



Integrating Traditional Water Wisdom into Sustainable Urban Water Management

A Case Study of Indore

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Abstract-

Rapid urbanization in India has intensified groundwater depletion, surface runoff, flooding and water pollution, and has made cities increasingly reliant on water brought from outside. Traditional systems such as bawdis, wells, tanks, kunds and linked storage networks embody practical strategies for retaining water locally, recharging aquifers, trapping sediment and managing water collectively. This review assesses how relevant these systems are to sustainable urban water management in Indore, a city on the basaltic Malwa Plateau. It draws on peer-reviewed studies, government reports and preliminary GPS-referenced site observations, and classifies the sites as hydraulic structures, water-related cultural landscapes or potential water-heritage sites. The review finds that a site's present usefulness for water management hinges on how well it is connected to its catchment, the state of its structure, the aquifer beneath it, its water quality and sediment load, and who owns and maintains it. To guide site assessment, functional classification, restoration and monitoring, a six-stage framework is proposed. Structures that pass this screening could contribute to groundwater recharge, stormwater detention, non-potable storage, ecological enhancement, groundwater monitoring and heritage conservation. The study thus offers a practical route for bringing traditional water systems into urban hydrology, groundwater management and heritage-sensitive planning.

Key words: Traditional water systems, Indian Knowledge System, urban water management, managed aquifer recharge, water heritage, Indore

I. INTRODUCTION

Traditional Indian water systems evolved in response to the variability of monsoon rainfall and to local topography, geology, settlement patterns, livelihoods and community practice. They did more than store water. Stepwells and bawdis gave access to groundwater whatever its seasonal level, tanks and chains of ponds

regulated runoff and sediment, and local wells served domestic, agricultural, religious and landscape needs. Each structure was thus one element of a community water-management system rather than a stand-alone hydraulic work.

The Indian Knowledge System (IKS) framework approaches traditional water wisdom through three linked perspectives. *Gyan* and *Parampara* concern how place-based knowledge is recorded, interpreted and handed down between generations. *Vigyan* and *Laukik Prayojana* concern its practical evaluation and adaptation with the help of geospatial technology, hydrology, hydrogeology, engineering and water-quality assessment. *Jeevan Darshan* and *Drishti* express an ecological worldview in which water is not only an economic resource but a shared, life-sustaining element embedded in the relationships between communities, landscapes and natural processes, an outlook consistent with the *Panch Mahabhuta* view of water as part of an interconnected environmental system. It is this outlook that explains why so many traditional systems relied on community stewardship, collective maintenance and locally negotiated rights of access.

These systems have become more, not less, relevant now that many Indian towns experience both flooding and water scarcity within a single hydrological year. Expanding impervious surfaces reduce infiltration and accelerate runoff, while over-abstraction of groundwater and the decay of local storage erode water security in the dry season; satellite observations have documented the scale of groundwater depletion in India (Rodell et al., 2009). The First Census of Water Bodies recorded 2,424,540 water bodies in India, of which only 2.9% lay in urban areas, and found a considerable share of the inventory non-functional because of drying, siltation, construction, pollution or physical damage (Ministry of Jal Shakti, 2023).

National groundwater assessments further show that local over-exploitation can persist even where the aggregate balance appears healthy (Central Ground Water Board, 2025). Traditional water wisdom does not, however, justify reproducing historical forms as they were. Its present value lies in transferable design principles:



distributed storage, retention of runoff near its source, gravity-fed conveyance, interception of sediment, seasonal access to groundwater, controlled overflow, protection of catchments and shared maintenance. Provided that hydrogeological suitability and water-quality protection are treated as primary design requirements, these principles align with managed aquifer recharge (MAR), rainwater harvesting, sustainable urban drainage, water-sensitive urban design and blue-green infrastructure.

Indore is a suitable setting in which to test these ideas. The city grew on the Malwa Plateau around the Khan and Saraswati rivers and retains wells, bawdis, palace and garden landscapes, temple precincts and river-related heritage sites. The district is underlain mainly by Deccan Trap basalt, in which groundwater occurrence is controlled by weathered zones, vesicular horizons, fractures, joints and interflow contacts (Central Ground Water Board, 2023). This study combines a structured review with a preliminary assessment of selected GPS-referenced sites in Indore, in order to give planners a scientifically sound basis on which traditional water wisdom can be joined to present-day hydrology, aquifer management and the planning of historic areas.

II. REVIEW AND CASE STUDY METHODOLOGY

A. Literature Synthesis

A structured narrative review was adopted because the relevant literature spans hydrology, hydrogeology, urban drainage, history, environmental management and structural survey, and its studies differ widely in design and in the outcomes they report. The sources comprise peer-reviewed articles and government reports on traditional water harvesting, stepwells, tank cascades, rainwater harvesting, MAR, groundwater depletion, water-sensitive urban design, urban water quality and Indian water policy.

The sources were organized under four analytical themes: (i) traditional systems as hydro-social infrastructure; (ii) rainwater harvesting and managed aquifer recharge; (iii) sustainable urban drainage and blue-green infrastructure; and (iv) water quality, heritage and governance. Because the studies work at different spatial scales and with different indicators and methods, a quantitative meta-analysis was not attempted. The review instead identifies design principles that recur across studies, mechanisms by which systems repeatedly fail, and the conditions under which traditional structures can be given a working role in modern urban systems.

a) Traditional Systems as Hydro-Social Infrastructure

Traditional water systems in India were adapted to their locality rather than built to a standard design. Bamboo diversion channels, Apatani irrigation, kunds, tanks, stepwells and other rainwater-harvesting structures each answered a particular combination of terrain, rainfall, geology and livelihood (Bhattacharya, 2015). How well they worked depended as much on rules for access, desilting, repair, allocation and catchment protection as on their physical form. Studies of tank cascades make the importance of connectivity especially clear: a single tank offers local storage, but the wider hydrological benefit relies on feeder channels, surplus weirs, downstream tanks, sediment pathways and coordinated upkeep. Work in southern India shows that urbanization, siltation, encroachment and weak institutional ownership can erode storage and drought protection even where the tanks themselves remain visible (Chinnasamy and Srivastava, 2021; Srivastava and Chinnasamy, 2021). For Indore, the implication is that cleaning or beautifying a structure in isolation will rarely restore its hydrological function while its catchment and overflow system remain severed.

b) Rainwater Harvesting and Managed Aquifer Recharge (MAR)

Rainwater harvesting is frequently treated as beneficial by definition, yet its effect depends on where runoff would otherwise go, on local demand and storage capacity, on aquifer properties and on consequences downstream. Kumar et al. (2006) showed that poorly planned local harvesting may simply redistribute water within a basin instead of increasing the total available. For urban bawdis and wells, then, the question is not only how much runoff can be captured, but whether the structure has spare storage, whether the aquifer can accept recharge, whether the source water is safe and whether downstream users or systems would suffer. Efforts to revive traditional harvesting alongside artificial recharge face the same questions (Laskar, 2022).

MAR offers a modern engineering framework for answering them. It can diversify urban water sources, limit evaporative losses from open storage, and complement stormwater harvesting and water recycling (Page et al., 2018; Zhang et al., 2020). A historical well or bawdi should be called a MAR system, however, only when recharge is deliberate, water quality is controlled, compatibility with the aquifer has been established, clogging is managed and performance is monitored. In Indore's Deccan Trap setting this screening is indispensable, because massive basalt, weathered horizons, vesicular zones and fractures can differ greatly in how they take in and store water.

c) Sustainable Urban Drainage and Blue-Green Infrastructure

Whether labelled Sustainable Urban Drainage Systems, Low Impact Development, Best Management Practices, Green Infrastructure or Water Sensitive Urban Design, current approaches to urban drainage converge on source control, reduction of runoff volume, detention, infiltration, treatment and integration with urban form (Fletcher et al., 2015). Traditional structures can serve these aims if they form one stage of a treatment train, rather than acting as pits that receive untreated runoff directly.

Such a train might comprise litter screens, first-flush diversion, sediment forebays, vegetated swales, bioretention, polishing in a constructed wetland, controlled inflow, monitored infiltration and a safe connection for overflow. The structure can then be given a site-specific role, whether detention, recharge, storage, landscape irrigation, ecological enhancement or public interpretation. Jebamalar et al. (2023) likewise argue that urban rainwater-harvesting systems should be judged by their functional condition, the adequacy of their recharge area, their connection to the aquifer and their spatial distribution, not by the number installed.

d) Water Quality, Heritage and Governance

Water quality is the main constraint on returning urban heritage structures to hydraulic use. Urban stormwater can carry sediment, pathogens, nutrients, hydrocarbons, metals, detergents and sewage. Groundwater observations in Indore reveal spatial variation and undesirable parameters at some locations, so recharge cannot proceed on the assumption that either the source water or the receiving aquifer is uniformly clean (Gurjar et al., 2013). Where contamination cannot be controlled reliably, a structure may still have heritage, public-space, thermal or detention value without being used for recharge.

Conserving heritage and restoring hydraulic function are related goals but not the same one. Stepwells carry architectural, cultural and social value, yet reviving them as working structures demands structural safety, rehabilitation of the catchment, control of source water and sustained maintenance (Selvaraj et al., 2022). Communities



can contribute surveillance, cleaning, cultural programming and local monitoring, but statutory agencies must retain responsibility for engineering design, water-quality compliance, protection of land and long-term funding. The contribution of traditional systems to sustainable development therefore rests on co-management, not on shifting public responsibilities onto local communities (Sharma and Ji, 2024).

III. PRELIMINARY SITE INVENTORY

The Indore component of the study draws on the city's history, its urban and hydrogeological context and its geological constraints, as outlined below.

a) Historical Background

Indore began in the sixteenth century as a trading settlement on the banks of the Kanh (Khan) and Saraswati rivers, well placed on the routes between northern India and the Deccan. Its commercial standing grew under the Holkar dynasty in the eighteenth century, and it became a significant administrative, military and trading centre. The move of the Holkar capital to Indore in 1818, followed by the railway in 1875, electricity in 1906 and the first master plan in 1918, accelerated planned and industrial growth. After the city became part of Madhya Pradesh in 1956, it expanded rapidly from a traditional commercial town into a major industrial, educational and metropolitan hub of central India.

b) Geomorphology

Indore lies on the Malwa Plateau, an undulating surface with scattered flat-topped hills that slopes generally northwards. Plateau elevations lie mostly between about 487 and 579 m above mean sea level. The south is more rugged and hilly because of the denudational Vindhyan ranges, aligned from west-southwest to east-northeast, and the region reaches its greatest height at Singhgarh, about 881 m above mean sea level. The main geomorphic units are alluvial plains, upper and undissected plateaus, and denudational hills (Fig. 1). Narrow alluvial strips follow the Khan, Kshipra and Gambhir rivers.

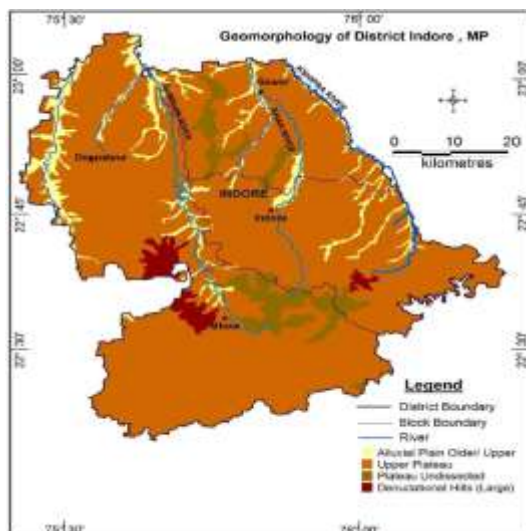


Fig. 1. Geomorphological map of Indore (M.P.), showing alluvial plains, upper plateau, undissected plateau, denudational hills and major river systems. Source: Central Ground Water Board (2017–18).

c) Climate and Rainfall

Indore's climate is dominated by the monsoon, with hot summers, mild winters and a distinct southwest monsoon season. Normal annual rainfall is about 920 mm, roughly 91% of which falls between June and September, with July the wettest month. This concentration of rainfall in a few months governs most surface runoff, soil-moisture replenishment and groundwater recharge, and it is the reason why storage and recharge structures matter so much in this setting.

d) Hydrology

The hydrological regime of Indore District is driven largely by the monsoon. The Gambhir, Khan and Kshipra rivers form the main drainage network (Fig. 2) and flow broadly from south to north towards the Ganga system, while the southern fringe beyond the Vindhyan hills drains to the westward-flowing Narmada. Most rivers and streams are seasonal: they carry heavy runoff, and occasionally flood, during the monsoon, and dwindle to sluggish flows in summer. Surface-water availability, groundwater recharge and flood generation are therefore closely controlled by seasonal rainfall, terrain, drainage connectivity and the infiltration behaviour of the basaltic landscape.

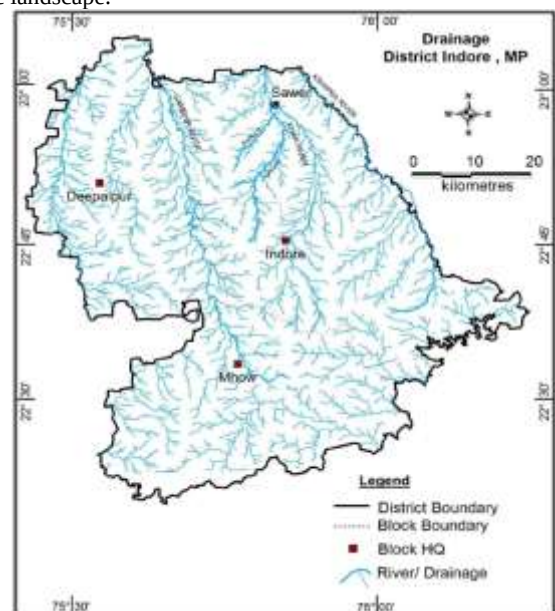


Fig. 2. Drainage network of Indore District (M.P.), showing district and block boundaries, block headquarters and the major river systems. Source: Central Ground Water Board (2017–18).

IV. STUDY AREA AND EVIDENCE CLASSES

A. Classification of selected sites

The sites considered in this review are listed in Table 1 with their coordinates, construction period, evidence status and potential contemporary role. To avoid over-classifying them, each site was placed in one of three evidence classes: (1) direct hydraulic structures, where a well, bawdi, tank or other groundwater-access feature is visible; (2) water-associated cultural landscapes, whose historical setting is linked to rivers, gardens or religious practice; and (3) candidate water-heritage sites, where a water feature is reported but its form and function have yet to be verified.



TABLE 1. PRELIMINARY CLASSIFICATION AND EVIDENCE STATUS OF SELECTED SITES IN INDORE.

Site	Coordinates	Site category	Construction period	Evidence status	Potential contemporary role
Vishram Bagh Well	22°41'58" N, 75°49'57" E	Direct hydraulic structure	ca. 1926 CE	Visible well; a substantial stepped, masonry-lined water structure with perimeter railings	Monitoring well, storage, heritage interpretation, possible recharge after screening
Ranjeet Hanuman Bawdi	22°42'1" N, 75°50'8" E	Direct hydraulic structure	ca. 1906 CE	Visible Bawdi; presently covered at the surface	Heritage conservation, detention or recharge subject to catchment and water-quality assessment
Bank Colony Well	22°41'36" N, 75°50'12" E	Direct hydraulic structure	Early 20 th century CE	Visible well; circular masonry-lined well with visible water	Groundwater monitoring, neighborhood heritage, recharge only if safe
Champa Bawdi, Lalbagh	22°42'3" N, 75°50'42.77" E	Direct hydraulic structure	Probable developed in ca. 1726CE	Visible stepwell; a substantial stepped, masonry structure with multiple access levels, retaining walls and a defined lower storage area	High heritage priority; storage or recharge after structural and hydrogeological assessment
Jagga Bagicha Bawdi	22°42'30" N, 75°51'51" E	Direct hydraulic structure	ca. 1826 CE	Visible Bawdi; rectangular or linear water structure protected by a full metal grating, garden and railway associations	Neighborhood heritage, detention or recharge after structural and water-quality screening
Dravidn eshwar Shiv Temple	22°42'8" N, 75°50'11" E	Candidate water-heritage site	ca. 1906 CE	Temple documented; landscaped public space, water-heritage site	Survey and documentation before water-management classification
Badi Ganga Bagichi	22°42'45" N, 75°49'30" E	Water-associated cultural landscape	ca. 1326 CE	Living religious garden; masonry-lined water feature	Heritage landscape, public engagement, site-specific water survey
Lal Bagh Ground	22°42'11" N, 75°50'50" E	Water-associated cultural	Palace estate developed	Royal garden with masonry-	Landscape drainage, detention,

		landscape	mainly ca. 1726CE	lined chamber containing standing water within the Lal Bagh landscape.	irrigation and heritage-sensitive restoration
Krishna pura Chhatris	22°42'43" N, 75°51'8" E	Water-associated cultural landscape	Early 16 th century CE	stepped masonry, physical presence of the hydraulic structure is available	Riverfront heritage, flood and moisture-risk management, not automatic recharge
Ram Mandir, Kumaw atpura	22°42'34" N, 75°51'49" E	Candidate water-heritage site	ca. 1846 CE	Temple and iconography known; a well, Kund or service opening,	Cultural heritage; assess any separate well, Kund or storage feature
Parwati Turkeshwar Mandir	22°40'45" N, 75°50'22" E	Candidate water-heritage site	Early 19 th century CE	temple and a separate narrow, sunken masonry-lined feature within the precinct	Survey before classification; possible rainwater-harvesting demonstration site

a) Direct Hydraulic Structures

Vishram Bagh Bawdi and Well

The Vishram Bagh Bawdi is a rectangular masonry structure measuring 7.616 m × 9.347 m, giving a plan area of 71.18 m², with a reported depth of 25 m. Water depth varies seasonally from about 16 m in the monsoon to 13 m in summer. The same garden contains a circular masonry well with a radius of about 7.375 m, a plan area of 170.87 m² and a reported depth of 25 m, whose water depth likewise ranges from about 16 m in the monsoon to 13 m in summer. Set together within a historic garden (Fig. 3(a, b)), the bawdi and well may once have provided groundwater access, runoff retention and irrigation for the landscape. Conversion of the garden into a municipal park may, however, have cut or rerouted the paths by which water once reached it. Only a combination of structural survey, sediment measurement, water-quality analysis and groundwater observation across seasons can show what part, if any, it still plays hydraulically.

Ranjeet Hanuman Bawdi

The Ranjeet Hanuman Bawdi is a narrow rectangular structure of about 5.321 m × 3.764 m, with a plan area of 20.03 m² and a reported depth of 25 m (Fig. 3(c, d)). Its water depth falls from about 16 m in the monsoon to 13 m in summer. The narrow, deep form points to a structure built mainly for access to groundwater rather than for extensive surface storage. The bawdi belongs to the Ranjeet Hanuman temple and akhara precinct, but its date of construction, patron and original purpose are undocumented. Given the ongoing redevelopment of the site, its geometry, masonry, sediment, water quality and inflow–overflow connections should be recorded in detail.

Bank Colony Well

The Bank Colony Well (Fig. 3(e)) is a circular masonry well with a radius of about 4 m, a plan area of 50.27 m² and a reported depth of 25 m. Its water depth is about 20 m in the monsoon and 18 m in summer, suggesting a fairly reliable supply through the year. The



well is known today only by the name of the surrounding residential colony; its original name, ownership and date are unknown, and it may survive from an earlier agricultural or peri-urban landscape. Urban development has probably increased its exposure to sewer leakage, contaminated runoff and solid waste, so historical research, structural survey, groundwater monitoring and water-quality analysis should precede any assignment of a recharge or reuse role.

Champa Bawdi, Lalbagh

Champa Bawdi (Fig. 3(f)) is a large, multi-level rectangular stepwell of about $32 \text{ m} \times 8.5 \text{ m}$, with a plan area of 272 m^2 and a reported depth of 20 m. Its water depth varies from about 18 m in the monsoon to 16 m in summer. Its size and stepped form indicate a design that accommodated fluctuating water levels and suggest historical use for groundwater access, storage, garden irrigation or the needs of the palace. Local accounts place it in the nineteenth century, but its chronology and patronage are unverified. Structural, archaeological, hydrogeological and water-quality assessments are needed to establish both its historical significance and its potential for restoration.

Jagga Bagicha Bawdi

Jagga Bagicha Bawdi is a rectangular structure of about $8.5 \text{ m} \times 11 \text{ m}$, with a plan area of 93.5 m^2 and a reported depth of 10 m (Fig. 3(g)). Its water depth ranges from about 10 m in the monsoon to 8 m in summer. The broad plan suggests possible historical use for storage, garden irrigation, domestic supply or groundwater access, and the word *bagicha* points to a garden or enclosed estate, but the builder, ownership and date are undocumented. A protective metal grating prevents inspection of the internal masonry and sediment. Any proposal to restore or reuse it should wait until historical maps have been consulted, its structure examined, and its water levels and quality measured.



(a) Vishram Bagh, Exterior

B. Water-associated cultural landscapes and candidate sites

Dravidneshwar Shiv Temple precinct

A circular water structure is reported within the Dravidneshwar Shiv Temple precinct, with a radius of about 5 m, a plan area of 78.54 m^2 and a structural depth of about 26 m (Fig. 4(a)). The reported water depth varies from about 16 m in the monsoon to 13 m in summer. Although the precinct lies close to the Vishram Bagh and Ranjeet Hanuman structures, the feature has not yet been positively identified as a well, kund, bawdi or tank, and its geometry, condition, age and hydraulic function require field documentation. Pending that verification, the precinct is best regarded as a temple garden in which water may have served ritual, household and horticultural purposes.

Badi Ganga Bagichi

Badi Ganga Bagichi contains a small rectangular water structure of about $3.6 \text{ m} \times 3.8 \text{ m}$, with a plan area of 13.68 m^2 and a reported depth of 10 m (Fig. 4(b)). Its water depth is estimated at 7 m in the monsoon and 5 m in summer. The site, associated with the temple (Fig. 4(c)) and the Panch Dashnam Juna Akhara, is a living religious garden landscape. The feature may have served ritual use, local storage or garden irrigation, but whether it is a well, kund or tank remains to be verified, and it should be documented separately from the wider bagichi precinct.

Lal Bagh Ground

The Lal Bagh Ground (Fig. 4(d, e)) is a royal garden within the Lal Bagh palace estate, developed mainly around 1726 CE according to Table 1, and contains a masonry-lined chamber holding standing water. Its potential roles include landscape drainage, detention, irrigation and heritage-sensitive restoration, but the chamber's form, connections and water quality need to be documented before any of these is assigned.



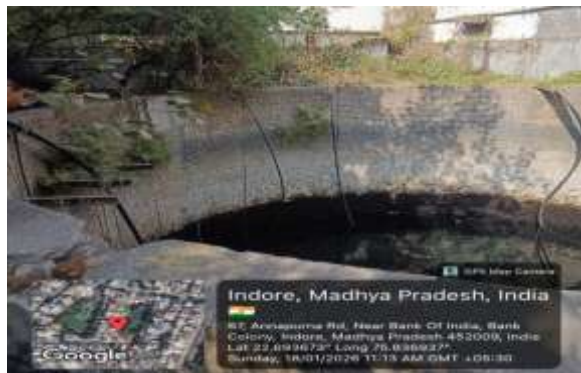
(b) Vishram Bagh, Interior



(c) Ranjeet Hanuman Bawdi



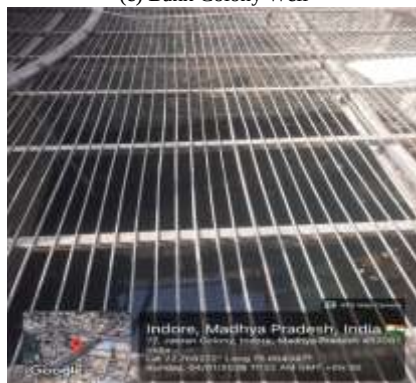
(d) Ranjeet Hanuman Bawdi



(e) Bank Colony Well



(f) Champa Bawdi



(g) Jagga Bagicha Bawdi



(h) Jageshwar Temple

Fig.3. GPS-referenced field photographs of selected traditional hydraulic structures in western Indore: (a-b) Vishram Bagh Well, (c-d) Ranjeet Hanuman Bawdi, (e) Bank Colony Well (f) Champa Bawdi and (g) Jagga Bagicha Bawdi (h) Jageshwar Temple



(a) Dravidneshwar Precinct



(b) Badi Ganga Bagichi



(c) Badi Ganga Tank



(d) Lal Bagh Site (Interior)



(e) Lal Bagh Bawdi (Interior)



(f) Krishnapura Bawdi



(g) Krishnapura Chhatris





(h) Ram Mandir, Kumawatpura



(i) Water Feature Inside Precinct



(j) Parwati Turkeshwar Temple



(k) Parwati Turkeshwar Precinct

Fig. 4. Site investigation of selected traditional hydraulic structures in western Indore: (a) Dravidneshwar Precinct, Badi Ganga Bagichi (b-c), Lal Bagh(d-e), Krishnapura Chhatris(f-g), Ram Mandir, Kumawatpura (h-i), and the Parwati Turkeshwar (j-k).

Krishnapura Chhatris

A rectangular water structure associated with the Krishnapura Chhatra precinct measures about 10 m × 12 m, with a plan area of 120 m² and a reported depth of 10 m (Fig. 4(f, g)). Its water depth falls from about 7 m in the monsoon to 5 m in summer. This feature merits its own inventory entry as the Krishnapura Bawdi, distinct from the chhatris beside it, which belong in the category of river-associated cultural landscape. Because the memorial complex, dating from the mid-nineteenth century, grew up in close relation to the Khan River, its rituals and its riverfront buildings, any management plan has to address flood exposure, polluted inflows, sedimentation, damp-related decay and heritage-sensitive restoration of the riverfront.

Ram Mandir, Kumawatpura

The Ram Mandir at Kumawatpura (Fig. 4(h)), dated to about 1846 CE in Table 1, is a temple whose iconography is documented and whose precinct contains a water feature (Fig. 4(i)) that may be a well, kund or service opening. The site is classified as a candidate water-heritage site, and any separate well, kund or storage feature should be assessed on its own before a water-management role is considered.

Parwati Turkeshwar Mandir, Scheme No. 103

The Parwati Turkeshwar Mandir precinct contains a rectangular water feature of about 10 m × 4.5 m, with a plan area of 45 m² and a reported depth of about 10 m (Fig. 4(j, k)). Reported water depths of about 10 m in the monsoon and 8 m in summer suggest that it retains

water well through the year. Its type and hydraulic function are nonetheless uncertain: field verification is needed to establish whether it is a well, kund, bawdi, tank or drainage chamber. The temple stands in a planned residential area, and its age, official name and historical link with the water feature are unverified, so the precinct is classified for now as a candidate water-heritage site. Subject to ownership, structural safety and water quality, it could also serve for community-based monitoring or as a demonstration of contemporary rainwater harvesting. All the surveyed sites lie within the historic urban landscape shaped by Holkar rule.

C. Analytical Framework

The literature and the site inventory were brought together through five assessment dimensions: historical evidence, structural condition, catchment and drainage connectivity, hydrogeological suitability, and the feasibility of water-quality control and governance. Taken together, these dimensions indicate which contemporary role, if any, a site can take on: recharge, detention, non-potable storage, ecological enhancement, public-space use, or a restriction on hydraulic use.

V. PROPOSED FRAMEWORK FOR FUNCTIONAL REJUVENATION

The evidence reviewed argues for differentiated restoration rather than turning every site into a recharge structure. Fig. 5 sets out a six-stage pathway: evidence rating and inventory; assessment of the catchment and groundwater system; assessment of physicochemical water quality and structural integrity; functional classification; site-



specific restoration planning and implementation; and monitoring, governance and adaptation. Feedback from the later stages returns to the inventory, design and maintenance, so that the framework adapts as evidence accumulates.

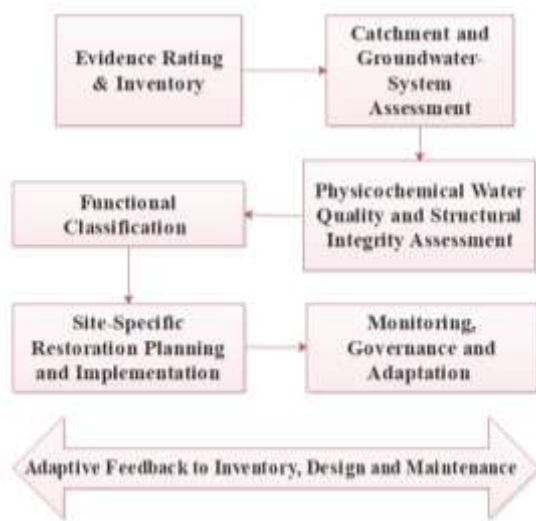


Fig. 5 Proposed assessment and adaptive-management framework for integrating traditional water structures into sustainable urban water management.

A. Functional Screening and Assignment

Table 2 groups the structures into six functional classes, from recharge and detention priority to heritage priority and restricted hydraulic use. For each class it states the objective, the minimum evidence required and the interventions appropriate to the site.

TABLE 2 FUNCTIONAL CLASSIFICATION FOR SITE-SPECIFIC REJUVENATION.

Functional class	Primary objective	Minimum evidence required	Typical intervention
Recharge priority	Aquifer replenishment	Aquifer connection, available storage, acceptable source-water quality, infiltration testing	Pretreatment, controlled inlet, recharge shaft or infiltration zone, monitoring wells
Detention priority	Reduce local runoff and peak flow	Catchment model, stage-storage curve, safe overflow route	Controlled inflow, temporary storage, overflow redesign, sediment forebay
Storage and non-potable reuse	Local water supply for landscaping or cleaning	Water balance, demand assessment, treatment and storage reliability	Rooftop capture, filtration, covered storage, reuse distribution
Heritage priority	Protect historic fabric and interpretation	Documented heritage value, structural assessment, conservation plan	Masonry repair, access control, interpretation, non-invasive drainage
Ecological and public-space priority	Habitat, cooling, recreation and education	Water-quality suitability, landscape and safety assessment	Vegetated buffers, wetland treatment, public access and signage
Restricted hydraulic use	Conserve structure without	Uncontrolled contamination, structural risk or	Pollution isolation, stabilization,

	recharge or reuse	unsuitable hydrogeology	monitoring and restricted access
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B. Monitoring and Performance Indicators

Claims that a restored structure improves recharge, reduces flooding, strengthens drought resilience or revitalizes heritage should rest on measured indicators, not on the appearance of the site after restoration. Table 3 proposes indicators for each dimension of assessment.

TABLE 3. SUGGESTED INDICATORS FOR PERFORMANCE-BASED MONITORING.

Assessment dimension	Core indicators	Recommended frequency	Interpretive caution
Groundwater response	Pre- and post-monsoon levels, hydrographs, yield and recovery, comparison well	Monthly or continuous at pilots	Separate intervention effect from rainfall and pumping variability
Storage and runoff	Rainfall, inflow, stage-storage, retention time, overflow frequency	Event-based and seasonal	Storage does not automatically equal aquifer recharge
Water quality	pH, EC, TDS, turbidity, nutrients, microbial indicators, site-specific pollutants	Baseline, monsoon events and periodic operation	Treatment must reflect source and intended use
Structural condition	Cracks, settlement, masonry loss, sediment depth, access safety	Annual and after extreme events	Desilting can destabilize old masonry if undertaken without engineering review
Heritage and social value	Condition score, authenticity, access, participation, maintenance compliance	Annual or biennial	Visitor numbers alone are not a sufficient conservation indicator
Governance and cost	Ownership, budget, maintenance frequency, response time, lifecycle cost	Annual	Community participation cannot replace statutory responsibility

VI. DISCUSSION

The synthesis suggests that the most valuable contribution of traditional water wisdom to urban planning is its design logic: distributed, multifunctional and specific to place. Historical systems kept water within the settlement, tied storage to social institutions and built maintenance into everyday practice. These qualities fit well with modern blue-green infrastructure, but historical form is no guarantee of hydrological performance today.

Three implications stand out for Indore. First, a structure and its catchment stand or fall together: a bawdi that is desilted while its inlets, pretreatment and overflow are left unrepaired or unredesigned is unlikely to regain a useful role in managing water. Second, recharge must be handled as a controlled engineering intervention, because the heterogeneity of basaltic aquifers, the risk of contamination and clogging can make direct diversion of stormwater ineffective or unsafe. Third, decisions on heritage conservation and on hydraulic reuse must be taken separately but in coordination: a structure of great cultural value may be unsuitable for recharge, while an unremarkable well may be valuable for groundwater monitoring or detention.

The preliminary inventory also shows why evidence must be graded. Several sites are culturally significant but have no verified hydraulic component, and treating temples, memorials or gardens as



recharge structures merely because they are historically linked with water would undermine the scientific basis of the study. Equally, visible wells and bawdis should not be credited with recharge benefits in the absence of evidence on water levels, infiltration and water quality.

The proposed framework is consistent with AMRUT 2.0, with guidance on rejuvenating urban water bodies and with CGWB recharge planning, all of which stress source sustainability, rejuvenation of water bodies and wells, rainwater harvesting, aquifer management, wastewater control and community participation (Ministry of Housing and Urban Affairs, 2021, 2023). Its distinctive addition is a screening step informed by heritage, which ensures that a site's conservation value, the safety of the public and its hydraulic suitability are weighed in a single assessment.

VII. LIMITATIONS AND FUTURE RESEARCH

This review is constrained by the small and uneven evidence base for Indore's individual structures. A number of the historical claims rest on oral or local tradition, unsupported by inscriptions, archival drawings or published historical scholarship. The site inventory is preliminary and does not cover the whole city, and the GPS-referenced photographs record present appearance, not construction date, ownership or hydraulic performance.

The next step is a verified geodatabase in which every site is documented: its boundary and ownership, the historical sources that describe it, its structural geometry and stage-storage relationship, the depth of accumulated sediment, the extent of its catchment and the routes by which water enters and leaves, together with groundwater levels, aquifer properties and water quality across the seasons. Georeferencing old maps and revenue records would allow lost catchments and past land-use change to be reconstructed. Pilots ought to span contrasting basaltic conditions and be evaluated against control wells or catchments left untreated.

VIII. CONCLUSIONS

Traditional Indian water systems are best understood not as obsolete hydraulic works but as a source of principles that can be carried into contemporary urban water management. Their reliance on decentralized retention, groundwater access, sediment control, catchment protection, controlled overflow and collective maintenance speaks directly to cities facing groundwater depletion, urban flooding, declining water quality and growing dependence on external supplies.

The Indore sites demonstrate that no single water-management role can be prescribed for wells, bawdis, tanks, temple precincts, gardens and riverside heritage alike. Their potential depends on structural condition, catchment connectivity, aquifer characteristics, water quality, accumulated sediment, ownership, land-use pressure and long-term maintenance. Hydraulic restoration should therefore follow site-specific evidence, not visual appearance. Some structures may be suited to managed aquifer recharge, stormwater detention, non-potable storage, groundwater monitoring, ecological enhancement or public-space improvement; others should be conserved without active recharge or reuse.

The proposed framework of evidence grading and functional classification provides a systematic basis for

building an inventory, screening sites scientifically, planning restoration, running pilots and monitoring adaptively. By separating direct hydraulic structures from water-associated cultural landscapes and candidate heritage sites, it also reduces the risk of inappropriate intervention. For Indore, revival will succeed only if hydrogeological study, protection of water quality, conservation of the fabric and properly engineered inlets and outlets are pursued together, with each agency's responsibilities clearly defined.

If inherited water knowledge is brought together with present-day urban hydrology, aquifer recharge, blue-green infrastructure and planning that respects heritage, Indore has the means to build a model of resilient water management that is both rooted in its own setting and defensible on scientific grounds. What is required now is verification in the field, monitoring through the seasons and pilot projects that measure the hydrological gains, so that the approach can be extended with confidence to other fast-growing Indian cities.

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