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Implementation of Horizontal Infiltration Pipes System for Sustainable Drainage at Demakan Village Office, Banyubiru, Semarang Regency

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ABSTRAK

Permasalahan utama di Kelurahan Demakan, Banyubiru, Kabupaten Semarang adalah tingginya limpasan air hujan yang sering memicu genangan di area publik akibat terbatasnya kapasitas infiltrasi tanah. Tujuan pengabdian ini adalah mengimplementasikan teknologi Pipa Resapan Horizontal (PRH) sebagai solusi drainase ramah lingkungan sekaligus meningkatkan pemahaman masyarakat mengenai pengelolaan air hujan yang berkelanjutan. Metode pelaksanaan meliputi sosialisasi kepada perangkat kelurahan dan masyarakat sekitar, survei lokasi, perancangan sistem, serta instalasi teknis pipa perforasi yang ditanam secara horizontal pada 15 November 2025. Hasil kegiatan menunjukkan bahwa sistem PRH berhasil diterapkan sebagai sistem drainase yang berfungsi dengan baik, mampu mengurangi genangan permukaan di area kantor kelurahan, meningkatkan infiltrasi air ke dalam tanah, serta menjadi sarana percontohan dan edukasi mengenai teknologi drainase berkelanjutan bagi masyarakat. Kesimpulannya, implementasi PRH merupakan langkah efektif sebagai alternatif terhadap sumur resapan vertikal, khususnya pada lokasi dengan keterbatasan ruang dan kondisi tanah tertentu. Sistem yang telah dibangun berpotensi menjadi model penerapan konservasi air berbasis infiltrasi di Kabupaten Semarang. Untuk menjaga kinerja sistem dalam jangka panjang, diperlukan pemeliharaan rutin serta pemantauan berkala terhadap kondisi sistem dan muka air tanah guna mendukung upaya konservasi sumber daya air tanah.

Keywords:
Demakan village; groundwater; horizontal infiltration pipe; runoff; sustainable drainage

ABSTRACT

The primary issue in Demakan Village, Banyubiru, Semarang Regency, is the high volume of rainwater runoff that frequently causes puddles in public areas. This community service aims to implement Horizontal Infiltration Pipe (HIP) technology as an eco-friendly drainage solution. The implementation method consisted of coordination and socialization with village officials and residents, site surveys, system design, and installation of a perforated horizontal infiltration pipe network at the Demakan Village Office on 15 November 2025. The implementation resulted in the successful establishment of a functional HIP system that reduced localized ponding

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around the office area, facilitated rainwater infiltration into the surrounding soil, and served as a practical demonstration of sustainable drainage technology for the community. The activity also strengthened the understanding of village stakeholders regarding environmentally sound drainage management and groundwater conservation. In conclusion, the HIP system proved to be a feasible alternative to conventional vertical infiltration structures, particularly in areas with limited space and specific soil conditions. The installed system can serve as a pilot model for sustainable drainage management in Banyubiru, while routine maintenance and periodic monitoring are recommended to ensure long-term system performance and support groundwater recharge.

INTRODUCTION

Rapid urbanization and the expansion of built-up areas, such as office complexes and residential zones, have significantly increased impervious surface. In Demakan Village, Banyubiru, Semarang Regency, this phenomenon has led to a decrease in natural soil permeability. During the rainy season, high-intensity rainfall often results in excessive surface runoff because the existing conventional drainage system are unable to accommodate the water volume. According to Sunjoto (2011), conventional drainage concepts that focus on discharging water as quickly as possible to the nearest river area are no longer sustainable, as they contribute to downstream flooding and depleting local groundwater reserves.

To overcome these challenges, the implementation of sustainable urban drainage systems (SUDS) has become an increasingly important strategy, emphasizing not only the rapid conveyance of stormwater but also the enhancement of infiltration and groundwater recharge. Among various infiltration-based measures, infiltration wells are considered an effective and practical solution for public facilities with limited open space because they can reduce peak surface runoff, increase rainwater storage within the soil, and alleviate the burden on existing drainage networks (Astuti, 2024). Their performance, however, depends on local hydrogeological conditions, including soil permeability, rainfall characteristics, and groundwater depth, making site-specific planning essential to ensure optimal functionality. Recent studies have demonstrated that properly designed infiltration facilities can significantly improve urban drainage performance while supporting long-term groundwater conservation and reducing flood risk in densely developed areas (Pamungkas et al., 2025).

The Demakan Village Office serves as a central hub for public services, yet it frequently experiences inundations in its courtyard and surrounding areas during heavy rainfall events. The absence of effective infiltration facilities causes stormwater to accumulate, disrupting public access and accelerating pavement deterioration. Furthermore, the local community continues to rely heavily on groundwater as a primary water source; consequently, limited rainwater infiltration reduces natural aquifer recharge and threatens long-term water availability. Recent studies have emphasized that sustainable infiltration systems should not only reduce localized flooding but also improve groundwater recharge while maintaining long-term operational performance. Horizontal-flow managed aquifer recharge (MAR) systems have demonstrated stable recharge capacity, high treatment efficiency, and minimal performance degradation through simple maintenance procedures, indicating their suitability for decentralized stormwater management and groundwater conservation in water-stressed areas (Hossain et al., 2025). As shown in Figure 1, the northern part of Banyubiru is categorized as a high-risk zone due to its topography, highlighting the need for adaptive infiltration-based drainage infrastructure.

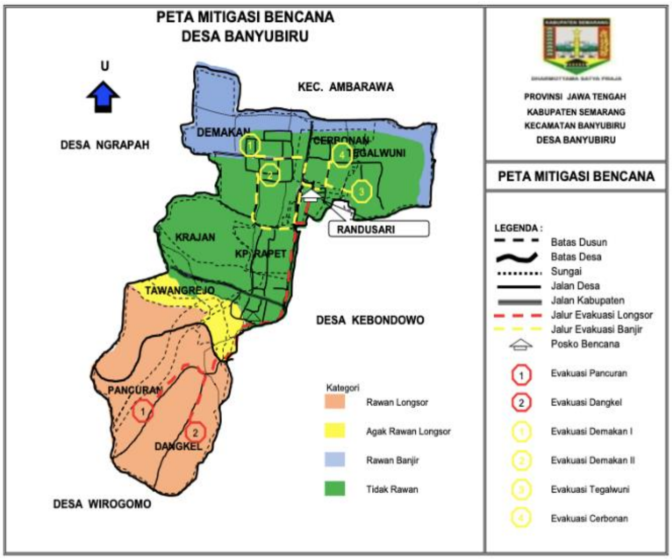

Figure 1. Disaster Mitigation Maps of Banyubiru

The primary objective of this community service is to implement Horizontal Infiltration Pipe (HIP) technology at the Demakan Village Office as an innovative infiltration-based drainage solution. The HIP concept adopts the principle of horizontal subsurface infiltration by increasing the contact area between stored rainwater and the surrounding soil, thereby enhancing infiltration and promoting groundwater recharge. This approach is consistent with the principles of Sustainable Urban Drainage Systems (SUDS), in which infiltration-based facilities are designed to reduce runoff volume, restore groundwater recharge, and improve the hydrological balance in urban catchments (Bonneau et al., 2017). Furthermore, infiltration structures with elongated subsurface flow paths, such as infiltration trenches and horizontal infiltration systems, have been recognized as effective measures for attenuating stormwater runoff while enhancing artificial groundwater recharge when properly designed according to local hydrogeological conditions (Chahar et al., 2012). Therefore, the implementation of HIP is expected not only to eliminate recurrent ponding around the village office but also to improve groundwater replenishment and serve as a practical demonstration model for sustainable stormwater management and community-based groundwater conservation.

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LITERATURE REVIEW

The implementation of sustainable drainage system through community development requires a synergy between technical innovation and social participation. Theoretical studies suggest that community service project involving infrastructure should prioritize "Low Impact Development" to mimic natural hydrological processes. According to Prince and Jha (2020), integrating green infrastructure like infiltration systems into public facilities serve as a catalyst for urban resilience, provided that the local community is involved in the planning and maintenance phases.

Previous community service activities have demonstrated that vertical infiltration wells often face limitations in areas with shallow water tables or high soil density. In such contexts, Horizontal Infiltration Pipe (HIP) technology offers a superior alternative. A study by Susilo et al. (2020) on infiltration system effectiveness highlighted that horizontal configurations provide a large surface area for water absorption compared to vertical wells, making them significantly more efficient in reducing surface runoff in clay-heavy soils. This research strengthens the importance of the current project in Demakan Village, where soil characteristics and space constraints require a more adaptive approach than traditional methods.

Recent studies have further strengthened the role of infiltration-based technologies as an effective nature-based solution for urban flood mitigation. Research on bio-pore infiltration systems demonstrated that increasing infiltration capacity through distributed green infrastructure can substantially reduce flood depth in urban environments. Nevertheless, the study also emphasized that infiltration structures must be designed according to site-specific hydrological conditions because insufficient numbers or inappropriate sizing will limit their effectiveness. This finding suggests that infiltration facilities should be determined through runoff estimation, land-use characteristics, and rainfall intensity rather than relying solely on empirical implementation. Such an approach supports the development of Horizontal Infiltration Pipe (HIP) systems, whose hydraulic performance can be optimized according to local environmental conditions while simultaneously enhancing groundwater recharge and reducing surface runoff (Fitri et al., 2025; Bhattacharya, 2010).

In addition to hydraulic performance, the long-term sustainability of infiltration systems depends on their operational efficiency and maintenance. A recent study on a Managed Aquifer Recharge (MAR) system employing an innovative horizontal-flow configuration demonstrated high recharge capacity, effective pollutant removal, and a significant rise in groundwater level during long-term monitoring. The horizontal configuration also minimized clogging and enabled the recharge capacity to be largely restored through routine backwashing, indicating that maintenance is a crucial component of sustainable recharge systems. Likewise, investigations on constructed rapid infiltration systems confirmed that properly designed infiltration facilities can improve groundwater recharge while maintaining groundwater quality within acceptable limits, particularly when filtration media such as zeolite are incorporated. These findings indicate that

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infiltration infrastructure should be evaluated not only from the perspective of flood reduction but also from its contribution to long-term groundwater conservation and water quality protection (Abd-Elaziz et al., 2025; Guo et al., 2022).

The engineering design of horizontal infiltration structures also plays a decisive role in determining their effectiveness. Numerical investigations on horizontal drainage systems have shown that drainage performance is strongly influenced by the placement and inclination of horizontal pipes, whereas pipe length alone contributes less significantly. Complementary experimental studies on perforated horizontal recharge pipes further demonstrated that infiltration capacity is governed by several interacting variables, including soil permeability, pipe wall porosity, pipe length, and hydraulic head. The resulting regression models provide a scientific basis for optimizing recharge system dimensions according to local site characteristics. These findings are particularly relevant to the proposed HIP installation in Demakan Village, where limited land availability and clay-dominated soils require a carefully designed horizontalinfiltration configuration to maximize runoff reduction and groundwater recharge (Zhang et al., 2023; Susilo et al., 2023).

Finally, recent developments in horizontal recharge technology have highlighted its potential as an adaptive solution to increasing flood risk caused by urbanization and land-use change. Experimental research on Horizontal Recharge Pipes (HRP) revealed that conventional recharge wells and biopores are often insufficient to achieve significant runoff reduction, whereas perforated horizontal pipelines provide substantially greater infiltration capacity and can be designed to offset increases in runoff resulting from urban development. Artificial groundwater recharge has similarly been recognized as an effective strategy for restoring groundwater resources, particularly in regions experiencing groundwater depletion and declining natural infiltration. The selection of recharge techniques should therefore consider hydrogeological conditions, technical feasibility, economic efficiency, and community acceptance. Consequently, implementing HIP technology through community-based programs represents an integrated strategy that combines flood mitigation, groundwater conservation, and sustainable environmental management, making it highly suitable for replication in rapidly developing settlements (Susilo et al., 2023; Bhattacharya, 2010).

Furthermore, the success of community-based water conservation is highly dependent on the “demonstration effect”. Research by Maryono (2020) suggests that implementing infiltration technology in government offices or public centers (such as the Village Office) serves as an effective educational tool. When residents observe the direct benefits such as the absence of puddles and improved drainage, they are more likely to adopt similar practices on their own properties. Therefore, this community service activity is not merely a technical installation but a strategic effort to foster regional environmental awareness and long-term groundwater sustainability.

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METHODS

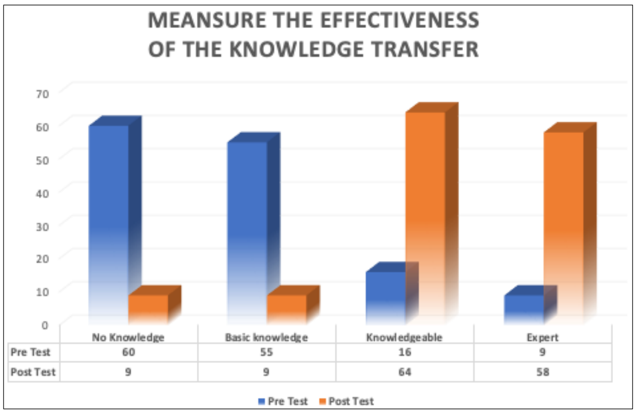
This community service activity at the Demakan Village Office utilizes the diffusion of appropriate technology method, combined with socialization and technical demonstration. This approach is designed to introduce a practical technical solution to the community while ensuring the transfer of knowledge and skills. The framework for this activity followed four systematic stages:

a. Identification: Assessing the drainage issues and soil characteristics at the Demakan Village Office.
b. Design: Planning the Horizontal Infiltration Pipe (HIP) layout, including the calculation of pipe dimensions and perforation density based on the catchment area.
c. Implementation: Technical installation of the system as a pilot project.
d. Evaluation: Measuring the increase in participant knowledge and the technical performance of the system.

The implementation took place on November 15, 2025, targeting village officials and local community leaders who serve as stakeholders in environmental management. The activity was divided into two main phases.

a. Theoretical Session: A socialization workshop held in the village hall to explain the hydrological cycle and the importance of groundwater conservation.
b. Practical Session: A field demonstration where the HIP system was installed. This allowed the 14 participants to observe the technical requirements, such as trench depth, gravel bedding and the use of geotextiles.

To measure the effectiveness of the knowledge transfer, a quantitative approach was used through pre-test and post-test instruments. These tests assessed the participants understanding of water resource sustainability and the technical aspects of HIP. The results and discussion from 14 participants showed a significant increase in scores between the pre-test post-tests. The diagram through pre-test and post test show in Figure 2.



	No Knowledge	Basic knowledge	Knowledgeable	Expert
Pre Test	60	55	16	9
Post Test	9	9	64	58

Figure 2. Measure The Effectiveness of Knowledge Transfer

The community service project effectively bridging the knowledge gap regarding groundwater conservation. The sharing knowledge session yielded a significant shift in participant competency. Based on the evaluation of 14 participants, the pre-test results indicated a lack of technical mastery, with 42.86% having no knowledge, 39.29% possessing only basic knowledge, 11.43% being knowledgeable and only 6.43% categorized as experts.

Following the socialization and technical demonstration, the post-test data revealed a remarkable transformation participant in the “no knowledge” and “basic knowledge” categories dropped to 6.43% each, while those categorized as knowledgeable rose to 45.71% and expert levels surged to 41.43%. These results confirm that the diffusion of appropriate technology through direct pilot projects at the Demakan Village Office is a highly effective strategy for fostering community-based environmental resilience. In summary, the project has not only provided a physical solution to surface ponding but also has successfully empowered local stakeholders with the expertise required for sustainable water management.

RESULT AND DISCUSSION

The implementation of the Horizontal Infiltration Pipe (HIP) system at the Demakan Village Office yielded significant results in terms of both technical infrastructure and community service activity knowledge. Figure 3 illustrates a knowledge sharing activity focused on the technical benefit and implementation of horizontal infiltration pipe.

Figure 3. A Knowledge Sharing Activity

The installation of the HIP system was strategically executed in the office’s catchment area, which previously suffered from chronic water pooling. The process began with the excavation of a 1,00 m depth trench, followed by the placement of a sand and gravel foundation to facilitate initial drainage. A 6-inch perforated PVC pipe, wrapped in high permeability geotextile, was then laid a 1% slope to ensure steady water flow. The pipe was encased in a gravel envelope to provide temporary storage space before the water eventually infiltrated the surrounding soil. This configuration significantly increases the horizontal contact area compared to traditional vertical wells, making it highly effective for the local soil condition in Demakan Village. The implementation of Horizontal Infiltration Pipe, show in Figure 4 below.

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The choice of a horizontal system was justified by the soil's saturation levels, where vertical wells might have hit the water table too quickly, the horizontal pipes utilize the upper, more permeable soil layers. This ensures that even during peak rainfall, the runoff is effectively distributed and absorbed, reducing the burden on the village's primary drainage channels. Ultimately this activity demonstrates that low cost, appropriate technology can be a primary solution for climate change adaptation at the village level.

Figure 4. Implementation of Horizontal System

CONCLUSION

The community service project successfully achieved its primary objective by implementing Horizontal Infiltration Pipe (HIP) technology as a functional and educational model for sustainable drainage at the Demakan Village Office. The finding confirms that the HIP system is a highly viable alternative to traditional vertical soal pits, particularly in areas with specific spatial and soil constraints. By shifting the drainage paradigm from "rapid disposal" to "horizontal infiltration", the project has effectively addressed the localized flooding issues while simultaneously enhancing groundwater recharge capabilities. In summary, the horizontal system at the office site now serves as a tangible benchmark for localized water conservation efforts in Banyubiru, Semarang Regency.

Based on the implementation experience, the Village administration should establish a routine schedule to inspect and clean the sediment trap basins (control boxes) to prevent siltation and ensure the long-term permeability of the system. Local authorities are encouraged to integrate HIP technical specification into village level infrastructure planning, particularly for paved public areas and densely populated residential zones. Future community service activities or research should involve periodic measurements of the local groundwater table near the installation site to quantify the long-term impact of the horizontal system on aquifer replenishment.

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