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# SmartHydra Twin Flow Maintenance Training for Sustainable Clean Water Supply in Tlahap Village, Temanggung, Indonesia

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**Abstract.** Tlahap Village in Temanggung Regency continues to experience clean water shortages, particularly in higher-elevation areas inhabited by approximately 280 households. The SmartHydra Twin Flow system, comprising two hydraulic ram pumps and a stabilizer tube, was developed to lift water up to 190 meters without electricity or fuel. This community service program aimed to strengthen residents' knowledge and practical skills in operating, maintaining, and repairing the system. Hybrid training was conducted on July 3, 2026, using actual discharge measurements recorded in June 2025 (133 L/s) and October 2025 (34.3 L/s at the principal intake and 1.72 L/s at the overflow). Following theoretical instruction and hands-on practice, participants could distinguish mechanical faults from seasonal reductions in water availability, select appropriate pump configurations, and perform routine maintenance and minor repairs. A local management team was also established. These outcomes strengthened community capacity to operate the system independently and support a sustainable clean water supply in Tlahap Village.

**Keywords:** hydraulic ram pump; community training; system maintenance; clean water supply; appropriate technology

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## INTRODUCTION

Tlahap Village is located in Kledung District, Temanggung Regency, on the highland slopes between Mount Sindoro and Mount Sumbing (Yunizar et al., 2022). The village lies at approximately 1,310 meters above sea level and covers an area of about 333 hectares (Retyanto & Hendriani, 2018). As shown in Figure 1, most of its territory consists of dry agricultural land (*tegalan*) and hilly terrain, with no irrigated rice fields. The village has a cool climate, with an average temperature of 17–22 °C and approximately nine wet months per year, making the area suitable for horticultural agriculture (Asnawi et al., 2025; Elawati, 2024).

According to the latest village profile, Tlahap Village has a population of 1,252 people and a residential area of approximately 1.18 km². Most residents depend on agriculture and farm labor for their livelihoods. Approximately 30% are landowning farmers, while another 30% work as tenant farmers or agricultural laborers. In addition, approximately 20% of residents are small-scale traders, while the remaining 20% work in construction or other informal occupations (Alif Syahputri et al., 2023; Supari et al., 2024). Household income is generally unstable because it depends on agricultural seasons and the availability of temporary employment. The average daily income is approximately IDR 100,000 per household head (Pinandita, 2024).

Educational attainment also affects the community's capacity to adopt and manage new technologies. Approximately 70% of residents have completed junior or senior high school, while the remaining 30% have not completed formal education. Consequently, introducing an appropriate technological system is insufficient without providing clear explanations, practical demonstrations, and continued technical assistance. Community participation and skills transfer are therefore essential to ensure that the technology can be operated, maintained, and repaired independently after the community service program has ended.

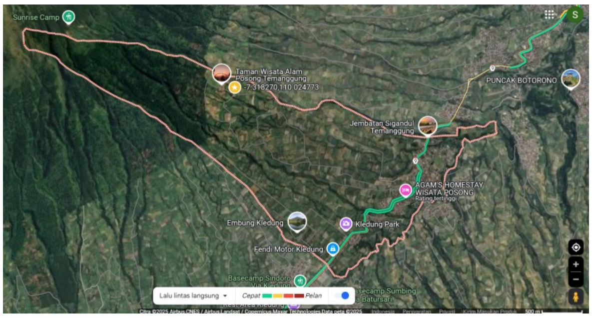

**Figure 1.** Tlahap Village, Kledung District, Temanggung Regency

Despite its highland location, Tlahap Village has considerable natural water potential, particularly from Sidandang Spring. The spring is recognized as one of the major water sources in the area. However, although it is located relatively close to the village, its water has not been fully utilized to meet residents' daily needs. This situation illustrates a contradiction between the availability of natural water resources and the community's limited access to clean water.

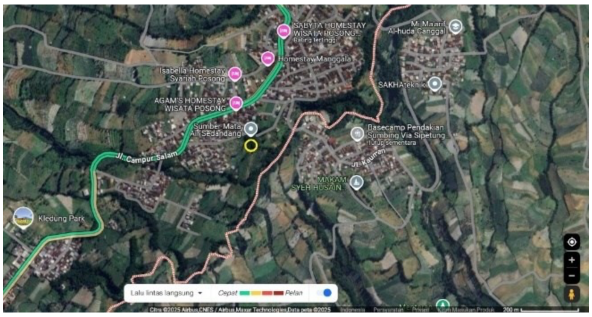

**Figure 2.** Location of Sidandang Spring near Tlahap Village (yellow circle)

The primary obstacle is the difference in elevation between the spring and the residential areas. Some houses are located below Sidandang Spring and can receive water through gravity-fed distribution. By contrast, approximately 280 households are located above the spring and cannot access its water without a pumping system. These households, particularly those in RW 03 which comprises six neighborhood units (*Rukun Tetangga* or RTs) constitute the main beneficiaries of the program. The terrain in this area is steep, while Sidandang Spring is approximately 160 meters below and 1,200 meters from the targeted residential area.

Because of these geographical conditions, water from Sidandang Spring naturally flows to lower areas, including Parakan and Temanggung City, rather than to the higher residential areas of Tlahap Village. Delivering the water uphill requires specialized pumping technology. The community previously attempted to use an electric jet pump, but the system operated for only approximately two months because the pump frequently broke down and generated high electricity costs. This experience demonstrated that conventional electric pumps were neither technically reliable nor economically sustainable for the community.

Residents currently depend on seepage water originating from a highland area in neighboring Serebut Village. However, this source has a very limited discharge and becomes increasingly unreliable during the dry season. Even during the rainy season, the water flow is only approximately the thickness of a small stick, as illustrated in Figure 3. During prolonged dry periods, the flow can stop completely. Therefore, the source cannot reliably meet the community's daily clean water requirements.

**Figure 3.** Water flow from the source in Serebut Village compared with the thickness of a stick, June 2025

When the seepage source becomes insufficient, residents must purchase water transported by pickup trucks from outside the village. Approximately 1,100 liters of water costs IDR 125,000. This expenditure creates a significant financial burden, particularly for farming and informal-worker households with uncertain incomes. Regular water purchases can reduce the funds available for food, education, healthcare, and agricultural production. The water shortage is therefore not merely a technical infrastructure problem; it also affects household welfare, public health, economic resilience, and social equity.

The disparity between the abundance of water at Sidandang Spring and the community's inability to access it highlights the need for appropriate, efficient, affordable, and environmentally sustainable technology. The selected solution is the SmartHydra Twin Flow system, which combines two hydraulic ram pumps with a stabilizer tube. A hydraulic ram pump uses the energy generated by flowing water and hydraulic pressure to lift part of the water to a higher elevation. It does not require electricity or fossil fuel, making it particularly suitable for rural and highland areas where electricity costs and pump maintenance can be prohibitive.

The stabilizer tube represents an important technological innovation within the SmartHydra Twin Flow system. It is designed to stabilize water pressure and support more consistent system performance. The use of two hydraulic ram pumps also improves operational capacity and provides greater flexibility than a single-pump arrangement. Through this configuration, water from Sidandang Spring can be lifted toward the residential area without creating recurring electricity or fuel expenses.


**Figure 4.** SmartHydra Twin Flow system combining hydraulic ram pumps with a stabilizer tube

The proposed distribution system uses a one-inch high-density polyethylene pipe to convey output water approximately 907 meters to the main storage tank. Once stored, the water is distributed by gravity to a transit tank located approximately 222 meters below the main tank. From the transit tank, the water is divided into several distribution branches serving one community unit (RW) comprising six neighborhood units. Distribution to RT 16 and RT 19 uses half-inch pipes with a combined length of approximately 1,840 meters. This configuration integrates water lifting, storage, and gravity-based distribution to reduce energy requirements and support access across the targeted residential area.

The SmartHydra Twin Flow system contributes to several Sustainable Development Goals (SDGs). Its principal contribution is to SDG 6 by supporting affordable and sustainable access to clean water. More reliable water availability can also contribute to SDG 3 by improving hygiene and sanitation and reducing health risks associated with insufficient clean water. Because the hydraulic ram pumps operate without electricity or fossil fuels, the system supports SDG 7 on affordable and clean energy. Its efficient use of natural water resources is relevant to SDG 12 on responsible consumption and production, while its low-carbon operation and contribution to community resilience during dry periods support SDG 13 on climate action. Protecting Sidandang Spring and its surrounding environment is also relevant to SDG 15 on terrestrial ecosystems.

Nevertheless, the installation of appropriate technology does not automatically guarantee its long-term sustainability. Experience with hydraulic ram pumps in other locations shows that system efficiency can decrease and operation can eventually stop when routine inspection and maintenance are neglected. Components such as the waste valve, delivery valve, rubber seals, intake strainer, pipelines, and stabilizer tube require periodic inspection. Blockages, worn seals, incorrect valve settings, air leakage, seasonal changes in water discharge, and sediment accumulation can reduce pressure and disrupt water delivery.

The distinction between technical failure and natural fluctuation in water availability is also important. A decrease in output does not always indicate that the pump is damaged; it may result from reduced source discharge during the dry season or inappropriate adjustment of inlet and outlet flows. Without adequate knowledge, operators may dismantle functioning components unnecessarily or fail to identify actual mechanical problems. The community therefore requires both theoretical understanding and practical skills related to system operation, seasonal adjustment, routine maintenance, troubleshooting, and minor repairs.

Previous community-based technology programs demonstrate that infrastructure sustainability depends not only on technical performance but also on local ownership, institutional arrangements, and users' maintenance capacity. A system managed entirely by external technicians may become inactive when technical support is no longer immediately available. Conversely, transferring knowledge and skills to local operators can reduce dependence on outside assistance, accelerate responses to operational problems, and extend the service life of the equipment. Establishing a local management team is therefore necessary to distribute responsibilities for inspection, maintenance, financial management, documentation, and coordination with technicians.

Based on these conditions, the central problem addressed by this community service program is the limited capacity of the Tlahap Village community to operate, maintain, and repair the SmartHydra Twin Flow system independently. The program does not focus solely on installing or introducing the technology. It emphasizes the transfer of practical knowledge and technical skills required to sustain its operation. This orientation is essential because the continued availability of clean water for approximately 280 households depends on the community's ability to manage the system after the initial implementation stage.

Accordingly, this community service program aims to improve community members' knowledge and practical skills in operating, maintaining, caring for, and performing minor repairs on the SmartHydra Twin Flow system. It also aims to help participants distinguish between mechanical failures and seasonal changes in water discharge, appropriately adjust inlet and outlet flows, and establish a local team responsible for system management. Through these activities, the program is expected to strengthen community ownership, reduce dependence on external technicians, and support the sustainable provision of clean water in Tlahap Village.

## METHODS

The community service program was conducted in Tlahap Village, Kledung District, Temanggung Regency, on July 3, 2026. It aimed to strengthen the community's knowledge and practical skills in operating, maintaining, and performing minor repairs on the SmartHydra Twin Flow system. The program employed a participatory approach and was delivered in a hybrid format that combined online instruction with on-site demonstrations and hands-on practice. Village representatives and community members from the beneficiary neighborhood units participated in the activity. The training materials were developed from a preliminary field assessment and water-discharge measurements conducted at Sidandang Spring on June 27 and October 4, 2025, allowing the instruction to reflect actual wet- and dry-season conditions.

The preliminary assessment examined water availability at the intake points, elevation differences, penstock length and inclination, pipeline configuration, equipment condition, and community water-use patterns. Water discharge was estimated using the velocity–area method, expressed as $Q = A \times v$ where $Q$ is the discharge ($m^3/s$), $A$ is the cross-sectional area of the flow ($m^2$), and $v$ is the average flow velocity (m/s). The resulting measurements were used to develop adaptive operating scenarios for high-, moderate-, and low-discharge conditions. They also informed three instructional components: basic discharge measurement, practical hydraulics, and seasonal operating procedures. These components were intended to help participants distinguish between reduced performance caused by insufficient source discharge and problems caused by mechanical failure.

The program comprised five stages: coordination and field assessment, education and socialization, theoretical and practical training, establishment of a local management team, and evaluation and follow-up assistance. Participants received instruction on the operating principles and principal components of the SmartHydra Twin Flow system before practicing start-up and shutdown procedures, valve adjustment, intake-strainer cleaning, seal inspection and replacement, leak detection, stabilizer-tube maintenance, and basic troubleshooting. Their understanding was evaluated through questions before and after the instructional session, while their practical competence was assessed through direct demonstrations of system operation, fault identification, component maintenance, and the selection of operating scenarios based on the available discharge. Representatives from each neighborhood unit were then assigned to a local management team responsible for routine inspections, maintenance records, seasonal adjustments, and coordination with external technicians when repairs exceeded the community's capabilities.

## RESULTS AND DISCUSSION

The community service program conducted in a hybrid format in Tlahap Village, Kledung District, Temanggung Regency. The program focused on strengthening the community's capacity to operate the system, conduct routine maintenance, identify common problems, and perform minor repairs. It also introduced adaptive operating procedures based on seasonal changes in the discharge of Sidandang Spring. The results were evaluated from participants' responses during the instructional session, their performance in practical exercises, their ability to interpret field-discharge data, and the establishment of a local management team.

The program objectives were achieved through the integration of theoretical instruction, field-data interpretation, direct demonstration, and hands-on practice. The participants learned that the performance of the SmartHydra Twin Flow system was determined not only by the mechanical condition of the pumps but also by the amount and stability of water available at the intake. This understanding was particularly important because, before the training, a reduction in delivered-water output was commonly interpreted as evidence of pump failure. The training enabled the participants to use a more systematic diagnostic process by examining the source discharge, intake condition, valve movement, pipe connections, stabilizer tube, and delivered-water flow before deciding whether the system required mechanical repair.

### Field Conditions and Selection of the Water-Intake Point

The field assessment identified two potential water-intake points at Sidandang Spring: the principal intake near the small Regional Drinking Water Company facility, locally referred to as the small PDAM facility, and the overflow located beside it. The principal intake shown in Figure 5 provided a more stable water supply than the adjacent overflow. It was therefore selected as the preferred intake, particularly during the dry season.

The condition of the intake was found to have a direct influence on pump operation. Leaves, sediment, small stones, and other debris could obstruct the strainer and reduce the amount of water entering the drive pipe. A restricted intake could produce symptoms resembling mechanical failure, including irregular valve movement, unstable water-hammer cycles, and reduced delivered-water output. Consequently, participants were taught to examine and clean the intake before dismantling any pump components.

**Figure 5.** Water intake point outside the small PDAM facility

The location of the intake also influenced water availability. Although the principal intake and the overflow were relatively close to each other, they produced substantially different discharges during the dry season. This finding demonstrated that the visual presence of flowing water did not necessarily indicate that the flow was sufficient to operate a hydraulic ram pump. Participants therefore learned that intake selection should be based on measured or carefully observed discharge rather than convenience alone.

During the practical session, community members examined the principal intake and identified points where debris or sediment could accumulate. They also discussed the frequency of inspection required during different weather conditions. More frequent cleaning would be necessary after heavy rainfall because increased runoff could transport sediment and organic material into the intake. During prolonged dry periods, the focus would shift from debris removal to monitoring whether the available flow remained sufficient to operate one or both pumps.

The selection of the principal intake as the preferred source constituted an important operational result. It provided the local management team with a clear reference for dry-season operation and reduced uncertainty about which water source should be prioritized. Nevertheless, the intake still required regular observation because seasonal changes could alter its discharge and physical condition.

### Seasonal Variation in Water Discharge

The training materials incorporated actual discharge measurements collected at Sidandang Spring on June 27 and October 4, 2025. These measurements represented contrasting seasonal conditions and showed that the water available to operate the SmartHydra Twin Flow system changed considerably throughout the year.

On June 27, 2025, the average surface-flow velocity measured near the small PDAM facility was approximately 0.556 m/s, while the flow cross-sectional area was approximately 0.24 m². Based on the velocity–area calculation, the estimated discharge was 0.133 m³/s, equivalent to approximately 133 L/s. This discharge was substantially greater than the estimated combined inlet requirement of the two hydraulic ram pumps.

Each pump required an estimated inlet discharge of approximately 16.05 L/s, giving a total estimated requirement of 32.1 L/s when both pumps operated simultaneously. With an initial recovery assumption of 30%, each pump was expected to lift approximately 4.8 L/s. The combined theoretical delivered-water flow was therefore approximately 9.6 L/s under adequate and stable intake conditions. These calculations served as initial operational references rather than guaranteed output values because actual performance was also influenced by pressure, effective head, friction losses, valve adjustment, component condition, and pipeline configuration.

The second measurement, conducted on October 4, 2025, showed a substantial decline in source discharge. The flow measured at the principal intake was approximately 0.0343 m³/s, equivalent to 34.3 L/s. Meanwhile, the overflow beside the small PDAM facility produced only approximately 0.001715 m³/s, or 1.72 L/s. The principal intake could potentially support one pump under controlled conditions, but the overflow did not provide sufficient water for continuous pump operation.

The difference between 133 L/s in June and 34.3 L/s in October demonstrated that the system could not be operated using a fixed configuration throughout the year. Under high-discharge conditions, the two pumps could be operated simultaneously. When the source discharge decreased to approximately 30–50 L/s, one pump had to be prioritized or the two units had to be operated alternately. When the available discharge fell below the minimum operational requirement, particularly when only the 1.72 L/s overflow was available, pump operation had to be suspended until sufficient water accumulated.

These operational thresholds were introduced as practical guidance rather than rigid limits. The decision to operate one or both pumps also needed to consider the stability of the intake, pressure response, valve rhythm, delivered-water flow, and system losses. For example, a measured source discharge slightly above the combined theoretical inlet requirement might still be insufficient for stable two-pump operation if the flow fluctuated rapidly or if part of the water could not be directed into the drive pipes. A safety margin was therefore necessary.

The use of field measurements improved the relevance of the training. Participants did not receive only abstract information about flow and pressure; they worked with data taken from their own water source. They learned to associate the June measurement with high-discharge operation and the October measurement with dry-season restrictions. This helped them understand that a decrease in pump output could be caused by a reduction in the source discharge rather than by damaged equipment.

**Storage-Tank Function and Filling Performance**

The field assessment also examined the function of the 2,925-liter storage tank shown in Figure 6. The tank served as a temporary storage facility and operational buffer before water was distributed to the beneficiary households. It helped separate the intermittent operation of the hydraulic ram pumps from household water-distribution requirements.

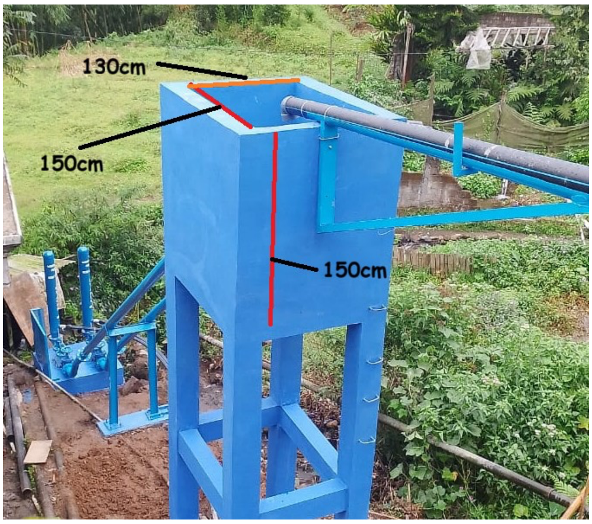


**Figure 6.** The 2,925-liter main storage tank in the SmartHydra Twin Flow distribution system

One important point clarified during the training was that the tank-filling time depended on the water delivered by the pumps, not on the total discharge available at Sidandang Spring. The June source discharge of approximately 133 L/s could not be used directly to calculate tank-filling time because most of the intake water was used to generate the hydraulic energy required by the pumps and was not delivered to the tank.

Based on the estimated combined lifted-water output of 9.6 L/s, the theoretical time required to fill an empty 2,925-liter tank was approximately 305 seconds, or slightly more than five minutes. This calculation represented an ideal condition in which both pumps operated continuously at the estimated output and no water was simultaneously distributed. In practice, filling would take longer because of friction losses, pressure variations, leakage, valve conditions, fluctuating intake discharge, and simultaneous water consumption.

Participants learned that changes in filling time could serve as a simple performance indicator. If the tank required substantially more time to fill under otherwise similar source conditions, the management team could inspect the intake, valves, seals, pipe connections, stabilizer tube, and delivery line. However, a longer filling time during the dry season did not automatically indicate a technical defect because lower source discharge would naturally reduce pump output.

During very low-discharge conditions, the tank became particularly important as a buffer. The pumps could be stopped while water accumulated at the intake, and operation could resume when the minimum required volume and flow became available. Water distribution could then be managed according to an agreed schedule. This strategy was intended to prevent unstable operation, reduce unnecessary wear, and support more equitable distribution among beneficiary households.

The discussion of the storage tank also encouraged participants to consider water management beyond pump operation. Maintaining the system required not only technical skills but also collective decisions regarding distribution schedules, priority needs, and conservation during dry periods. Thus, the tank functioned as both a technical component and an important element of community-based water management.

## Elevation and Pipeline Configuration

Figure 7 presents the elevation difference and pipeline configuration connecting the intake, pump system, and storage tank. The geographical conditions of Tlahap Village created a major technical challenge because water had to be lifted from Sidandang Spring to a substantially higher residential area.

The SmartHydra Twin Flow system was designed to lift water through a vertical elevation of up to approximately 190 meters without using electricity or fuel. Its operation depended on the hydraulic energy generated by water flowing through the drive pipes. The available driving head, penstock length and inclination, pipe diameter, friction losses, valve characteristics, and source discharge collectively influenced the amount of water that could reach the storage tank.


**Figure 7.** Elevation difference, storage-tank position, and penstock configuration of the SmartHydra Twin Flow system

During the training, participants learned that the four-inch intake pipeline was not necessarily the primary limitation during low-discharge periods. When the source produced only a small volume of water, increasing pipe capacity would not resolve the problem because the natural supply itself was insufficient. This understanding was important because communities may otherwise assume that reduced output requires replacing the pipe or modifying the pump.

Participants were also introduced to the distinction between theoretical and actual performance. Calculations based on elevation, flow, and recovery rate provided useful estimates, but actual system output had to be verified through pressure observations, valve rhythm, delivered-water volume, and tank-filling time. This practical verification allowed operators to identify deviations caused by leakage, friction, incorrect adjustment, or component wear.

The field configuration also demonstrated the suitability of hydraulic ram technology for the local environment. Conventional electric pumps previously used by the community generated high electricity costs and frequently broke down. By contrast, the hydraulic ram system used the energy of flowing water. Nevertheless, the absence of electricity and fuel costs did not mean that the system could operate without maintenance. The technical benefits of the system could be sustained only when community members understood how its components worked and how local environmental conditions affected performance.

**Changes in Participants' Knowledge and Diagnostic Ability**

Before the training, many participants assumed that any decrease in delivered-water output was caused by mechanical failure. Possible causes commonly mentioned included broken valves, worn rubber seals, clogged strainers, damaged pipes, or malfunctioning pumps. This interpretation was understandable because the residents' previous experience with an electric jet pump involved frequent mechanical failure and high operating costs.

After the theoretical explanations and practical exercises, participants demonstrated a more comprehensive understanding. They learned to begin troubleshooting by examining water availability at the source. When the intake discharge decreased but valve movement and pressure behavior remained relatively normal, the likely problem was insufficient supply rather than mechanical damage. Conversely, leakage, restricted strainer flow, irregular valve movement, worn seals, loss of the stabilizer-tube air cushion, or unstable water-hammer cycles could indicate technical problems.

The improvement in diagnostic reasoning was an important achievement because incorrect diagnosis could result in unnecessary dismantling and replacement of functional components. Such actions could increase costs, cause additional damage, and interrupt the water supply. By using actual June and October data, participants could relate technical decisions to measurable environmental conditions.

The training also clarified that diagnosis should follow a systematic sequence. Operators should first inspect the source discharge and intake condition, followed by the strainer, drive pipes, connections, waste valves, delivery valves, stabilizer tube, delivery line, and tank-filling performance. This sequence helped participants avoid immediately focusing on the pump's internal components.

Although the change in understanding was evident during discussions and demonstrations, future programs should document it more quantitatively through standardized pre- and post-tests. Numerical scores would provide stronger evidence of learning outcomes and identify topics requiring additional instruction. Nevertheless, participants' responses and practical performance indicated that they had developed a more accurate understanding of the relationship between water availability and system performance.

**Adaptive Seasonal Operation**

Participants learned to select an operating configuration according to actual source conditions. Under high-discharge conditions comparable to those measured in June, both hydraulic ram pumps could operate simultaneously. Before starting the two pumps, operators still needed to confirm that the intake remained stable and that sufficient water entered both drive pipes.

Under moderate- or low-discharge conditions, one pump was prioritized. Operating a single pump reduced the inlet requirement and could provide greater stability than attempting to operate both pumps with an inadequate supply. Alternating the two pumps could also help distribute mechanical use and allow routine inspection of the inactive unit.

When the source discharge became extremely low, the appropriate action was to stop the pumps rather than force continued operation. The available water could be allowed to accumulate, and operation could resume during periods of relatively higher flow. Participants discussed the possibility of scheduling operation during the morning or late afternoon if these periods provided a more stable supply.

The seasonal operating strategy also required adjustments to valve settings and monitoring of delivered-water output. A configuration suitable during the wet season might become unstable during the dry season. Participants practiced observing valve rhythm, listening for changes in water-hammer cycles, monitoring pressure stability, and comparing the amount of water delivered to the tank.

The ability to adapt operation to seasonal conditions supported both technical and environmental sustainability. It reduced the risk of operating the equipment under unsuitable conditions and encouraged the community to use the available water responsibly. However, these operating scenarios should continue to be evaluated using periodic discharge and output measurements.

**Figure 8.** Smart Hydra Twin Flow system combining two hydraulic ram pumps with a stabilizer tube to lift water through a vertical elevation of up to 190 meters in Tlahap Village

**Practical Maintenance and Minor-Repair Skills**

The hands-on component of the program allowed participants to practice routine maintenance directly on the SmartHydra Twin Flow system shown in Figure 8. SmartHydra Twin Flow system combining two hydraulic ram pumps with a stabilizer tube to lift water through a vertical elevation of up to 190 meters in Tlahap Village

One of the main activities was cleaning the intake strainer. Participants learned that a blocked strainer could restrict flow into the drive pipe and reduce the energy available to operate the pump. They practiced removing leaves, sediment, and other debris and were advised to increase the frequency of inspection after rainfall.

Participants also inspected rubber seals and valve components. Damaged or worn seals could cause leakage and pressure loss, while debris or inappropriate adjustment could interfere with valve movement. The practical exercise demonstrated how to identify visible deterioration, remove damaged seals, install replacements, and check whether the connection was secure. Participants were reminded that excessive tightening could damage seals or fittings.

Pipe joints and connections were checked systematically for leakage. The participants learned that even relatively small leaks could affect pressure and delivered-water output. They also practiced tightening loose connections while avoiding excessive force that could damage the components.

The maintenance of the stabilizer tube was another important learning component. Participants learned to inspect the tube, remove excess accumulated water when necessary, and ensure that an adequate air cushion remained inside it. An inappropriate balance between air and water could reduce its stabilizing effect and contribute to irregular pressure. The training therefore emphasized that the stabilizer tube required periodic attention even when no visible external damage was present.

Participants also observed the waste and delivery valves. The repeated operation of the waste valve generated the water-hammer effect required to lift water, while the delivery valve controlled movement into the delivery pipe. Changes in sound, frequency, or movement could indicate inadequate intake flow, debris, wear, air leakage, or incorrect adjustment. Developing observational skills was especially valuable because advanced diagnostic instruments might not always be available.

The practical activities showed that community members could perform basic maintenance and minor repairs after receiving instruction and supervised practice. However, more complex damage would still require assistance from qualified technicians. Community independence should therefore be understood as the capacity to conduct routine maintenance, diagnose common problems, perform minor repairs, and determine when external technical assistance is necessary.

**Local Management and Institutional Sustainability**

A local management team was established using representatives from the participating neighborhood units. This outcome was important because the long-term operation of the SmartHydra Twin Flow system depended not only on individual technical competence but also on clear organizational responsibility.

The team was assigned responsibility for intake inspection and cleaning, leak detection, observation of valve operation, stabilizer-tube monitoring, seasonal adjustments, maintenance documentation, and coordination with technicians. Representatives could also communicate operational information and water-distribution schedules to residents in their respective areas.

The establishment of the team reduced dependence on a single operator. When technical knowledge is concentrated in one individual, system continuity can be threatened if that person becomes unavailable. Distributing responsibilities and knowledge across several community members created greater institutional resilience.

Maintenance records were recommended as an important management instrument. The team could record the date of inspection, source conditions, pump configuration, observed output, tank-filling time, components cleaned or replaced, and any technical problems. These records would make it easier to distinguish recurring mechanical problems from seasonal performance changes.

The local team could also manage an inventory of critical spare parts, including rubber seals, valve components, fasteners, and strainer materials. Ensuring that commonly required parts were available locally would reduce repair time and prevent extended interruptions in the water supply.

**Indicators of Program Achievement**

The program's success was assessed qualitatively through several indicators. The first was participants' ability to explain the basic operating principle of the SmartHydra Twin Flow system. They understood that the pumps used hydraulic energy and the water-hammer effect rather than electricity or fuel.

The second indicator was participants' ability to interpret seasonal discharge data. They could distinguish the high-discharge conditions measured in June from the dry-season conditions recorded in October and relate those measurements to the appropriate number of operating pumps.

The third indicator was diagnostic ability. Participants learned to differentiate between reduced output caused by inadequate source discharge and that caused by blocked strainers, worn seals, leakage, valve problems, or stabilizer-tube conditions.

The fourth indicator was practical maintenance competence. Participants demonstrated intake-strainer cleaning, connection inspection, seal checking and replacement, valve observation, and stabilizer-tube maintenance under facilitator supervision.

The fifth indicator was the establishment of a local management team. The team provided an organizational structure for sustaining routine maintenance, seasonal adjustment, documentation, and technical coordination.

**Table 1.** Indicators of Achievement in the SmartHydra Twin Flow Training Program

| No | Indicator | Evidence of Achievement | Practical Significance |
|---|---|---|---|
| 1 | Understanding of operating principles | Participants explained the use of hydraulic pressure and the water-hammer effect | Reduced misunderstanding of how the system operates |
| 2 | Interpretation of seasonal discharge | Participants related the June and October measurements to different operating scenarios | More appropriate selection of one-pump, two-pump, or suspended operation |
| 3 | Technical diagnosis | Participants distinguished source limitations from mechanical problems | Reduced unnecessary dismantling and component replacement |
| 4 | Maintenance and minor-repair skills | Participants practiced cleaning, inspection, adjustment, and basic component replacement | Greater capacity for independent routine maintenance |
| 5 | Community-based management | A local management team was established | Clearer responsibilities and greater continuity after the program |

These indicators demonstrate that the program extended beyond one-way information delivery. It combined conceptual understanding, field-data interpretation, practical competency, and institutional organization. However, the achievement evidence remained primarily observational. Future implementation should employ documented test scores and practical-assessment rubrics to strengthen the evaluation.

**Challenges Encountered**

The primary technical challenge was the substantial seasonal fluctuation in water discharge. The difference between approximately 133 L/s in June and 34.3 L/s in October meant that the system could not maintain the same operating configuration throughout the year. Community expectations regarding consistent output therefore needed to be aligned with the natural limitations of the source.

A second challenge was changing participants' initial assumption that reduced output always indicated mechanical failure. This perception could not be corrected through explanation alone. Actual field data and direct observation were needed to demonstrate the relationship between source discharge and pump performance.

A third challenge was the variation in participants' technical backgrounds. Concepts such as discharge, pressure, effective head, friction loss, water hammer, and recovery rate could be difficult to understand. The facilitators addressed this by combining simplified explanations, visual materials, actual measurements, direct demonstrations, and supervised practice.

The hybrid format also created limitations. Online sessions were useful for theoretical explanations and coordination, but maintenance and repair skills required face-to-face demonstrations. Participants needed opportunities to handle components and repeat procedures under supervision. Future programs should allocate more time to direct practice.

The availability of tools and spare parts presented another potential challenge. Although participants could perform routine maintenance and minor repairs, certain failures required specialized equipment or replacement components. The local team therefore still needed access to suppliers and qualified technicians.

Finally, the sustainability of the program depended on management consistency. Establishing a local team was an important first step, but the team would need maintenance schedules, records, agreed responsibilities, and periodic coordination. Without these mechanisms, the knowledge gained during training could gradually be lost.

**Opportunities for Future Development**

Several opportunities can improve the program and the sustainability of the SmartHydra Twin Flow system. First, periodic water-discharge monitoring should be institutionalized. Simple measurement tools, fixed observation markers, and standardized recording forms could help the management team identify seasonal trends and select operating configurations more accurately.

Second, written standard operating procedures should be placed near the pump installation. The procedures could include start-up and shutdown steps, one- and two-pump operating requirements, low-discharge responses, inspection sequences, maintenance schedules, and emergency contact information.

Third, periodic refresher training should be conducted before and during the dry season. Refresher sessions could include simulated faults, discharge calculations, valve adjustments, seal replacement, strainer cleaning, and evaluation of maintenance records. New members of the local management team should receive equivalent training.

Fourth, future evaluation should use structured pre- and post-tests. Practical assessment could employ a checklist measuring whether participants could operate the system, identify critical components, calculate discharge, select an appropriate seasonal configuration, diagnose faults, and perform maintenance independently.

Fifth, the community should establish a maintenance fund and a transparent mechanism for purchasing replacement parts. Although the pumps do not consume electricity or fuel, they still require periodic maintenance. A small collective contribution could prevent delays when seals, valves, pipe fittings, or tools need to be replaced.

Sixth, technical management should be integrated with water conservation and spring protection. Sustainable water supply depends not only on pump maintenance but also on the ecological condition of Sidandang Spring, responsible household consumption, equitable distribution, and preparation for prolonged dry periods.

The program strengthened the community's understanding of the relationship between seasonal water availability and the performance of the SmartHydra Twin Flow system. Participants gained basic diagnostic, operational, maintenance, and repair skills and learned to avoid unnecessary interventions when reduced output resulted from natural discharge fluctuations. Figures 5–8 illustrate the interconnected field conditions, storage infrastructure, elevation configuration, and pump technology discussed during the training. The establishment of a local management team further strengthened the prospects for community-based operation. Continued mentoring, systematic monitoring, practical reassessment, and formal management procedures will be necessary to sustain these achievements and support a reliable clean water supply in Tlahap Village.

## CONCLUSION

The community service program successfully improved the Tlahap Village community's knowledge and practical skills in operating, maintaining, and performing minor repairs on the SmartHydra Twin Flow system. Participants gained a better understanding of the system's components, routine maintenance requirements, seasonal operating adjustments, and basic troubleshooting procedures. Most importantly, they learned to distinguish mechanical problems from reductions in pump output caused by natural fluctuations in the discharge of Sidandang Spring during the dry season. This ability is expected to prevent unnecessary dismantling or replacement of functional components and support more appropriate operational decisions. The establishment of a local management team also strengthened community ownership and clarified responsibilities for inspection, maintenance, documentation, and coordination with external technicians. Continued mentoring, periodic refresher training, discharge monitoring, and adequate maintenance records are recommended to sustain these outcomes. Through these measures, the SmartHydra Twin Flow system is expected to contribute to the sustainable provision of clean water for household and agricultural needs in Tlahap Village.

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