TECHNICAL REPORT

Performance and Cost-Benefit Evaluation of Farmer-Managed Solar-Powered Groundwater Irrigation in Attapeu Province, Lao PDR: Interim Results from the First Year of Operation of Four Pilot Systems

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October 2025

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Acknowledgments

The authors wish to express their gratitude to the Lao Government partners, particularly the Provincial Agriculture and Forestry Office (PAFO) of Attapeu Province, the District Agriculture and Forestry Office (DAFO) of Sanamxay and Samakkixay, and farmers for their cooperation and participation during field interview.

This work was carried out under the CGIAR Multifunctional Landscapes Program. We would like to thank all funders who supported this research through their contributions to the CGIAR Trust Fund (https://www.cgiar.org/funders).

Citation

Douangsavanh, S.; Pavelic, P.; Kotchofa, P.; Dubois, M. 2025. *Performance and cost-benefit evaluation of farmer-managed solar-powered groundwater irrigation in Attapeu Province, Lao PDR: interim results from the first year of operation of four pilot systems*. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Multifunctional Landscapes Program. 32p.

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Front cover photo:: A top-down view of the solar-powered groundwater site in Inthee village, Sanamxay District, Attapeu Province, Lao PDR, where a group of farmers utilize groundwater for an integrated and rotational agricultural system - rainfed rice, vegetables, watermelon, and a rice-fish pond (*photo*: Somphasith Douangsavanh/IWMI).

Back cover photo: A solar groundwater site in Donephay Village, Sanamxay District, Attapeu Province, Lao PDR. The photo shows elderly residents enjoying a bath and utilizing groundwater for their daily domestic needs (*photo*: Somphasith Douangsavanh/IWMI).

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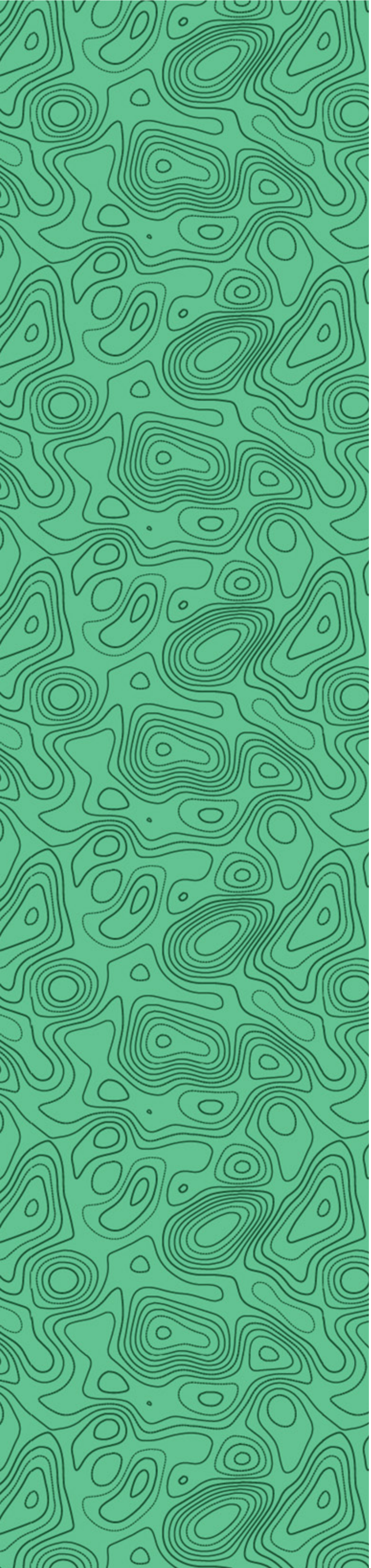

Summary

Solar-powered groundwater irrigation systems introduced in Attapeu Province, Lao PDR in 2024, with support from CGIAR and IWMI, are helping small-scale farmers to build more productive and resilient agricultural production systems. This study evaluates the functioning of these systems, together with the costs and benefits after one year of operation. A mixed-methods approach was used, involving field surveys, and water user group interviews. This study assesses the system's impact on farmers' incomes and overall livelihood improvements, as well as the environmental benefits across the four sites where the system has been implemented. We report interim results of system operation and performance. At this stage, the report does not focus extensively on quantitative socio-economic analysis such as cost-benefit comparisons in monetary terms since the system is still in its early operational phase. Instead, it aims to qualitatively highlight the broader aspect of benefits, including non-monetary advantages related to the environmental sustainability and other positive impacts. Furthermore, this report aims to provide potential entry points for other interventions, enabling synergies or bundled approaches at larger landscape and basin scales; this aligns with the vision of "multifunctional landscapes" supported by integrated interventions

Overall, the solar irrigation systems provided relatively positive impacts across multiple areas: (1) environmentally, the systems helped address climate variability, supporting agricultural production during dry spells in the wet season and into the dry season; (2) socially, improved water access enhanced domestic use and irrigation, reduced the burden on women and children responsible for fetching water for their families, and strengthened community governance; (3) economically and nutritionally, the elimination of electricity costs made systems more cost-effective, while year-round vegetable farming improved food security and livelihoods. In terms of sustainable water resources management, the establishment of the water user groups, along with regulation frameworks, monitoring systems, and hydrological assessments, contributed to better management of important wetlands within the area and the broader landscape. These efforts have enhanced understanding of hydrological connectivity and provided key insights for developing wetland water use regulations; the monitoring system will help to prevent potential long-term negative impacts from water extraction.

For example, at the Inthee site, which farmers most intensively used, the collective farming model employed intercropping, supported by the intervention most intensively used has shown positive results. It has enabled households to produce a variety of vegetables for both consumption and sale, generating additional incomes for families, and improving dietary diversity in daily meals. To further improve farming outcomes, farmers can potentially try either or both of these options: (1) strengthened focus on higher-value crops such as long green beans or cucumbers, as these crops already showed good sales in the first year of testing (e.g., nine cucumber plots yielded 3,000,000 kips (USD 137) in total sales (Table4); (2) combining rice-fish farming, using plastic-lined trenches with groundwater system; this could provide year-round fish production, and natural fertilizer for crops. The lessons learned from this pilot site could potentially be adapted and scaled up to other geographic regions, including lowland and upland areas, where local water resources are sufficient to support such practices.

While these interventions have shown success, some challenges remain in implementation. In Hom and Tamaleuy, farmers currently use groundwater from the solar pump only for initial stage of watermelon growth before switching to surface water from the adjacent wetland for full irrigation until harvest, as this provides more water and time saving despite the higher fuel costs. This highlights the trade-offs farmers make between water reliability, labour demands, and operational costs when selecting irrigation sources. To address this challenge, two potential solutions could be introduced: (1) improving irrigation planning: Water User Group (WUG) could create a schedule to take turn using the water; or (2) selecting alternative crops whereby farmers could grow other crash-crops that need less water instead of watermelon.

1. Context and Background

Groundwater is a vitally important water resource that plays a crucial role in providing water security and enhancing rural livelihoods in Lao PDR, especially during the dry season (Clément et al., 2018; Douangsavanh, 2022). Groundwater is also used to supplement wet season irrigation when there is a prolonged drought or dry spell. Recently, the combination of groundwater and solar-powered pumping systems has started to be recognized by the government and farmers, as the groundwater solar-powered pumping systems are considered a numbers of positives options in terms of reliable water resources for domestic water supply in households, low-cost investment in the long run with zero electricity costs, and improvement of livelihoods for rural communities by providing access to safe water for household consumption and subsistence vegetables growing during the dry seasons (Douangsavanh et al., 2024). Most recently, the government of Laos, especially the Department of Irrigation (DOI), and the Provincial Agriculture and Forestry Office (PAFO) of Attapeu, have begun to recognize the essential importance of the groundwater solar-powered pumping systems (Inphonephong et al., 2024).

In response, and as part of the CGIAR Initiative on Agroecology, the International Water Management Institute have supported the development of solar-powered groundwater irrigation (SPGI) in Sanamxay and Samakhyxay districts, Attapeu Province, Lao PDR. The construction of four SPGI systems was completed in March 2024 and since handed over to the communities for self-management. Each SPGI aims to improve domestic water access, support cash crop production during the off-season of rainfed rice, and provide supplementary irrigation for wet-season rice during dry spells. This report presents an initial cost-benefit analysis (CBA) of the solar-powered groundwater irrigation performance and its impacts on the communities. The evaluation examines broader aspects of benefits, including the economic viability, environmental sustainability, social benefits, and scalability of SPGI systems after one year of operation involving a complete cropping cycle. The evaluation applied mixed methods including a semi-structured group interview format to gather information from small-scale farmers who participated in the trial, and consolidating relevant information during the co-designed and co-developed processes of SPGI. Key findings will provide opportunities for further actions that could work together at a larger scale, supporting the goal of a multifunctional landscape through integrated solutions or interventions.

2. Project Background

2.1 Site Location and Challenges

SPGI was implemented in Sammakhyxay and Sanamxay districts of Attapeu Province. The majority of farmers within the selected sites are various ethnic minority groups, who practice their own cultural traditions as detailed in Table 1. Rice is the primary staple crop, with most villagers engaged in its cultivation, particularly in the lowland areas near the Xekong River. Rainfed rice cultivation during the wet season is the primary agricultural practice in this region, and most farmers own paddy fields ranging from 0.6 to 3.5 hectares. Most rice productions consists of local varieties and organic rice, grown for household consumption and for sale to IDP Co.Ltd (Clayton et al., 2023). During the off season for rice, farmers also cultivate cassava on nearby private and rented lands or chose to work as day laborers on sugar and banana plantations.

Table 1. Statistical information of villages and their ethnic composition. Source: Year Book of the Village, 2023

Village Name	District	Longitude	Latitude	Ethnic composition	House holds	Popu lation	Female	Rice paddy (ha)
Inthee	Sanamxay	106.670637	14.742242	Oy (majority)	306	2076	1086	569,3
Donephay	Sanamxay	106.653336	14.709461	Jeng (93.21%), Lao (0.15%), Yui (0.3%), Brao (0.2%), Oy (0.46%), Khamu (0.15%), Talieng (0.05%)	290	1931	865	414
Hom	Samakhyxay	106.7400028	14.77505	Lao (80%), Oy (10%), others (10%)	348	2,205	1,125	219
Tamaleuy	Samakhyxay	106.75005	14.7883166	Oy (97%), others (3%)	201	1,046	485	Not available

The groundwater solar-powered pumping systems were constructed and tested in four villages (Figure 1), using co-design and fully participatory processes to address specific issues. Each of the four villages has specific opportunities and challenges as follows:

In Donephay village, the primary challenges include the absence of a power grid, lack of surface water, and insufficient water for domestic use and gardening during the dry season. The solar groundwater system here is designed to serve multiple purposes:

- Domestic Use: Providing reliable water supply for household needs, reducing the time and distance for young females and elderly people who are responsible for fetching water their families, improving quality of living conditions.
- Home-Vegetable gardening: Ensuring a steady water supply for growing vegetables for households or collectively in community vegetable gardens during the dry season, which can provide additional income and improve dietary of the communities.

In Inthee village, the main challenges are the lack of surface water, limited plot space for home garden vegetables, and the high cost of electricity for crop irrigation pumping. The SPGI aims to provide reliable water sources for a group of farmers to produce vegetables and crash crops on the rice paddies during the off-rice season, and to reduce production cost, especially electricity bills. Here, the specific SPGI will focus on:

- Vegetable Gardening: Facilitating and collectively growing vegetables for household consumption and for sales, such as herbs, green beans, chilies, watermelon, cucumbers, etc., to improve the economic conditions and nutrition of the villagers.
- Integrated rice-fish culture with SPGI: Adding value to the unit of crop land area and ensuring water use efficiency by integrating rice-fish pond irrigation. The pond or trench was construed and covered with a plastic sheet to prevent water losing to the ground. Vegetables were irrigated using water from the fishpond, and the fish pool could help fertilize the vegetables.

In Hom and Tamaleuy villages, the SPGI systems were constructed in the rice paddies, which are relatively far from the residential areas and about 400-500 meters north of the Nonglom wetland. The challenges in these areas include the remoteness to the power grid, limited understanding of the hydrological connectivity between the wetland and the surrounding groundwater system, and unregulated and excessive water pumping from the wetland, which can potentially lead to unsustainable and depletion of the wetland's water resources. The SPGI specifically aims to provide:

- Irrigation for watermelon farms and other cash crops: Providing a sustainable water source for watermelon farms and other cash crops, with low production cost, especially regarding electricity and fuel expenditures.
- Supplementary Irrigation during Wet Season Rice Cultivation: Ensuring that rice fields receive adequate water even during the wet season dry spell events to enhance crop yields and food security.
- In addition, the site provides opportunity to gaining insight into the hydrological connection between the wetland and the surrounding groundwater system, geological formations, aquifer capacity and characteristics, monitoring systems, and minimizing the dependency on the wetland for water, which helps in preserving the local ecosystem.

By addressing these specific issues through the implementation of solar-powered groundwater pumping systems, the project aims to improve water availability, support agricultural activities, and enhance the overall livelihoods of the villagers.

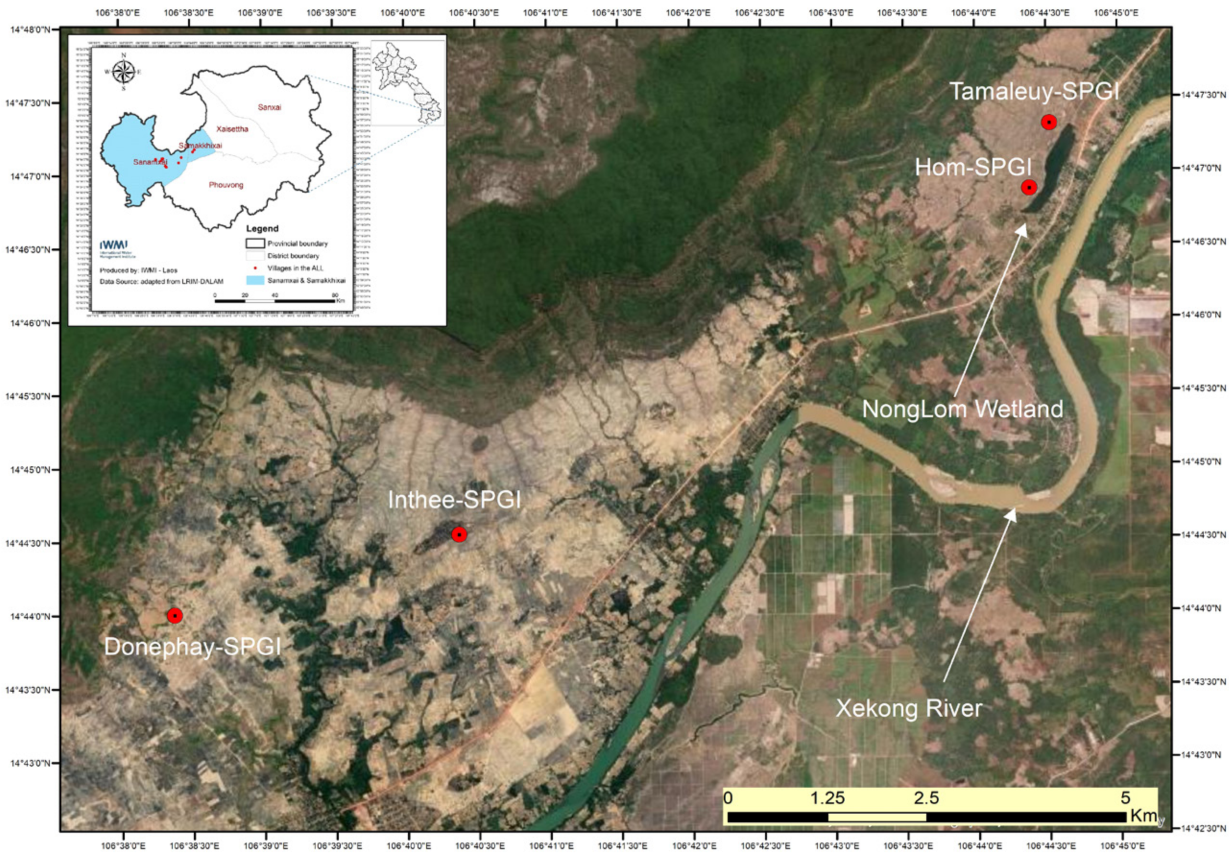

Figure 1. Location map of the Solar-Powered Groundwater Irrigation sites in the four villages. Source of image: modified and adapted from Esri, and Earthstar Geographics.

2.2 Process of Site Selection

By working closely with the community and local authorities at the district and village levels, we identified the most suitable sites for the SPGI systems in the four respective villages. Key factors for site selection included community willingness, geographical suitability, support from local authorities, and hydrogeological potential. We employed a fully collaborative approach, involving several consultations and co-designing with the communities to ensure the SPGI systems align with the local context, landscape and their specific requirements. The site selection process included rapid-field hydrogeological assessments (Specific Discharge Test), community consultations, and negotiations with landowners and local authorities to secure construction permission. This ensured not only the technical feasibility of the project but also the willingness of stakeholders to share water resources with neighboring farmers, as well as to meet the specific requirements of each farmer. The specific discharge results measured in the existing drilled wells across the selected sites are summarized in Table 2 and the water level drawdown and recovery are illustrated in Figure 2.

Table 2. Summary of well testing results conducted in October 2023.

	Village	Latitude	Longitude	Well depth	Standing WL (m)	pH	EC (µS/cm)	Pump Discharge (L/s)	Drawdown 15 min (m)	Specific Discharge (L/s/draw down)	Acceptable drawdown: 5m pumping capacity (L/sec)
A	Donephay1	14.71459	106.6541	28	7.77	7.2	217	0.91	2.45	0.37	2.23
B	Donephay2	14.70973	106.6572	40	7.67	6.78	412	0.63	0.10	6.35	38.10
C	Samakhyxay	14.82005	106.8266	30	4.4	6.84	237	0.83	3.34	0.25	1.50
D	Tamaleuy	14.78851	106.7446	28	2.12	7.28	644	0.77	3.57	0.22	1.29
E	Hom	14.77263	106.7388	32	4.8	6.65	117	0.44	1.22	0.36	2.19
F	Inthee	14.74279	106.6728	20	4.37	7.56	472	0.57	3.96	0.14	0.87
G	Inthee	14.74485	106.6761	35	3.8	7.31	173	0.59	0.21	2.80	16.81

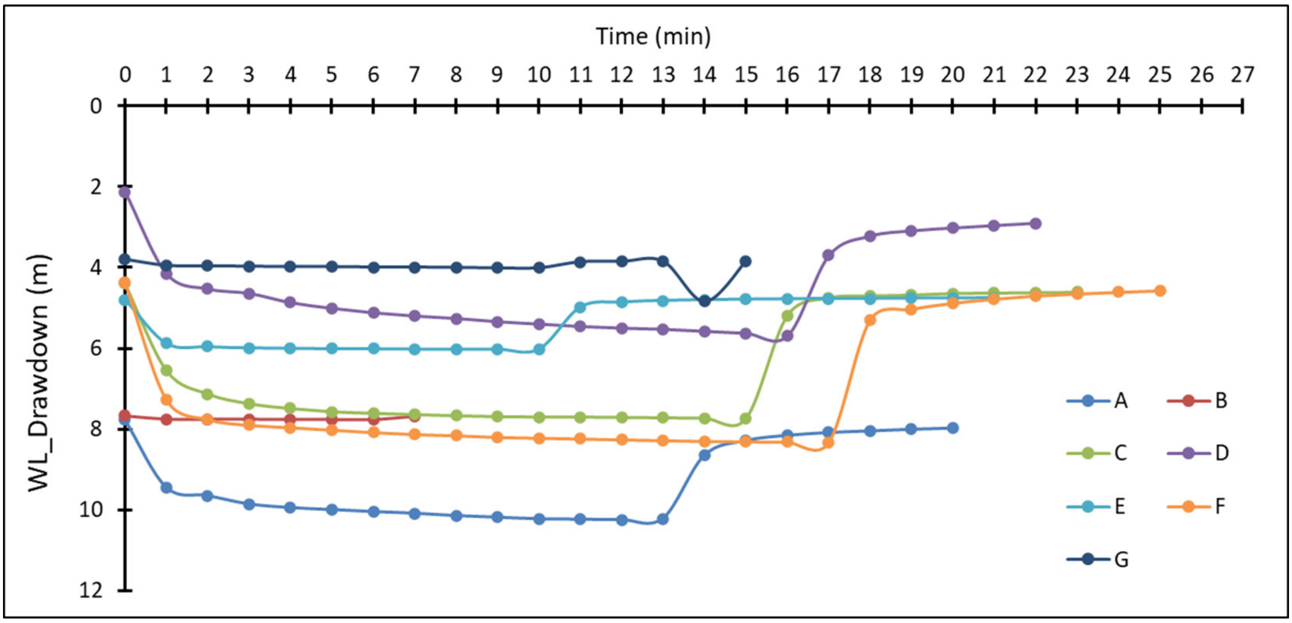

Figure 2. Groundwater levels drawdown results during the pumping and recovery phrases at the seven wells identified in Table 2

During our field visits, for example, Donephay village in Sanamxay district, we observed that some communities still depend heavily on spring water that originates from plateaus northwest of the village. These springs occur in elevated areas at the edge of the plateau north of the village, where the ground water table intersects the ground surface at the terrain, creating natural groundwater outlets. The water is collected a concrete weir, built years ago by the district government with support from an international organization, and then distributed to the village via gravity-fed pipes. This system serves as primary water source for both daily household consumption and agriculture. However, during the dry season particularly from April to May, the spring water is insufficient to reach the community. As a result, villagers must collect water manually from the spring outlet, where the spring water still flows at a very reduced rate (Figure 3).

To address this challenge, we successfully consulted with the community and local authorities to introduce SPGI system. This intervention is fully supported by the Head of the Provincial Agriculture and Forestry Office (PAFO) of Attapeu.

Figure 3. Women and young girls patiently waiting in line to collect spring water flowing from the hill in Ban Donephay, Sanamxay District, Attapeu Province, in May 2023. Photo credit: Somphasith Douangsavanh-IWMI

2.3 Infrastructure Co-designed with Communities

Community consultations and the co-design of the concept and infrastructure of the interventions were conducted at the sites and further discussion in the administrative office of the villages. These consultations involved participation from a diverse group of stakeholders to ensure that the design process was inclusive and considered the perspectives and needs of all relevant parties. The goal was not just to create functional infrastructure, but this inclusive approach aimed to foster a sense of ownership and commitment among the community members, as they played a direct role in shaping the intervention from visioning to action.

The stakeholders involved in these consultations included farmers, who provided insights into agricultural needs and practices; local authorities (chief of the villages), who offered regulatory and logistical support; and the school principals, who highlighted the educational and community aspects. Additionally, youth representatives contributed their perspectives on future sustainability, while the women's union ensured that gender considerations were integrated into the planning. Agricultural extension officials (DAFO and PAFO) also participated, bringing technical expertise and facilitating the alignment of the interventions with broader agricultural policies and strategic plan outlined by the Ministry of Agriculture and Forestry (Figure 4). The co-design process was an important collaborative event that brought together a diverse range of voices and expertise to ensure that the infrastructure would not only functional but also widely supported by and fully engaged by the communities.

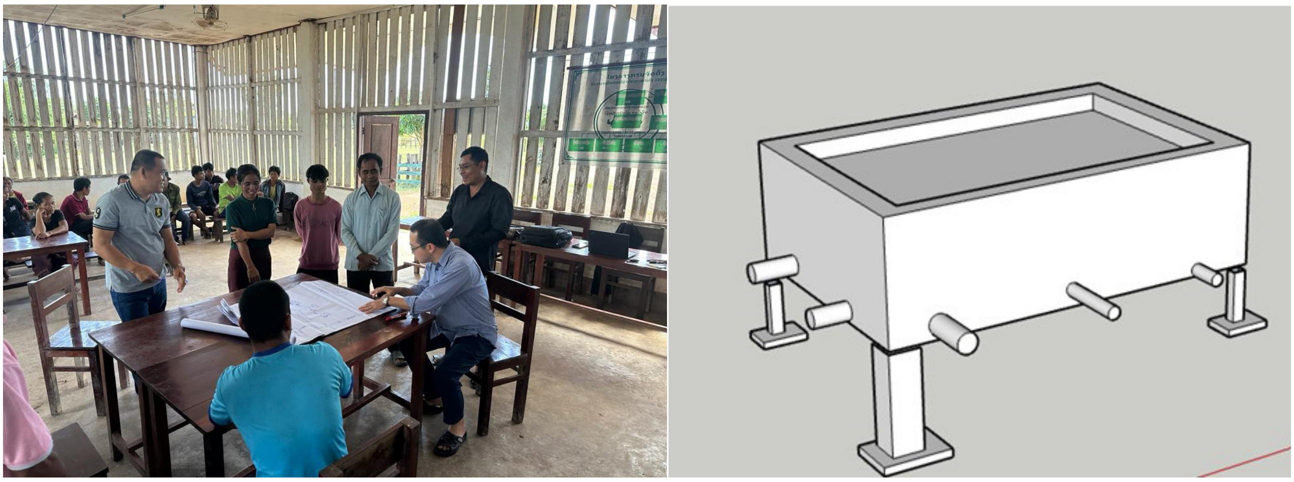

Figure 4. Photograph from the consultation and co-design process for solar-powered groundwater irrigation systems and water tanks. The sketch indicated on the right-hand side was created to help farmers and contractors visualize the concept during the later bidding stages. This activity took place in May 2023 at Donephay Village.
Photo credit: Ammala Chanthalath-IWMI

2.4 Recruitment and Bidding for Construction

Following the hydrogeological assessment, our research team entered into discussions with a selection of drilling contractors or companies operating groundwater development in the local area. These discussions aimed to gather detailed information about their company profiles, equipment capabilities, drilling techniques, and previous successful solar irrigation projects. Additionally, we sought to understand their local knowledge of hydrogeology, and likely supply potential, which is important factor for the design phrase. This informal interaction allowed us to evaluate their expertise and capacity before inviting them to participate in the bidding process.

After that, we prepared a simple Bill of Quantities (BOQ) for the construction work, along with a conceptual model of the solar-powered groundwater pumping system. This documentation was then distributed to the potential drilling contractors for their cost estimation.

Finally, we evaluated the submitted bids from three contractors in total, considering key factors such as cost, contractor experience, and technical capability. Based on this assessment, we selected one out of three with the most suitable conditions and successfully negotiated and finalized the contract to construct the SPGI systems in all villages. This comprehensive approach ensured that we partnered with qualified contractors who could deliver high-quality work and align with our project timelines and budget.

3. Bore Well Construction Component

3.1 Well Drilling and Stratigraphic Logging

Bore wells were successfully drilled to a depth of 40 m in the four selected villages, each with a 100 mm inner diameter. The drilling process employed a combination of rotary drilling and compacting vibration methods with air lifting, which is effective for penetrating various types of unconsolidated to semi-consolidated geological formations. The well was cased with PVC pipes from the surface down to the red mudstone layer at approximately 6 m depth. From 6 to 40 m depth, the borehole is open (uncased), without PVP pipe with slots or a screened interval. Most drilled wells in this area are constructed as opened bores once they penetrate the consolidated of Sedimentary (Mesozoic) formation, which is mostly dominated by conglomerate, medium-bedded sandstone, dark-red sandstone and siltstone (Viossanges et al. 2018). This casing not only provides structural support but also helps prevent contamination of the groundwater. Throughout the drilling process, geological samples were collected every 2 meters, allowing for a comprehensive analysis of the subsurface material formation.

We compiled detailed geological description, which are presented in a table format that includes a detail stratigraphic log. This log provides information including depth, casing specification, airlift yield, and static water levels. A visual representation of this data is provided in Figure 5, which illustrates the stratigraphic profile and highlights the geological characteristics that we found during the drilling process. This log not only enhances our understanding of the local geology but also helps to size the right pump to ensure pumping is efficient and sustainable.

3.2 Borewell Productivity and Solar Pump Discharge

Borewell productivity was also measured using the airlift test method during the drilling process. The airlift practice is typically designed to helps remove fine sediments, cuttings, debris from the borehole during the well drilling to ensure water pumped is clean. Additionally, the airlift test is also a practical and efficient method to estimate borewell productivity by measuring the rate of groundwater flows into the well, typically expressed in liters per second (L/s). Understanding this flow rate is essential for designing pumping systems, ensuring a long-term water supply, and well potential yield. Our measurement, conducted during the drilling, found that the average airlift yields ranged from1.8 L/s for Hom to 4.6 L/s for Inthee. Yields for Tamaleuy and Donephay were 4.2 L/s and 4.1 L/s, respectively. A detailed breakdown of yields by depth is given in Table 3.

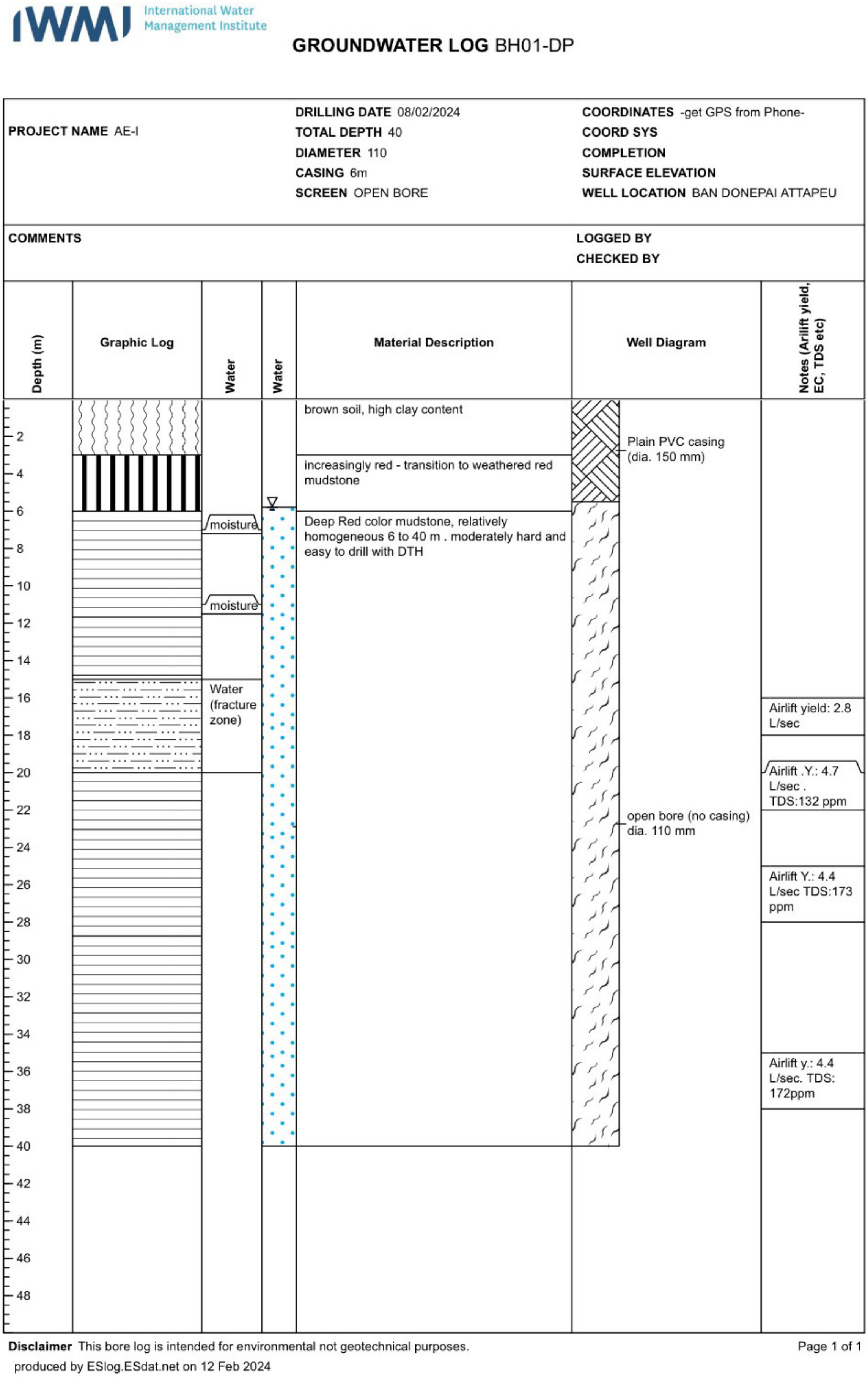

Figure 5. Stratigraphic log of a bore well of Donephay Village

Table 3. Summary of airlift test during the well drilling

Site	At depth (m)		Airlift yield		Average yield
		liter(L)	second(s)	L/s	L/s
Tamaleuy	18	18	6	3.0	4.2
	22	18	4	4.5	
	32	20	4	5.0	
Donephay	15	20	7	2.9	4.1
	20	20	4.5	4.4	
	37	20	4	5.0	
Hom	35	10	11	0.9	1.8
	38	10	5	2.0	
	40	10	4	2.5	
Inthee	24	18	4	4.5	4.6
	34	18	3.8	4.7	

Once drilling and water tank construction were completed, solar panels and water pump were installed. Each of the SPGI systems includes two solar panels with a total capacity of 1,080W (2 x 540W) and a 600W submersible solar water pump. An automatic water level controller was also installed to regulate the pump's operation. The pump's discharge rate varies depending on solar radiation levels. During the field measurements conducted in October 2024 at 10:14 AM, the pump delivered 0.65 L/s. Based on more detailed measurements of discharge rates from a SGPI site in nearby Phouvong district by Pavelic et al., (in prep.), readings at this time of day were higher than the daily average. Hence a more conservative value of 0.45 L/s is applied as the daily average. At this rate, the system could extract approximately 15 m³/day, assuming 9 hours of daily operation. The system's delivery rate of 15 m³/day appear to be sufficient to meet domestic water requirement among the water users. For instance, in Inthee village, the water user group consists of nine households, each household estimates their usage at up to three water containers (150 liters per container), which is approximately 450 liters per household, giving an approximate figure of 4.1 m³/day for the entire group, while the remaining water 10.9 m³/day is expected to be allocated for crop irrigation.

3.3 Water Quality

Electrical Conductivity (EC) was measured on-site during the drilling process to ensure that the EC remained within acceptable levels as the well depth increased. As the drilling progressed deeper, it was crucial to ensure that the EC did not exceed the acceptable standard. If the EC value increased during drilling, we needed to stop drilling at the certain depth of the bore well. The EC values of the four bore wells are acceptable, ranging from 400 to 940 microsiemens per centimeter (μS/cm). These values are below the acceptable standard level set by the Department of Environmental Health and Rural Water Supply of Attapeu Province, which is 1,200 μS/cm.

Moreover, water samples were taken for further analysis in the water quality laboratory to ensure that the water was free from arsenic and safe for human consumption and agriculture. The water quality parameters tested included E. coli, arsenic (As), residual chlorine (Cl2), fluoride (F), iron (Fe), manganese (Mn), nitrate (NO3), nitrite (NO2), color, pH, conductivity, turbidity, and hardness (CaCO3). The groundwater quality test results are presented in Figure 6, which illustrates all parameters and their compliance with acceptable standard levels defied by the Department of Environmental Health and Rural Water Supply of Attapeu Province. For reference, scanned copies of the original water quality analysis reports from the laboratory are provided in the Appendix.

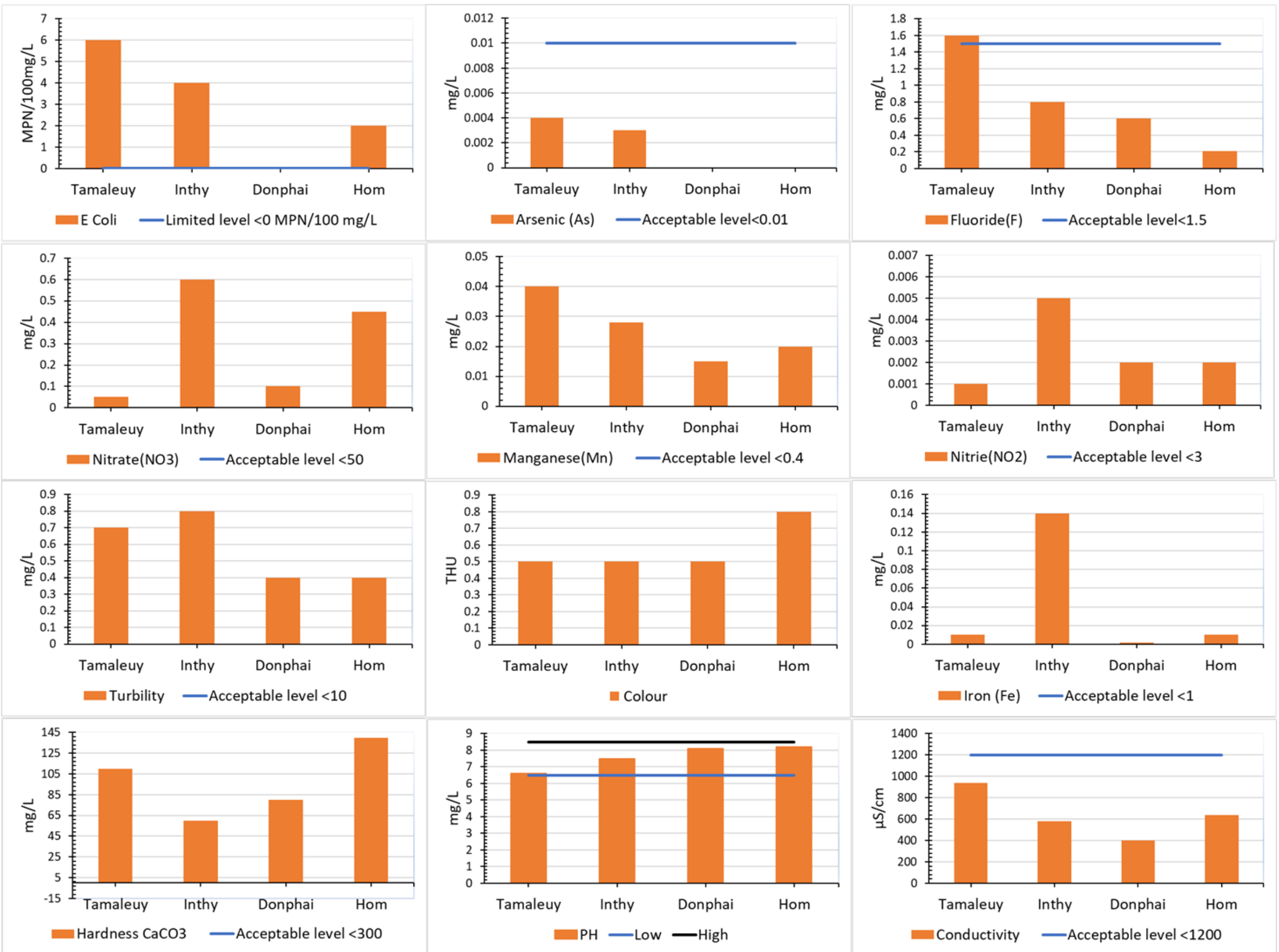

Figure 6. Groundwater quality at the four SGPI sites compared to the acceptable levels set by the Department of Environmental Health and Rural Water Supply of Attapeu Province

4. Cost Benefit Analysis Framework

4.1 Cost Elements

4.1.1 Capital costs for solar-powered groundwater irrigation systems

The total cost of setting up the solar groundwater irrigation system for each site was 76,809,600 Lao Kip (LAK), equivalent to approximately USD 3,600 (based on the exchange rate at the time of investment). This investment cost covered materials, labour cost for construction, the installation of key components, including solar panels, submersible pumps, PVC pipes, water gates, automatic floating water level switches, and other associated infrastructure to enable groundwater extraction for domestic and agricultural use. Additionally, this investment cost also included a one-year warranty on equipment and infrastructure systems to ensure reliability after the completion of the construction.

4.1.2 Additional costs contributed by farmers

Inthee: In addition to the facilities provided by the project, the nine-member group contributed their own resources to support the trial. They collectively funded the purchase of additional water PVC pipes to deliver water to their home/fields, a water hose, and a bucket with a shower, costing 2,500,000 LAK (USD 115). Furthermore, they invested in wood planks, wooden poles, nails, and gasoline (for tractor transportation) to construct protective fencing around the crop areas, which amounted to 1,713,000 LAK (USD 79). In total, the group's supplementary financial contribution reached 4,213,000 LAK (USD 194). Moreover, the farmer group also invested in additional vegetables seeds beyond those provided by the project. A detailed breakdown is presented in the Table 4.

Table 4. The investment costs for vegetables seeds contributed by farmers and project

Vegetable seeds	Providers	Cost for seeds(kips)	Site of Inthee
Chilli	project	90,000 (USD 4)	
Herbs (Coriander, green onion, mint)	Project	120,000 (USD 5.5)	
Morning glory (1kg)	Project	80,000 (USD 3.7)	
Asian spinach	project	90,000 (USD 4)	
Chinese mustard greens	project	90,000 (USD 4)	
Bok choy	project	90,000 (USD 4)	
Salad	Farmers		
Watermelon	farmers	850,000 (USD 39)	
Long green bean	farmers	No data	
Cucumber	farmers	No data	

Donephay: The group consists of twenty-five members. Together, they contributed funds to construct a concrete slab on the ground directly beneath the water tank. This will level the ground, providing a stronger and more stable foundation for the infrastructure. It will also keep the area clean and usable for everyone who comes to use the facility for bathing, collecting water, and washing clothes.

Each member contributed 50,000 LAK (USD 2.3), totaling 1,250,000 LAK, (USD 57.4) to purchase construction materials such as cement, gravel, sand, wooden planks, and nails. They did not have to pay for labor costs since they completed the work themselves. Additionally, they built a bamboo ladder for climbing up to the tank for periodic cleaning and maintenance.

Hom and Tamaleuy: The farmers at these two villages made minimal additional investments, primarily utilizing the existing facility provided by the project. They recycled used water pipes from a banana plantation, installing them to channel water from the tank to their watermelon plots. This reuse of materials helped reduce production costs.

4.1.3 Monitoring and maintenance costs

Groundwater Monitoring: Groundwater levels are monitored automatically using sensors fitted with data loggers installed in the pumping borewells. Data is recorded hourly, starting from the beginning of the borewell's construction.

Maintenance (Water Tank & Solar Panel): Routine maintenance of the water tanks and solar panels is conducted every two weeks, or as needed, depending on the level of dirt and dust accumulation. While all group members share responsibility for cleaning, this task is most frequently handled by the head of the water user group and members who frequently use the water. Currently, there is no major costs for the cleaning work, as water user group members utilize locally available cleaning equipment, such as brushes, brooms, rags, and cleaning solution to remove algae, tree leaves, and dust from the water tanks and solar panels.

Record-Keeping & Financial Management

A logbook is maintained to document all activities related to vegetables growing, harvesting, and sales. Each water user group (WUG) has been assigned specific roles and responsibilities to manage these tasks. For instance, Mrs. Buasouk, the financial manager of the Inthee WUG, is responsible for the record-keeping process.

As agreed during the WUG's establishment meeting, each member contributes 10,000 kip per month (USD 0.5) to generate a collective fund for the WUG. However, if any additional costs arise, such as for maintenance or spare parts exceeding the available fund, the group will discuss and collectively decide on a fair-cost sharing arrangement to pay for these expenses.

4.2 Benefit Elements

4.2.1 Household access to SPGI system for both domestic and irrigation use

Inthee: A total of nine households collectively utilizes the solar-powered groundwater facility for vegetable cultivation and crop irrigation; however, only three households among the nine currently use this system for daily domestic uses. Those households access groundwater through PVC pipes connected from their homes to the solar-powered storage tank, with each household consuming approximately 3-4 water containers daily (150-liters container, totaling around 600 liters). The remaining households rely on alternative water sources, including privately drilled wells, and the community groundwater supply. Those who use water from the community groundwater supply have to pay a monthly water fee, which is usually around 30,000 kips (USD 1.4) per household.

Crops are irrigated once daily during the late afternoon using different methods according to crop type. Vegetables and herbs receive irrigation through buckets fitted with a shower rose attachment, while watermelons are watered directly using hoses. The irrigation system requires 7-8 buckets of water (5 liters each) per plot, with 35 plots currently under cultivation. This translates to approximately 1,400 liters of water used daily (5 L × 8 buckets × 35 plots) for vegetable and herb irrigation only, excluding watermelon irrigation.

Donephay: Approximately 25 households regularly use the SPGI system for domestic purposes. Rather than installing water pipes to their homes, they typically come to the facility to take a wash, do laundry, and collect water in containers to carry homes. Additionally, non-members occasionally come to fetch water as well, using two-wheeled tractors equipped with containers.

Households roughly estimated their daily water consumption at about 144 liters (6 trips carrying two 12-liter buckets), which includes cooking and washing dishes, while bathing and laundry activities are performed on-site of the facility.

At present, one household (Mrs. Chai) has established a small vegetable home garden approximately 100 meters away from the water tank. She grows small plots of cucumbers, vegetables, and herbs for household consumption, using groundwater from the system.

Hom and Tamaleuy

In Hom, six farmers access groundwater from this site for watermelon cultivation to some extent during the beginning stage, as well as to supplement irrigation during rice bed seedling preparations. According to farmer reports, watermelon plants require minimal irrigation during their establishment stage. One farmer described her irrigation method using a bucket attached with a shower, estimating daily groundwater use at approximately 168 liters (14 buckets x 12 liters each) during seven-day period. This translates to a total water consumption of 1,176 liters per cultivation cycle for the early growth stage alone. After that farmers switch to using surface water from the wetland for full irrigation until harvest.

Similar to Hom, the groundwater facility in Tamaleuy currently supports just one farmer for agricultural purposes. This farmer utilizes the groundwater primarily during watermelon's critical initial growth stage. Additionally, the water serves as a supplementary irrigation supply for rainfed rice cultivation during the periods of insufficient rainfall.

4.2.3 Economic benefits

The farmer group in Inthee has demonstrated greater economic benefits from utilizing the solar groundwater facility compared to the other sites. These farmers have exhibited strong potential for collective vegetables growing, producing both for household consumption and sale to generate extra incomes. During their first cropping year, they successfully managed to cultivate various crops across a total land area of 3,236 sqm, with 903 sqm (21.5m by 42m) dedicated to vegetable growing, and the remaining 2,333 sqm for watermelons. Figure 7 shows an aerial view of cropland with the solar groundwater facility, where a group of farmers collectively grow divers vegetables and crash crops.

Figure 7. Aerial view of cropland for vegetables utilizing solar-powered groundwater irrigation in Inthee, photographed during the field interview in March 2025. Photo credit: Somphasith Douangsavanh-IWMI

4.2.4 Crop yields, household consumption, and sales at Inthee village

Most vegetable production was primarily for household consumption, and the group sell any surplus to others villagers. Accurately measuring the absolute weight of each type of vegetable was challenging, as they traditionally recorded crop yields in kilograms only for certain crops like cucumbers and long green beans. However, other type of vegetables and herbs were not weighed, as farmers typically sold them in small bunches on a regular basis, depending on what customers demand and villagers wanting to buy. Instead, they recorded the total number of bunches sold and the accumulated amount of revenue that they made. For a detailed breakdown, please refer to Table 5.

Farmers also confirmed that the proportion of vegetables consumed by their households, which could not be precisely recorded, was far greater than the documented sales. The first year's crop production relatively reduced household expenditure on markets compared to the previous years. Based on the total first-year sales of 9,378,000 kips, it would take approximately 7-8 years to repay the 3,500 USD investment in solar-powered groundwater construction. This estimation grossly underestimates the total benefits of the system as detailed in the sections below.

Table 5. A detailed breakdown of crop production, including capital costs, yields, and sales at Inthee village

Vegetable seeds	Providers	Cost for seeds (kips)	Total yield (kg)	Sale (kg)	Total sales in kips and (USD)	HH consumption (kg)	plots	notes
Chilli	project	90,000					1	
Herbs (Coriander, green onion, mint)	project	120,000			267,000 (USD 12.3)		2	The proportion of HH consumption was larger than sales
Morning glory(1kg)	project	80,000					2	Most vegetables were for HH consumption, helping to cut down market expenditure a lot.
Asian spinach	project	90,000			802,000 (USD 36.8)		2	
Chinese mustard greens	project	90,000					1	
Bok choy	project	90,000					1	
Salad	farmers	50,000					4	
Watermelon	farmers	850,000			4,969,000 (USD 228.3)			Approximately 50% of the total seeds were used
Long green bean	farmers	70,000	37	17*20,000	340,000 (USD 15.6)	20	8	
Cucumber	farmers	95,000	250	200*15,000	3,000,000 (USD 137.8)	50	9	
Total sum of costs and sales		1,625,000			9,378,000 (USD 430.8)			Animal manure was excluded from the cost, as they were sourced locally.

4.2.5 Social and living quality improvement

In **Inthee**, vegetable production has increased significantly compared to previous years. Mrs. Buasouk, one of WUG shared her thought during group discussion *"Before, we only grew small amounts of herbs in a small home garden due to limited crop land areas. But now, thanks to our new solar-powered water system and bigger community farms, we are growing so much more for household consumption and we even produce surplus for sales; this could supplement household incomes. It made a huge difference in vegetables growing in Inthee village".* This development has also been particularly beneficial for the WUG as the system operate without electricity costs, cutting down the overall cultivation costs.

Additionally, non-members of the WUG in the village also benefit from this initiative through production sharing, exchanges, and the ability to buy vegetables at reasonable prices locally, reducing the need to travel to the markets. Households are consuming more home-grown produce, leading to more nutritious diets. If the money saved from not buying this food at the market, the payback period could potentially be reduced.

In Donephay: The SPGI provided by the project has significantly reduced the heavy workload for women and children in fetching water for their families. Previously, community members had to travel long distances to fetch water, particularly during the dry season when they went to the foothills to find spring water. The new system has eliminated this labor-intensive practice, saving time and effort in daily water collection.

The facility has also particularly benefited elderly residents, for instance, *Mr. Bounlum, who recently has had difficulty walking due to a knee injury. He expressed his heartfelt gratitude for the community water tank and facility, which is now easy to get water whenever he needs it throughout day and night.* This infrastructure improvement has not only solved critical dry season water shortage but has also enhanced overall living quality by ensuring consistent water availability for drinking, bathing, and other domestic needs.

In Hom and Tamaleuy: This system offers significant benefits to the community by operating without any electricity costs. Since the facilities are located directly in the agricultural fields, they provide easy access to water for supplemental irrigation, particularly for watermelon growing during the seedling stage. Additionally, the system supplies clean water for personal hygiene, cleaning, and other on-site needs such as washing, food preparation, and bathing.

4.2.6 Genders impacts

Farmers have observed that using solar-powered groundwater for vegetable irrigation has been particularly beneficial for women. During a field interview, Mrs. Chansone Deaninthee shared how SPGI impacts on her village of Inthee. *"Farmers here, especially women are seeing big benefits from using the systems for vegetable growing. Women can earn extra money by farming closer to homes; they don't need to travel far for work. They can manage gardens while handling households' chores and caring for their children".* She also added *"Because the vegetables gardens are right near our houses, even our children can help after school".* This SPGI creates more work opportunities and responsibilities for women and children, as the vegetable plots are close to their homes, they can assist their parents after school such as watering, weeding, harvesting, and cleaning the water tank. It also gives children meaningful tasks that contribute to the family's livelihood, keeping them engaged in productive activities rather than spending their time on unproductive activities.

Moreover, the SPGI system has significantly reduced the heavy workload for women and children in fetching water for their families. *For instance, in Donephay village, during the critical dry season, they no longer have to walk long distances between 600 - 1,700 m to reach the foothill where spring water was still running, as they did before. And they would have to wait in long line, fill their containers, and carry back homes that often took 1 to 2 hours each trip.* Now, with the SPGI system, they save both time and energy. This improvement also helps elderly villagers who struggle with walking long distances.

4.3 Environmental Benefits

4.3.1 Groundwater monitoring systems

All of the SGPI systems have been equipped with groundwater level monitoring systems. The primary purpose of this equipment is to collect accurate long-term data on how the aquifer responds to the system's operations. The data gathered helps to establish baseline groundwater levels before and after the project operations, and to inform management decisions. This data was critical for assessing the system's impact on local hydrology over time. Figure 8 shows a photo of installation, schematic of data logger setting, and a hydrograph of water levels fluctuation. By analyzing long-term trends, stakeholders can make informed decisions to balance water extraction with natural recharge rates. Moreover, we can properly analyze and summarize each site showing key metrics: the highest and lowest groundwater level, the average operating hours per season (wet and dry), and the total estimated water pumped.

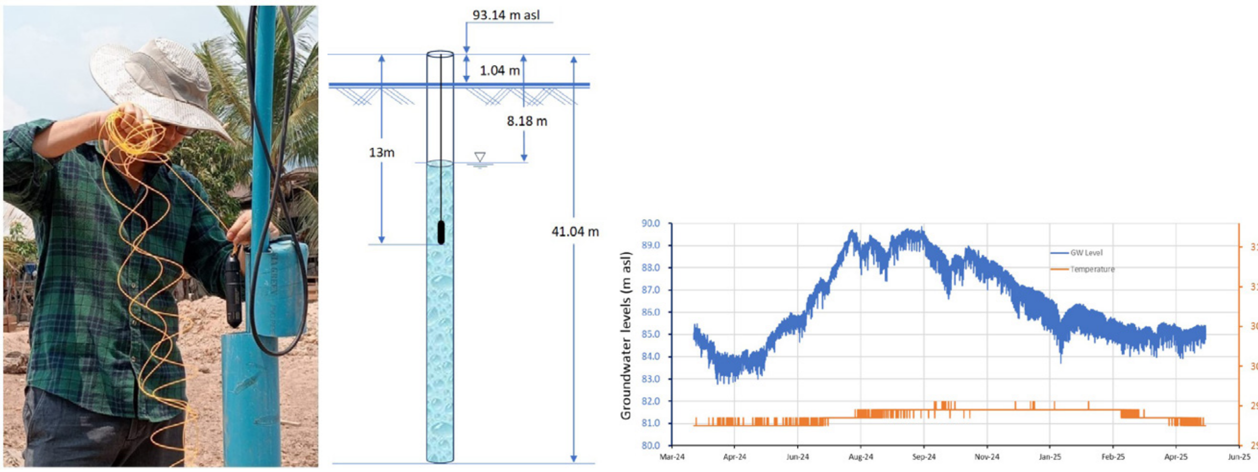

Figure 8. Groundwater levels monitoring in the pumping well in Inthee village. Photo credit: Viengxay Xaydala-IWMI

4.3.2 Connectivity between wetland and surround groundwater systems

In addition to monitoring groundwater levels at the SPGI sites, a broad-scale comprehensive hydrological survey was conducted in March 2024 to assess the hydrological dynamics and interactions between the groundwater and the wetland systems at the site and broader landscape scale. Surface water levels were measured at the main river of Xekong, the wetland (Nong Lom) and groundwater levels were measured from the existing drilled wells, using a Real-Time Kinematic GPS instrument (RTK-GPS).

Figure 9 illustrates the comparative water levels of wetland and hydraulic head of surrounding groundwater. Groundwater head contours were generated using observed groundwater levels by applying diffusion interpolation with barriers techniques in ArcMap. These results suggest that, the wetland is a "window" to the groundwater system. During the dry season the groundwater head at three drilled wells in the vicinity of the wetland (84.36, 87.86, 88.6, 84.91 masl) was slightly lower than wetland surface water level (91.3 masl), potentially due to local pumping effects. However, continued water level monitoring across different seasons is required to clearly confirm if the wetland is in a losing or gaining condition. This finding is an important piece of information for the wetland management committee to optimize water abstraction strategies and ensure sustainable water use. The wetland experienced its extremely lowest water level and dried up in 2009. Later, a concreate dyke about 1 meter high, was constructed to increase the wetland water storage capacity.

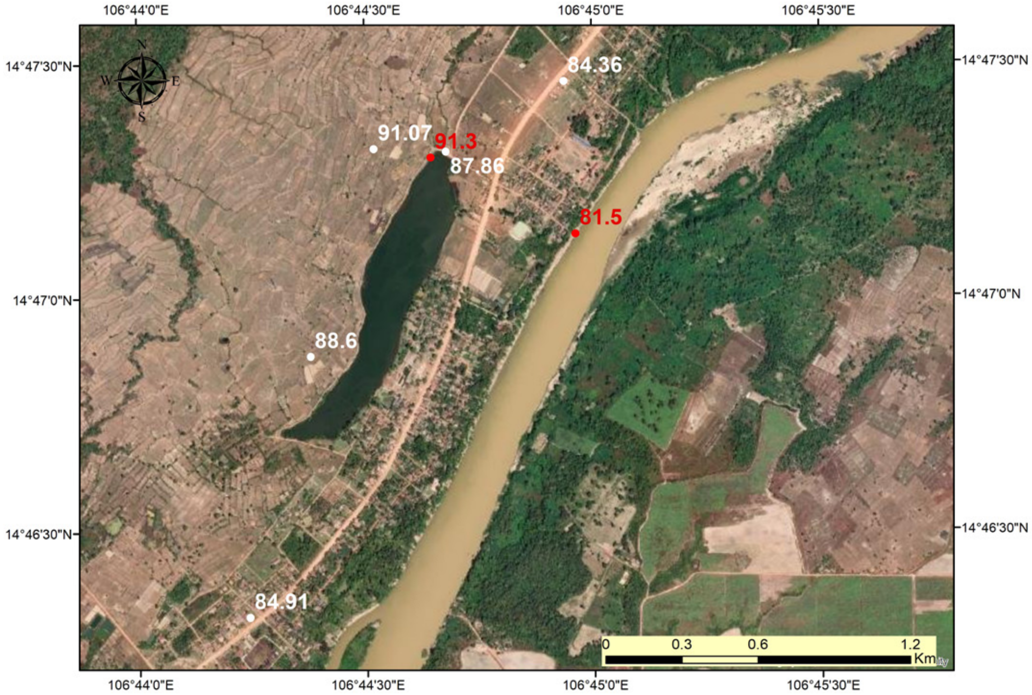

Figure 9. A comparison between groundwater heads measured in drilled wells highlighted in white dots and with absolute values and the absolute surface water elevations in red (March 2024). Source of image: modified and adapted from Esri, and Earthstar Geographics.

In addition to assessing hydrological connectivity within the wetland area, our analysis extended to the broader agroecological living landscape during the dry season (March 2024). Figure 10 presents a comparative analysis of surface elevation and groundwater hydraulic heads across this larger area. The interpolated groundwater head contours show two key finding: (1) the regional groundwater flow patterns, and (2) the interaction dynamics between surface water and subsurface water systems at a landscape scale.

The results clearly show that groundwater flows topographic gradients, flowing from the areas of higher hydraulic heads in the northwest and eastern hills toward the lower elevation of Xekong River. This flow direction aligns with the region's natural topography and provides important insights into the basin-scale water balance, as well as water movement connecting to different ecosystems across the landscape.

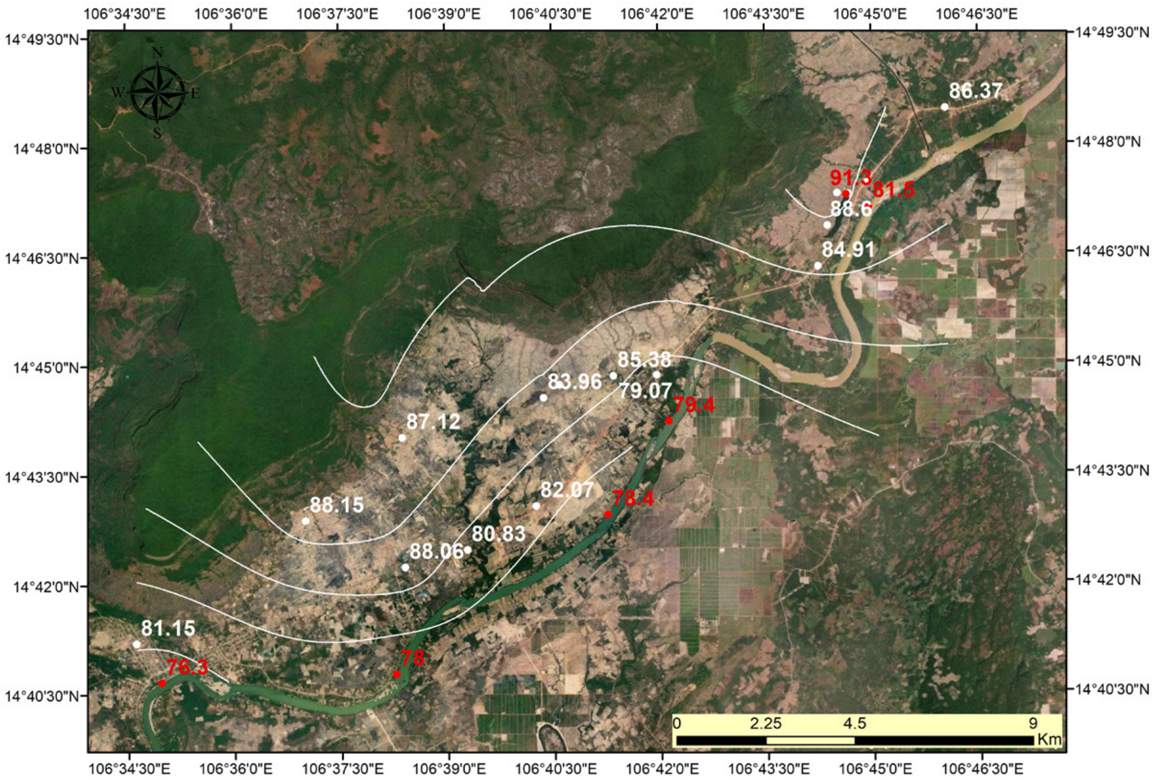

Figure 10. Interpolated groundwater contours and surface water elevations illustrating general dynamic groundwater flow pattern in the study area (March 2024). Groundwater heads are indicated with white dots with their contours, and water surface elevations are highlighted in red. Source of image: modified and adapted from Esri, and Earthstar Geographics.

4.3.3 Climate resilience

The SPGI systems utilizes green and renewable energy to enhance climate resilience of local communities. This intervention helps address climate variability by supporting rainfed agriculture during drought period. Through a trial with solar-powered irrigation, farmers have gained reliable access to groundwater for both domestic use and agricultural production. Additionally, the adoption of more diverse paddy rice with other crops further strengthened agricultural sustainability, reducing dependency on single-crop systems. By integrating renewable energy with adaptive farming practices, this intervention supports long-term environmental and economic benefits.

4.3.4 Sustainable groundwater management through water user groups

The project established groundwater user groups in the sites with clearly defined management rules and operational principles. These groups were formed through inclusive participatory processes that considered gender balance and ethnic representation. Local participants agreed to form these user groups with two primary objectives: (1) to maintain the water facilities and (2) to ensure sustainable groundwater use. This community-led approach serves as an important mechanism for preventing potential conflicts that could arise from long-term groundwater utilization in the area.

4.4 Policy Engagement

The outcomes of this innovation were presented and discussed at the annual stakeholder forum of the Sub-sector Working Group on Irrigation (SSWG-IR) organized by the Department of Irrigation (DOI) under the Ministry of Agriculture and Forestry (MAF), with financial support from the Asian Development Bank (ADB) through the International Water Management Institute (IWMI). The forum provided a key platform for policy dialogue. The intervention highlighted the co-design process of small-scale solar-powered irrigation systems, emphasizing full participation from both communities and authorities to optimize water use efficiency. This engagement also showed the potential for scaling up community managed renewable energy-based irrigation solutions as part of national climate-resilient agriculture strategies.

5. Conclusions

The innovations related to farmer-managed solar-powered groundwater irrigation (SPGI) have been tested in the agroecological living landscape (ALL) of Attapeu province for one year and monitoring remains ongoing. SPGI was shown to provide socioeconomic and environmental benefits in the following areas: (1) environmental: the systems overcome climate variability, supporting rainfed agriculture during dry spells and droughts; (2) social: reliable water access improved domestic use and irrigation, reducing the burden on women and strengthening community governance; (3) economic and nutritional: solar-powered systems eliminated electricity costs, providing a cost-effective solution. Year-round vegetable farming enhanced food security and financial stability; (4) sustainable water resources management: the establishment of the water user groups, along with regulation rules and principles management frameworks, monitoring systems, and hydrological dynamic assessments, improved water resources management in the wetland area and broader landscape.

Moreover, non-water user group members, specifically farmers and extension workers involved with the ALL in Attapeu province, have significantly strengthened their capacities to drive agroecology transitions. This outcome was achieved in collaboration with the Initiative on National Policies (NPS), which facilitated learning visits for senior officials from the Ministry of Agriculture and Forestry (MAF) and National Policy Think Tank Network. Through research, training, workshops and visits, farmers and extension staff from the District Agriculture and Forestry Office (DAFO) and Provincial Agriculture and Forestry Office (PAFO) deepened their understanding of agroecological practices.

While these interim findings are valuable, this report also highlights critical areas that are not yet fully understood and will be the focus of the next phase of research. They can be expressed as the following questions:

- Why do farmers at Hom and Tamaleuy villages switch from solar-powered groundwater irrigation to surface water from the wetland, even though the costs are higher? In order to improve the solar-powered groundwater irrigation in these villages we need to understand their motivation and perceptions and whether they over-irrigating compared to the actual crop requirement?
- How much watermelon can be produced with the SGPI system if farmers irrigate in an efficient manner?
- What is contribution of groundwater to the wetland? A full water balance is required to understand this, and we need to collect data from both the wet and dry seasons.
- What is the economic comparison of alternative water sources? An analysis of the costs and benefits of surface water and groundwater sources is missing.

6. Recommendations

In Inthee, the collective farming system has shown good results with intercropping methods. To further improve farming outcomes, two important changes could be made: (1) Try different cash crops: farmers could grow long green beans or cucumbers to reduce water demand and lead to better prices. These crops already showed good sales in the first year of testing; (2) Combine rice-fish culture: farmers could create trenches lined with plastic sheets and use groundwater to raise fish. This system would allow year-round fish production, and natural fertilizer for crops from the fish pools.

In addition to addressing domestic water issues in Donephay, and since the SPGI system is right near to the community, it is highly potential to adopt agricultural practices from the Inthee village. These include integrated community vegetables farming with rice-fish pond. Through collaborative discussions with the WUG, members have expressed agreement and support the ideas to advance this initiative.

In Hom and Tamaleuy, farmers use groundwater only at the beginning stage of the watermelon growing stage. Later, they switch to surface water from wetland for full irrigation until harvest. This is because farmers can access a larger amount of water and save time on irrigation, even though they still have to pay for gasoline to run the water pumps. Two possible solutions could be recommended such as improving irrigation planning through a WUG-managed schedule, or farmers choosing to grow different cash crops that need less water

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Appendix. Water Quality Analysis Reports.

ແບບຟອມການສຳຫລວດຄຸນນະພາບນ້ຳ

ແຂວງ/ Province name .ອັດຕະປື ,ເມືອງ/District. ສະໜາມໄຊ. ບ້ານ/ Village. ດອນໄຜ່, ວັນເດືອນ,ປີ.ກວດນ້ຳ/ Month 12 / 02 / 2024

ລະດູການ Season

ຝົນ Rain [ ] ແລ້ງ Dry [√]

ວິທີທົດລອງ Test Metnod

ພາກສະໜາມ Field [ ] ຫ້ອງການ office [✓]

ຊື່ທາດ	ຂອບເຂດອານຸຍາດ	ຜົນກວດ	ຊື່ທາດ	ຂອບເຂດອານຸຍາດ	ຜົນກວດ
ອີໂຄລາຍ (E Coli ຫຼື ເຊື້ອພະຍາດທີ່ຕິດຕໍ່ຈາກອາຈົມ)	< 10 /100 mg/L)	0	ໄນໄຕຼNitrie (NO_2)	<3 (mg/L)	0.002
ອາເຊນິກ Arsenic (As)	< 0.01(mg/L)	0	ສີ Colour TCU	ເປັນທີ່ຍອມຮັບ	0.5
ກຼໍລີນ Residual Chlorine (Cl2)ສານກຼໍລີນຕົກຄ້າງ)	0.1-2 mg/L)	0	PH	6,5 – 8,5	8.1
ຟູໂອໄຣFluoride (F)	<1,5 (mg/L)	0.60	Conductivity	<1.200 (Us/cm)	400
ເຫຼັກIron (Fe)	<1 (mg/L)	0.002	Turbidity	< 10 NTU	0.4
ມັງການີສ Manganese (Mn)	<0,4 (mg/L)	0.015	ຄວາມກະດ້າງຂອງນ້ຳHardness $CaCO_3$	< 300 (mg/L)	80
ໄນເຕຣດNitrate (NO_3)	<50 (mg/L)	0.10			

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Year of well construction:Name ot well user

- ຄວາມເລິກຂອງສ້າງ (Depth) [ ] ລະດັບນ້ຳເບີບໍ່ນ້ຳ [ ] ອັດຕາການໄຫຼຂອງນ້ຳ/ຊົ່ວໂມງ [ ]
- **ຜ່ານການກວດກາ** ໃນຈຳນວນ 13ທາດ: ເຫັນວ່າຢູ່ໃນມາດຕະຖານທີ່ກະຊວງສາທາລະນະສຸກວາງອອກ.

Hereby I certify to have followed the sampling instiuctions as outlined in th Water Sample Protocol.

ອະນຸຍາດໃຫ້ນຳໃຊ້ [✓] ບໍ່ອະນຸຍາດໃຫ້ນຳໃຊ້ [ ]

ຄຳແນະນຳຕ່າງໆ:ນຳໃຊ້ໄດ້

ວັນທີ: Date...13/2/2024

ຢັ້ງຢືນໂດຍ

ຜູ້ຮັບຜິດຊອບວຽກງານ ນ້ຳສະອາດແລະ ອະນາໄມສິ່ງແວດລ້ອມແຂວງ

ພົມມາ ຄູນສົມສິດ

Phomma KHOUNSOMSITH

ວັນທີ:/Date....13...2...2024

ວິຊາການຜູ້ວິໄຈ

ແບບຟອມການສຳຫລວດຄຸນນະພາບນ້ຳ

ແຂວງ/ Province name .ອັດຕະປື ,ເມືອງ/District. ສາມັກຄີໄຊ. ບ້ານ/ Village ຕະມໍ່ເລີຍ . ວັນເດືອນ,ປີ.ກວດນ້ຳ/ Month 12 / 02 / 2024

ລະດູການ Season

ຝົນ Rain [ ] ແລ້ງ Dry [√]

ວິທີທົດລອງ Test Metnod

ພາກສະໜາມ Field [ ] ຫ້ອງການ office [✓]

ຊື່ທາດ	ຂອບເຂດອານຸຍາດ	ຜົນກວດ	ຊື່ທາດ	ຂອບເຂດອານຸຍາດ	ຜົນກວດ
ອີໂຄລາຍ (E Coli ຫຼື ເຊື້ອພະຍາດທີ່ຕິດຕໍ່ຈາກອາຈົມ)	< 10 /100 mg/L)	6	ໄນໄຕຼNitrie ($N0_2$)	<3 (mg/L)	0.001
ອາເຊນິກ Arsenic (As)	< 0.01(mg/L)	0.004	ສີ Colour TCU	ເປັນທີ່ຍອມຮັບ	0.5
ກຼໍລີນ Residual Chlorine (Cl2)ສານກຼໍລີນຕົກຄ້າງ)	0.1-2 mg/L)	0	PH	6,5 – 8,5	6.62
ຟູໂອໄຣFluoride (F)	<1,5 (mg/L)	1.60	Conductivity	<1.200 (Us/cm)	940
ເຫຼັກIron (Fe)	<1 (mg/L)	0.01	Turbidity	< 10 NTU	0.7
ມັງການີສ Manganese (Mn)	<0,4 (mg/L)	0.040	ຄວາມກະດ້າງຂອງນ້ຳHardness $CaCO_3$	< 300 (mg/L)	110
ໄນເຕດNitrate ($N0_3$)	<50 (mg/L)	0.05			

ແຫຼ່ງນ້ຳ: ບາດານ

supported wii

- ວັນ , ເດືອນ , ປີກໍ່ສ້າງ [ ] ຈຳນວນຄົນຊົມໃຊ້ເຈົ້າຂອງນ້ຳ/ທີ່ຕັ້ງບໍ່ນ້ຳ [ ] ເຈົ້າຂອງແຫຼ່ງນ້ຳ/ຕິດແປະຄົນ [ທ ກິແກ້ວ ນ ຂັນ]

Year of well construction:Name ot well user

- ຄວາມເລິກຂອງສ້າງ (Depth) [ ] ລະດັບນ້ຳເບີບໍ່ນ້ຳ [ ] ອັດຕາການໄຫຼຂອງນ້ຳ/ຊົ່ວໂມງ [ ]
- ຜ່ານການກວດກາ ໃນຈຳນວນ 13ທາດ: ເຫັນວ່າຢູ່ໃນມາດຖານທີ່ກະຊວງສາທາລະນະສຸກວາງອອກ.

Hereby I certify to have followed the sampling instiuctions as outlined in th Water Sample Protocol.

ອະນຸຍາດໃຫ້ນຳໃຊ້ [✓] ບໍ່ອະນຸຍາດໃຫ້ນຳໃຊ້ [ ]

ຄຳແນະນຳຕ່າງໆ:ນຳໃຊ້ໄດ້

ວັນທີ: Date...13/2/2024...... ວັນທີ:/Date..13....2.....2024

ຢັ້ງຢືນໂດຍ ວິຊາການຜູ້ວິໄຈ

ຜູ້ຮັບຜິດຊອບວຽກງານ ນ້ຳສະອາດແລະ ອະນາໄມສິ່ງແວດລ້ອມແຂວງ

ພົມມາ ຄູນສົມສິດ

Phomma KHOUNSOMSITH

ແບບຟອມການສຳຫລວດຄຸນນະພາບນ້ຳ

ແຂວງ/ Province name .ອັດຕະປື ,ເມືອງ/District. ສະໜາມໄຊ. ບ້ານ/ Village ອິນທີ . ວັນເດືອນ,ປີ.ກອດນ້ຳ/ Month 12 / 02 / 2024

ລະດູການ Season — ວິທີທົດລອງ Test Metnod

ຝົນ Rain [ ] ແລ້ງ Dry [✓] — ພາກສະໜາມ Field [ ] ຫ້ອງການ office [✓]

ຊື່ທາດ	ຂອບເຂດອານຸຍາດ	ຜົນກວດ	ຊື່ທາດ	ຂອບເຂດອານຸຍາດ	ຜົນກວດ
ອີໂຄລາຍ (E Coli ຫຼື ເຊື້ອພະຍາດທີ່ຕິດຕໍ່ຈາກອາຈົມ)	< 10 /100 mg/L)	4	ໄນໄຕຼNitric (NO_2)	<3 (mg/L)	0.005
ອາເຊນິກ Arsenic (As)	< 0.01(mg/L)	0.003	ສີ Colour TCU	ເປັນທີ່ຍອມຮັບ	0.5
ກຼໍລີນ Residual Chlorine (Cl2)ສານກຼໍລີນຕົກຄ້າງ)	0.1-2 mg/L)	0	PH	6,5 – 8,5	7.5
ຟູໂອໄຣFluoride (F)	<1,5 (mg/L)	0.80	Conductivity	<1.200 (Us/cm)	580
ເຫຼັກIron (Fe)	<1 (mg/L)	0.14	Turbidity	< 10 NTU	0.8
ມັງການີສ Manganese (Mn)	<0,4 (mg/L)	0.028	ຄວາມກະດ້າງຂອງນ້ຳHardness $CaCO_3$	< 300 (mg/L)	60
ໄນເຕດNitrate (NO_3)	<50 (mg/L)	0.60			

ແຫຼ່ງນ້ຳ: ບາດານ

supported wil

- ວັນ , ເດືອນ , ປີກໍ່ສ້າງ [ ] ຈຳນວນຄົນຊົມໃຊ້(ເຈົ້າຂອງນ້ຳ/ທີ່ຕັ້ງບໍ່ນ້ຳ [ ] ເຈົ້າຂອງແຫຼ່ງນ້ຳ/ຕົວແທນຄົນ [ນາງ ບັນທະໄລ]

  Year of well construction:Name ot well user
- ຄວາມເລິກຂອງສ້າງ (Depth) [ ] ລະດັບນ້ຳເປີບໍ່ນ້ຳ [ ] ອັດຕາການໄຫຼຂອງນ້ຳ/ຊົ່ວໂມງ [ ]
- ຜ່ານການກວດກາ ໃນຈຳນວນ 13ທາດ: ເຫັນວ່າຢູ່ໃນມາດຖານທີ່ກະຊວງສາທາລະນະສຸກວາງອອກ.

Hereby I certify to have followed the sampling instiuctions as outlined in th Water Sample Protocol.

ອະນຸຍາດໃຫ້ນຳໃຊ້ [✓] — ບໍ່ອະນຸຍາດໃຫ້ນຳໃຊ້ [ ]

ຄຳແນະນຳຕ່າງໆ:ນຳໃຊ້ໄດ້

ວັນທີ: Date....13/12/2024 — ວັນທີ:/Date..13..2..2024

ຢັ້ງຢືນໂດຍ — ວິຊາການຜູ້ວິໄຈ

ຜູ້ຮັບຜິດຊອບວຽກງານ ນ້ຳສະອາດແລະ ອະນາໄມສິ່ງແວດລ້ອມແຂວງ

ພົມມາ ຄູນສົມສິດ
Phomma KHOUNSOMSITH

ແບບຟອມການສຳຫລວດຄຸນນະພາບນ້ຳ

ແຂວງ/ Province name .ອັດຕະປື ,ເມືອງ/District. ສາມັກຄີໄຊ. ບ້ານ/ Village ຮົມ . ວັນເດືອນ,ປີ.ກວດນ້ຳ/ Month 12 / 02 / 2024

ລະດູການ Season — ຝົນ Rain [ ] ແລ້ງ Dry [√]

ວິທີທົດລອງ Test Metnod — ພາກສະໜາມ Field [ ] ຫ້ອງການ office [✓]

ຊື່ທາດ	ຂອບເຂດອານຸຍາດ	ຜົນກວດ	ຊື່ທາດ	ຂອບເຂດອານຸຍາດ	ຜົນກວດ
ອີໂຄລາຍ (E Coli ຫຼື ເຊື້ອພະຍາດທີ່ເກີດຈາກອາຈົມ)	< 10 /100 mg/L)	2	ໄນໄຕຼNitrie (NO_2)	<3 (mg/L)	0.002
ອາເຊນິກ Arsenic (As)	< 0.01(mg/L)	0	ສີ Colour TCU	ເປັນທີ່ຍອມຮັບ	0.8
ກຼໍລີນ Residual Chlorine (Cl2)ສານກຼໍລີນຕົກຄ້າງ)	0.1-2 mg/L)	0	PH	6,5 – 8,5	8.2
ຟູໂອໄຣFluoride (F)	<1,5 (mg/L)	0.21	Conductivity	<1.200 (Us/cm)	640
ເຫຼັກIron (Fe)	<1 (mg/L)	0.01	Turbidity	< 10 NTU	0.40
ມັງການີສ Manganese (Mn)	<0,4 (mg/L)	0.020	ຄວາມກະດ້າງຂອງນ້ຳHardness $CaCO_3$	< 300 (mg/L)	140
ໄນເຕດNitrate (NO_3)	<50 (mg/L)	0.45			

ແຫຼ່ງນ້ຳ: ບາດານ

supported wii

- ວັນ , ເດືອນ , ປີກໍ່ສ້າງ [ ] ຈຳນວນຄົນຊົມໃຊ້(ເຈົ້າຂອງນ້ຳ/ທີ່ຕັ້ງບໍ່ນ້ຳ [ ] ເຈົ້າຂອງແຫຼ່ງນ້ຳ/ຕິດແປະດິນ [ນາງ ທອງສີ]

  Year of well construction:Name ot well user
- ຄວາມເລິກຂອງສ້າງ (Depth) [ ] ລະດັບນ້ຳເບີບໍ່ນ້ຳ [ ] ອັດຕາການໄຫຼຂອງນ້ຳ/ຊົ່ວໂມງ [ ]
- ຜ່ານການກວດກາ ໃນຈຳນວນ 13ທາດ: ເຫັນວ່າຢູ່ໃນມາດຕະຖານທີ່ກະຊວງສາທາລະນະສຸກວາງອອກ.

Hereby I certify to have followed the sampling instiuctions as outlined in th Water Sample Protocol.

ອະນຸຍາດໃຫ້ນຳໃຊ້ [✓] ບໍ່ອະນຸຍາດໃຫ້ນຳໃຊ້ [ ]

ຄຳແນະນຳຕ່າງໆ:ນຳໃຊ້ໄດ້

ວັນທີ: Date 12 /2 /2024 — ວັນທີ:/Date 13 - 2 - 2024

ຢັ້ງຢືນໂດຍ — ວິຊາການຜູ້ວິໃຈ

ຜູ້ຮັບຜິດຊອບວຽກງານ ນ້ຳສະອາດແລະ ອະນາໄມສິ່ງແວດລ້ອມແຂວງ

ພົມມາ ຄູນສົມສິດ

Phomma KHOUNSOMSITH