SOLVING FOR WATER SECURITY IN A MICRO-WATERSHED

Modeling Environmental Sustainability of Community Drinking Water Solutions in India

Our Safe Water Stations are sustainable businesses that deliver reliable and affordable safe water. This Field Insight describes how Safe Water Network's Water Resource Management team in India measured the hydrologic footprint of multiple Stations in a micro-watershed to ensure that environmental requirements are also used to inform evaluation, site assessment, and the potential of Station operators and field staff to promote efficient water resource use.

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KEY INSIGHTS

- Sustainability of groundwater is threatened by agricultural overuse. A local water balance and education by Station managers can help change this.
- A Safe Water Station uses 0.03% of total water used in its village. Agriculture uses over 99%, indicating a need for improved efficiency.
- Aquifer use by a community-sized Station is a small fraction of natural groundwater recharge and of total village water use. Sustainable expanded Station operations are possible.
- Environmentally responsible disposal of wastewater is possible but requires control and regular monitoring.

Parched water bodies and rain-fed farming: a common scenario in Telangana

A Hydrologic Footprint Covers Sustainability, Use, and Disposal

Across rural India, there is a massive and growing need for reliable, affordable, and safe drinking water. Safe Water Network has established 88 off-grid commercial Stations in Telangana State to create sustainable and scalable operations that begin to meet this need. These Stations treat water to national quality standards using reverse osmosis (RO) technology to remove contaminants such as fluoride, nitrate, and dissolved solids, and provide access to more than 350,000 people.

Each Station impacts its environment by using groundwater and controlling wastewater disposal. To understand these impacts, our Water Resource Management Team developed a model of the water balance in a watershed containing Stations. Data and villager knowledge were used in the model to calculate the hydrologic footprint of three Stations in the watershed using three criteria:

Water Sustainability: Comparing total inputs and extractions and calculating groundwater use as a percentage of natural recharge from rainfall to determine long-term source sustainability.

Water Use: Quantifying Station use as a percentage of the total community water use to clarify accountability.

Wastewater Disposal: Comparing wastewater quality to discharge regulations to ensure compliant and safe disposal.

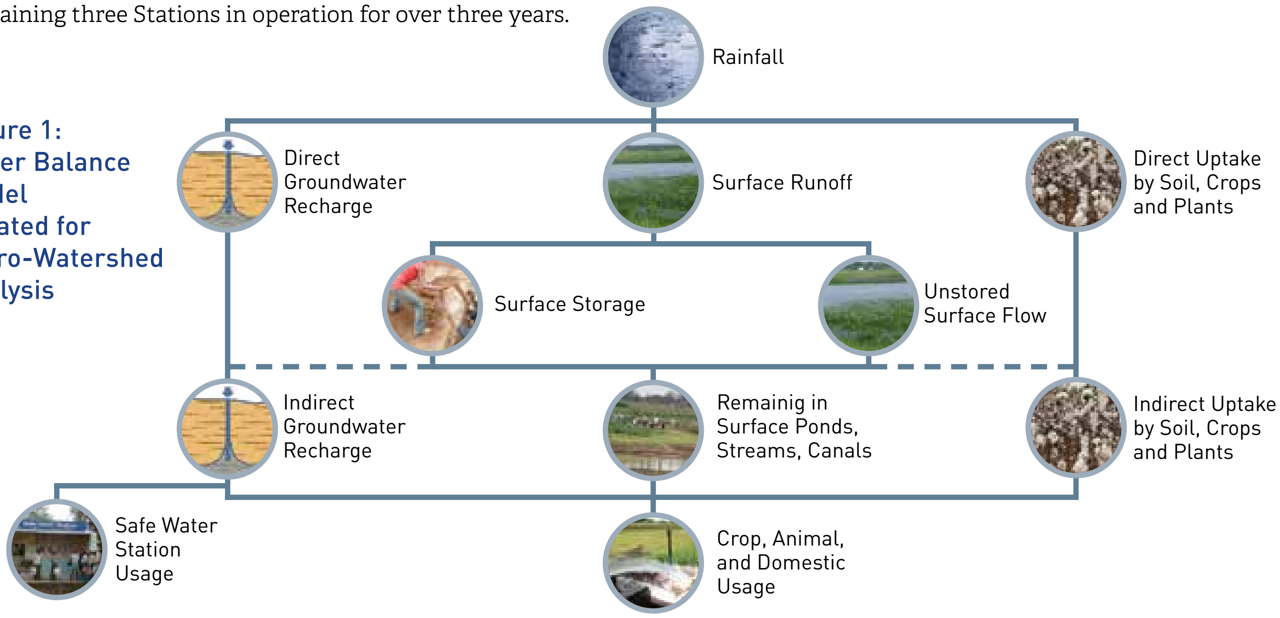
This information is used to monitor Stations and assess sites where we will expand operations. It also provides data that operators and field staff use to promote efficient water use.

Telangana Water Sources Are Threatened by Contaminants, Overuse, and Pollution

Telangana is a semi-arid, rural state in India's southern region. High concentrations of nitrate and natural fluoride in groundwater first drew us to establish Stations there. With local partner Modern Architects for Rural India (MARI)[1], we learned from farmers and other villagers that overuse of groundwater and its contamination with fertilizers, animal waste, and human excreta are primary threats to its sustainability.

In 2012, we launched a Water Resource Management program by developing a model to guide decision-making, monitor and control environmental impacts, and support education and action to mitigate sustainability threats (see Figure 1). Model development emerged from the study of a micro-watershed containing three Stations in operation for over three years.

Figure 1: Water Balance Model Created for Micro-Watershed Analysis



Creating a Water Balance Model to Guide Decision-making

A water balance is used to describe the water input to an area, its distribution, and the amount of water used. If use is found to exceed input, water resource sustainability is at risk.

Safe Water Network's water balance model is shown in Figure 1. Rainfall is the primary input to the area. It is distributed as (1) groundwater recharge, (2) runoff on the surface of the ground, or (3) uptake by soil, crops, and plants. As shown in Figure 1, some of the surface runoff is stored by farmers, with the remainder unstored. Eventually, a portion of these surface waters percolates indirectly into groundwater while another portion is used by soil, crops, and plants. The remainder stays on the surface in ponds and streams. A Safe Water Station uses only groundwater.

Data from public sources[2] and geological analyses[3] of the area indicate that the micro-watershed is dominated by highly weathered granite. For these conditions, 18% of rainfall is considered to move to groundwater recharge and 35% to surface runoff. The remaining 47% is moisture for soil, crops, and plants. The model assumes that evapotranspiration is equal to the requirement of soil, crops and plants, and does not consider water inflow from canals in absence of reliable data.

Calculating Sustainability Risk and Our Footprint

Using this water balance model to clarify sustainability and calculate our hydrologic footprint required several steps that combined multiple years of operational data, publicly available electronic data, and findings from community-wide discussions. First, we characterized the micro-watershed containing the three Stations with publicly available satellite imagery. We collaborated with India's Water and Resources Institute (WARI) to generate the digital elevation model (DEM) shown in Figure 2.

[1] See Field Insight: Sharing Values to Market Rural Water (www.safewaternetwork.org)
[2] National Remote Sensing Centre (NRSC), Hyderabad
[3] Water And Resource Institute (WARI), Delhi

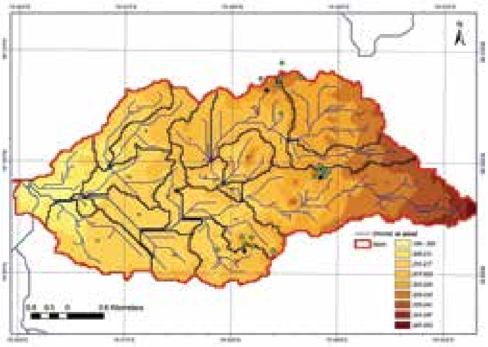


Figure 2: Digital Elevation Model (DEM) showing gradual slope from east to west in the study area

The DEM shows a micro-watershed area of 1,650 hectares and a drop in elevation from east to west of approximately 50m—a gradual slope that supports retaining rainfall in the micro-watershed. Public data from the Indian Meteorological Department revealed the average annual rainfall as 895mm.

The total annual water input to the micro-watershed was calculated by multiplying the amount of rainfall by the area of the micro-watershed as shown in Table 1.

Table 1: Annual Rainfall Input to the Micro-Watershed

Item	Quantity
Village Area (hectare or 10,000 m^2)	1,650
Average Annual Rainfall (m/yr)	0.895
Annual Rainfall Input (1000 m^3/yr)	**14,768**

Next, we calculated water use by characterizing the cultivated area of the micro-watershed by type of crop. This information was based on knowledge learned from farmers and included an additional 10% over their reported values to provide a conservative estimate of use. Farmers provided information on the hectares used for a variety of purposes. We combined this knowledge with global guidelines to estimate the respective needs of crops, animals, and domestic water use, shown in Table 2.

Table 2: Annual Use of Micro-Watershed Water

Item	(1,000 m^3/yr)
Crop Water Usage	15,190
Farm Animal Water Usage	41
Domestic Water Usage	110
Non-Station Water Usage	**15,341**

It is clear from this analysis that water use (15,341 1,000 $m^{3/yr}$) exceeds water input (14,768 1,000 $m^{3/yr}$) to the micro-watershed. The long-term sustainability of the groundwater supply is therefore at risk—the primary cause is the large volume of crop water usage.

It is similarly important to know the volumetric use of annual rainfall that reaches the groundwater by the three Stations. This tells us the relative size of the hydrological footprint of our operations on the source.

The amount of rainfall moving to groundwater recharge is the maximum amount of naturally occurring groundwater available for sustainable use. As described in the Water Balance Model, 18% of the total annual rainfall input to the micro-watershed reaches the groundwater. Based on actual use records for the Stations in the micro-watershed, we calculated the total annual volume of groundwater they extract as 5,100 cubic meters. Recharge and Station use are compared in Table 3.

Table 3: Safe Water Station Use of Rainfall-Recharged Groundwater

Items	(1,000 m^3/yr)
Annual Rainfall Input	14,768
Groundwater Recharge	2,658
Station Water Usage	5.1
Station Usage / Groundwater Recharge	**0.19%**

The three Stations in the micro-watershed use only 0.19% of the groundwater recharge from annual rainfall. This gives us confidence that establishing dozens of Stations using a single groundwater source is environmentally viable—if the overall sustainability of the source is addressed.

Comparing Station Water Use to Other Water Uses

Data in Tables 1 and 2 indicate that groundwater overuse threatens sustainability. Quantifying Station use as a percentage of total water use clarifies our contribution to overuse. To analyze this, Station water use is compared to the volume of water used outside the Stations in Table 4.

Table 4: Comparative Use of Micro-Watershed Water

Item	(1,000 m^3/yr)
Non-Station Water Usage	15,341
Safe Water Station Usage	5.1
Total Water Usage	15,846
Station Usage / Total Water Usage	**0.03%**

The annual groundwater usage by the three Stations is 0.03% of the Total Water Usage. This clearly demonstrates the small hydrologic footprint of our operations in the micro-watershed.

[4] Ministry of Drinking Water & Sanitation (MDWS), Food and Agriculture Organization of the United Nations (FAO), Indian Council of Agricultural Research, Delhi (ICAR)

Based on the calculations in Tables 1–4, Safe Water Network concludes that the sustainability of the groundwater source is at risk because of the large volume used to water crops. In locations where water use exceeds natural recharge, our field staff and partners are well positioned and equipped to work with communities to reduce crop water by supporting increased agricultural efficiency.

Monitoring and Controlling Wastewater Discharge

Safe Water Network and MARI monitor operations in Telangana to ensure that wastewater disposal complies with national standards. Typical results of wastewater analyses for the three Stations in the micro-watershed are compared with disposal standards in Table 5.

Table 5: Station Wastewater Chemical Analyses and Standards

Parameter	India Wastewater Disposal Standards[5] By Disposal Option			Station Location		
				1	2	3
	Inland Surface Water	Public Sewer	Land for Irrigation	Wastewater Quality (mg / liter)		
Nitrate	10	none	none	156	355	440
Fluoride	2.0	15.0	none	1.7	1.6	1.7

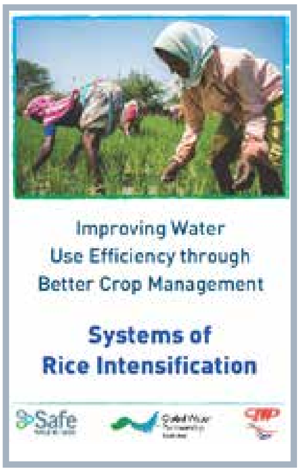
Recognizing high nitrate concentrations in reject water, Station wastewater is responsibly discharged into public sewers (village wastewater disposal drains) or onto land for irrigation only. Wastewater is not discharged to inland surface water, in compliance with national wastewater disposal standards.

Stations as Future Environmental Stewards

Safe Water Network is using these findings to expand our environmental stewardship by strengthening site assessments and actions. The work has provided us with an understanding of water use practices in our communities and their impact on the sustainability of underground water sources.

To promote reduced agricultural water use, Safe Water Network worked with the with the India Water Partnership and Global Water Partnership to create community-focused educational materials on more efficient agricultural water use. These were designed for use by Station operators with communities to conserve groundwater resources.

Moving forward, our Water Resource Management Team is pursuing partnerships to use the model, educational materials, and years of groundwater monitoring records to develop a digital decision support tool. The tool would be used in site assessments to determine and record aquifer vulnerability as part of sanitary surveys to identify, monitor, and diminish threats to Safe Water Station water sources.



Our goal is to use the tool as we enter new locations to engage community members in determining the local water balance, appreciating the importance of source sustainability, taking action to conserve resources, developing safe methods to reuse wastewater, and initiating efforts to maximize rainwater harvesting. With partner support, Safe Water Network field staff and operators will address the vulnerability of water resources and serve as stewards skilled in both sustainable provision of water for agriculture and reliable, affordable, and safe water for health.

[5] India Environment (Protection) Rules, 1986 (amended 1993)

CONTACT US

For more information, please visit **www.safewaternetwork.org**, or email the author at **info@safewaternetwork.org**.

ABOUT SAFE WATER NETWORK

Safe Water Network develops market-based, community-level solutions that deliver safe, affordable, and reliable water to populations in need. We engage the diverse capabilities of our public- and private-sector partners to advance our model for broad replication, and document and share our insights through forums, workshops, and reports. Our operating footprint of over 100 safe water systems, providing safe water access to over 400,000 people in Ghana and India, forms the basis for research and innovation to systematically address the challenges of local sustainability. Safe Water Network was co-founded in 2006 by actor and philanthropist Paul Newman, along with prominent civic and business leaders.

NEWMAN'S OWN® FOUNDATION

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