cleaning, vegetation control, sediment removal, gate maintenance, minor repairs, and supporting maintenance activities. Compared with operation costs, routine maintenance represents the largest proportion of the total AKNOP budget, emphasizing the necessity of continuous maintenance to sustain irrigation performance.

The relatively high maintenance cost reflects the aging condition of the Cikahuripan Irrigation Network, which was originally constructed in 1929. Long-term exposure to environmental factors and inadequate maintenance have contributed to structural degradation, requiring more extensive maintenance interventions. Periodic maintenance is required for infrastructure components that have experienced significant deterioration and cannot be adequately addressed through routine maintenance. The estimated periodic maintenance costs are presented in Table 8.

Table 8. Final Periodic Maintenance Cost Requirement

| No | Maintenance Activity                | Amount (IDR) |
|----|-------------------------------------|--------------|
| 1  | Periodic Maintenance (Routine Care) | -            |

| No                              | Maintenance Activity              | Amount (IDR) |
|---------------------------------|-----------------------------------|--------------|
| 2                               | Periodic Repair Works             | 3,444,201    |
| 3                               | Replacement of Damaged Components | 22,731,003   |
| Total Periodic Maintenance Cost |                                   | 26,175,204   |

The analysis indicates that periodic maintenance requires a budget of IDR 26,175,204. These activities mainly involve structural repairs, replacement of damaged gates, and rehabilitation of hydraulic components that have exceeded their serviceability limits. Although periodic maintenance represents the smallest expenditure category, it plays a crucial role in extending infrastructure service life and preventing costly emergency repairs. The overall AKNOP budget was calculated by combining operation costs, routine maintenance costs, and periodic maintenance costs. The final budget allocation is summarized in Table 9.

Table 9. Final AKNOP Budget Summary

| No | Activity                  | Amount (IDR) |
|----|---------------------------|--------------|
| A  | Operation Cost            | 132,302,800  |
| B  | Routine Maintenance Cost  | 293,306,813  |
| C  | Periodic Maintenance Cost | 22,731,003   |
|    | Subtotal                  | 448,340,617  |
|    | VAT (10%)                 | 44,834,062   |
|    | Total Budget Requirement  | 493,174,678  |
|    | Rounded Total AKNOP       | 493,240,000  |

The results show that the total operation and maintenance cost requirement for the Cikahuripan Irrigation Network is IDR 493,240,000 after rounding. This value represents the annual budget required to maintain operational reliability and service performance throughout the irrigation area. To better illustrate the distribution of expenditures among the three cost categories, the percentage composition of the AKNOP budget is presented in Figure 2.

As shown in Figure 2, routine maintenance accounts for 65% of the total budget, followed by operation costs at 30%, while periodic maintenance contributes only 5%. These findings indicate that continuous maintenance activities dominate irrigation management expenditures. Consequently, implementing preventive maintenance strategies and regular inspections could reduce long-term rehabilitation costs and improve the sustainability of irrigation services.

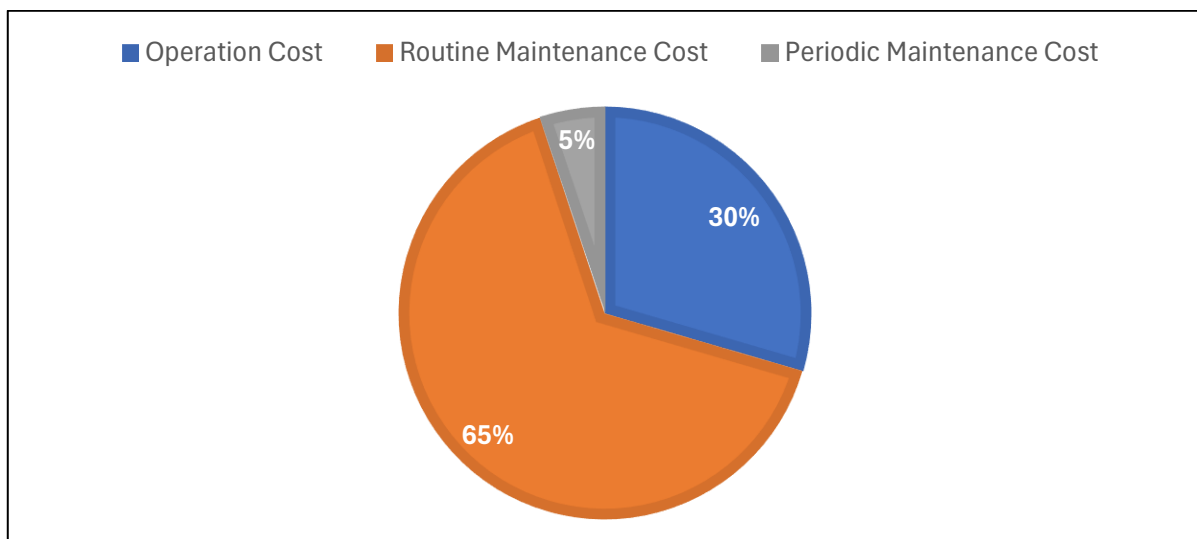


Figure 2. Percentage distribution of AKNOP components

The results demonstrate that adequate budgeting for operation and maintenance is essential to ensure reliable water delivery to agricultural lands. Improving maintenance practices and allocating sufficient financial resources can enhance irrigation efficiency, support agricultural productivity, and contribute to regional food security objectives in Sukabumi Regency.

The results indicate that routine maintenance accounts for the largest proportion of the total AKNOP budget, representing approximately 65% of the overall expenditure. This finding demonstrates that maintaining the functionality of irrigation infrastructure requires continuous and systematic maintenance activities rather than relying solely on corrective actions after severe damage occurs. Similar observations have been reported in infrastructure management studies, where preventive and routine maintenance strategies contribute significantly to improving asset performance and extending service life while reducing long-term rehabilitation costs [13].

The prioritization of sediment removal, vegetation control, gate maintenance, and canal repairs identified in the Cikahuripan Irrigation Network reflects the importance of sustainable infrastructure management. Sustainable maintenance practices ensure that irrigation systems continue to deliver water efficiently while minimizing future repair requirements and supporting long-term agricultural productivity. This perspective is consistent with sustainability-oriented asset management approaches that emphasize efficient resource utilization and long-term operational performance [14].

The findings also highlight the importance of effective information management in irrigation operation and maintenance. Accurate inventory records, updated irrigation maps, operational documentation, and condition assessments are essential for determining maintenance priorities and allocating resources appropriately. Effective information sharing among stakeholders has been recognized as a critical factor in improving infrastructure management efficiency and supporting informed decision-making processes [15].

From an operational perspective, the proposed AKNOP framework provides a structured basis for planning maintenance activities and budget allocation. Well-organized operational management systems facilitate the coordination of personnel, equipment, maintenance schedules, and financial resources, thereby improving overall infrastructure performance [16]. The need for updated operational documentation and maintenance planning identified in this study further supports the adoption of systematic management practices within irrigation agencies.

The condition assessment results also demonstrate the importance of implementing a comprehensive maintenance framework that integrates inspection, monitoring, maintenance planning, and performance evaluation. Previous studies have shown that structured maintenance frameworks can improve maintenance effectiveness, optimize resource allocation, and support the long-term functionality of infrastructure assets [17]. Therefore, the AKNOP approach applied in this study can serve as an important tool for supporting evidence-based maintenance planning in irrigation systems.

Infrastructure management is not only concerned with physical repairs but also with organizational capacity, asset monitoring, and risk management. Effective infrastructure management practices contribute to improved operational efficiency and better utilization of maintenance budgets [18]. In addition, maintaining the reliability of irrigation systems is crucial because service interruptions may directly affect agricultural production and water distribution. Reliable infrastructure systems are generally characterized by continuous operation, effective maintenance practices, and timely interventions when deterioration is detected [19].

Furthermore, the operational principles recommended for public infrastructure management emphasize the importance of planning, coordination, resource allocation, monitoring, and continuous evaluation to ensure effective service delivery [20]. These principles are highly relevant to irrigation management and

support the implementation of AKNOP as a strategic planning instrument for improving the operational performance and sustainability of the Cikahuripan Irrigation Network.

#### 4. Conclusion

This study evaluated the Actual Operation and Maintenance Cost Requirement (AKNOP) of the Cikahuripan Irrigation Network in Sukabumi Regency through field observations, infrastructure condition assessments, and cost analysis of operation and maintenance activities. The results revealed that several irrigation structures and canal sections have experienced deterioration due to sediment accumulation, erosion, and malfunctioning sluice gates, which negatively affect water distribution efficiency and irrigation performance.

The analysis showed that the total AKNOP required for the Cikahuripan Irrigation Network is IDR 493,240,000 per year. This budget consists of operation costs amounting to IDR 132,302,800, routine maintenance costs of IDR 293,306,813, and periodic maintenance costs of IDR 22,731,003. Routine maintenance represents the largest expenditure component, accounting for 65.42% of the total budget, followed by operation costs (29.51%) and periodic maintenance costs (5.07%).

The findings indicate that routine maintenance activities, particularly sediment removal, vegetation control, canal cleaning, and repair of minor structural defects, should be prioritized to maintain the functionality of the irrigation network. In addition, replacement of damaged gates and rehabilitation of moderately damaged structures are necessary to improve water distribution reliability and reduce future maintenance burdens.

The results of this study provide practical information for irrigation managers and local government agencies in planning annual operation and maintenance budgets. Adequate funding allocation and implementation of preventive maintenance programs are expected to enhance irrigation system performance, support agricultural productivity, and contribute to long-term food security in Sukabumi Regency.

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