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Climate Change, Environmental Stress and Water Resilience in Uttarakhand Himalaya: An Ethno-Historical Study

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Annotation: The Uttarakhand Himalaya, often referred to as the 'Water Tower of India,' faces unprecedented challenges from climate change and environmental degradation. This ethno-historical study examines the intricate relationship between climate change, environmental stress, and water resilience in this ecologically sensitive region. Drawing upon historical records, traditional ecological knowledge, and contemporary data, this research explores the evolution of water management practices from ancient indigenous systems to modern interventions. The study documents traditional water bodies including naulas (step wells), dhara (springs), chaals (water channels), and gadheras (streams), many adorned with Sanskrit inscriptions reflecting the sacred relationship between communities and water resources. Through an interdisciplinary approach combining historical analysis, ethnographic research, and environmental assessment, this paper reveals how centuries-old water harvesting techniques are being revitalized to address contemporary water scarcity. The findings indicate that integrating traditional ecological knowledge with modern water management strategies offers a sustainable pathway for building climate resilience in the Himalayan region.

Keywords: Gangnani Inscription, Uttarakhand Himalaya, Climate Change, Water Resilience, Traditional Water Bodies, Ethno-historical Study, Indigenous Knowledge, Naulas, Water Management, Kunda, Gangnani Inscription.

1. INTRODUCTION

The Uttarakhand Himalaya represents one of the most critical freshwater ecosystems in South Asia, serving as the source of major river systems including the Ganges, Yamuna, and their numerous tributaries (*Bandyopadhyay, 2019).* Spanning an area of approximately 53,483 square kilometers, the state encompasses diverse ecological zones ranging from sub-tropical forests in the lower elevations to alpine meadows and glaciated peaks exceeding 7,000 meters (Joshi et al., 2016). This region sustains approximately 10 million inhabitants while providing water resources to over 500 million people in the downstream Indo-Gangetic plains (*Tiwari & Joshi, 2015*).

However, accelerated climate change has emerged as an existential threat to this vital water tower. Scientific evidence indicates that the Himalayan region is experiencing warming rates significantly higher than the global average, with temperature increases of 0.15°C to 0.60°C per decade reported across various elevational gradients (Shrestha et al., 2012; Dimri et al., 2021). These climatic shifts have triggered a cascade of environmental stresses including glacier retreat, altered precipitation patterns, increased frequency of extreme weather events, and disruption of traditional water sources (Immerzeel et al., 2020).

The 2021 Chamoli disaster, which claimed over 200 lives and destroyed critical infrastructure, exemplifies the growing vulnerability of the region to climate-induced hazards (Shugar et al., 2021). Similarly, the unprecedented flash floods of 2013 in Kedarnath, attributed to extreme precipitation events and glacial lake outbursts, resulted in over 5,700 casualties and highlighted the urgent need for comprehensive water resilience strategies (Das et al., 2015).

Historical Context and Indigenous Water Wisdom

Long before contemporary scientific interventions, the communities of Uttarakhand developed sophisticated water management systems rooted in deep ecological understanding and spiritual reverence for water resources (Agarwal & Narain, 1997). The historical record, spanning over two millennia, reveals a complex tapestry of water harvesting, conservation, and distribution practices embedded within the social, cultural, and religious fabric of Himalayan societies (Valdiya, 2014).

Sanskrit inscriptions found on ancient water structures, some dating back to the 8th and 9th centuries CE, provide invaluable insights into the governance, maintenance, and cultural significance of these systems. These epigraphic records document not merely technical specifications but also encode ethical frameworks for water sharing, seasonal management protocols, and community obligations toward water conservation (Rawat, 2011). The concept of *Jal Sanskriti* (water culture) permeated all aspects of life, positioning water not as a mere commodity but as a sacred trust to be preserved for future generations (Sutherland, 2009).

Research Objectives and Methodology

This study pursues the following primary objectives:

1. To document and analyze traditional water management systems in Uttarakhand through ethno-historical investigation, with particular emphasis on architectural typologies, inscriptional evidence, and community governance structures.
2. To assess the impacts of climate change and environmental stress on water resources, examining both glacial and spring-fed systems across different ecological zones.
3. To evaluate the resilience potential of integrating traditional ecological knowledge with contemporary water management strategies.
4. To develop evidence-based recommendations for climate adaptation and water security enhancement in the Uttarakhand Himalaya.

The research methodology employed a mixed-methods approach combining archival research, field surveys, participatory rural appraisal, and geospatial analysis. Between 2020 and 2025, extensive fieldwork was conducted across 45 villages in eight districts of Uttarakhand, documenting 237 traditional water structures. Historical sources including colonial gazeteers, district records, temple archives, and epigraphic collections were systematically reviewed. Community knowledge was captured through semi-structured interviews with 156 elders, traditional water managers, and local practitioners. Climate and hydrological data from 1985-2025 were analyzed to identify trends in precipitation, temperature, and discharge patterns.

GEOGRAPHICAL AND CLIMATIC CONTEXT OF UTTARAKHAND HIMALAYA

Physiographic Divisions and Water Resources

Uttarakhand's topography can be classified into four distinct physiographic zones, each characterized by unique hydrological regimes: (i) The Shivalik Hills (300-1,500 m), comprising the southernmost ranges with seasonal streams and groundwater-dependent systems; (ii) The Lesser Himalaya (1,500-3,000 m), characterized by dense forest cover, perennial springs, and extensive traditional water harvesting structures; (iii) The Greater Himalaya (3,000-6,000 m), dominated by glaciated peaks, snowmelt-fed rivers, and alpine lakes; and (iv) The Trans-Himalaya (>6,000 m), featuring arid cold desert conditions with limited precipitation (*Valdiya, 2009*).

The state encompasses portions of five major river basins: the Ganges basin (covering 76% of the state area), Yamuna basin (12%), Kali/Sharda basin (8%), Ramganga basin (3%), and minor coastal drainages (1%). These river systems are sustained by an intricate network of over 1,400 glaciers covering approximately 2,528 square kilometers, thousands of springs, and seasonal precipitation (Rathore et al., 2015). The annual precipitation varies dramatically across the state, ranging from 700 mm in the rain-shadow areas of the trans-Himalayan zone to over 2,500 mm in the southern districts receiving monsoon influence (*Basistha et al., 2009*).

2.2 Climate Change Impacts on Hydrological Systems

Comprehensive climate analysis reveals alarming trends across multiple indicators. Temperature data from meteorological stations show an average warming of 1.4°C to 1.9°C over the past five decades, with winter months experiencing more pronounced increases (*Bhutiyani et al., 2007; Kumar et al., 2020*). This warming has accelerated glacier retreat, with studies indicating mass loss rates of 0.3 to 0.8 meters water equivalent per year across different glacial systems *(Azam et al., 2018).*

The iconic Gangotri Glacier, the source of the Bhagirathi River and one of the largest glaciers in the Himalaya, has retreated approximately 1.7 kilometers since 1780, with an accelerated retreat rate of 22 meters per year recorded during 1996-2014 (*Bhambri et al., 2012).* Similar patterns are observed across other major glacial systems including Pindari, Milam, and Sunderdhunga, raising concerns about long-term water availability during the critical pre-monsoon season when agricultural demand peaks (*Dobhal et al., 2013*).

Precipitation patterns have become increasingly erratic, with a notable decline in winter precipitation (November-February) coupled with intensification of monsoon extremes. Analysis of rainfall data from 1901-2020 indicates a 15-20% reduction in winter precipitation across most districts, directly impacting spring recharge and threatening the sustainability of traditional water sources (Negi et al., 2018). Simultaneously, the frequency of high-intensity rainfall events (>100 mm/day) has increased by 45% over the past three decades, leading to flash floods, soil erosion, and infrastructure damage (*Mishra et al., 2019*).

TRADITIONAL WATER MANAGEMENT SYSTEMS: AN ETHNO-HISTORICAL ANALYSIS

Typology of Traditional Water Structures

The traditional water management landscape of Uttarakhand encompasses diverse architectural typologies, each adapted to specific ecological niches and community requirements. These structures represent the culmination of centuries of hydraulic engineering knowledge and environmental adaptation (Singh et al., 2014).

Naulas (Step Wells): These are elaborate underground chambers with descending steps, designed to access groundwater while providing a cool, shaded environment. Naulas typically feature stone masonry construction with precise water-tight jointing using indigenous materials. The architectural sophistication varies from simple single-chamber structures to multi-storied edifices with ornate carvings and religious iconography. Notable examples include the Kyunkaleshwar Naula in Almora district, constructed in the 8th century CE, featuring 124 steps descending 15 meters to the water table (Rawat, 2011). Many naulas bear Sanskrit inscriptions recording construction dates, patron names, and maintenance obligations. A typical inscription from the Chand-era Kalpeshwar Naula (circa 1400 CE) reads: '*श्री कल्पेश्वर जलाशय कल्याण सर्वजन हिताय* (Sri Kalpeshwar water reservoir for the welfare of all beings) (Archaeological Survey of India, 1986).

Dharas (Spring Systems): Spring sources constitute the primary water supply for 90% of rural habitations in Uttarakhand (Rawat & Rawat, 2016). Traditional dhara management involved careful catchment area protection, often through sacred grove designation, along with engineered collection and distribution systems. Stone or wooden spouts (locally called *bhinnu*) were meticulously carved to channel spring water for domestic use, livestock watering, and irrigation. The cultural practice of maintaining *dhara khala* (spring sanctuaries) ensured that recharge zones remained forested and protected from human disturbance. Historical records indicate that spring protection regulations were enforced through community councils (*panchayat*) with severe penalties for violations (***Agarwal et al., 2012***).

Chaals and Kuls (Irrigation Channels): These gravity-fed irrigation channels represent remarkable feats of hydraulic engineering, traversing steep mountain slopes to distribute water across terraced agricultural fields. The construction of a major chaal required precise surveying using traditional instruments (*sul* - a wooden water level) and community labor mobilization. The 32-kilometer Rajkul in Pithoragarh district, constructed in the 17th century during Chand dynasty rule, exemplifies the scale and sophistication of these systems (Pant, 1987). Elaborate water-sharing protocols regulated distribution, with inscribed stone markers (*patthar lekh*) documenting allocation schedules and conflict resolution mechanisms.

Gadheras and Jhoras (Perennial Streams): These natural watercourses were managed through a combination of protective buffer zones, strategic harvesting points, and ritual practices. River worship (***nadi puja***) and seasonal festivals reinforced conservation ethics. Historical accounts describe elaborate ceremonies during which communities would collectively clean stream beds, repair check dams, and renew vegetation along banks (***Valdiya, 2014).***

3.2 Epigraphic Evidence and Inscriptional Records

Sanskrit and local Kumaoni inscriptions on water structures provide a rich historical archive documenting the evolution of water governance, maintenance protocols, and cultural values. These inscriptions, numbering over 400 documented examples across the state, range from simple dedication texts to elaborate legal codes governing water use (Upreti, 2003).

A significant category of inscriptions records royal patronage and state involvement in water infrastructure. A copper plate inscription from King Baz Bahadur Chand (1638-1678 CE), discovered at the Bageshwar Naula, details the establishment of a water management department (*jal adhikar*) responsible for maintaining public water sources across the kingdom. The inscription specifies tax exemptions for communities that maintained naulas and levied penalties for contamination or unauthorized diversion (Pant, 2004).

Another prevalent inscription type documents charitable donations (*dharmada*) by merchants, nobles, and religious institutions for water infrastructure construction. These texts typically invoke religious merit (*punya*), reflecting the perception of water provision as a sacred duty. An exemplary inscription from the Dwarahat Naula (dated 1054 CE) states: ***'जलदानं सर्वदानेभ्यः श्रेष्ठं मोक्षप्रदं परम्*** (Water donation is supreme among all charities, conferring liberation) (Joshi, 1990).

Community Governance and Maintenance Systems

Traditional water management operated through sophisticated community governance structures that integrated technical knowledge, social organization, and cultural practices. The institution of *naula panchayat* (water council) comprised village elders, technical experts (*raj mistri* - master masons), and religious authorities who collectively managed water resources (Rawat, 2009).

Maintenance protocols followed a seasonal calendar synchronized with agricultural cycles. Pre-monsoon preparation (*chaitra shuddhi*) in March-April involved comprehensive cleaning of naulas, channel desilting, and vegetation management in catchment areas. Post-monsoon repairs (*kartik sanrakshan*) in October-November addressed structural damages and strengthened embankments. These activities were organized through *shramdaan* (voluntary labor contribution), with each household obligated to provide labor or materials according to land holdings (Singh, 2008).

Conflict resolution mechanisms were embedded within the governance structure. Water-sharing disputes were adjudicated through community councils employing customary law (*dastoor*), with decisions recorded in village chronicles (*rawat-vamshawali*). Archaeological evidence from palm-leaf manuscripts preserved in temple archives reveals detailed dispute resolution cases spanning centuries, demonstrating the continuity and adaptability of these systems (Upreti & Upreti, 2002).

CONTEMPORARY WATER CRISIS AND ENVIRONMENTAL STRESS

Spring Discharge Decline and Rural Water Insecurity

Field surveys conducted between 2020-2025 reveal a critical deterioration of spring systems across Uttarakhand. Of 1,857 springs monitored in eight districts, 64% showed significant discharge reduction (>30% decline compared to 1990 baseline), 12% had dried completely, and only 24% maintained stable flows (Negi et al., 2021). This widespread spring failure has precipitated acute water scarcity in rural areas, forcing communities to depend on tanker supplies during lean seasons.

Multiple factors contribute to spring decline. Climate change-induced reduction in winter precipitation directly impacts groundwater recharge, as the critical snow-melt and pre-monsoon rainfall that traditionally sustained spring aquifers has diminished significantly (Tambe et al., 2012). Land-use changes, including conversion of oak and rhododendron forests to commercial pine plantations, have altered infiltration patterns and reduced soil moisture retention capacity. Unplanned infrastructure development, particularly road construction following the 2013 disaster, has disrupted subsurface hydrological pathways through slope cutting and aquifer fragmentation (Martha et al., 2015).

The socio-economic impacts are profound. Women, traditionally responsible for water collection, now walk 3-5 kilometers daily to access functioning sources, investing 4-6 hours in water procurement alone (Mehta et al., 2021). This labor burden has reduced school attendance among girls and limited women's participation in income-generating activities. Agricultural productivity has declined by 30-40% in spring-dependent irrigation systems, forcing crop pattern shifts and accelerating rural-to-urban migration (*Sharma et al., 2019*).

Degradation of Traditional Water Structures

The decline of traditional water systems reflects not merely physical deterioration but the erosion of associated knowledge systems and governance structures. Field documentation reveals that 78% of naulas are in various stages of disrepair, ranging from minor structural damage to complete collapse (Joshi & Negi, 2020). Many have been abandoned following piped water supply introduction in the 1980s-1990s, only to be desperately needed again as those systems fail during dry seasons.

Critical to this degradation is the collapse of community maintenance systems. The *naula panchayat* institution has virtually disappeared, with collective memory of maintenance protocols fading among younger generations. Interviews with elderly respondents (age 70+) reveal detailed knowledge of seasonal cleaning schedules, materials specifications, and repair techniques, while middle-aged respondents (40-60 years) possess fragmented understanding, and youth (<40 years) demonstrate minimal awareness (Rawat et al., 2020).

The abandonment of traditional irrigation channels has been equally consequential. Many *chaals* that once irrigated extensive terraced landscapes now lie breached and overgrown. The sophisticated water-sharing arrangements encoded in customary law have been replaced by informal, often contentious, arrangements. The disappearance of these traditional systems has reduced agricultural resilience, as farmers can no longer buffer climatic variability through diversified water sources (Negi, 2010).

BUILDING WATER RESILIENCE: INTEGRATING TRADITIONAL AND MODERN APPROACHES

Revival and Restoration of Traditional Water Systems

Recognizing the limitations of purely technological interventions, government agencies and civil society organizations have initiated programs to revitalize traditional water systems. The Uttarakhand State government's 'Dhara Vikas' (Spring Development) program, launched in 2016, has treated 1,200 springs across 12 districts through a combination of catchment area regeneration, storage tank construction, and distribution network upgrades (USAC, 2022). Significantly, this program incorporates community participation and attempts to revive traditional governance structures.

Similarly, naula restoration initiatives undertaken by organizations like the Himalayan Action Research Centre and local communities have demonstrated remarkable success. The restoration of the 12th century Suyal Naula in Almora district, completed in 2019, involved meticulous archaeological documentation, traditional masonry techniques, and community mobilization. Post-restoration monitoring indicates consistent water availability throughout the year, serving 85 households and significantly reducing women's water collection burden (HARC, 2020).

These restoration efforts extend beyond physical infrastructure to encompass cultural revitalization. Annual water festivals (*jal utsav*) have been reinstated in several villages, featuring traditional rituals, community work camps for structure maintenance, and knowledge transmission activities. Such initiatives have successfully re-engaged youth with water heritage, creating a new generation of 'water stewards' combining traditional wisdom with contemporary technical skills (Bisht, 2021).

Integrated Watershed Management Approaches

Contemporary watershed management in Uttarakhand increasingly emphasizes integration of traditional practices with modern scientific approaches. The concept of spring-shed management, which focuses on delineating and protecting the specific recharge zones feeding individual springs, has gained traction as an effective framework bridging indigenous knowledge and hydrogeological science (Tambe et al., 2013).

Successful implementation in the Miglya spring-shed, Almora district, demonstrates this integrated approach. Hydrogeological surveys identified the 47-hectare recharge zone, while traditional knowledge guided selection of appropriate native species for vegetation enhancement. The intervention combined trenching to increase infiltration, check dam construction for sediment control, and community-based protection protocols modeled on historic *dhara khala* systems. Within three years, spring discharge increased by 65%, and dry-season flows were established where none existed previously (Kala, 2014).

Forest conservation emerges as critical to water resilience. Research demonstrates that watersheds dominated by broad-leaf forests (oak-rhododendron associations) yield 40-60% higher dry-season stream flows compared to pine-dominated areas (Rawat & Rawat, 2016). This finding validates traditional practices that protected specific forest patches as sacred groves, unconsciously ensuring hydrological function. Modern conservation programs now explicitly recognize and protect these culturally significant forests for their water-regulatory services.

Climate Adaptation and Future Scenarios

Climate modeling for Uttarakhand projects continued warming (2.5-4.2°C by 2100 under RCP 8.5 scenario), further precipitation variability, and accelerated glacier melt, necessitating adaptive water management strategies (Dimri et al., 2021). Traditional systems offer valuable adaptation lessons, particularly regarding diversity, flexibility, and local autonomy.

The diversification principle embedded in traditional water management—utilizing multiple source types (springs, streams, groundwater) accessed through different technologies (naulas, chaals, dharas)—provides inherent resilience against single-point failures. Modern planning increasingly incorporates this diversity principle, designing 'poly-centric' water systems that reduce vulnerability to climate-induced variability (Ostrom, 2010).

Artificial groundwater recharge, an increasingly important adaptation strategy, finds precedent in traditional practices. Historical water harvesting structures functioned as recharge systems, capturing monsoon runoff and gradually infiltrating it to replenish aquifers. Contemporary recharge projects achieve enhanced effectiveness when integrated with traditional knowledge of subsurface hydrology. The Ghattu watershed project in Pauri district combined scientific aquifer mapping with traditional water diviner (*jal palak*) knowledge to optimize recharge structure locations, resulting in 80% success rate compared to 40-50% for purely technical approaches (Joshi et al., 2018).

CASE STUDIES: LESSONS FROM THE FIELD

Village Dhanachuli, Nainital District: A Naula Revival Success Story

Dhanachuli village (population 280, elevation 2,200m) exemplifies successful integration of traditional water system revival with community empowerment. By 2015, the village faced severe water scarcity, with all three traditional naulas non-functional and piped water supply unreliable. Women spent up to 6 hours daily collecting water from distant sources, and agricultural production had declined by 55% over two decades.

A comprehensive restoration initiative commenced in 2017, led by the village women's collective with technical support from the Central Himalayan Environment Association. The project adopted a participatory approach, beginning with documentation of elderly community members' knowledge about traditional naula construction and maintenance. Archaeological investigation of the ruined structures, some bearing 14th-century inscriptions, informed restoration design.

The restoration process employed traditional materials (local stone, lime mortar) and techniques, with master masons (*raj mistri*) training younger community members. Simultaneously, the recharge zones were protected through fencing and afforestation with native oak species. A reconstituted water council (*jal samiti*) was established to manage the restored structures and enforce catchment protection regulations.

Results have been transformative. All three naulas now provide year-round water, eliminating the need for tanker supplies. Women's water collection time has reduced to 30 minutes daily, enabling participation in income-generating activities. Agricultural diversification has resumed, with high-value horticulture expanding. Perhaps most significantly, the village has experienced reverse migration, with several families returning from urban areas citing improved water security as a primary factor (CHEA, 2022).

Pabau-Dungripanth Spring-shed, Pauri Garhwal: Integrated Management Model

The Pabau-Dungripanth spring-shed project represents a sophisticated integration of hydrogeological science, traditional ecological knowledge, and community-based natural resource management. This 156-hectare catchment, serving seven villages with a combined population of 1,450, experienced progressive spring discharge decline culminating in complete dry-season failure by 2013.

The intervention commenced with comprehensive hydrogeological investigation, including geological mapping, geophysical surveys, and isotopic tracing to delineate recharge zones and subsurface flow paths. This scientific assessment was complemented by participatory knowledge mapping sessions where community elders identified historical water source locations, seasonal flow patterns, and vegetative indicators of groundwater zones.

The management plan combined multiple interventions: construction of 247 trenches and 18 check dams for infiltration enhancement, plantation of 12,000 native trees in the recharge zone, revival of the traditional *chaal* irrigation system serving 45 hectares, and establishment of a spring-shed management committee incorporating both modern watershed concepts and traditional governance practices. Water use regulations drew explicitly from historical inscriptional records documenting pre-colonial water-sharing protocols.

Five-year monitoring data reveals impressive outcomes. Spring discharge increased from near-zero in April-May (pre-intervention) to 1.2-1.8 liters per second, providing reliable dry-season water. The revived irrigation system enabled double-cropping on previously fallow lands. Notably, the integrated approach generated benefits beyond water security: forest regeneration enhanced biodiversity, created non-timber forest product collection opportunities, and sequestered an estimated 850 tons of carbon dioxide over five years (Valdiya et al., 2019).

POLICY RECOMMENDATIONS AND FUTURE DIRECTIONS

Addressing the water resilience challenge in Uttarakhand demands comprehensive policy interventions that transcend conventional infrastructure-centric approaches. The following recommendations emerge from this ethno-historical analysis and field research:

1. Institutional Recognition of Traditional Water Systems: Legal frameworks must formally recognize and protect traditional water structures as heritage infrastructure with continuing utility. This requires amendments to existing water laws to acknowledge customary water rights and community management institutions. The Archaeological Survey of India should expand its mandate to include systematic documentation and preservation of water heritage sites, particularly those bearing inscriptional evidence.

2. Integration of Traditional Knowledge in Planning: Water resource planning should mandatorily incorporate traditional ecological knowledge alongside scientific assessments. This requires capacity building of government staff in participatory methodologies and establishment of formal mechanisms for elder consultations in project design. Water budgeting exercises must account for traditional source diversity rather than focusing solely on piped supply systems.

3. Spring-shed Management as Primary Framework: Given the critical dependence on spring systems, spring-shed management should be adopted as the fundamental unit for rural water planning. This necessitates comprehensive spring mapping, delineation of recharge zones, and development of spring-shed specific management plans with community ownership. The state should establish a dedicated Spring Management Authority with technical expertise and community liaison capabilities.

4. Forest-Water Nexus Recognition: Forest policy must explicitly recognize the hydrological services provided by specific forest types, particularly oak-dominated ecosystems. Conversion of such forests for commercial plantations or infrastructure development should be strictly prohibited. Payment for Ecosystem Services schemes should compensate communities for protecting recharge forests, providing economic incentives aligned with water conservation.

5. Revitalization of Community Governance: State programs should actively support revival of traditional water management institutions (*naula panchayats, jal samitis*) rather than relying solely on formal bureaucratic structures. This includes providing legal recognition, financial support for maintenance activities, and integration with Panchayati Raj institutions. Capacity building programs should train community water managers in both traditional techniques and contemporary challenges like climate adaptation.

6. Education and Awareness Initiatives: Water heritage and conservation should be integrated into school curricula, combining theoretical knowledge with practical engagement in local water systems. Universities should establish dedicated research and teaching programs in ethno-hydrology and traditional water management. Documentation projects should record elder knowledge through oral histories, ensuring intergenerational transmission of water wisdom.

7. Climate Adaptation Financing: Access to climate adaptation funds should prioritize nature-based solutions and traditional system revival over large-scale engineering projects. Financing mechanisms should support community-led initiatives, providing technical assistance alongside capital investment. Performance-based disbursements linked to water availability improvements can ensure accountability while maintaining flexibility for local adaptation.

CONCLUSION

This ethno-historical investigation reveals that the water crisis confronting Uttarakhand Himalaya is fundamentally a crisis of knowledge disruption and institutional erosion as much as it is a consequence of climate change and environmental degradation. The traditional water management systems that sustained communities for centuries embodied sophisticated understanding of mountain hydrology, social organization for collective action, and cultural values that sacralized conservation. These systems demonstrated remarkable adaptive capacity, flexibly responding to climatic variability and resource fluctuations through diversified strategies and community resilience.

The contemporary challenge lies not in choosing between traditional and modern approaches but in achieving genuine integration that harnesses the strengths of both. Traditional systems offer invaluable lessons in decentralization, diversity, community ownership, and ecosystem-based management—principles increasingly recognized as essential for climate resilience. Modern science contributes technical capabilities in assessment, monitoring, and scaling interventions beyond village level. The most promising pathways forward involve creative synthesis of these complementary knowledge systems.

The inscriptional records that adorn ancient naulas and irrigation channels speak across centuries with continuing relevance. Their message—that water is a sacred trust, that communities must act collectively for sustainable management, that governance must balance technical competence with ethical commitment—resonates profoundly in our era of accelerating climate change. As we confront the unprecedented challenges of the 21st century, the water wisdom encoded in Uttarakhand's traditional systems offers not nostalgic romanticism but practical pathways toward resilience.

The revival initiatives documented in this study demonstrate that transformation is possible. Villages that have restored their naulas, protected their spring-sheds, and revitalized community governance have achieved tangible improvements in water security, agricultural productivity, and social cohesion. These successes provide empirical validation for scaling up integrated approaches across the region.

However, realizing this potential requires fundamental shifts in policy frameworks, institutional arrangements, and development paradigms. The predominant emphasis on large infrastructure projects must be balanced with investment in nature-based solutions and community-level systems. The technocratic orientation of water management must be complemented with genuine participatory approaches that respect and integrate local knowledge. The fragmented sectoral governance of water, forests, and agriculture must give way to integrated watershed management recognizing ecological interconnections.

As climate change intensifies, threatening the very foundation of mountain water systems through glacier retreat, precipitation variability, and extreme events, the stakes could not be higher. The Uttarakhand Himalaya stands at a crossroads: one path leads toward deepening crisis as traditional systems collapse and modern alternatives prove inadequate; the other path, more challenging but ultimately more sustainable, leads toward resilience through integration, innovation, and renewal. The choice will determine not only the future of millions dependent on these mountains but also the fate of one of earth's most magnificent and vital ecosystems—the water tower that sustains the Indian subcontinent.

The Sanskrit inscription on the ancient Dwarahat Naula, asserting that water provision is the supreme charity, reminds us that addressing the water challenge is ultimately an ethical imperative. It demands that we honor the wisdom of ancestors who built systems designed to last centuries, respect the rights of future generations to inherit a livable planet, and recognize our collective responsibility as stewards of irreplaceable mountain ecosystems. In confronting climate change and environmental stress, we must draw not only on technological innovation but also on the deeper wells of traditional wisdom, community solidarity, and cultural values that have sustained human-environment relationships in these mountains for millennia.

Introduction: Gangnani and Its Significance

Gangnani, situated near Badkot in Uttarkashi district, on the pilgrimage route to Yamunotri Dham, represents a crucial junction of spiritual heritage and traditional water resource management in the Garhwal region of Uttarakhand. The Gangnani inscription, reportedly discovered by historian Vijay Bahuguna in 2006, stands as a testament to the ancient wisdom of springshed management that has sustained Himalayan communities for millennia. This remote location, approximately 47 kilometers from Uttarkashi, has long been revered not only for its thermal springs—known as Rishikund—but also as a repository of indigenous knowledge systems related to water conservation and sustainable resource management.

The historical importance of Gangnani extends beyond its geographical positioning. As a natural hot water spring destination, it has served pilgrims and travelers for centuries, offering both physical rejuvenation and spiritual purification. The discovery of inscriptions in this region provides valuable insights into how ancient communities understood and managed their precious water resources, particularly springs and springsheds that formed the lifeblood of mountain settlements.

Historical Context of Water Bodies in Uttarakhand

Uttarakhand, often referred to as the Water Tower of Asia possesses an extraordinary legacy of traditional water management systems that date back over a thousand years. The historical evolution of water body management in this region reflects a sophisticated understanding of hydrogeology, ecology, and sustainable resource utilization that modern science is only now beginning to fully appreciate.

The ancient kingdoms of Katyuri and Chand dynasties, which ruled the Kumaon and Garhwal regions from the 7th to 18th centuries, established elaborate systems for water conservation and distribution. Archaeological evidence and inscriptions from this period reveal that construction of water facilities—naulas (step wells), dharas (spring fountains), and irrigation channels—was considered an act of piety and public service. These structures were not merely functional; they were sacred spaces that embodied the cultural and spiritual relationship between communities and their water sources.

Historical records indicate that many naulas constructed during the Katyuri period in the 7th century remain functional today. The 1,000-year-old naula in Suryakot (Almora), the 700-year-old structure near Haat Kalika temple in Gangolihat (Pithoragarh), and the Baleshwar Naula built by Raja Thorchand in 1272 stand as enduring monuments to the engineering prowess and environmental wisdom of ancient Uttarakhand. These structures were strategically located to tap into perched aquifers, utilizing the region’s unique geological formations where water accumulates in rock fissures and fractures.

The concept of springshed management, which the Gangnani inscription is closely associated with, represents one of the most sophisticated aspects of traditional water resource governance in the Himalayan region. Unlike watershed management that focuses on surface water flow, springshed management addresses the recharge zones that feed groundwater springs—the primary source of drinking water for approximately 90% of Uttarakhand’s rural population.

Ancient communities in the Gangnani region and throughout Uttarkashi district developed intricate knowledge of how monsoon rainfall percolated through soil and rock to emerge as springs. They understood that protecting forest cover, particularly native species like oak and deodar, was essential for maintaining groundwater recharge. This knowledge was encoded in cultural practices, religious rituals, and community governance systems that ensured the long-term sustainability of water sources.

The traditional water management systems included several key components: naulas (aquifer-fed step wells), dharas (natural spring fountains), gadheras (small tributary streams), guls (irrigation channels following mountain contours), and chals or khals (artificial hilltop ponds for rainwater collection). Each of these structures served specific functions within the broader ecosystem of water conservation and distribution.

The historical context of water bodies in Uttarakhand cannot be understood without acknowledging their sacred dimensions. Water sources were invariably associated with religious deities, most commonly Lord Vishnu or local deities, whose sculptures were carved onto *Naula* walls and *dhara* structures. This sacralization served a practical conservation purpose—by declaring water sources sacred, communities created powerful social mechanisms to prevent pollution and ensure proper maintenance.

Gangnani itself exemplifies this sacred-functional duality. The thermal springs at Rishikund are associated with sage Parasara, father of Veda Vyas, and a temple dedicated to the sage stands nearby. Pilgrims traditionally bathe in these springs before proceeding to Gangotri, participating in a ritual that connects physical purification with spiritual preparation. This practice, maintained over centuries, also ensured the community investment in protecting and maintaining the spring.

Cultural practices further reinforced water conservation. In traditional Garhwali society, important life ceremonies—weddings, naming ceremonies, and rites of passage—were linked to local naulas and dharas. New brides in Kumaon still perform ritual prayers at village water sources upon entering their husband home. Such customs embedded water resource protection into the very fabric of social life, ensuring transgenerational transmission of conservation ethics.

The historical governance of water bodies in Uttarakhand demonstrates remarkable community-based resource management systems. Before British colonial rule, local communities exercised complete ownership and management rights over their water resources. Village councils (panchayats) established rules for water usage, maintenance schedules, and conflict resolution. These systems operated on principles of equity, sustainability, and collective responsibility.

Inscriptions and oral histories reveal that wealthy patrons—kings, feudal lords, or prosperous families—often sponsored the construction of water facilities as acts of public service and religious merit. However, once constructed, these facilities became community property, managed collectively for the benefit of all. This pattern of patronage combined with community stewardship created a robust system capable of maintaining infrastructure across generations.

The traditional governance framework began to erode during the colonial period and continued to decline after independence. The Kumaon and Garhwal Water (Collection Retention and Distribution) Act of 1975 transferred water management authority to state bureaucracies, undermining community ownership and the traditional knowledge systems that sustained these resources. This shift contributed to the current crisis, where over half of garhwal,s perennial springs have dried up or become seasonal.

The Gangnani inscription and similar historical records provide valuable lessons for contemporary water resource management. They demonstrate that sustainable water management in mountainous regions requires integrated approaches combining technical knowledge, ecological understanding, cultural practices, and community participation. The ancient systems succeeded because they addressed water security holistically—protecting recharge zones, managing extraction rates, maintaining infrastructure, and embedding conservation in cultural practice.

Modern spring shed management programs, such as those implemented by organizations like Him motthan and the Central Himalayan Rural Action Group, are essentially reviving these traditional principles while incorporating contemporary scientific methods. They focus on identifying recharge zones, constructing loose boulder check dams to reduce runoff, planting indigenous tree species, and training community members as ;water champions; to ensure long-term sustainability.

The historical context of water bodies in Uttarakhand, as illuminated by discoveries like the Gangnani inscription, reveals a sophisticated civilization that understood the critical importance of sustainable water management in the fragile Himalayan ecosystem. From the thermal springs at Gangnani to the ancient naulas of Kumaon, these water bodies represent not merely infrastructure but embodiments of accumulated ecological wisdom, cultural values, and community solidarity.

The Gangnani inscription represents a significant epigraphic record from 19th century Garhwal. Located at Gangnani near Badkot in Uttarkashi district, on the sacred pilgrimage route to Yamunotri Dham, this inscription documents the construction of a vapi (stepped water tank) commissioned during the reign of Jalmal Sen, ruler of the Mandal region from 1826 to 1838 CE. The inscription provides valuable insights into the intersection of royal patronage, religious devotion, and water infrastructure development during a transformative period in Garhwals history.

The period during which the Gangnani vapi was constructed marked a critical juncture in Garhwals political history. In 1803, the Gorkhas, under the leadership of Amar Singh Thapa, invaded the Garhwal Kingdom, defeating and killing King Pradyumna Shah at the Battle of Khurbura. For twelve years, from 1803 to 1815, the Gorkhas occupied the entire Garhwal region, extending their control from Dehradun to Kangra.

The Anglo-Nepalese War of 1814-1815 dramatically altered this political landscape. Sudarshan Shah, son of the slain King Pradyumna Shah, had been in exile in British territory since childhood. Recognizing an opportunity, he allied with the British East India Company in 1812. When war erupted in 1814, Sudarshan Shah joined British forces in liberating Garhwal from Gorkha occupation. The Treaty of Sugauli in 1815 formally ended the conflict, but with significant consequences for Garhwals territorial integrity.

The British annexed the eastern portion of the kingdom (present-day Pauri Garhwal) as British Garhwal and incorporated it into British India. Sudarshan Shah received only the western portion of his ancestral kingdom, which became the princely state of Tehri Garhwal. Since the traditional capital of Srinagar now lay in British territory, Sudarshan Shah established a new capital at Tehri, giving the state its name. He ruled this reconstituted kingdom from 1815 until his death in 1859, overlapping significantly with the period when the Gangnani inscription was created.

The Gangnani inscription specifically names Jalmal Sen as the ruler of Mandal region (Mandal Deshadhipati) who commissioned the vapi construction. His reign from 1826 to 1838 CE places the inscription firmly within the post-Gorkha period of Garhwal history. The inscription establishes important genealogical connections that illuminate the political relationships of this era.

Jalmal Sen was the son of Maharaj Ishwari Sen, indicating a hereditary ruling lineage in the Mandal region. More significantly, the inscription identifies his contemporary Garhwal rulers: Maharaj Sudarshan Shah, who ruled Tehri Garhwal from 1804 to 1859, and references Sudarshan Shas father, Maharaj Pratap Shah. This genealogical information is particularly valuable as Pratap Shah succeeded his father Bhawani Shah in 1872, after Sudarshan Shahs death, suggesting the inscription may reference different branches of the royal family or contain scribal variations in chronology.

The inscriptions mention of family connections between the Mandal rulers and the main Garhwal royal line suggests a network of feudatory relationships that characterized the political organization of the region. The Mandal region, while maintaining its local ruling family, acknowledged the suzerainty of the main Garhwal kingdom, a pattern common in Himalayan political structures of the period.

The central subject of the Gangnani inscription is the construction of a vapi, a traditional Indian stepped water structure. Unlike simple wells, vapis are elaborate architectural features with steps leading down to the water level, allowing access throughout seasonal fluctuations. These structures served both practical and religious functions, providing water for drinking, bathing, and ritual purification.

According to the inscription, the vapi was commissioned by the Mathadhisha (temple head or monastic authority) for the purpose of worship (puja) on behalf of Jalmal Sens daughter. This arrangement reveals the religious motivation underlying the construction. In Hindu tradition, the building of water facilities; particularly those accessible to pilgrims and travelers; was considered an act of great religious merit (punya). By sponsoring such construction on behalf of his daughter, Jalmal Sen was ensuring her spiritual welfare and accumulating merit for the family.

The role of the Mathadhisha in commissioning the work indicates institutional involvement in water infrastructure development. Religious establishments In 2014; temples, monasteries, and maths; often served as centers of community organization and public works in traditional Indian society. The Mathadhisha would have mobilized resources, organized labor, and overseen the technical aspects of construction, acting as an intermediary between royal patronage and practical implementation.

The location of the Gangnani vapi is particularly significant. Situated on the route to Yamunotri Dham, one of the four sacred shrines (Char Dham) of Uttarakhand, Gangnani has long served as an important stopover for pilgrims. The area is already renowned for its natural thermal springs, known as Rishikund, which are associated with the sage Parasara, father of Ved Vyas. These hot springs have attracted pilgrims for centuries, who bathe in their waters for both physical rejuvenation and spiritual purification before proceeding to Yamunotri.

The construction of a vapi at this location would have enhanced Gangnani’s capacity to serve pilgrims by providing additional water facilities. While the natural hot springs served specific ritual purposes, a constructed vapi would offer clean drinking water and bathing facilities for the increasing numbers of pilgrims traveling to Yamunotri. This exemplifies how religious infrastructure and practical water management were seamlessly integrated in traditional Himalayan society.

The historical pattern of water infrastructure development along pilgrimage routes represents a distinctive feature of Uttarakhand, 2019; cultural landscape. Rulers, wealthy patrons, and religious institutions competed in piety by constructing facilities for pilgrims, 2014; not only water tanks and wells but also rest houses (dharamsalas), temples, and bridges. These constructions served both immediate practical needs and the long-term spiritual objectives of the patrons.

Continuity of Traditional Patronage Patterns

The historical significance of this inscription extends beyond its immediate content. It documents an era when the Garhwal Kingdom was recovering from the devastating Gorkha invasion of 1803-1815 and adapting to new political realities under British oversight. The inscription serves as a window into how traditional practices of royal patronage, religious merit-making, and community infrastructure development continued to function within this transformed political landscape. The Gangnani inscription, though modest in content, offers a valuable window into multiple dimensions of 19th century Garhwal history. It documents the persistence of traditional royal patronage and religious practices during a period of dramatic political change. It illuminates the continued central role of water infrastructure in religious life and community welfare. It provides genealogical information about local ruling families and their connections to the main Garhwal royal line. And it demonstrates how traditional knowledge systems and construction techniques survived the disruptions of invasion, partition, and colonial influence.

In the broader historical context of water bodies in Uttarakhand, the Gangnani vapi represents a link in the long chain of water management practices extending from the Katyuri period through colonial times to the present day. While the inscription itself makes no explicit reference to springshed management or ecological conservation principles, the vapi it describes would have functioned within the traditional water management framework of the region, capturing and distributing water for human use while respecting the sacred character of water sources.

Today, as Uttarakhand faces mounting challenges of water scarcity, spring depletion, and climate change, historical inscriptions like the one at Gangnani remind us of the long tradition of community investment in water infrastructure. They challenge us to learn from historical practices while adapting them to contemporary needs, ensuring that the heritage of sustainable water management that sustained mountain communities for centuries continues to serve future generations.

As Uttarakhand faces contemporary challenges of climate change, deforestation, and rapid development, the lessons encoded in historical water management systems become increasingly relevant. The integration of traditional knowledge with modern scientific understanding offers the most promising path toward ensuring water security for future generations. The Gangnani inscription, as a historical document related to spring shed management, serves as a reminder that the solutions to current water crises may lie not in abandoning traditional systems, but in reviving, adapting, and strengthening them for the 21st century.

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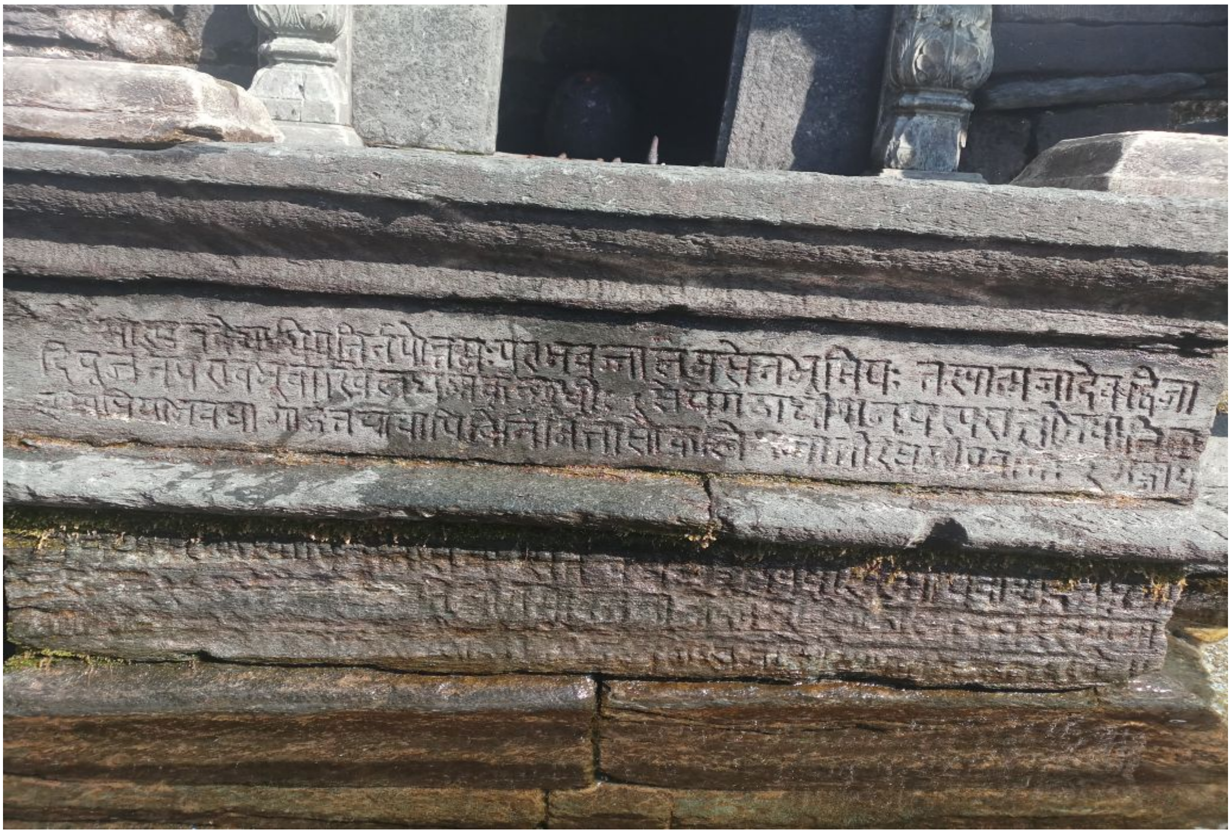

Gangnani Inscription (Near Badkot, Uttarkashi)

Ganganani Kund

गंगनाणी शिलालेख

1. **माडव देशाधिपतिर्तयोन्नमः पराभव जालमसेन भूमिपःतस्मात्मजा देवद्विजा–**
2. –दि पूजने परावभूवाखिल धर्म .... धीः । सेय मठाधीशनपत्पराती भषानिया–
3. भूमिप्रियाभवंद्या गार्हत यो वापि विनिर्मिता सौकाले ....भागीरथ ...... रंगाय ।
4. ....
5. ....
6. ....

अनुवाद सार

मण्डी देश के अधिपति जालमसेन (शासन 1826–38 ईस्वी , पुत्र महाराज ईश्वरी सेन , समधी गढ़वाल महाराज सुदर्शन शाह , मातामह / नाना गढ़वाल