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A Community-Oriented and Climate-Adaptive WASH Framework for Disaster Risk Mitigation and Recovery in Rural India

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ABSTRACT

Climate change, uncontrolled land use, and environmental degradation have increased the frequency and severity of natural disasters, with a particular impact on rural Water, Sanitation, and Hygiene (WASH) systems in countries like India. Floods, cyclones, droughts, and earthquakes frequently disrupt water supplies, destroy sanitation facilities, and hinder hygiene services, increasing disease risk and slowing recovery. Although WASH systems are important for responding to and recovering from disasters, they have not fully integrated climate adaptation and disaster risk reduction into their planning. This paper offers a community-oriented framework to reduce disaster risk and support the recovery of WASH services in rural India. The framework is based on seven strategic pillars: a climate-resilient water supply, adaptive sanitation, promotion of hygiene and public health, nature-based solutions, reform of institutions and governance, digital monitoring and early warning, and community capacity building. It draws together research, policy papers, and practical experience from programmes such as the Jal Jeevan Mission (JJM) and the Swachh Bharat Mission (SBM)-Grameen. The key principles are to build back better, promote decentralised governance, ensure gender-responsive leadership, and adopt ecosystem-based approaches. The framework aims to reduce service disruptions, speed recovery, and build lasting resilience in rural WASH systems, offering a model applicable to other disaster-prone developing countries.

INTRODUCTION

Climate-related disasters have become a major problem for societies, economies, and ecosystems. From 1998 to 2017, total direct loss from disasters worldwide was about US\$2,908 billion, nearly 77 per cent of which was caused by weather-related events (Wallemacq & House, 2018). Annual economic losses have risen from an average of US\$70 to US\$80 billion during 1970–2000 to US\$180 to US\$200 billion per year between 2001 and 2020 (UNDRR, 2025). Munich Re forecasts that global losses from natural disasters will amount to US\$224 billion in 2025, 92 per cent of which will be due to weather-related hazards (Munich Re, 2025).

India has high disaster exposure; it is the second most flood-prone country in the world, with around 40 million hectares at risk. The country frequently suffers floods in the Gangetic plains, cyclones on both coasts, droughts in the dry areas, and earthquakes in the Himalayan and peninsular regions (Observer Research Foundation, 2024). Without adequate adaptation measures, climate change is likely to cause these events more frequent and more severe.

Water, Sanitation, and Hygiene (WASH) systems in India are among those most affected by natural disasters; damage to pipelines, hand pumps, storage tanks, and treatment plants quickly restricts access to safe water. Although WASH systems play a fundamental role in both emergency response and longer-duration recovery, the sector still has serious deficiencies in climate adaptation

planning and in integrating disaster risk reduction. Existing infrastructure is generally based on standards in place before disasters and does not account for expected future hazard profiles. Coordination between WASH departments and disaster management authorities remains limited. In most rural areas, community-level preparedness—this including locally trained responders, emergency stockpiles, and participatory monitoring systems—has not been properly developed. This paper tackles these problems by presenting a structured, community-focused framework for disaster risk reduction and for WASH recovery in rural India. It is based on international research, national policies and on key programmes such as JJM and SBM-Grameen. The framework centres on seven closely linked strategic pillars, each with specific interventions. The main goal is to make rural WASH systems more resilient, ensure services continue to function during disasters, speed up recovery, and improve infrastructure beyond its pre-disaster state.

LITERATURE REVIEW

Disaster Losses, Global and Regional Trends

In recent decades, disaster losses have increased considerably because of more severe hazards, more people and assets located in risky areas, and insufficient investment in resilience. According to UNDRR (2025), the total cost of disasters, including both indirect and ecosystem losses, amounts to more than US\$2.3 trillion each year worldwide. Without additional investment

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in climate resilience, household income growth in environmentally vulnerable areas could decline by 11 to 29 per cent by 2050, particularly in low-latitude and low-income areas such as much of South Asia.

In India, the combination of macroeconomic trends and high human vulnerability is especially evident in rural areas, where households have limited capacity to cope with difficulties, institutional safety nets are inadequate, and WASH infrastructure is not appropriate for disaster situations. Disasters keep on reinforcing poverty cycles, destroy livelihoods and set back earlier development achievements – a fact which demonstrates how important it is to have risk-informed planning in all social service sectors, including WASH (Chandel *et al.*).

The impact of disasters on rural WASH systems

In rural areas, natural disasters affect WASH systems in a variety of ways. When floods occur, open wells and shallow aquifers fill with surface-level water contaminated by agricultural runoff and human and animal excreta, making the water microbiologically unsafe. Cyclones and storm surges damage elevated water storage tanks, overhead tanks, and the piped distribution system. Earthquakes destabilise latrine superstructures. In drought, groundwater levels drop, contaminants become more concentrated in the smaller remaining water supply, and the amount of water needed for proper hygiene decreases.

Research on the impact of Cyclone Amphan on WASH systems in coastal West Bengal and Odisha clearly reflects this situation. The cyclone destroyed thousands of handpumps and piped water supply schemes, rendered many community latrines inoperative because of structural damage or flooding, and disrupted the supply chains for water purification chemicals and hygiene materials (as shown in various MDPI case studies), with the waterborne disease surveillance records showing an increase in cases of acute diarrhoeal illness in the affected districts in the weeks following the cyclone's landfall.

Women in rural areas, together with disadvantaged groups including the Scheduled Castes and Scheduled Tribes, and families who depend on a sole source of water, are more at risk should there be a disruption of the WASH system. When the piped water supply is interrupted, the additional burden of collecting water falls heavily on women, and the lack of proper sanitation in emergencies and during displacement creates specific protection risks (UNICEF, 2024).

The metrics to be used for recovery and staged response models

For the WASH sector to recover effectively after a disaster, it must follow a multi-stage, results-based approach that moves from emergency stabilisation to improved, sustained resilience. The key performance indicators to use when monitoring recovery are the percentage of the population who have regained access to safe drinking water, the number of sanitation facilities that are working

after the disaster (this includes the temporary ones set up to avoid open defecation), the extent to which water supplies meet bacteriological quality standards, the rates of illness in the affected populations that are linked to WASH, and the length of time it takes to restore full services (Department of Drinking Water and Sanitation, 2023).

Recovery plans are now moving toward a step-by-step operational approach that includes immediate emergency actions (such as setting up temporary water and sanitation facilities), short- to medium-term restoration efforts (involving the repair and reestablishment of damaged infrastructure), and long-term resilience-building measures aimed at raising standards above those that existed before the disaster. The 'build back better' idea, which is part of the Sendai Framework for Disaster Risk Reduction (2015–2030), forms the conceptual basis for this third stage by stressing that reconstruction should be seen as a chance to make structural improvements, not exclusively as a way of restoring the situation as it was.

Institutional and social capital is central to recovery effectiveness. Evidence from past disasters in India shows that communities with active Village Water and Sanitation Committees (VWSCs), trained youth volunteer networks, and engaged Self-Help Groups (SHGs) recover WASH services more rapidly and equitably than those lacking these organisational assets (Kanjilal, Repaul *et al.*).

Nature-Based Solutions for Resilience regarding WASH

Nature-based solutions (NbS) are a valuable, cost-effective complement to engineered infrastructure for planning durable WASH systems. Wetland ecosystems provide several functions relevant to disaster management, including reducing flood peaks, retaining sediment, filtering pathogens, and storing water during drought periods (Ferreira *et al.*, 2023). Likewise, mangrove belts act as natural coastal barriers by reducing wave energy and storm-surge height during cyclones, thereby reducing physical damage to coastal WASH infrastructure (Kamil *et al.*).

In India, groundwater recharge structures such as percolation tanks and infiltration pits have proven capable of maintaining water table levels in regions with crystalline aquifers, even during drought years (Boisson *et al.*, 2014; CGWB, 2025). The collection and reuse of greywater, particularly for agricultural irrigation, offer another way to extend the availability of fresh water during drought (Nhenderere, 2025). Vegetative buffer zones around water bodies help reduce sedimentation and the influx of agricultural contaminants, helping preserve water quality year-round.

Ecosystem-based approaches go hand in hand with community-led governance because they involve local people in maintenance, benefit both crop production and biodiversity, and can be integrated into current village-level environmental management practices.



Digital Technologies in Disaster WASH Management

Digital monitoring and communication technologies have great potential for managing WASH services, especially for improving disaster preparedness, response, and recovery. Geographic Information System (GIS) platforms support a spatial analysis of the exposure to hazards, the positions of water sources, and the vulnerability of infrastructure, which in turn aids in the risk-informed location of new facilities and in prioritising emergency response actions (Chen *et al.*, 2022). Internet of Things (IoT) sensors installed at water supply and quality monitoring sites deliver real-time data on system performance, enabling the early detection of supply failures or contamination events (Forhad *et al.*, 2024).

SMS alerts on mobile phones effectively convey evacuation and emergency instructions to rural areas, but coverage remains limited in areas with low connectivity (Elejalde *et al.*, 2025). Connecting rapid response teams with central emergency resource registers can also speed up and improve disaster response.

The Gaps That Were Identified and the Role of the Research

Although the evidence has been reviewed, important gaps remain in both research and practice. Monitoring diseases linked to WASH in the aftermath of disasters is inconsistent, particularly regarding indirect health effects. Although policies refer to gender and social inclusion, they are not well implemented. Long-term data on nature-based solutions for WASH in India remain scarce, and funding for climate adaptation and disaster risk reduction remains scattered.

The paper considers these gaps via compiling the existing evidence into a simple and usable framework which links resilience, disaster management, and community governance in India.

MATERIALS AND METHODS

The study uses a qualitative, descriptive-analytical method, systematically examining available data and incorporating several conceptual models. Its aim is to create a conceptual framework for community-centred WASH disaster risk reduction and recovery in rural India, not exclusively to test hypotheses or make quantitative predictions.

Data Sources

The framework is supported by evidence from four main types of secondary sources: (i) peer-reviewed journal articles in the areas of WASH, disaster risk reduction, climate adaptation and public health; (ii) national and international policy documents such as India's Manual for Disaster Management Plan for Rural Water Supply Schemes, the JJM operational guidelines, and the SBM-Grameen programme frameworks; (iii) technical reports and global assessments produced by organisations

including UNDRR, UNICEF, Munich Re and Swiss Re; and (iv) government statistical data relating to the impact of disasters provided by the Ministry of Emergency Management, the NDMA and the state-level WASH authorities.

Studying the Framework

The review process used thematic and comparative analysis, and the literature was organised into five main areas: disaster economics and loss trends; the vulnerability of WASH infrastructure and its recovery; governance and institutional structures; nature-based approaches to aimed toward resilience; and the use of digital technology. A cross-cutting analysis also looked at how these areas interact in different disaster situations (such as floods, cyclones, droughts, and earthquakes) and for different groups of people (including women, marginalised communities, and children).

The analysis was set within three internationally recognised normative frameworks: the UNDRR Sendai Framework for Disaster Risk Reduction (2015–2030), which includes the build-back-better principle and the multi-stakeholder governance model; the Sustainable Development Goals, specifically SDG 6 (Clean Water and Sanitation) and SDG 13 (Climate Action); and the UNFCCC climate adaptation framework, which is responsible for the assimilation of ecosystem-based approaches.

Framework Development

The framework developed in four successive stages. In the first stage, the team reviewed existing WASH disaster management in India to identify structural shortcomings and operational gaps. In the second stage, the team identified the main thematic aspects of WASH resilience through a literature review and an analysis of policy documents. In the third stage, the team selected efficient strategies and technical interventions from evidence from India and around the world, then grouped them into clear strategic clusters. In the fourth stage, these clusters were combined to form a seven-pillar framework, with specific references to national programme instruments and a four-phase operational timetable.

The resultant framework is conceptual and exploratory, designed to be tested in the future through pilot projects in different regions. It is structured to scale across several disaster types, ecological zones, and state oversight systems.

Suggested Framework: The Seven Strategic Pillars

The proposed framework has seven strategic pillars, each handling a different but related part of WASH disaster resilience. Together, they create an integrated approach where community empowerment, ecological sustainability, technology, and strong institutions work together. Table 1 shows the full framework.



Table 1: Proposed Framework for WASH Sector Disaster Risk Reduction and Recovery in Rural India

1	Disaster-Resilient Water Supply Systems	• Diversification of water sourcing across surface water, groundwater, and rainwater capture systems • Solar-powered pumping stations with elevated control infrastructure to prevent flood inundation (Nejad <i>et al.</i>, 2024) • Construction of village-level emergency water reservoirs for supply continuity (Pande <i>et al.</i>, 2014) • Rapid water quality screening and chlorination protocols post-disaster • Disaster relevance: applicable across flood, cyclone, drought, and seismic events
1	Climate-Resilient	• Elevated and watertight latrine structures designed for flood-prone geographies (Ali <i>et al.</i>) • Promotion of twin-pit, composting, and ecological sanitation alternatives (Austin, 2005) • Fecal sludge management systems with flood-safe containment design (Singh <i>et al.</i>, 2024) • Deployment of temporary emergency sanitation units during population displacement • Disaster relevance: floods, cyclones, and landslides
3	Hygiene Promotion and Public Health Protection	• Installation of communal handwashing stations at relief centres and water access points • Hygiene kit distribution, including ORS packets, soap, chlorine tablets, and menstrual products • Behaviour change communication delivered through frontline ASHA/Anganwadi workers • Active surveillance and response for waterborne diseases, including cholera, typhoid, and diarrhea • Disaster relevance: applicable to all disaster types, especially floods and heatwaves (Gnanasekaran <i>et al.</i>, 2025)
4	Nature-Based Solutions for WASH Resilience	• Restoration of wetlands and village ponds as natural flood attenuation and water filtration systems (Ferreira <i>et al.</i>, 2023) • Establishment of coastal mangrove belts as bio-shields in cyclone-prone areas (Kamil <i>et al.</i>) • Construction of percolation tanks and recharge pits for aquifer replenishment (Boisson <i>et al.</i>, 2014) • Vegetated buffer zones around water bodies to limit runoff and soil erosion • Greywater harvesting and reuse to conserve freshwater during drought conditions (Nhenderere, 2025)
5	Institutional and Governance Strengthening	• Activation and training of Village Water and Sanitation Committees (Paani Samitis) for local disaster response • Defined coordination protocols across national (NJJM), state (SWSM), district (DWSM), and village (Gram Panchayat) tiers • Allocation of WASH-specific recovery budgets via the National Disaster Response Fund (NDRF) • Gender-responsive governance with women in leadership of monitoring and management functions • Inclusive planning mechanisms to address vulnerabilities among Scheduled Castes, Scheduled Tribes, and other marginalized groups
6	Digital Monitoring, Early Warning, and Preparedness Systems	• GIS-based spatial mapping of hazard zones, water sources, and vulnerable settlements (Chen <i>et al.</i>, 2022) • IoT-enabled remote water quality and supply monitoring at treatment and distribution points (Forhad <i>et al.</i>, 2024) • SMS and community radio-based early warning dissemination through local volunteer networks (Elejalde <i>et al.</i>, 2025) • Maintenance of emergency resource registers and pre-positioning of rapid response teams • Integration of WASH early warning triggers with NDMA national disaster alert systems



7	Capacity Building And Community Empowerment	• Structured training programs for youth volunteers, Self-Help Groups (SHGs), VWSCs, and pump operators • School-based WASH disaster preparedness curriculum to build community readiness from an early age • Simulation drills for flood, cyclone, and drought response scenarios at village level • Women-led sanitation and water quality monitoring as a cornerstone of community governance • Documentation and integration of indigenous knowledge into local disaster response planning
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Water Supply Systems That Are Capable Of Surviving Disasters

Securing continuous access to safe water during and after disasters is the framework's main priority. To build stability of the water supply system, it is necessary to diversify sources so no single disaster can eliminate all available supply options. In locations prone to floods and cyclones, where grid electricity is often one of the first things to be affected by a disaster (Nejad *et al.*, 2024), solar-powered pumping systems with raised control panels offer considerable benefits. Village-level emergency water storage tanks, which are designed with sufficient capacity and flood-proof structural specifications, serve as an important source of backup water in the hours and days after a disaster until tanker services or repair work can be carried out (Pande *et al.*, 2014).

Field-deployable test kits that allow quick water quality testing enable community-level monitoring of bacterial contamination without relying on laboratory facilities. Chlorination procedures must be standardised, and necessary supplies stored in advance in the village's emergency stockpiles. The technical measures needed vary by disaster type. For floods, rapid evaluation of well contamination and reactivation of elevated water sources are necessary. During droughts, demand management and additional supply methods are required. In seismic disasters, a quick assessment of the structural condition of pipelines and tanks is needed.

Climate-Resilient Sanitation Systems

Keeping sanitation facilities operational during and after disasters prevents open defecation, which increases disease risk and undermines years of progress under SBM-G. In zones prone to flooding, latrines should have raised superstructures, lined pits to prevent water intrusion, and securely fastened covers to prevent flooding and contamination (Ali *et al.*). The twin-pit toilet design, widely promoted as part of SBM-G, offers both functionality and durability, since one pit can remain in use while the other is maintained or repaired.

Faecal sludge management (FSM) systems need to have special provisions for disasters, such as sealed storage facilities and an emergency desludging capability in order to avoid overflow during floods (Singh *et al.*, 2024). When temporary emergency latrines are installed during population displacement, their placement and maintenance should ensure users' dignity and safety, with special regard to the needs of women and girls.

Sanitation recovery plans after a disaster should evaluate ecological sanitation and composting systems as part of the rebuilding efforts that promote both hygiene and agricultural yield (Austin, 2005).

Encouraging hygiene and defending public health

In developing countries, the disruptions to cleanliness routines during disasters pave the way for rapid disease contagion and transmission. This can disrupt already strained health and sanitation systems. Community handwashing stations at water access points and emergency shelter sites should be established as a standard component of disaster response operations. Pre-positioned hygiene kits containing soap, oral rehydration salts, chlorine tablets, and menstrual hygiene products enable frontline ASHA and Anganwadi workers to rapidly distribute critical supplies to vulnerable households.

Behaviour change communication (BCC), when carried out by trusted community health workers, is more effective than mass media campaigns in disaster situations in which misinformation disseminates quickly, and people are under considerable psychological stress. Active epidemiological surveillance for WASH-related diseases—using clear case definitions, established reporting procedures, and rapid outbreak-response indicators—should be incorporated into standard operating procedures for disaster response (Gnanasekaran *et al.*, 2025). In India, heat waves, which are becoming more frequent and severe, pose particular risks of dehydration and stress on water sources and therefore require specific hygiene messaging.

Solutions based on nature for building resilience related to WASH

Ecosystem-based methods supply a durable and inexpensive way to enhance WASH resilience, supplementing engineered infrastructure while also benefiting agriculture, biodiversity, and local livelihoods. Restoring wetlands in and around rural settlements creates natural shields against flooding and stores water, which lowers peak flood levels and increases water availability during dry seasons (Ferreira *et al.*, 2023). In coastal regions, restoring and protecting mangrove belts measurably reduces storm surge intensity and thus lessens the physical damage to coastal WASH infrastructure during cyclone events (Kamil *et al.*).

Inland, percolation tanks and recharge pits, built in



suitable geological conditions, have been found to raise the water table in neighboring crystalline aquifer formations and increase the output of wells and boreholes during drought years (Boisson *et al.*, 2014). The Central Ground Water Board has recorded successful cases of such recharge structures in a number of Indian states (CGWB, 2025). Vegetative buffer zones situated around water bodies help to reduce soil erosion and the entry of agricultural chemicals, thus protecting the quality of the raw water. Greywater reuse systems, especially for gardens and small-scale irrigation, help maintain freshwater supplies during drought and reduce demand on main water sources (Nhenderere, 2025).

Strengthening of institutions and governance

Strong institutional arrangements are a necessary condition for achieving effective disaster preparedness, response, and recovery at the community level. Although the Paani Samiti (Village Water and Sanitation Committee) at the Gram Panchayat level is the suitable main body for community WASH governance, in a number of cases these organisations need to have their capacity enhanced, their roles made more clearly defined, and they need financial resources if they are to carry out a substantial disaster management function. Evidence shows that achieving gender parity in committee membership and placing women in leadership roles for monitoring and accountability improves WASH outcomes across a range of programme contexts.

Coordination agreements between village committees, local administrative bodies, district WASH management units, state water and sanitation mission offices, and national JJM programme management must be established before a disaster occurs, not assembled during a crisis. Although the National Disaster Response Fund (NDRF) offers an important financial means for WASH recovery, better procedures for allocating funds specifically for WASH and faster disbursement are needed to prevent delayed recovery. Inclusive planning processes that specifically involve Scheduled Caste and Scheduled Tribe communities help ensure that recovery benefits are not concentrated among those already in privileged positions.

Systems for digital monitoring, early warning, and preparation

Technology-aided monitoring and communication systems greatly improve people's ability to prepare for and respond to disasters. By using GIS platforms that combine information on hazard zones, the locations of water sources, population distribution, and infrastructure condition, evidence-based planning can be carried out before a disaster and priority decisions made in real time during an event (Chen *et al.*, 2022). Internet of Things (IoT) sensors placed at pumping stations and water-quality distribution points enable uninterrupted monitoring of water supply quality and identify system

failures before they cause long-lasting interruptions to the water supply (Forhad *et al.*, 2024).

By using mobile SMS warnings, community radio broadcasts, and a network of trained local volunteers to disseminate early warnings at the community level, it is possible to carry out preparedness measures—such as storing emergency water, distributing hygiene kits, and securing latrines—before the disaster arrives (Elejalde *et al.*, 2025). Having emergency resource registers in advance and trained rapid response teams in place helps shorten mobilisation delays during the most critical early stages of disaster response. These digital and organisational systems should be incorporated into the NDMA's national warning framework so that WASH-specific alerts are included in the wider multi-hazard early warning communications.

Building capacity and empowering the community

Sustainable WASH resilience cannot be imposed from the outside; it must be based on local knowledge, existing social organisation, and the community's governance capabilities. Training schemes designed for young volunteers, SHG members, VWSC officials, and pump operators result in a large number of responders at the community level who have the practical skills needed for testing water quality, carrying out minor repairs to infrastructure, supporting hygiene, and managing emergency logistics (Kanji, Repaul *et al.*). WASH disaster preparedness curricula delivered in schools build awareness and practical skills from an early age, establishing a body of community knowledge passed on from one generation to the next.

By carrying out simulation exercises for floods, cyclones, and droughts coordinated by local government and civil society organisations, communities can practise coordination procedures, spot logistical shortcomings, and develop the social trust needed for collective action under pressure. The role of women in monitoring sanitation facility use, water quality, and latrine maintenance operates as both a quality control measure and a document integrating community governance. Incorporating documentation of indigenous water management—such as traditional flood-predicting ponds, seasonal customs for harvesting water, and local flood indicators—adds to community resilience through locally relevant insights offering technical and policy knowledge alone cannot offer.

Operationalisation: the four-phase implementation model

The four-phase lifecycle model, which is in line with the disaster management cycle, is used to put the seven strategic pillars of the framework into practice. It offers a temporal structure for coordinating actions during the phases of preparedness, acute response, recovery and ongoing mitigation. A summary of the main actions and responsibilities linked to each phase is given in Table 2.



Table 2: Four-Phase Operational Framework for WASH Disaster Management

A. Preparedness (Pre-Disaster)	• Hazard-Vulnerability-Capacity (HVC) mapping to identify disaster risk profiles by geography (e.g., flood belts in Bihar, drought zones in Rajasthan) • Adoption of disaster-resistant infrastructure standards: elevated handpump platforms, twin-pit latrines in low-lying areas • Integration of WASH alert systems with NDMA early warning protocols to trigger preemptive community responses
B. Response (During Disaster)	• Rapid Needs Assessment (RNA) completed within 24 hours of disaster onset to quantify water and sanitation gaps • Emergency deployment of water purification units, mobile water tankers, and floating/temporary latrines • Immediate bacterial contamination testing of open water sources and shallow wells
C. Recovery & Reconstruction (Post-Disaster)	• Post-Disaster Needs Assessment (PDNA) to determine scope of infrastructure losses and long-term rehabilitation requirements • Application of 'build-back-better' principles: upgraded climate-proof standards for all restored facilities • Priority restoration of WASH services in health centers, schools, and community shelters
D. Mitigation (Ongoing)	• Water source protection through watershed management and pollution control • Rainwater harvesting and greywater reuse to maintain supply during drought periods • Ecosystem conservation, including aquifer recharge infrastructure and wetland preservation

Integration of technical and policy strategies

To implement the four-phase model effectively, it is necessary to consider India's current technical standards and policy systems. Solar-powered piped water systems, a key element of JJM implementation, ensure a continuous water supply during grid power interruptions caused by cyclones and storms. The Uniform Drinking Water Quality Monitoring Protocol sets out the bacteriological and chemical standards against which post-disaster water quality assessments should be compared (Ministry of Drinking Water and Sanitation, 2013). When carrying

out build-back-better interventions, the NDRF funding mechanisms should be used together with previously agreed technical specifications in order to prevent delays in procurement and construction.

Multi-Tier Governance Structure

To implement the framework smoothly, it is necessary to define roles and coordination procedures clearly at all levels of the governance system. Table 3 shows the multi-tier governance structure in which the framework functions.

Table 3: Multi-Tier Governance Structure for WASH Disaster Management

National (NJJM/MoJS)	Policy formulation, programme funding, and standard-setting for national WASH resilience
State (SWSM)	Adaptation of national guidelines to regional contexts, inter-district coordination, and emergency resourcing
District (DWSM)	Deployment of mobile WASH units, real-time monitoring, and field supervision of response operations
Village (Gram Panchayat / Paani Samiti)	Community awareness campaigns, local implementation, on-site water quality testing, and citizen oversight

Discussion

The framework set out in this paper addresses a structural weakness in India's rural WASH disaster management system: the lack of an integrated, community-based resilience approach that covers the entire disaster management cycle and links international best practices with the practical circumstances of national programmes such as JJM and SBM-G. Several issues that cut across the various areas deserve further examination.

The principle of build-back-better, at the heart of the Sendai Framework, calls for a fundamental modification in how WASH recovery is understood and financed. If

recovery efforts simply restore pre-disaster infrastructure without addressing existing vulnerabilities, communities will remain vulnerable to similar or even greater damage in future events. To address this, the framework insists on all post-disaster reconstruction activities to meet improved design standards—such as raising buildings in flood-prone areas, using cyclone-resistant materials in coastal regions, and constructing sealed and reinforced latrines in earthquake-prone areas—if they are to receive funding from the NDRF.

The gender aspects of WASH resilience remain worth focusing on, since women and girls bear a heavier share



of the burden when WASH systems break down—they have to walk longer distances to obtain water, manage household hygiene with limited supplies, and face greater safety risks in poorly functioning emergency sanitation facilities. If programming is to be genuinely gender-sensitive, it must not only involve women in planning but also commit in women's leadership in VWSC monitoring committees, female-led hygiene promotion networks, and the collection of gender-disaggregated data during post-disaster needs assessments.

The application of nature-based solutions to WASH disaster planning is especially appropriate for India's rural area, since the village commons, the water bodies administered by the panchayats, and the community forests provide numerous possibilities for ecosystem restoration at a reasonable cost. Yet, the effectiveness of NbS depends on continuous community management, protecting restored ecosystems from encroachment, and long-term monitoring of hydrological and water-quality outcomes—capacities that must be deliberately developed through the framework's capacity-building component. Digital monitoring and early warning systems have both advantages and disadvantages, including equity concerns. Although IoT monitoring devices and GIS platforms have great potential to facilitate real-time situational awareness, the most vulnerable communities will not access these benefits unless there is investment in information infrastructure, community digital knowledge, and offline backup communication systems. The framework points to community volunteer networks as a means of distributing early warnings so the reach of technological systems can extend to areas where smartphone use is limited or mobile connectivity is unreliable.

The framework's relevance does not stop at India's borders. Many of the characteristics of the rural WASH situation in India—such as decentralised infrastructure, existing community governance practices, the variety of hazard types, financial limitations regarding capital investment, and the high level of social vulnerability among disadvantaged groups—are also found in rural areas throughout South Asia, Sub-Saharan Africa, and Southeast Asia. By adjusting to local policy settings and ecological conditions, the strategic pillars and operational model described here can serve as a transferable approach for climate-resilient WASH programmes in other disaster-vulnerable developing countries.

CONCLUSION

The combined effects of climate change, population growth, and environmental deterioration are increasing disaster risk for rural WASH systems in India, with repercussions ranging from acute public health crises to serious long-term developmental problems. Because no clear, evidence-based framework unites disaster risk reduction, climate adaptation, and community-centred governance in the rural WASH sector, yet a major gap remains in both planning and practice.

To fill that gap, the paper presents a community-based,

climate-resilient WASH framework which incorporates disaster risk reduction and recovery, is consistent with India's national programme structure, and draws on both domestic and international evidence. The framework delivers practical and context-appropriate strategies in the areas of disaster-resilient water supply, adaptive sanitation design, hygiene and public health promotion, nature-based solutions, institutional strengthening, digital monitoring, and capacity building—all of these being put into action through a four-phase lifecycle model and being incorporated within a well-defined multi-tier governance structure.

The following areas should be focused on in the coming years. First, the framework must be empirically tested through pilot implementations in the field across a variety of geographical areas and disaster types, with particular emphasis on high-risk regions such as Bihar, Odisha, Rajasthan, and coastal Andhra Pradesh. Second, long-term studies are needed on the effectiveness of nature-based solutions in the context of WASH in India to build the evidence base needed to justify and expand funding for ecosystem-based initiatives. Third, integrated financial mechanisms should be created and made official to link the JJM/SBM-G programme budgets with the NDRF disaster recovery funds, to remove the fiscal fragmentation that currently hinders recovery operations. Fourth, standardised, gender-segregated monitoring frameworks should be developed and incorporated into state-level WASH programme management systems to enable consistent monitoring of recovery indicators and resilience outcomes.

Ultimately, transitioning India's rural WASH sector from reactive disaster response to proactive resilience is both technically feasible and economically rational. The costs of infrastructure hardening, community capacity building, and ecosystem restoration are modest compared with the cascading health, livelihood, and economic losses from preventable WASH system failures. Investment in climate-resilient, community-focused WASH programmes through JJM and SBM-G represents a high-return strategy to advance SDG 1 (No Poverty), SDG 6 (Clean Water and Sanitation), and SDG 13 (Climate Action) simultaneously — while guaranteeing that India's rural communities are genuinely equipped to withstand, respond to, and recover from the disasters that a changing climate will increasingly bring.

REFERENCES

- Austin, L. M. (2005). *Ecological sanitation: Literature review. FSM Toolbox*. Retrieved from https://www.fsmttoolbox.com/assets/pdf/125_-1439-1-06.pdf
- Boisson, A., Baisset, M., Alazard, M., & Perrin, J. (2014). Comparison of surface and groundwater balance approaches in the evaluation of managed aquifer recharge structures: Case of a percolation tank in a crystalline aquifer in India. *Journal of Hydrology*, 519, 1620-1633. <https://doi.org/10.1016/j.jhydrol.2014.09.022>



- Central Ground Water Board. (2025). *Simple and practical methods of artificial recharge for groundwater*. Government of India. <https://cgwb.gov.in/cgwbpm/public/uploads/documents/1739866191814353122file.pdf>
- Chen, Y. (2022). Flood hazard zone mapping incorporating geographic information system (GIS) and multi-criteria analysis (MCA) techniques. *Journal of Hydrology*, 612, 128268. <https://doi.org/10.1016/j.jhydrol.2022.128268>
- Department of Drinking Water and Sanitation. (2023). *Manual for disaster management plan for rural water supply schemes* (aligned with Jal Jeevan Mission). Ministry of Jal Shakti, Government of India.
- Elejalde, E., Naushirvanov, T., Kalimeri, K., Omodei, E., Karsai, M., Bravo, L., & Ferres, L. (2025). Use of mobile phone data to measure behavioral response to SMS evacuation alerts. *International Journal of Disaster Risk Reduction*, 131, Article 105919. <https://doi.org/10.1016/j.ijdrr.2025.105919>
- Ferreira, C. S. S., Walsh, R., Ferreira, A. J. D., Keizer, J. J., & Prats, S. A. (2023). Wetlands as nature-based solutions for water management and climate resilience. *Geography and Sustainability*, 4(3), 100-112. <https://doi.org/10.1016/j.geosus.2023.03.002>
- Forhad, H. M., Uddin, M. R., Chakrovorty, R. S., Ruhul, A. M., Faruk, H. M., Kamruzzaman, S., Sharmin, N., Molla Jamal, A. S. I., Haque, M. M.-U., & Morshed, A. M. M. (2024). IoT based real-time water quality monitoring system in water treatment plants (WTPs). *Heliyon*, 10(23), e40746. <https://doi.org/10.1016/j.heliyon.2024.e40746>
- Gnanasekaran, S., Gupta, M. K., Goel, A. D., Bhardwaj, P., Srinivasan, S., Jain, V., Rajendran, V., & Raghav, P. (2025). Water, sanitation and infection control practices in rural health facilities of Jodhpur District, India: An intervention through supportive supervision. *BMC Health Services Research*, 25, 1171. <https://doi.org/10.1186/s12913-025-12689-7>
- International Organization for Migration. (2023). *DTM Ethiopia: National displacement report 16*. <https://dtm.iom.int>
- Mahmoudi, A., Mousavi, S. A., & Darvishi, P. (2021). Greywater as a sustainable source for development of green roofs: Characteristics, treatment technologies, reuse, case studies and future developments. *Journal of Environmental Management*, 295, 112991. <https://doi.org/10.1016/j.jenvman.2021.112991>
- Ministry of Drinking Water and Sanitation. (2013). *Uniform drinking water quality monitoring protocol*. Government of India.
- Mizutori, M., & Guha-Sapir, D. (2018). *Economic losses, poverty and disasters: 1998-2017*. UNISDR & CRED.
- Munich Re. (2025). Natural disaster figures 2025. Munich Re Group. Retrieved from <https://www.munichre.com>
- Nejad, H. J., Jamshidi, A., & Ghasemi, A. (2024). An innovative solar pump applicable in water distribution systems. *Engineering Proceedings*, 69(1), 107. <https://doi.org/10.3390/engproc2024069107>
- Nhenderere, O. C. (2025). *Reuse of greywater for irrigation in crop production: A review*. Sustainable Water Resources Management. <https://doi.org/10.1007/s40899-025-01296-3>
- Observer Research Foundation. (2024). *India's flood vulnerability: A review*. ORF Issue Brief.
- Pande, V. C., Singh, R., & Tiwari, S. (2014). Community-based water storage structures and management practices. *Journal of Public Administration and Policy Research*, 6(2), 24-32.
- Ritchie, H., Rosado, P., & Roser, M. (2022). *Natural disasters*. Our World in Data. <https://ourworldindata.org/natural-disasters>
- Singh, S. (2024). *Faecal sludge management in India: A review*. Cleaner Engineering and Technology. <https://doi.org/10.1016/j.clet.2024.002698>
- Swiss Re Institute. (2026). *Global natural catastrophe losses in 2025*. Swiss Re Group. Retrieved from <https://www.swissre.com>
- UNICEF. (2024). *Global annual results report 2023: WASH section*. UNICEF. <https://clearinghouse.unicef.org>
- United Nations Office for Disaster Risk Reduction. (2025). *Global assessment report on disaster risk reduction 2025 (GAR 2025): Resilience pays*. UNDRR. <https://www.undrr.org>
- Wallemacq, P., & House, R. (2018). *Economic losses, poverty and disasters: 1998-2017*. UNISDR & CRED.
- Wang, T., Yang, L., Wu, S., Gao, J., & Wei, B. (2020). Quantitative assessment of disaster coping capacity. *Sustainability*, 12(15), 5949. <https://doi.org/10.3390/su12155949>