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DESIGN AND CONSTRUCTION OF A HYDRAULIC RAM PUMP

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Abstract
Areas whose land surface lies higher than the available water source often face difficulty obtaining a continuous water supply. Using an electric pump to lift water under such conditions increases operational costs because it depends on electrical energy, so an alternative technology is needed that can raise water from a lower to a higher elevation without fuel or electricity. This study aims to design and construct a hydraulic ram pump as a solution for community water needs in Argalingga Village, Argapura Subdistrict, Majalengka Regency, where the elevation difference between the water source and the settlement is approximately 21 m with a distance of about 100 m. Concept selection was carried out using the Analytic Hierarchy Process (AHP) on five design alternatives based on price, working performance, ease of use, maintenance, and service life criteria, with the hydram pump selected as the alternative with the highest final weight (0.290). The pump was constructed from PVC pipe with a 2-inch pump body diameter, a 3-inch delivery tank, and a 2-inch input pipe. Testing was conducted using five variations of input height and input pipe length. Results show that at an input height of 1 m and input length of 8 m, a maximum output height of 13 m was achieved with a discharge of 1.20 L/min; at 1 m and 12 m, output height 13 m with 1.71 L/min; at 2 m and 16 m, output height 17 m with 1.89 L/min; at 2 m and 20 m, output height 17 m with 3.00 L/min; and after extending the output pipe length at the 2 m/20 m configuration, a maximum output height of 21 m with a discharge of 2.12 L/min was obtained. These results indicate that increasing the input height and input pipe length improves both the lifting height and discharge output of the hydram pump.

Keywords: *hydraulic ram pump; input height; input length; output discharge; output length*

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Introduction

The need for clean water is a key factor in sustaining communities. Areas located at higher elevations than water sources often face challenges in securing a sustainable water supply. This situation is generally caused by elevation differences that hinder the natural flow of water to these areas. One solution that can be implemented to address this problem is the use of water pumps. However, operating conventional pumps requires an energy source—primarily electricity or fuel—which can increase operational and maintenance costs. Therefore, an alternative technology that is more economical and environmentally friendly is needed to meet the community's water needs. One technology that has been widely utilized is the hydraulic ram pump, which operates by harnessing the potential energy of water flow without requiring electricity or fuel as a power source.

Numerous studies have been conducted to optimize the performance of this type of pump. Parulian Siahaan and Tekad Sitepu (2013) conducted a study to determine the effect of variations in driven pipe length and air chamber diameter on a hydraulic ram pump with a 12-meter-long intake pipe. The resulting efficiency was 37.87% when calculated using the D'Aubuisson formula and 30.28% when calculated using the Rankine formula. This is consistent with the research conducted by Yusri Nadya et al. This study examined the performance of hydram pumps, focusing on the air chamber in relation to changes in water pressure caused by water hammer, as well as various output head

JMM :
Journal of Mechanical and Manufacture [Vol. 5, No. 2, April, 2026, pp. 86-93]

heights of the hydram pump in achieving the target head height. The highest water discharge was produced by a 6-meter pipe height variation, amounting to 2.62 liters, while the lowest water discharge was produced by a 12-meter pipe height variation, amounting to 1.3 liters.
This study was conducted to identify more effective approaches and methods for determining the appropriate technology to transport water from low-elevation areas to higher locations without relying on electricity or fossil fuels. This need is becoming increasingly critical in rural areas with limited access to energy sources and supporting infrastructure.

Literature Review

Working Principle of a Hydraulic Ram Pump

A hydraulic ram pump, or hydram for short, is an automatic pump whose driving force comes from water flowing into the pump's inlet pipe. With a continuous flow of water, the hydram operates continuously without an external energy source. [3]
The working principle of a hydraulic ram pump is as follows: water from the water storage tank flows into the body of the hydraulic ram pump through a pipe. When the pump body is completely filled with water, the water inside the pump body is pushed toward the waste valve, creating a water hammer effect that generates pressure within the hydraulic ram pump. The pressurized water resulting from the water hammer is then forced back toward the delivery valve, allowing water to enter and partially fill the air chamber. After the water enters the air chamber, the delivery valve closes again, and the compressed air in the chamber forces the water to flow through the outlet pipe, enabling it to be lifted to the desired height to be investigated. [1]

Hydram Pump Operating Diagram

There are several phases in the operation of a hydram pump. The operation of a hydram pump is divided into several phases, including the following:
1. Diagram A
Water from the source flows through the inlet pipe (A) into the hydram pump body to fill it, and begins to flow out through the discharge valve (B). The discharge valve (C) is still closed and not yet active because the outlet has not been opened. At this initial stage, there is no pressure in the tank (D), and no water is flowing through the outlet pipe (E) to the destination storage tank. [5]

2. Scheme B
In this phase, the discharge valve (B) begins to close, causing the pressure inside the pump body to rise. Consequently, water entering the pump through the inlet pipe (A) is immediately directed into the discharge valve (C) until the discharge valve (B) is fully closed. When the discharge valve (B) is completely closed, a water hammer effect occurs, forcing water toward the discharge valve (C). This causes the velocity in the inlet pipe to decrease rapidly.[5]

3. Scheme C
The water flowing through the inlet pipe (A) stops flowing due to a “shock wave” created by “water hammer,” causing the water to flow back into the inlet pipe and rise back into the storage tank. At this point, the drain valve (B) is still closed. Meanwhile, the volume of air inside the delivery tube (D) continues to expand to equalize the pressure, pushing a small amount of water out of the delivery pipe (E) and causing the delivery valve (C) to close completely. [5]

JMM :
Journal of Mechanical and Manufacture
[Vol. 5, No. 2, April, 2026, pp. 86-93]

4. Scheme D
With the occurrence of a shock wave resulting from water hammer within the pump body, the water inside the pump body experiences a drop in pressure. At this stage, the water that was forced back into the reservoir is pushed back into the pump body through the inlet pipe (A) to refill the space within the pump body. At this stage, the discharge valve (B) reopens, and the water in the inlet pipe (A) flowing into the pump then exits through the discharge valve (B). The delivery valve (C) remains closed until the pressure inside the pump housing increases and forces the delivery valve (C) to open.[5]

Research Method

This study was conducted using an experimental approach consisting of the following stages: site identification, design concept selection, prototype development, installation, and field testing. The research stages generally followed this sequence: site identification → needs assessment → information gathering → development of design alternatives → selection of the best concept → detailed design → material selection → prototype development → testing → analysis of results.

Site Identification

Site identification was conducted to obtain data on the characteristics of the water source, which served as the basis for the pump design. The data from the site identification are presented in Table 1.

Table 1. Water source location characteristics

No	Parameter	Value
1	Elevation of water source relative to site	± 21 m
2	Distance from the water source to the site	± 105 m
3	Water source flow rate	0,024 m^3/second (24 L/second)
4	Average flow velocity	0,44 m/second

Selection of Design Concepts Using the AHP Method

The selection of pump design concepts was conducted using the Analytic Hierarchy Process (AHP) method to determine the most suitable design alternative among five non-electric pump alternatives, namely: (1) a river-current-driven hose-type impeller pump, (2) an impeller pump with a V-belt transmission to the suction pump, (3) a windmill-driven pump, (4) a hose-type impeller pump with an alternative drive system, and (5) a hydram pump. These five alternatives were evaluated based on five criteria—cost, performance, ease of use, maintenance, and service life—using a pairwise comparison matrix on a 1–9 scale (Saaty). The weight of each criterion was obtained from the normalization of the comparison matrix, and the consistency of the evaluation was verified using the consistency ratio (CR), with the requirement that $CR < 0.10$ for the evaluation to be considered consistent.
The weighting results show that the performance criterion received the highest weight (0.4206), followed by service life (0.2493), price (0.1704), ease of use (0.0859), and maintenance (0.0738), with a consistency ratio of 0.066 (consistent). A summary of the final scores for each alternative is presented in Table 2.

JMM :
Journal of Mechanical and Manufacture
[Vol. 5, No. 2, April, 2026, pp. 86-93]

Table 2. Summary of AHP evaluation results for each design alternative

Alternative	Price	Performance	Ease of Use	Maintenance	Lifespan	Final Score	Ranking
Alt 1	0,1979	0,0984	0,1212	0,1697	0,1245	0,130	5
Alt 2	0,1244	0,3306	0,0654	0,1785	0,2465	0,239	2
Alt 3	0,2602	0,1302	0,1883	0,2818	0,1649	0,178	3
Alt 4	0,2932	0,1102	0,2866	0,1035	0,1399	0,163	4
Alt 5	0,1244	0,3306	0,3385	0,2664	0,3242	0,290	1

Based on the results in Table 2, Alternative 5 (hydram pump) received the highest final score of 0.290 and was therefore selected as the design concept to be developed into a prototype.

Pump Specifications and Design

The design of a hydram pump's dimensions is based on the Calvert method, which states that the ratio of the pipe length to the input pipe diameter (L/D) should be within the range of 150 to 1000:

$$L = 150 < L/D < 1000$$

With an inlet pipe diameter of 2 inches (0.05 m), an inlet pipe length of 8 m yields an L/D value of 160, which falls within the required range; therefore, the minimum inlet pipe length to be used is 8 m. The specifications for the designed hydram pump are presented in Table 3.

Table 3. Specifications of the designed hydram pump

Delivery Tube Diameter (inches)	Delivery Pipe Height (m)	Input Pipe Diameter (inches)	Pump Body Diameter (inches)
3	1	2	2

The primary material used is Rucika AW brand PVC pipe for the pump body, delivery tube, and inlet pipe, with supporting components including a waste valve and a delivery valve (valve/check valve) one-way, flange, rubber gasket, and iron valve weights. PVC was chosen to reduce manufacturing costs without compromising the pump's primary function.

Installation and Testing Procedures

The hydram pump was installed in the water source flow with the following configuration: storage tank – inlet pipe – pump body – discharge valve – delivery pipe – delivery tube – outlet pipe leading to the destination tank at an elevation of ± 21 m and a distance of ± 100–105 m.

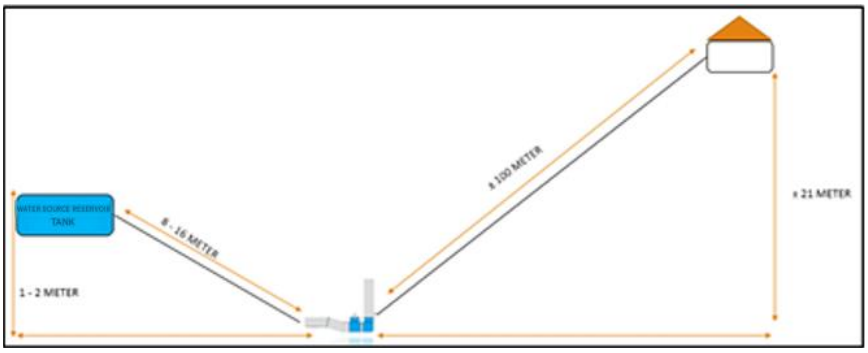

Figure 1. installation scheme

JMM :
Journal of Mechanical and Manufacture [Vol. 5, No. 2, April, 2026, pp. 86-93]

Testing was conducted using five different combinations of inlet pipe height and length, as shown in Table 4, with the outlet pipe diameter kept constant at 0.5 inches.

Table 4. Test configurations for the hydram pump

Testing	Input Height (m)	Input Length (m)	Output Pipe Diameter (inches)
1	1	8	0,5
2	1	12	0,5
3	2	16	0,5
4	2	20	0,5
5	2	20	0,5

The testing procedure was carried out in the following stages: (1) preparation of the reservoir as the input, (2) installation of the pump inlet pipe, (3) collection of water flow rate data at the inlet pipe, (4) installation of the pump and pressure gauge on the pump body, (5) collection of pressure data before the outlet valve was opened, (6) opening the output valve to direct water to the target elevation, (7) evaluating whether the target elevation has been reached—if not, readjusting the design details, and (8) if the target is reached, recording the output water flow rate as the final test data. Output flow rate measurements were performed using a volumetric method with a collection container and a stopwatch.

Results and Discussion

Design Results and Prototype Construction

Based on the concept selection results in Table 2, the hydram pump was designed using SolidWorks software to determine the dimensions and shapes of the components prior to fabrication. The prototype was constructed from PVC pipe through the steps of cutting, joining with pipe glue, and installing the discharge valve and delivery valve, complete with rubber gaskets and counterweights, according to the specifications in Table 3. The completed prototype was then installed directly at the research site following the planned installation diagram.

Figure 2. Hydram pump

JMM :
Journal of Mechanical and Manufacture
[Vol. 5, No. 2, April, 2026, pp. 86-93]

Hydram Pump Test Results

The tests were conducted five times with variations in the height and length of the inlet pipe; in the fifth test, the length of the outlet pipe was also increased. The complete test results are presented in Table 5.

Table 5. Summary of hydram pump test results (input pipe diameter: 2 inches; delivery tube: 3 inches; output pipe: 0.5 inches)

Testing	Input Height (m)	Input Length (m)	Input Flow Rate (L/min)	Delivery Pipe Height (m)	Output Length (m)	Output Height (m)	Output Flow Rate (L/min)
1	1	8	48,0	1	60	13	1,20
2	1	12	40,0	1	60	13	1,71
3	2	16	60,0	1	90	17	1,89
4	2	20	80,0	1	90	17	3,00
5	2	20	80,0	1	105	21	2,12

In Test 1, with an inlet head of 1 m and an inlet length of 8 m, the pump produced a maximum outlet head of 13 m at a flow rate of 1.20 L/minute. In Test 2, increasing the inlet length to 12 m while maintaining the same inlet head (1 m) increased the flow rate to 1.71 L/minute, although the maximum outlet head remained at 13 m. In the third test, increasing the inlet head to 2 m and the inlet length to 16 m increased the outlet head to 17 m with a flow rate of 1.89 L/min. In the fourth test, extending the inlet length to 20 m while keeping the inlet head at 2 m maintained the outlet head at 17 m but significantly increased the flow rate to 3.00 L/min. In the fifth test, using the same input height and length as in the fourth test but with the output pipe length increased to 105 m, the pump successfully achieved a maximum output head of 21 m with a flow rate of 2.12 L/min.

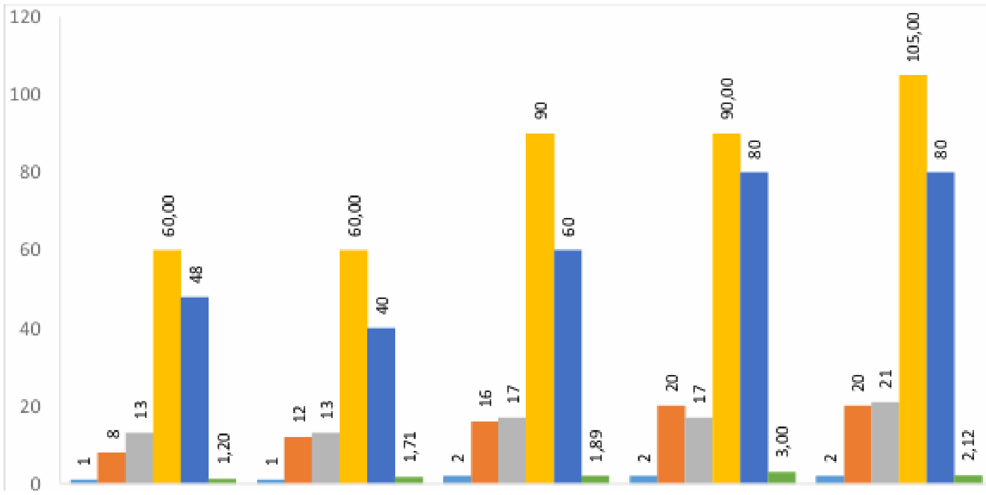

Figure 3. Analysis diagram

These results show a pattern in which increasing the input height and the length of the input pipe consistently increases the output flow rate of the hydram pump, as the increased kinetic energy of the flow entering the pump body amplifies the water hammer effect. Meanwhile, the maximum output head that can be achieved is more influenced by the combination of the input height and length with the output pipe length; increasing the output pipe length in Test 5 proved capable of raising the target head from 17 m to 21 m, although the resulting flow rate decreased compared to Test 4 due to increased friction losses (head loss) along the longer output pipe.

Discussion

The trend of increasing output flow rate with increasing height and length of the input pipe in this study is consistent with the findings of Siahaan and Sitepu (2013), who reported that an increase in the length of the driven pipe also affects the magnitude of water hammer pressure and the efficiency of the hydram pump. The results of this study are also consistent with the findings of Nadya et al. (2014), which demonstrated a relationship between variations in pipe height and the resulting water flow rate, although in that study the highest flow rate was actually obtained with a shorter pipe (6 m) due to differences in the air chamber configuration and head conditions used.

A comparison between the fourth and fifth tests reveals a trade-off between lift (head) and output flow rate: increasing the length of the outlet pipe allows the pump to reach a higher target elevation, but results in a decrease in flow rate due to increased flow resistance along the pipe. These findings underscore the importance of considering site characteristics—including head, source flow rate, inlet pipe length, and target distribution head—when designing a hydram pump system to achieve an optimal balance between the required lift and the flow rate needed by the community.

Based on the overall test results, the configuration used in the fifth test (input height of 2 m, input length 20 m, output length 105 m) was the configuration that best suited the field conditions at the study site, as it was able to meet the target distribution height of ± 21 m—corresponding to the elevation difference between the water source and the settlement—with a flow rate of 2.12 L/minute, or the equivalent of ± 3,052.8 L/day, which can be used to meet a portion of the local community's domestic water needs.

Conclusion

Based on the results of the design and testing of a hydram pump with a 2-inch pump body, a 3-inch delivery tube, and a 2-inch inlet pipe, it can be concluded that: (1) the selection of the design concept using the AHP method resulted in the hydram pump as the best alternative, with a final weighting value of 0.290 among the five non-electric pump alternatives compared; (2) the height and length of the hydram pump's inlet pipe have a significant effect on the lift height and output flow rate produced; the taller and longer the inlet pipe, the greater the resulting output flow rate tends to be; and (3) the optimal configuration was obtained in the fifth test with an inlet height of 2 m, an inlet length of 20 m, and an outlet length of 105 m, which produced an outlet head of 21 m with a flow rate of 2.12 L/min, meeting the water distribution needs at the study site.

Further research is recommended to examine the effects of variations in the diameter of the delivery pipe and air volume on pump efficiency, as well as to conduct long-term testing to evaluate the durability of PVC material against repeated pressure caused by water hammer, so that hydram pumps can be used sustainably to meet the water needs of communities in areas with similar topography.

Reference

Diwan, P., Patel, A., & Sahu, L. (2016). Design and fabrication of hydraulic ram with methods of improving efficiency. International Journal of Current Engineering and Scientific Research, 3(4), 8-13.

Hanafie, J., & de Longh, H. (1979). Teknologi pompa hidraulik ram: Buku petunjuk untuk pembuatan dan pemasangan. Bandung: PTP-ITB Ganesha.

JMM :
Journal of Mechanical and Manufacture
[Vol. 5, No. 2, April, 2026, pp. 86-93]

Herlambang, A., & Wahjono, H. D. (2006). Rancang bangun pompa hidram untuk masyarakat pedesaan. Jurnal Air Indonesia, 2(2).

Badan Pengembangan Sumberdaya Manusia. (2015). Penyusunan program investasi infrastruktur. Pusdiklat Jalan, Perumahan, Permukiman, dan Pengembangan Infrastruktur Wilayah.

Nadya, Y., Hasan, M. T., Subhan, S., & Swary, W. M. (2014). Pengujian karakteristik pompa hydraulic ram (hydram) menggunakan tabung udara 0,00455 m^3. Jurutera, 1(1), 8-11.

Ndache Mohammed, S. (2007). Design and construction of a hydraulic ram pump. Leonardo Electronic Journal of Practices and Technologies, 6(11), 59-70.

Riani, S., Dewanti, A. N., & Prasaningtyas, A. (2020). Analisis kebutuhan air baku Kecamatan Samboja tahun 2020.

Saaty, T. L., dikutip dalam Dieter, G. D., & Schmidt, L. C. (2009). Analytic hierarchy process. In Engineering Design (5th ed., pp. 286-287). New York: McGraw-Hill.

Siahaan, P., & Sitepu, T. (2013). Rancang bangun dan uji eksperimental pengaruh variasi panjang driven pipe dan diameter air chamber pada pompa hidram. Jurnal e-Dinamis, 2(12), 26-33.

Taye, T. (1998). Hydraulic ram pump. Journal of the Ethiopian Society of Mechanical Engineers, 2.

Yuli Satria, D. D., & Kurniawan, S. E. (2019). Rancang bangun pompa hidram (hydraulic ram pump) dengan 3 varian tabung udara untuk model sistem irigasi persawahan. Majamecha, 1(1), 48-59.

Arianta, A. N. (2010). Pengaruh variasi ukuran tabung udara terhadap unjuk kerja sebuah pompa hidram. Yogyakarta.