BLUE PAPERS

Water & Heritage for Sustainable Development

Edited by Carola Hein, Matteo D'Agostino & Zuzanna Sliwinska

Leiden-Delft-Erasmus Universities

2025 (Vol. 4 No. 1)

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Journal Description

Blue Papers: Highlighting the Critical Role of Water and Heritage in Sustainable Development

Water in all its forms is key to human survival and well-being. Humans have created intricate and ingenious solutions to survive and thrive in difficult and complex territories and to adapt changes in social and environmental conditions. Remnants of past practices, structures and objects are still with us – in the built environment, in our institutions, in our ways of living and in our languages. Sometimes we call these objects and practices heritage, but more often they are so much a part of our everyday lives that we take them for granted.

As emphasized in the *UNESCO Thematic Indicators for Culture in the 2030 Agenda,*[1] culture is an important part of the Goals and Targets of the 2030 United Nations' Agenda for Sustainable Development. Stand-alone technological interventions cannot solve the complexities of the social, cultural and economic implications of climate change in the long term. New solutions require the engagement of local interested parties and local knowledge to address social and cultural dimensions of water and to create a new embedded water awareness in the built environment, in institutions and culture(s), so that we can preserve and protect our heritage, understand and learn from the past and activate history and heritage for future sustainable and inclusive living.

The biannual peer-reviewed journal *Blue Papers* explores the complex relationship between water, culture and heritage to assess lessons from the past, to protect heritage sites, to make use of water heritage and to contribute to the development of inclusive and sustainable future water systems. The past can help build a new platform for awareness of water and heritage, which involves shared methodologies and terminologies, policies and tools that bridge disparate fields and disciplines. To achieve this, we also need to rethink the role of water in the UN Sustainable Development Goals (SDGs). Water is not fully captured in *Goal 6: Ensure access to water and sanitation for all*; it is also an integral and inseparable key to all SDGs that carry us forward to a more sustainable future.

All issues of the journal will be loosely based on themes that link to water, culture and heritage, including (but not limited to):

- Transcending the nature-culture divide
- Tangible and intangible aspects

1. The UNESCO Thematic Indicators for Culture in the 2030 Agenda (UNESCO Culture|2030 Indicators), https://whc.unesco.org/en/culture2030indicators/.

- Integrated discourses and practices
- Capacity building for holistic systems
- Long-term (living) history perspectives for comprehensive understanding
- Preservation, protection and reuse of water-related (living) heritage
- Human and non-human stakeholders
- New practices and rituals for water awareness and engagement
- Strategies for inclusive sustainable development, including those drawing on heritage.

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Icons as a Tool to Connect Water Practices, Functions and Values across Space and Time: A Second Attempt

Carola Hein, Lea Kayrouz, Zuzanna Sliwinska and Matteo D'Agostino

Humans have shaped water systems for millennia, creating complex networks of physical structures, institutions and cultural practices. These systems reflect locally embedded yet globally influenced values that evolve over time. From infrastructure and landscapes to rituals and laws, human engagement with water is both tangible and intangible, deeply influenced by societal preferences, climate conditions and historical choices. To better understand this diversity, we developed a set of icons to represent various water spaces, functions, practices and values. Rather than offering a fixed taxonomy, these icons are intended as tools for discussion – making visible the multiple dimensions of water and the meanings knowledge holders assign to it.

Originally introduced in 2022 (Hein et al. 2022), the icons were used by authors in our journal to highlight key themes in their work. While we envisioned them as a way to map specific water-related elements across time and geography, they also served as visual keywords, helping to reveal prominent aspects of water heritage and practice. This goal has guided our ongoing efforts to enhance the icons' interpretive and comparative value, stimulating deeper cross-contextual reflection (Hein et al. 2025). In our second attempt to build a taxonomy of water practices, functions and values, we have introduced new icons and revised others, notably by adding representations of aesthetic and economic aspects and refining examples.

Ultimately, these categories are suggestions – not exhaustive or mutually exclusive – designed to illuminate how water has been managed, valued and lived with across different times and places, and how the past continues to influence the present and shape our future.

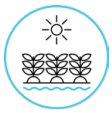
As we make the water icons open source (CC-BY) available for download on the *Blue Papers* website, we invite readers to build on the current set and expand it to fit their own context. The goal is to foster a dialogue around water values, invite collaborative engagement and spur new insights.

To represent situations where multiple water functions, values, and practices are considered together, we use a circle to group the corresponding icons.

< Fig. 1 Water icons (Source: Carola Hein, Lea Kayrouz, Zuzanna Sliwinska and Matteo D'Agostino, 2025).

Tangible

Drinking Water
Access to and provision of fresh, potable water is a universal need. Humans employ many different techniques and infrastructures to transport, store, filter, pump, redistribute and use drinking water. Examples include the use of reservoirs and pipelines for storage and distribution, both above and under the ground, as well as filtration systems that ensure water quality meets safety standards.



Agriculture and Irrigation
A wide range of strategies and technologies are used to harness water for food production, such as by irrigating crops and providing water for livestock. Agriculture and irrigation practices vary across different contexts ranging from agroforestry to terrace farming, including techniques that leverage seasonal water changes like flood agriculture.

Drainage Water and Sanitation Systems
The removal of excess and sewage water, including rainwater, runoff, black water and gray water, requires extensive infrastructure and treatment systems. Sanitation systems are essential for public health and environmental sustainability. Examples include wastewater treatment plants that recycle water, formal and informal sewer networks, and waterless solutions such as composting toilets.

Protection of Human Settlements
Humans have created architectural, urban and landscape structures to adapt to their environments and address challenges posed by water, animals and enemies. Responses to rain, snow, floods and droughts include canals, dikes and moats. Water has also been used defensively through fortification walls and floodable landscapes designed to deter or delay potential threats.

Water and Health
Access to clean water is essential for human well-being, with water quality playing a critical role in individual, public and ecosystem health. The purification of water for human consumption, for example, through boiling, filtration or adding chemicals, has influenced the development of public health, planning and environmental policy and has sparked private and public interventions.

Energy and Industry
Water management systems play a critical role in supporting energy production and industrial processes, often facing challenges related to resource efficiency, environmental impact and sustainability. Examples include the use of dams for hydroelectric power generation, water-cooling systems in machinery and factories, and water-intensive industries like mining and breweries.

Shipping
Water bodies, including seas, rivers and canals, are vital for moving people and goods, supporting daily mobility, tourism and commerce. Natural and manmade waterways are linked to the boats and ships they serve. Specialized infrastructure such as quays, cranes, warehouses, ports and dredging operations enables navigation, transport and the storage of goods.

Places of Leisure
Water bodies, natural and man-made, serve leisure practices in multiple ways. The tangible aspect of water leisure focuses on physical spaces and infrastructure designed for recreational activities at the intersection of land and water. Examples include waterfront promenades, swimming pools, water parks and beaches, which serve as functional features that facilitate human interaction with water.

Sacred and Spiritual Spaces
Humans have long created sacred spaces to honor water, using it as a medium for spiritual connection or reverence for the divine. Religious architecture often includes elements like fountains, baptismal fonts, ablution facilities and temple tanks. These features not only symbolize purity and renewal but can also play a role in local water management.

Aesthetic Water Sites
Physical spaces and structures, whether permanent or temporary, serve as tangible manifestations of cultural and artistic connections to water, often becoming sites of community significance. Examples include architectural interventions such as squares and fountains, as well as the urban design of coastlines, waterfront parks and promenades that celebrate water and encourage interaction with it.

Food from Water Bodies
Natural and artificial water bodies, such as rivers, lakes, seas and ponds, support diverse ecosystems and provide vital food sources through a wide variety of traditional and modern practices, from seashell collection to large-scale aquaculture and industrial fishing. These waters are home to a wide range of plant and animal species, sustaining local livelihoods and global food systems.

Intangible

Daily Water Practices
Daily water practices are fundamental to human well-being, woven into routines that sustain health and hygiene. These include sourcing water for cooking and drinking, communal laundry, bathing and showering practices. Such everyday habits highlight water's essential role in both practical needs and sociocultural practices across communities.

Preservation, Adaptation, Reuse
Diverse traditional and contemporary practices aim at preserving or strategically changing water bodies, related ecosystems and the social customs connected to them. Examples include the use of local knowledge in cultural heritage protection, wetland conservation, modern techniques of river restoration and community efforts to maintain traditions, rituals and structures tied to water.

Knowledge Systems and Capacity Building
Socialization and education are key to healthy and sustainable living with water. This can occur through community engagement, school curricula, capacity-building initiatives, the preservation of traditional wisdom about local water systems and sustainable practices, and all initiatives aimed at exchanging or transmitting knowledge and raising water awareness.

Laws, Policies and Planning
Water management, access and use have long been regulated through governmental policies, customary law and land use planning. These frameworks, implemented by state, corporate or traditional authorities, determine rights and responsibilities through tools like zoning regulations, land ownership policies and infrastructure planning that affect how water is distributed, accessed and controlled.

Language and Idioms
People's connection to water is expressed through diverse cultural and artistic forms, reflecting its deep symbolic and practical importance. This shapes how communities understand and relate to water. For example, language often includes words and proverbs about water, embedding traditional wisdom and values that arise from close daily interaction with water in different environments.

Economic Value of Water
The economic value of water is often realized through its exploitation for agriculture, industry and energy production, such as intensive irrigation in agribusiness, dam-based hydropower, and mining operations that rely heavily on water access. These practices can generate significant income and infrastructure but also raise questions about equity, environmental impact and long-term resilience.

Institutions, Organizations and Governance
Water management involves diverse institutions and governance structures across local, national and cross-border levels. Formal entities like ministries and water boards, informal groups such as activist movements and community alliances, and customary bodies like traditional councils all play key roles. They set and enforce rules, guide social behavior and enable public participation in water governance.

Leisure Practices
Water-related leisure practices encompass activities and traditions that highlight the interaction between land and water. Examples include water sports, cultural events like fishing festivals, seasonal celebrations, informal gatherings for picnics or swimming at local rivers and recreational practices that bring communities together at waterfronts.

Rites, Rituals and Ceremonies
Water holds deep cultural, religious and spiritual significance, reflected in many practices and traditions. These include purification rites, blessings, baptisms, water festivals, and rituals that commemorate historic water events or celebrate the opening of new water structures. Such ceremonies highlight water's vital role in faith, community identity and cultural heritage across societies.

Music, Arts and Dance
Various cultural and artistic forms reflect the deep symbolic and practical importance of water. Examples include dance, spoken and written words, music, visual arts and other creative expressions. These forms offer insights into how communities relate to and understand landscapes shaped by water, highlighting its central role in human life and culture.

Water Access and Equity
Water infrastructures serve different users in different ways, with their social, environmental and economic impacts varying widely across contexts. These variations often reflect deeper inequalities of gender, ethnicity or economic background, which are at the heart of water justice and the power dynamics shaping access to and control over water.

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Calling for Water-Based Design Strategies after COP30 in Belém

Moacyr Araújo
Scientific Coordinator of the Brazilian Research Network on Global Climate Change (Rede Clima) and the Center for Synthesis in Environmental and Climate Change; Vice-Rector of the Federal University of Pernambuco

The yearly Climate Conference of the Parties (COP), also known as the UN Climate Conference and COP30, is coming up November 10–21, 2025. This will be the 30th meeting since the first one in 1995 in Berlin, and 34 years since the first report by the Intergovernmental Panel on Climate Change (IPCC) was published in 1990. This year, the meeting will take place in Belém do Pará, Brazil, the natural gateway to the Amazon. After these last three decades, analyses indicate an international scenario that is far from what is necessary to guarantee the health of the planet and its inhabitants. We should perhaps be discouraged by the prospects for COP30 in Belém.

But often critical situations are windows of opportunity. Topics such as reducing greenhouse gas (GHG) emissions; adapting to climate change; financing developing countries, ecological transformation and the transition to renewable and low-carbon energy; preserving forests and biodiversity; and climate justice will be on the table for discussion in Belém. In a whirlwind of issues like these, it seems important to us to identify in advance, for each topic above, the main contributions of the connection between the material and cultural heritage of water and sustainable development in light of the growing urgency of preserving and valuing water resources in all regions of the world. In this context, records of methodological experiences and case studies, such as those being carried out by the journal *Blue Papers*, provide a valuable universe of analysis.

In Brazil, the Brazilian Research Network on Global Climate Change (Rede Clima) is an interdisciplinary network composed of 16 research groups interacting at various levels and through a variety of programs. Rede Clima has experience developing climate change cause-effect research from a "nexus+" perspective. In nexus+, an additional pillar is added to the classical water-energy-food nexus: socio-ecological security. This expands the approach by incorporating the political-territorial dimensions of interconnected social and ecological systems, within a collaborative research-practice frame.

The application of the nexus+ methodology has highlighted, among other things, the importance of recognizing the knowledge and heritage of Indigenous peoples in the development of nature-based solutions that simultaneously include reducing GHG emissions, adapting rural and urban environments to the effects of climate change, protecting forests, watercourses and biodiversity, while also promoting climate justice and facilitating the quantification of resources and the

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identification of possible sources of financing necessary for their implementation. In addition, the rich process underway in Brazil involving the updating of the National Policy on Climate Change and the preparation of the National Plan on Climate Change (Plano Clima), has been carried out with significant participation from academia and society. In parallel, the new Brazilian Nationally Determined Contributions, announced at COP29 in Baku (2024), establish a national reduction in GHG emissions of between 59 per cent and 67 per cent by 2035. These three instruments, to be consolidated in Belém, clearly emphasize the importance of connecting the material and cultural heritage of water with sustainable development.

COP30 in Belém offers a strategic moment to assess and define the agenda of global climate action. The host nation, Brazil, provides a compelling focus. Its immense scale, encompassing seven biomes with cities like Recife (pictured on the cover of this issue) facing the nation's highest threat level from extreme weather, presents profound climate adaptation challenges and opportunities. Simultaneously, Brazil's continental diversity — its varied territories, histories, and deep-seated inequities — makes it a strategic epicenter for developing globally relevant climate solutions. A special issue of *Blue Papers* dedicated to the theme of valuing water and heritage would be a welcome addition to the discussions, capturing outcomes of COP30, promoting policy recommendations and contributing to sustainable development worldwide.

Editorial Issue 1/2025
Narratives on Water History and Heritage: Agents of Value-Based Adaptive Design Approaches

Carola Hein, Matteo D'Agostino, Maëlle Salzinger and Zuzanna Sliwinska

Blue Papers aims to inspire new approaches to water, culture, heritage and sustainable development. We believe historical and historiographical analysis can help shift the discourse from strategies focused on short-term gains to long-term approaches that consider both historical dynamics and the potential consequences of future developments. An analytical focus on water – its materiality and flows – can help shift the discourse from disconnected, monodisciplinary approaches to spatial, social and cultural analysis, connecting multiple scales, diverse stakeholders and local characteristics over time.

In the TU Delft MSc courses Adaptive Strategies and Urban Archipelago, Carola Hein and her team invite students to develop a new "water mindset," to reflect on historic ecosystemic practices, rethink spatial typologies and develop new design methods (Hein et al. 2024; De Martino et al. 2023). By including these student projects in *Blue Papers* and on the PortCityFutures website, we hope to encourage water professionals, designers, citizens and decision-makers to think differently about water.[1]

Education and exhibitions also play a critical role in reshaping how we value water heritage outside academia. The Global Network of Water Museums (WAMU-NET) aims to reintegrate values of historical ecosystemic approaches into modern discourses, where water is often regarded solely as a commodity. Through its World Inventory toolkit,[2] WAMU-NET is facilitating the development of new narratives about water and new awareness of water among educators, cultural institutions and the wider public.

Together with WAMU-NET, *Blue Papers* has produced a thematic issue on ancient hydro-technologies (AHTs), comprised of articles published in the journal's first seven issues as well as an

1. Contributions from Adaptive Strategies 2023 and other years, https://www.portcityfutures.nl/ar0110-adaptive-strategies-designing-scenarios-for-port-cities; Urban Archipelago, https://www.portcityfutures.nl/ar2aa017-urban-archipelago-designing-for-new-maritime-mindsets.

2. The World Inventory of Water Museums is freely available through the WAMU-NET website. https://www.watermuseums.net/activities/world-inventory/.

original preface, editorial and a contribution to *The Voices of Water* – a video exhibition promoting ancient hydro-technologies showcased at the 10th World Water Forum.[3] This thematic issue draws on the collective wisdom of the past to rethink future approaches to water management and spatial design, providing examples of historically successful AHTs where community needs and values were in balance with ecosystem dynamics and local practices that prioritized environmental regeneration (Hein et al. 2025). It provides policymakers with insights into the multitude of approaches to drinking water, aquaculture, agriculture, transportation, and flood control, which although ingenious, have often been disregarded.

In the age of globalization and social media, citizens and (water) practitioners are bombarded with conflicting messages about the environment, climate change and social justice. Rather than pointing to particular narratives we think should be prioritized, we aim to provide tools that enable actors to reflect on the solutions they wish to support, help them identify underlying values and associated narratives. We emphasize the importance of tracing connections between values, narratives and water system design. In this way, we equip actors to become critical agents of change, with the skills and knowledge to co-create different ways of living and designing with water. Moreover, we believe that through a process of value deliberation and water-sensitive design new narratives about sustainable and inclusive futures can emerge organically and evolve over time. The value case approach, presented in this issue through several articles discussing its application in the analysis of water systems, offers a theoretical and methodological starting point.

Physical space supports narratives with sensorial experiences and images that people can relate to. For the lake of Annecy in France, discussed in two articles of this issue, the narrative of the lake's pristine waters – that enhance the city's attractiveness – is reinforced by the lived physical experiences of Annecy's residents and tourists who view the lake, hike around it, swim or sail in it. At the same time, physical spaces embody the values that guided their design, even if those values have changed. In this sense, the places we shaped in the past continue to shape us today — an idea expressed in a popular quotation from an address by Winston Churchill to the House of Commons in 1943: "We shape our buildings; thereafter they shape us." Some places shaped in the past, including water spaces, like wells or fountains, are readily apparent in a cityscape, while others often go unnoticed, such as underground water infrastructure. Everyday, people see water, bathe in it, drink it, cook and clean with it in buildings and cities, yet, few people connect these activities to the need to preserve and clean water. Calling attention to water, especially in innovative ways, can help raise awareness in a wider audience. Our design of the future reflects how we read and interpret the present and the past. Architects and designers can help by generating comprehensive design approaches. We need to put a renewed commitment to holistic, nature-aligned water management at the center of larger discourses, both in policymaking and in the field of practice.

3. The "Voices of Water" exhibition is accessible online through the WAMU-NET website. https://www.watermuseums.net/campaigns/the-voices-of-water/.

This issue brings together diverse contributions that address these themes and argue for the integration of historical and traditional knowledge in contemporary designs and water management systems.

Carola Hein opens part 1 of the issue, "Challenges, Concepts and New Approaches," by proposing a value case approach to the design of water systems that assumes that historical decisions about building, governing and living in cities and landscapes are more than purely technical or economic matters. In her article, she explains how her thinking has evolved over the years, leading her to connect changes in spatial, social and cultural conditions over time, informing both her pedagogy and research practice.

The article by Jordi Morató Farreras, Olga Lucía Sánchez Santander and José Luis Martin reminds us of the imminent future of water scarcity and ecosystem degradation, arguing for the integration of traditional knowledge into modern water management. Similarly, Vladimiro Andrea Boselli, Massimiliano Borroni, Jalal Kassout, Muhammad Houssni, Athmane Kettouch and Simone Cristoforetti analyze the evolution and spread of ingenious qanat systems and their role in fostering cultural continuity. Together, these contributions demonstrate that ancient hydro-technologies offer valuable lessons regarding the efficient use of resources with a minimal carbon footprint. Following this theme, Anne Poelina's interview foregrounds the management of Australia's Fitzroy River basin in local communities as a way to diverge from exploitative economies by organizing a multi-disciplinary and intergenerational council of river custodians.

Focusing on sustainability transition narratives and policies in France, Maëlle Salzinger echoes Anne Poelina's claim for approaches that speak to public interest. She critiques the tendency of dominant political narratives to emphasize the short-term costs of sustainability transitions, which encourages fear and results in low social support for climate policies. She offers an alternative, which places water heritage and local values at the center of sustainability transition narratives to inspire local communities and ground future policies.

The second article by Carola Hein closes the first section of this issue of *Blue Papers* by presenting methods to analytically connect dissociated water uses and practices, thereby facilitating holistic and long-term development and design. Hein presents the making of the value case approach through the connection and development of methodologies that allow for the investigation of spaces, stakeholders and sociocultural practices over time. This effort lays the foundation for creating shared missions and visions through participatory activities and workshops.

Part 2 features the application of the value case approach for Lake Annecy in France by Maëlle Salzinger, and the revival of the *peshwa nahar* system in the city of Pune, India, by Radhika Mulay and Pallavee Gokhale. The two articles describe the application of methodologies acquired through the professional education course Water Systems Design: Learning from the Past for Resilient Water Futures to leverage heritage and its linked ecological and local values to develop holistic visions and actionable development agendas in Annecy and Pune, respectively.[4]

The issue continues with three methodological case studies presented by students and instructors of the on-campus courses led by Carola Hein and colleagues. The three contributions hinge on the potential of integrating heritage conservation and traditional practices in modern design strategies.

Drawing on his personal experience, David Sauer considers the links between rural water management in Mexico and spatial development and the potential to promote water awareness and justice on the outskirts of Mexico City. Through research and design developed in his graduation thesis at Delft University of Technology, he highlights the efficiency and values of the *ejido* system and relates it to the diverse water needs of today's urban settlements. Regina Klinger, Nicola Vollmer and Aylin Yazici expand on their work in the MSc course Urban Archipelago, in which they explored the physicality and embodied experiences of the water system in Tetouan, Morocco. They designed a soundscape aimed at reconnecting local citizens with the historic *skundo* water system, while modern approaches to water distribution threaten the *skundo* system's structures and associated traditional values. Marlies Augustijn, Mila Avellar Montezuma, Beate Begon, Jean-Paul Corten and Carola Hein describe the education and research behind a multi-stakeholder workshop focused on the Netherlands' community of Scheveningen, which faces serious threats from sea level rise. They highlight the possibilities for safeguarding heritage and adapting the coast through nature-based approaches and urban blue-green networks featuring flexible infrastructures.

The historical analysis for informing spatial development in the issue's opening article is echoed by Roeland Emaus and Sylvia Leenaers, who call for landscape policies grounded in long-term material and sociocultural changes, using an innovative mapping technique that reconstructs decades of landscape transformation from historical aerial photos. Similarly, Zuzanna Sliwinska's study of the dynamics behind Hong Kong's declining wetlands and fishponds reframes them not as passive ecological sites, but as living environments shaped by cultural practices and historical land use. Building on the work of Emaus, Leenaers and Hein, Sliwinska highlights the importance of integrating cultural heritage into conservation efforts, arguing that only by recognizing the relevant values can we effectively connect ecological regeneration, climate adaptation and urban development.

This issue of the *Blue Papers* concludes with two interviews exploring the process of establishing a "water museum" as part of the Global Network of Water Museums. Lachie Carracher, a member of the Fitzroy River Council, introduces his efforts, along with researchers and local communities, to establish Living Water Heritage – a digital platform and virtual museum that collects and valorizes the multifold Indigenous knowledge and heritage of the Martuwarra (Fitzroy River) basin.

4. Water Systems Design: Learning from the Past for Resilient Water Futures is an online professional education course developed by Carola Hein, Matteo D'Agostino, Carlien Donkor, Lea Kayrouz and Zuzanna Sliwinska in collaboration with the TU Delft Extension School. More information is at: https://online-learning.tudelft.nl/courses/water-systems-design-learning-from-the-past-for-resilient-water-futures/.

Alioune Dème discusses the significance of the West Africa Museum of Water, based in Senegal. The museum was created following commitments made in Dakar during the 2022 World Water Forum and is the result of a partnership among several river basin organizations in the Senegal River region.

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A Taxonomy of Water Practices, Functions and Values across Space and Time: Water Icons 2.0

Carola Hein, Lea Kayrouz, Zuzanna Sliwinska and Matteo D'Agostino

In 2022, when we proposed capturing water, culture and heritage with a set of icons, we were hoping to gain a better understanding of the relationships between different types of water uses, spaces and practices. As a team, we were hesitant about categorizing water spaces and questioned the usefulness of doing so. However, after more than two years of working with the icons – through the *Blue Papers* journal, TU Delft's Water Systems Design course,[1] and numerous workshops – we have come to recognize the benefits of this type of categorization. Our experience has confirmed some of our initial assumptions while also offering new insights. To reflect on what we have learned, we decided to revisit and update the icons and their descriptions. Classification through the icons, per se, is not a solution to any particular problem involving water, culture and heritage. Yet, discussions around their use – for structuring research, connecting seemingly different practices and organizing exchanges of views among diverse groups – can lead to better understanding of diverse perspectives and potentially to the development of solutions. This contribution shares the process of visualizing, describing and activating the various water spaces and functions through design and practices. In this contribution we share how we have developed and used the icons. We also share our thoughts about the use of water icons and their relevance across various contexts, as well as their potential and limitations.

When planning the first issue of *Blue Papers*, we proposed developing a set of icons – a taxonomy – designed to capture the diverse conditions of water spaces and practices (Hein et al. 2022), building on earlier work on classifying water heritage (Hein 2020). We envisioned the icons as a way to capture and represent the various ways humans have engaged with water. Building on our work for *Blue Papers,* we started to use the icons in participatory exercises. We worked with stakeholders to help them grasp the multiple scales of water systems, their historical trajectories and contextual particularities. The use of the icons during workshops played a key role in facilitating discussions by highlighting different – often conflicting – perspectives and unveiling values that stakeholders attributed to the same water spaces and functions. As we refine our tools and methodologies, we see the need for a more nuanced and adaptable form of categorization, one that takes recent research efforts into account and is open to evolving practices and underrepresented uses.

1. Water System Design: Learning from the Past for Resilient Water Futures is an online professional education course developed by Carola Hein, Matteo D'Agostino, Carlien Donkor, Lea Kayrouz and Zuzanna Sliwinska in collaboration with the TU Delft Extension School. More information at: https://online-learning.tudelft.nl/courses/water-systems-design-learning-from-the-past-for-resilientwater-futures/.

< Fig. 1 Participants at a workshop held in Le Havre's Port Center debating water functions within the port infrastructures (Source: Lea Kayrouz, 2025).

Our reconceptualization of the icons stemmed from a strategic dismantling of the set we had developed, in a manner that can be described as "reflective disruption." This allowed us to find renewed meaning and confidence in some of our earlier decisions while questioning our assumptions and priorities along the way. This article 1) reflects on why we believe such a taxonomy is helpful, 2) explores the process of refining the icons and descriptions and 3) invites discussions on ways one might expand visual language, through which users can adapt and reinterpret the icons to suit their specific contexts.

Why a Taxonomy Helps: Visualizing, Awareness Raising, Discussion, Diagnostics

The taxonomy is designed to help a diverse group of people communicate about interconnected systems of water that humans have developed as they have engaged with the hydrological cycle. In providing a visual framework, we aim to address these systems' inherent complexity while providing abstractions to simplify it. This is especially important when working with diverse stakeholders and in multidisciplinary activities or programs: some may feel alienated by professional languages and perspectives, while experts who have trained and worked in a specific field for many years might find it challenging to consider water uses and functions they do not normally think about. It was with this in mind that we envisioned a taxonomy of water practices, functions and values that would be applicable at multiple scales and in relation to any point in time. We envisioned creating a helpful tool for use in abstraction and simplification.

The aim of the taxonomy is not to perfectly capture reality, but to enable experts and citizens to engage in more inclusive, grounded conversations backed up by mutual understanding and a strong grasp of the many interconnections between water, spaces, practices and culture. We imagined, and have experienced through our research activities, that this process helps people identify missing connections and reach shared solutions capable of protecting the interests and values of multiple stakeholders simultaneously. Using the icons not as fixed categories but as a base for understanding the evolving relationships shaped by social, political and environmental change, stimulated a broad range of conversations, indicating potential for their expanded use, which, in turn, led us to revisit and refine both the visuals and the descriptions of the icons. In addition to facilitating conversation and rethinking, the taxonomy documents the many water-related themes that surface in literature as well as in our research, projects, publications and working experience. Linking these diverse elements through classification helps foster conversations, invites comparisons and reveals connections across different localities as well as across spatial, temporal and social scales and contexts.

Since our first attempt at creating icons, we have encountered other successful ways of using icons in maps. The work of the Timorese NGO Rebia is a prime example of how taxonomies and icons can be used to gather knowledge and map different activities in catchment areas. Through participatory workshops, Rebia creates community land use plans that align the needs of people, animals and the environment. For example, animal free grazing and certain agricultural tech-

niques, such as slash-and-burn, created tensions and had a detrimental effect on residents and the ecosystem. By using icons in mapping exercises, the NGO raises awareness within communities about the cascading territorial effects of various activities, thereby promoting the adoption of more sustainable practices along the entire watershed (Raebia n.d.). Other uses of icons in mapping include the water points in Athens as presented in the Atlas for Mediterranean Liquidities (Goethe Institut/CDA Holon 2025).

To support this evolving approach, we make the updated icon visualization and description available open access. On the *Blue Papers* website,[2] readers can now access and download the icons in various formats and build upon the existing set according to their own contexts. This move acknowledges the limitations of a predefined and closed taxonomy: no fixed set of icons can fully capture the shifting, situated and often contested meanings of water practices across different geographies and communities. By making the icons adaptable and open-source (CC-BY), we aim to foster a dialogue around water values and invite collaborative engagement, one that remains responsive to ongoing research and grounded in local realities.

Why Visuals Help: Visualizations at Different Scales

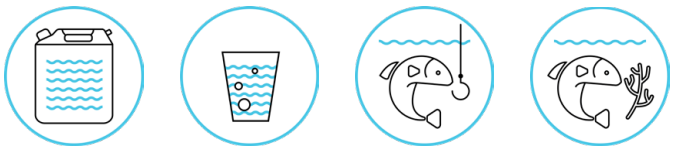
The use of icons in a variety of activities has sparked several relevant conversations, which have also helped refine the icons and their use. The following four segments show how the icons have evolved as a result of their use in discussions, workshops and trainings, as carriers of cultural specificities, as conveyors of complexity, as translators of overlooked values and as promoters of constructive binaries.

Icons as Carriers of Cultural Specificities

Some of the icons are culturally embedded. People in many countries may associate drinking water with a glass, given that they can drink tap water. Other parts of the world rely on bottled water, which could be represented by a (plastic) bottle. Because the context we are writing and thinking from is sensitive to the use of non-reusable waste, we decided not to use this representation. In many places people use canisters to carry water over large distances, which inspired our initial drinking water icon (fig. 2a). We opted for a change in iconography, without necessarily dropping the canister icon, but rather keeping it as a secondary option, to become part of a cluster of icons that cater to the cultural specificity of drinking water. These visualizations can also vary according to time period. For example, drinking water could be represented using a historic image for a water carrier, who would have served entire cities and has even an iconic character, such as the Hummel in Hamburg, captured in sculptures throughout the city and in the historic idiomatic greeting such as “Hummel, Hummel! Mors, Mors!” Capturing cultural and social mean-

2. https://bluepapers.nl/index.php/bp/index.

ings was a central motivation in rethinking our icon set, which also prompted us to reconsider the representation of humans within the taxonomy. Conversations with colleagues from ecology suggested that we also need an icon for nature, as space should be allocated to non-humans. We created a fish without a hook as an icon for aquatic ecosystems (fig. 2d), but moved it to the outer rim of the icon's circle as a secondary option, keeping the focus on the ways in which humans have interacted with their environment.



^ Fig. 2a Previous version of the "drinking water" icon.
Fig. 2b Current version of the "drinking water" icon.
Fig. 2c Current version of the "food from water bodies" icon.
Fig. 2d Current version of the "aquatic ecosystems" icon (Source: Zuzanna Sliwinska and Lea Kayrouz, 2025).

Icons as Conveyors of Complexity

The practice of using icons to advance debate also reveals the shortcomings of visualization. Each icon encapsulates a broader field of themes, yet participants may reflect upon it from their unique perspective, inviting different forms of visualization. Choosing a kayak as an emblem for leisurely practices on water (fig. 3a), for example, can alienate rowers or swimmers, who each have their own specific expectations of water spaces and uses. For example, in Nijmegen, people pointed out that kayakers and rowers have very different interests. Rowers need long water routes and sit backward while moving, not seeing where they are going, which can pose a threat to their safety and the safety of swimmers. Kayakers need less space and move at a much slower pace. The diversity of leisurely activities on water calls for a careful reflection on the implications of specific water practices and is one of the reasons why we propose an open-access set of icons that is adaptable for research or discussion purposes. Leisure practices on water depend on the water body itself – e.g., depth, currents, water quality – captured by the kayak icon without the access point represented (fig. 3a). The kayak icon also reflects the intersection between places of leisure and shipping, as the sheer size of the vessels captures the difference in water uses and speaks to the conflicts between commercial and leisurely water uses. However, leisure practices are also closely linked to access points. Steps, slopes and ladders all provide different types of access to the water and facilitate different water activities. A swimmer can enter and leave the water using a ladder, while putting a kayak in the water via a ladder is more difficult and a platform or quay would be preferable. This reasoning made us rethink the original design of the "places of leisure" icon, to also include considerations of the land-water interface related to leisure (fig. 3b). In light of these reflections, we decided to merge the icons for "recreation" and "festivals and ceremonies" into a single "leisure practices" icon (fig. 3c), while reassigning "ceremonies" to the icon representing "rites and rituals." This adjustment allowed us to make room for values and practices that had previously been overlooked.

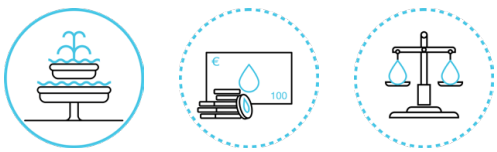
^ Fig. 3a Previous version of the "places of leisure" icon; current version of the "kayak" icon.
Fig. 3b Current version of the "places of leisure" icon.
Fig. 3c Current version of the "leisure practices" icon. (Source: Zuzanna Sliwinska and Lea Kayrouz, 2025).

Icons as Translators of Overlooked Values

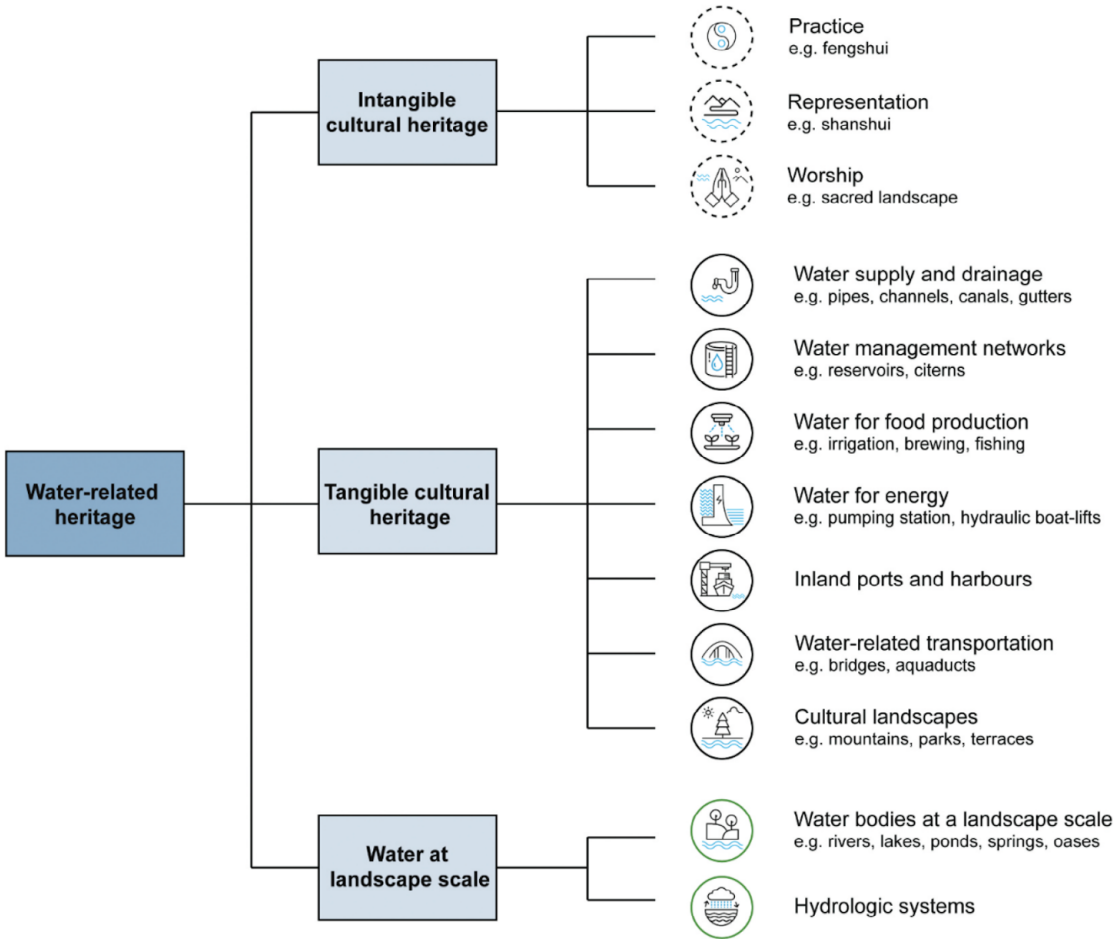
As we revisit the icons, we ask questions like "How do we categorize a fountain?" Fountains serve as refreshment points in urban centers, supply water to clean streets and mitigate urban heat island effects. Because it can serve such utilitarian purposes, a fountain could arguably be reduced to a tap. However, fountains, stepwells and similar structures introduce aesthetic qualities into urban spaces and embody spatial expressions of artistic human interaction, carrying sensible value and offering moments of enjoyment. A new "aesthetic water sites" icon (fig. 4a) allows for spatial quality considerations in the broader framework of water uses.

In the previous edition of the icons, artistic production was represented solely as an intangible practice, neglecting its spatial and material implications. Conversely, income-generating activities such as fishing or boat-building were depicted purely as physical tasks, omitting the broader dynamics of the blue economy. By including the "economic value of water" as an intangible icon (fig. 4b), we acknowledge the externalities created by the resources and networks enabled by fishing, trading, water extraction and related practices involving an economic dimension, or value, given to water. These activities often initiate multiple other practices that affect territories and communities' materialities, often sparking debates about social justice, making their inclusion critical.

Water access and equity are key issues in water governance. We are therefore adding an icon to foreground the distribution and access to water resources as a key dimension of water systems. In developing this icon (fig. 4c), we consider factors such as the role of privatization in water access, the disproportionate environmental impacts of water policies on different communities, and the efforts of local groups to participate in decision-making processes related to water governance.



^ Fig. 4a Current version of the "aesthetic water sites" icon.
Fig. 4b Current version of the "economic value of water" icon.
Fig. 4c Current version of the "water access & equity" icon. (Source: Zuzanna Sliwinska and Lea Kayrouz, 2025).



^ Fig. 5 The coding tree for categorizing water and heritage, developed to gain better understanding of water as related to the descriptions of UNESCO World Heritage properties (Source: Tianchen Dai and Carola Hein, 2023).

Icons and Clustering

We first established icons as visual keywords, but quickly also started to group them to explore themes to identify the water spaces and practices controlled by water managers such as "shelter and defense" and "energy and industry" or the ones apt to be studied by social scientists or humanities scholars (e.g., rituals and festivals). This can be a way to identify gaps, suggesting the benefit, for example, of courses for engineers that include historical and cultural knowledge.(e.g. Hein 2022)

Dai and Hein (2023) have also used a classification system to get a better understanding of UNESCO World Heritage descriptions and abstracts and to collect, code, categorize and interpret the descriptions of UNESCO World Heritage properties created by state members and approved by

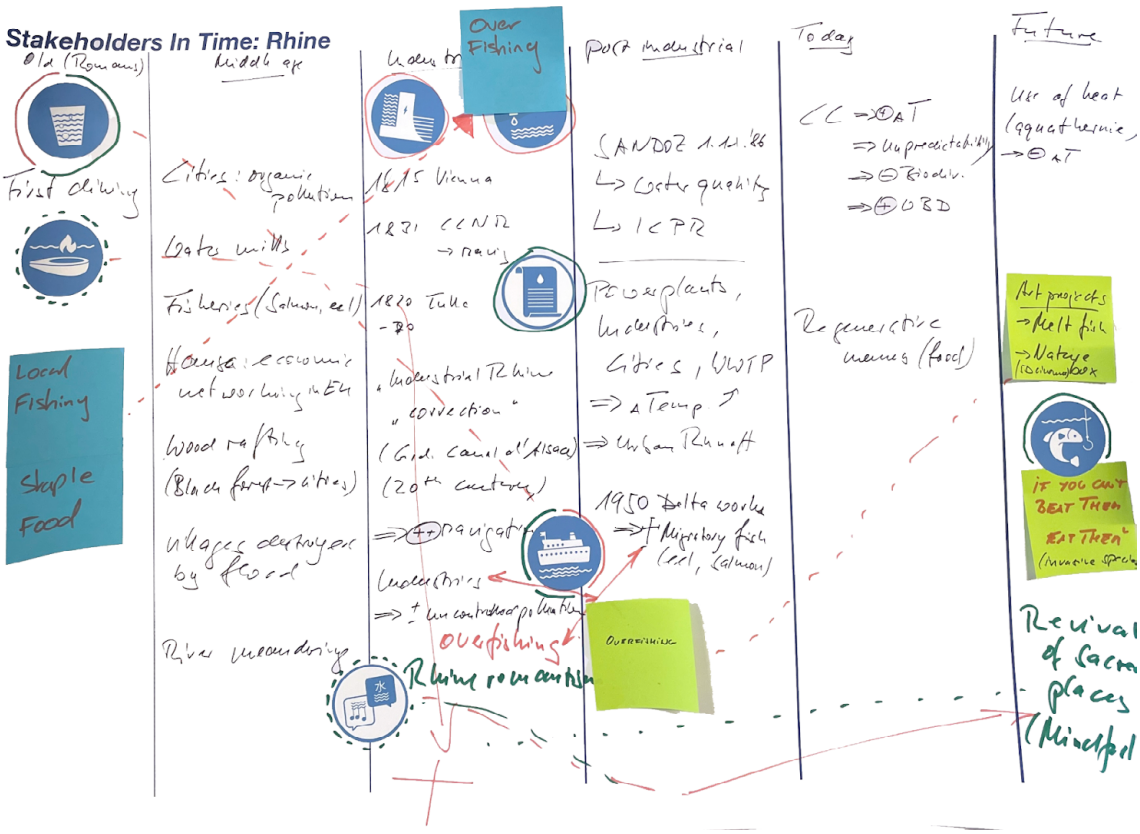
^ Fig. 6 Current configuration of the set of icons, with the main circle consisting of 22 icons and the outer rim of 5 additional ones. (Source: Carola Hein, Lea Kayrouz, Zuzanna Sliwinska and Matteo D'Agostino, 2025).

UNESCO (fig. 5). They built upon the first attempt with the goal of better understanding the role water systems play in the identification and protection of heritage properties. For the analysis of UNESCO abstracts, they developed additional icons to distinguish between natural, cultural and intangible heritage. For example, ports have a special icon, as do bridges. Natural water systems are also given their own visuals. Most of these aspects are covered by the existing icon system, for example, shipping references ports, water management includes bridges, but depending on where emphasis is needed, additional visualizations can help facilitate discussions.

Our discussions on the use and usefulness of the icons, their coverage of diverse water spaces and practices and the opportunities for clustering them led us to experiment with different ways of grouping them. Placing them in a radial configuration allowed us to reflect on connections between, for example, drinking water and sewage, but also the relationship between tangible and intangible practices. One can even imagine drawing lines between related or unrelated practices.

In the radial configuration of the proposed taxonomy (fig. 6), tangible and intangible icons are placed opposite one another, exploring possible counterparts. For example, “rites and rituals" faces “sacred spaces" and “aesthetic sites" is positioned opposite “music, arts, and dance." Some less-obvious pairings – “sewage and sanitation" paired with “education," and “shipping" paired with “institutions" – are intentionally placed on the circle to provoke discussion and suggest underlying conceptual or functional links.

Another major advantage of the circle is the opportunity to create clusters, or constellations, that stem from, or relate to, one specific icon, but that don't cover a larger field. For example, the kayak icon is related to both “places of leisure" and “shipping," as it can demonstrate properties relevant to either depending on the context in which it is used.



^ Fig. 7 A timeline of the Rhine River, co-created during a workshop in Nijmegen (Source: Lea Kayrouz, 2025).

How Icons Help

The updated water icons have been developed with versatility in mind, allowing them to be used in a wide range of formats and settings. In workshops, stickers have been proven especially effective as they allow participants to immediately translate thoughts to paper, using these visual markers on maps, timelines or stakeholder maps. The multiplicity of available stickers also prompts participants to consider categories outside their immediate expertise, getting into gray areas they might have otherwise overlooked. By presenting the full set of icons on a single sheet of stickers, we encourage workshop participants to use as many as possible, even if doing so initially feels unnatural, to start thinking about water systems in their entirety. For broader public engagement, we have also experimented with larger cardboard "tokens" that were particularly successful with younger audiences. As they often respond more readily to oversized illustrated elements, children were invited to play and reflect on their own water systems from an early age.

Icons can also play a diagnostic role, making visible the dissonances among siloed understandings of urban waters. In a workshop held at Le Havre's Port Center in March of 2025, participants used icons to identify water functions in space. The use of icons rendered the rupture between port and city more visible (fig. 1). It also pointed to the absence of a space for cultural activities within the port area. Participants argued for reconnecting the port to the city. Moving tokens slightly across the landscape triggered discussions on the potential for water spaces to reconcile port and city. In this way, icons are not merely representational tools, they are operative aids for discussion, negotiation and co-creation.

During a workshop held in Nijmegen with representatives from academia, the local and national government, as well as citizens, the participants first reflected on key historical moments and future trajectories related to the Rhine River, noting the events on a timeline (fig. 7). Participants then identified key water-related themes over time using stickers. In this group, concerns focused on fish, overfishing and the need to regenerate biodiversity. The question of invasive species emerged in the discussion as a challenge, with one participant proposing as a solution "If you can't beat it, eat it." Attention to locally sourced food and regenerative menus is growing, raising the question of how to integrate local ecosystems into daily routines.
The timeline started to clearly showcase a range of trajectories, where some values remained independent and others exhibited stark trade-offs, which swung back and forth due to various societal, cultural and climatic shifts. These trajectories, highlighting how certain values have been compromised to achieve other objectives, were color-coded in green and red, inspiring the decision to make available a set of water icons for each color.

These activation formats aim to equip users with tools that not only document but also help problematize water systems across space and time. To support such a reflective process, we have created red and green versions of the icons to indicate perceived negative (fig. 8b) or positive (fig. 8c) impacts, or to identify transformation strategies, such as using the goal of swimming in the Seine in Paris to transform river practices (IEA de Paris 2025; Hein 2025).

^ Fig. 8a Current version of the "aesthetic water sites" icon.
Fig. 8b Red version of the "aesthetic water sites" icon suggesting a negative connotation.
Fig. 8c Green version of the "aesthetic water sites" icon suggesting a positive connotation (Source: Zuzanna Sliwinska and Lea Kayrouz, 2025).

Conclusion: An Open Invitation

As we continue to refine and expand the water icons and their accompanying descriptions, we encourage their use and critical engagement. We also invite feedback from users who identify omissions or aspects that remain underrepresented so that future iterations may more accurately reflect the plurality of water-related practices and values.

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PART I Challenges, Concepts and New Approaches

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Toward a Value Case Approach for Designing Sustainable Water Systems

Carola Hein

Abstract
Designing water systems – interconnected networks of water-related structures and practices – is not only a matter of technology and economics, but also of history, institutions and culture. Understanding these multiple, overlapping and interconnected spaces and practices requires a holistic approach that contextualizes current projects and helps identify challenges and opportunities. The article introduces a value case approach, including tools and methods that can be used to connect spatial, social and cultural conditions and their change over time. Such comprehensive understanding can potentially be used to facilitate societal change and guide political decision-making. The article first explores the rationale and setup of a value-case approach in the context of the PortCityFutures Center and the work of the UNESCO Chair Water, Ports and Historic Cities. It concludes by introducing key elements and methodological tools.

Policy Recommendations

- Politicians and policy makers should take a contextual approach to water-related interventions, considering space, society and culture and their transformation over time. The value case approach has been designed to make such abstract aspects tangible and can help balance the dominance of technological and economic perspectives.

KEYWORDS

PortCityFutures
Port city territories
Adaptive strategies
Water systems design
Value case approach

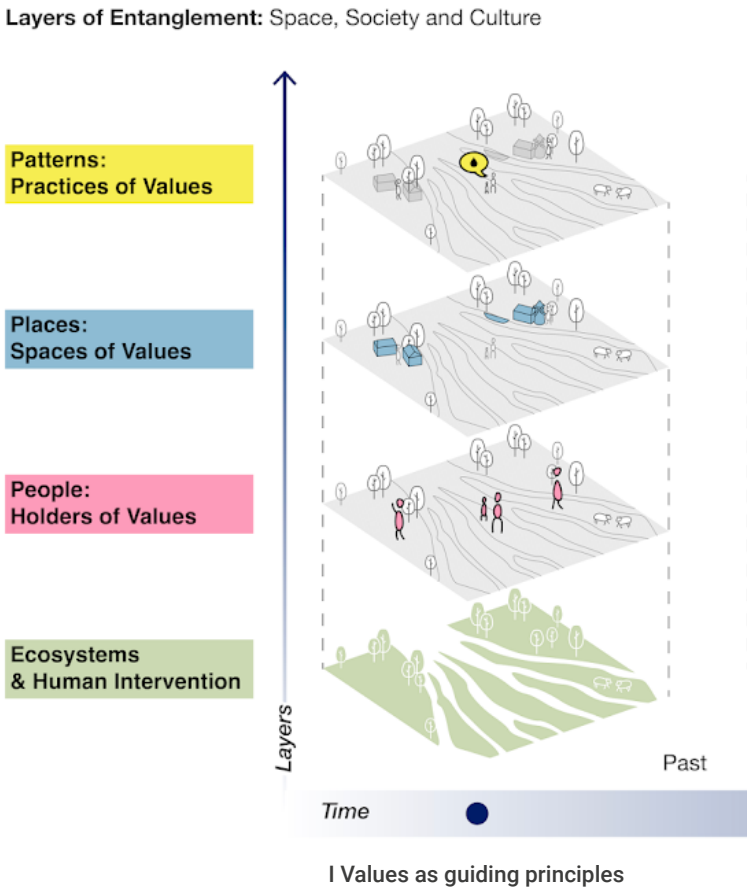
WATER ICONS

< Fig. 1 Aerial view of Venice (Source: Carola Hein, 2023).

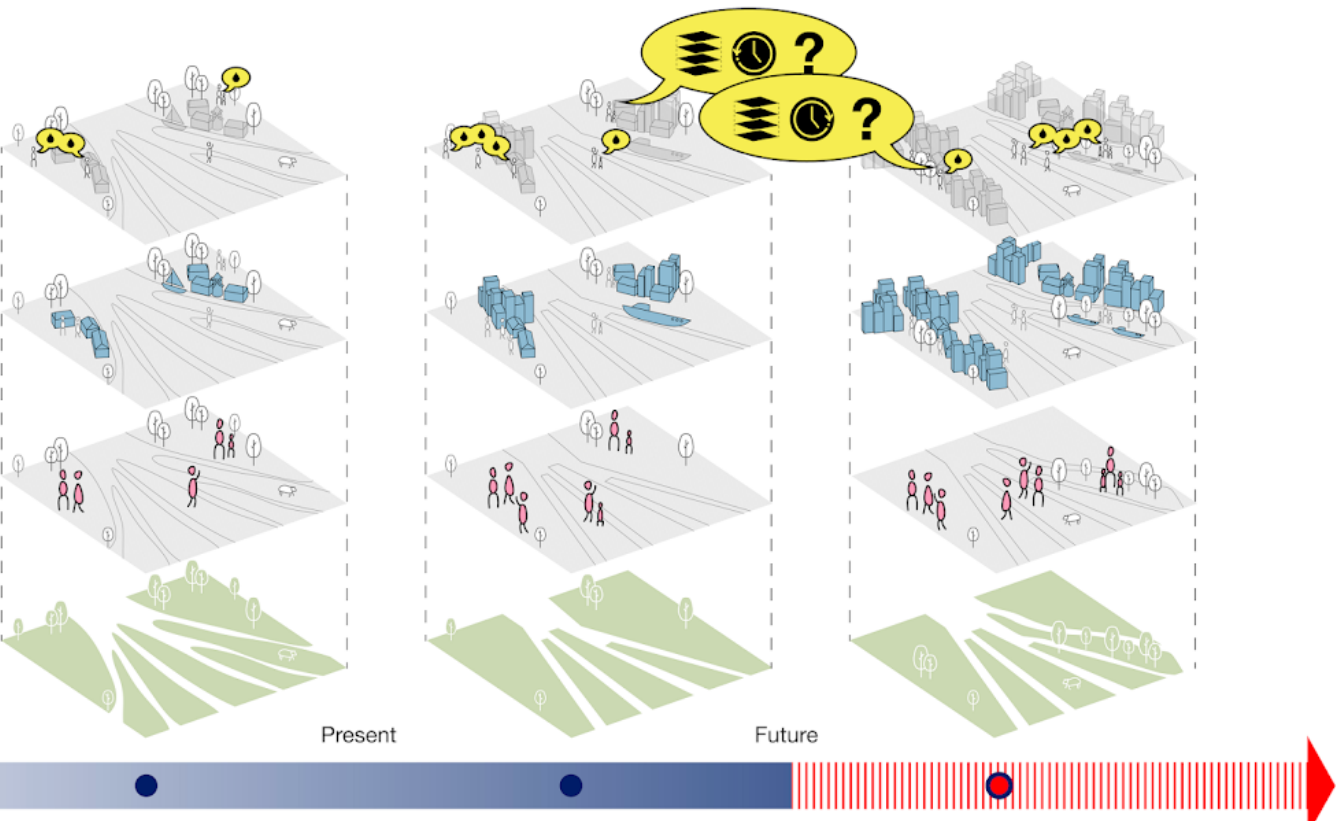
Introduction

Humans have shaped their built environments, institutions and practices to serve needs and values – understood here as socially and historically contingent beliefs that inform action. Across diverse and sometimes extreme climate conditions, people have developed varied spatial arrangements and ways of life. Decisions made in specific ecological, political and cultural contexts have generated spatial, economic, material and symbolic practices, some of which continue to influence contemporary projects. At the heart of many human interventions has been the availability or absence of water, leading people to transform a natural water cycle into a sociocultural one (Hein 2022).

Making the most of local conditions, people have controlled water flows through infrastructures, institutions and policies. How we manage drinking water, irrigation and sewage systems and defend against floods reflects the values of decision makers – who may opt for systems that benefit corporations or the public good, for extractive or nature-positive solutions. These decisions may not reflect the values of the entire population. To identify and potentially address points of contention, values can serve as a guide. At a time of climate change, uncertainty and risk, there are many reasons to question the tendency to place technological prowess and economic gain above all else. To solve complex problems, such as those that characterize water systems, we need an approach that elevates discussions to the level of values. The potential of values as guides of decision-making, actions and shaping the future is not fully recognized and appropriate methodologies are only in development. Value-based methodologies can provide participatory tools and support political decision-making. With input from members of PortCityFutures and the UNESCO Chair Water, Ports and Historic Cities, I have therefore developed a value case approach to complement existing frameworks. This article introduces the approach, its development and inspiration, as well as the advantages of taking a multi-scalar, multi-stakeholder, culture-driven long-term perspective.



^ Fig. 2 The transformation of physical space – such as cities or landscapes – and the development of institutions and practices occurs over time. Such space-time entanglements reflect decisions based on values and bring them to the fore, creating a palimpsest (Source: Carola Hein; visualization by Lea Kayrouz, 2025).



Exploring Values in Space and Time as Context for Design

Activities leave their trace over time on the physical environment, which includes natural and human-made structures such as cities, buildings and landscapes, creating a feedback loop that influences the future. Figure 2 visualizes the multiple interactions involving people and space and the role of institutions and culture in the creation of a palimpsest that evolves over time. The illustration shows a natural ecosystem that is transformed over time. People adapt physical spaces to their own needs. They create places in which they can perform specific activities and establish policies, laws and institutions that guide later developments. Designs for the future are always embedded in these decisions and investments of the past, yet the impact of the past is often underestimated. These developments need to be seen as interconnected in space and time.

As illustrated in figure 2, this analysis puts space and its multiple layers of engagement with tangible and intangible practices at the center of investigation. It proposes that the physical environment is where values become tangible. To give just a few examples:

Health and safety have long been key values influencing human interventions in the built environment. Well-to-do people around the world have been able to build in healthier locations – in Tokyo, for example, on higher ground, leaving floodable areas to workers. Edward Seidensticker (1991) describes this well for Edo (now Tokyo); similar examples can be found in Hamburg, Jakarta and many other cities. Health and the prevention of disease has been a key theme for the construction and location of workers' housing since the industrial revolution, when planners began arguing that access to fresh air and sunlight was key to improving health for the working class, leading to the construction of multi-story blocks and high-rise apartments in green surroundings and to policies that promoted high-rise housing in greenery. The built environment is also where value dynamics over time become evident. Blocks and towers built for health reasons in the 1920s, for example, are no longer considered as embedding health values. Situated on the outskirts of cities, new towns have often become the model of car-reliant areas without spaces for walking, which has contributed to health deficiencies.

Multiple authors have recognized the importance of values in shaping spatial and social practices and guiding our decision-making. They have discussed the multiple characteristics of values – diverse, multiple, dynamic, embedded, local – and the need for value literacy (D'Agostino and Hein 2024; Hein et al. 2021; Hofstede 2001; Steinert 2023; Stephenson 2008). Some experts have proposed a paradigm shift: building on the notion, often used in the fields of business and project management, of "business case" – that is, as the Cambridge English Dictionary defines it, "an explanation or set of reasons describing how a business decision will improve a business, product, etc., and how it will affect costs and profits" – to develop a "value case" (Dittrich and Dijk 2013; Tulder and Mil 2023; Beutell 2018). Activating values for better design, also called value-sensitive design (Friedman and Hendry, 2019), has been proposed by several initiatives (Ritvala and Salmi 2010), including Delft Design for Values.[1]

Given the longevity of buildings, cities and human-made landscapes, values of the past inscribed in the built environment form a palimpsest that affects the future. Economic flows, governance, or literature can be seen as disconnected, yet, their objects of study can all relate to the same physical location, collectively providing a more complex understanding of a site and its development. Physical space thus forms a meeting point for a variety of investigations that develop in the natural sciences, social sciences and humanities. Placing space at the center of analysis is in line with Henri Lefebvre's understanding of space as socially produced and then appropriated (Lefebvre 1974), thus combining the spatial dimension with the representation of space, and with the spaces of representation. The construction of spaces over time adds another facet to Lefebvre's argument. I have argued elsewhere that spaces, their representation and their lived experience create a feedback loop and that space, society and culture effectively reinforce each other (Hein 2018, 2019a).

Such a spatialization of values does not need to be continuous physically. Inspired by Arjun Appadurai's (1990) use of the suffix *-scape* to represent the "new global cultural economy as a complex, overlapping, disjunctive," collaps-

1. Delft Design for Values, "Values to Design For," https://www.delftdesignforvalues.nl/values-to-design-for/.

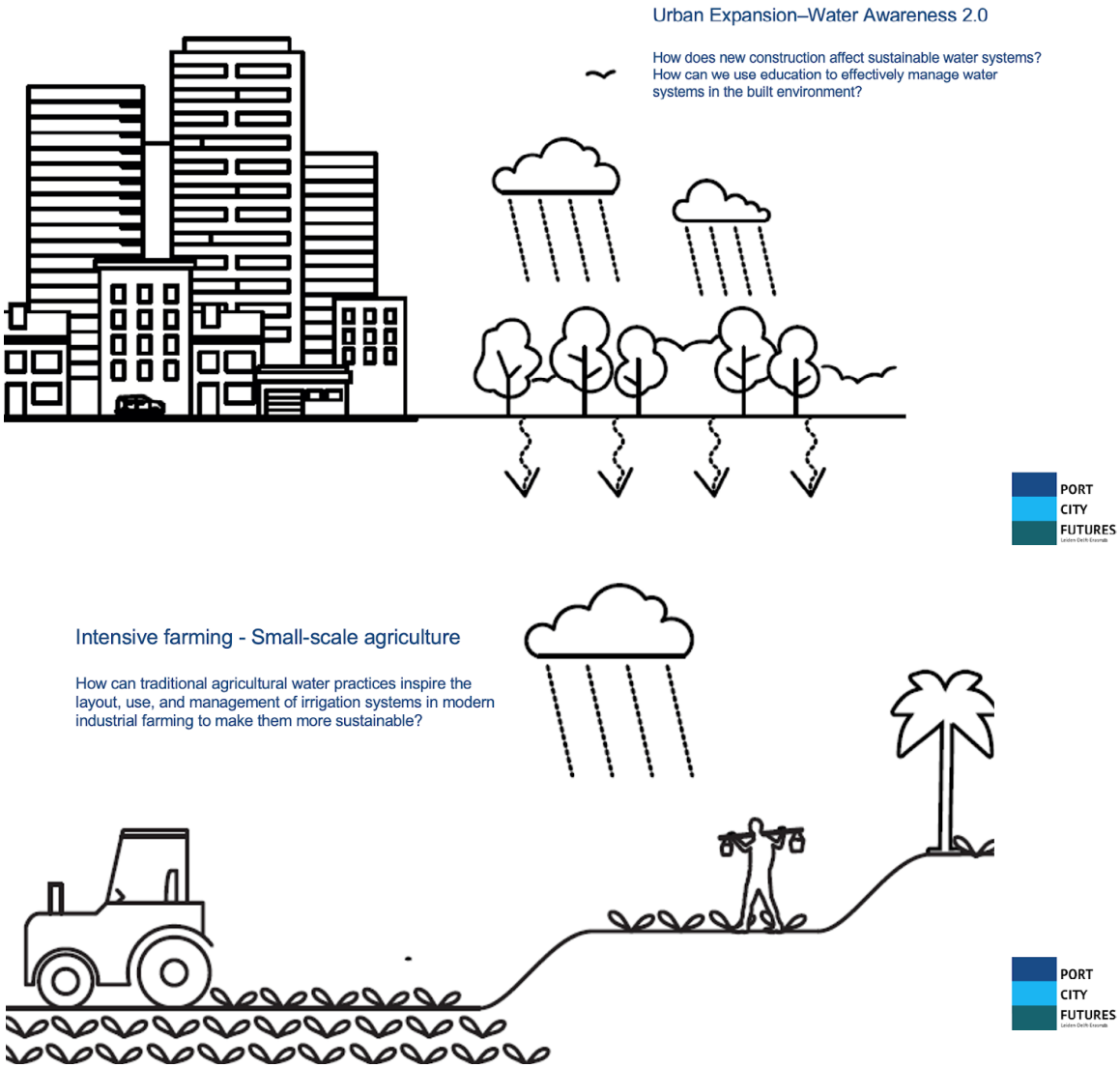
ing distinctions between city and periphery, I have found it helpful to use *petroleumscape* and *portcityscape* to describe the impact of a single commodity and the impact of port flows on disconnected spaces. This approach can be connected to the theory of affordance, that is, the ways in which the qualities of an object communicate certain behaviors (Gibson 1979). Exploring the impact of decisions that reflect values and their impact on spatial development over time and at different scales, as stakeholders and their views change, can provide a more complex understanding of a specific situation and help develop a broader framework for decision-making and future design.

A Value Case Approach for Water: Concepts and Tools

Water systems – complex systems of spatial, social and cultural practices involving water – are an example of space-time entanglement across scales, involving multiple stakeholders. Water is always moving or transforming, and water systems form interconnected spaces that cross the border of water bodies and land, linking diverse water uses – from drinking water to shipping, energy generation to irrigation. The values associated with water systems depend on specific types of and forms of engagement with water – clean or polluted, fresh or salty. Historically, where water was scarce, people built water distribution systems that were publicly accessible and beautiful. The value placed on community access to drinking water can be seen in public fountains in the squares of Marrakech and the pumps in medieval European cities. Such water distribution sites were closely connected to public spaces; they served as gathering places and were depicted in paintings, literature and music. The protection of drinking water often requires interventions in other aspects of water systems. Sewage, for example, has often posed a great threat to healthy drinking water, and people have developed extensive systems of separating fresh and polluted water, involving distinctive water-related spaces and practices. Public toilets are excellent examples, even if typically they are less remarkable than the "designer toilets" of Tokyo celebrated in Wim Wenders' 2023 film *Perfect Days*.

Values related to water develop in specific contexts and change over time. When there are competing uses of water, people need to negotiate preferences in line with values. For example, rivers have long been the source of drinking water. The use of river water for industrial production and the use of rivers as sewage canals or for shipping can conflict with demands for high quality fresh water. Such conflicts have repeatedly arisen over time along with compromises. Historically in villages, practices such as fetching drinking water, bathing, and washing clothes were carried out in a sequential progression from clean water to dirty. Another example involves the introduction of petroleum refineries in the mid-nineteenth century. Some of the early refineries were built above the water intake of cities such as Rotterdam, Hamburg and Philadelphia. Eventually, to maintain drinking water quality, the refineries were relocated downstream. If such competing interests are not addressed, conflicts can easily arise. How different interests are balanced is influenced by cultural practices and societal values. There are also practical considerations, such as the availability of tools and energy.

Values pertaining to water change over time for example as people have demanded safe drinking water and fought polluters, creating

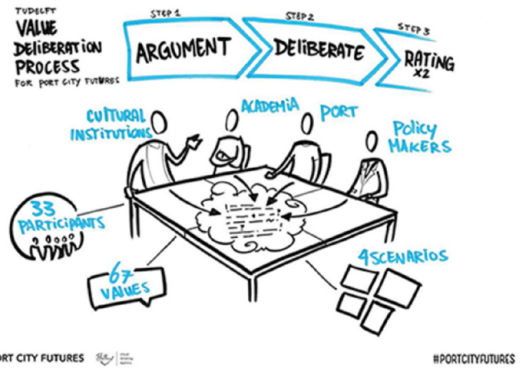


^ Fig. 3 Water dualities (Source: PortCityFutures, 2022).

new challenges. Industrialization facilitated the emergence of public "modern water" systems that improved health for large parts of the population (Linton 2013); yet in general, people lost much awareness of water and the system of which it is a part. Figure 3 illustrates some of the conflicts that can arise between different water uses and how uses may change over time. For example, many historic cities were built to accommodate traditional needs related to drinking water, sewage and transport. Industrialization has increased pollution and water consumption and cities have expanded in ways that fail to align with the watershed, leading to water conflicts, social injustice and health challenges. A new balance for the water system must be found that doesn't deplete water sources or pollutes but improves water quality.

Understanding the specific role of water in each natural and cultural context, its representation and interrelation is an important precondition to designing sustainable future water systems. Such understanding is particularly important at a time of climate-related water systems change and its impact on human and non-human actors and serves as a foundation for identifying opportunities and challenges for future design. The absence of widespread understanding of water has gone hand in hand with the decay of many natural water bodies, including lakes, rivers and oceans. Today, we are seeing signs of renewed awareness of water, as places that were used for shipping become sites for swimming or other leisure activities. The current climate-related transformation of water systems, changes in the frequency and intensity of floods and droughts, shortages of drinking water, and pollution challenge current water systems and require a new holistic approach to water system design, one that recognizes and acknowledges different values and their transformation over time.

In 2018, as part of a Delft Design for Values kick-off grant, we developed a Value Deliberation Methodology concerning the future of port city territories (Hein 2019b). Using a visualization of four different scenarios of port-city interaction, we invited stakeholders from academia and practice to identify relevant values – such as sustainability, safety, efficiency, cooperation or continuity – and discuss the scenarios based on values. Participants were asked to think beyond a specific technological choice and instead discuss underlying values, as figure 4 shows. These discussions aimed at opening up a wider perspective on the topic; the discussions remained academic, but they did help start the work of PortCItyFutures. While productive, this value deliberation did not include the dimension of change over time.



^ Fig. 4 Value deliberation methodology (Source: PortCity-Futures, 2022).

Developing a Value Case Approach for Water Spaces and Practices: Icons, Mapping and SDGs

The value case approach aims to bring together diverse interests and generate shared benefits. Exploring the role of water in society is also a way to test the ecosystemic approach underlying the UN Sustainable Development Goals (SDGs). As figure 5 proposes, if we put water at the center of analysis and explore its climate and energy context, we can classify the SDGs in terms of individual survival and community structures; more broadly, we can explore the values that drive the solutions that have emerged over time and that continue to influence contemporary decision-making (Hein 2022a). As we aim for socially just and sustainable development, we need to identify and address side effects, stimulating potential positive impact and avoiding negative repercussions. Understanding the multiple impacts and side effects of a project beyond its main goal and group of stakeholders can encourage new alliances of stakeholders, including those that are otherwise under represented.

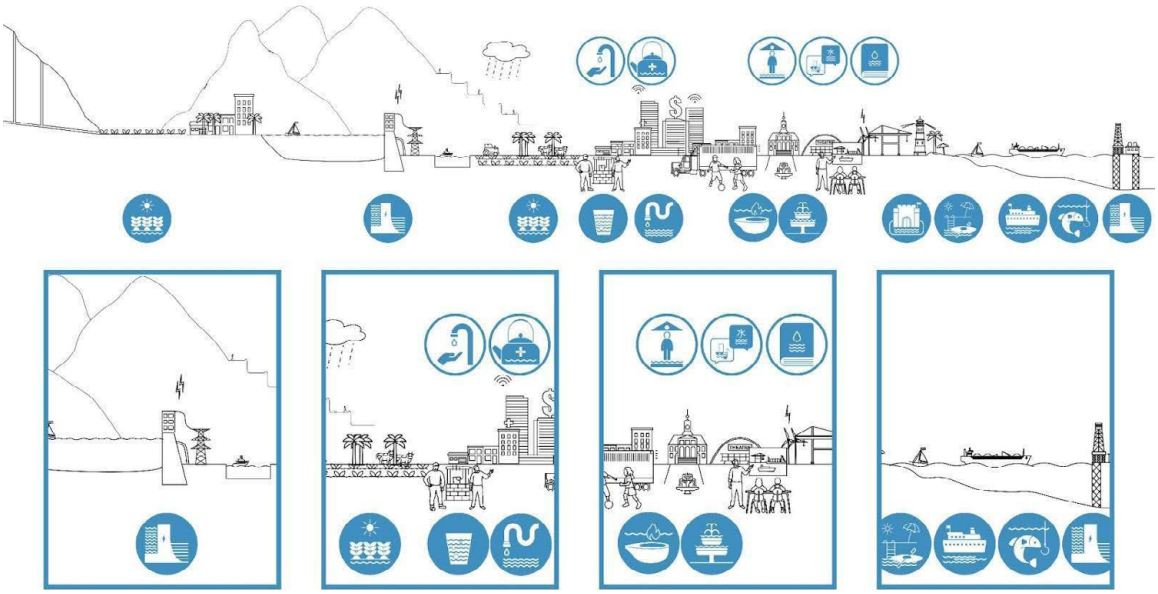
The SDGs provide a framework for reflecting on direct and indirect consequences of water management for various sectors of society and aspects of the environment and the economy.

^ Fig. 5 Visualization of the SDGs as an ecosystem through time, with a focus on water. Originally published in figure 4 in *Blue Papers* 2022 (Vol. 1, No. 1), pp. 12–23 (Source: Carola Hein, 2022).

Each of these approaches to water – captured here through the visualization of the SDGs in time – has its own spaces, institutions and practices. For example, for people to use a water body for drinking or swimming, it needs to be accessible – think of beaches, stairs and pontoons. By contrast, a sewage canal can be hidden in underground canals or behind walls. Different uses of water also elicit different types of narratives, education and literature. This separation can be advantageous for decision-makers. Planning a port for large ships is easiest when there are no other water-related needs – no citizens who would like to swim, need to be able to get across the port or who complain about noise or pollution. Depending on how we see and value water, we will include different structures and institutions than if we see it as a partner and part of an ecosystem (Hein 2016).

To facilitate engagement around values pertaining to water and the diverse functions that are related to it, it is important to provide a shared language and set of imaginaries. Together with other researchers in the UNESCO Chair Water, Ports, and Historic Cities (Matteo D'Agostino, Lea Kayrouz, Zuzanna Sliwinska and others) we have developed and tested a set of icons that reflect different types of intangible water practices and tangible spatial patterns of water (Hein et al. 2022). First introduced in 2022, after experimenting in different cultural contexts, we have further refined and detailed the icons (Hein et al. 2025). Visualizing various water functions in space can encourage conversations in line with the value deliberation presented earlier, leading to a better understanding of potentially conflicting water practices in a certain location.

To gain a better understanding of how water uses exist in space, figure 6 shows a section of an abstract landscape with its multitude of natural and cultural conditions and their connection to water. It uses icons that relate to



^ Fig. 6 Visualizing the spatial, social and cultural conditions of water in its tangible and intangible form as a water grammar provides insight regarding water systems' conflicts and opportunities as related to natural landscapes, cultural developments and tangible and intangible practices (Source: Carola Hein; visualization by Lea Kayrouz, 2025).[2]

different uses of water and their location in the landscape to identify potential conflicts and opportunities in water use as well as how these are imagined, including their intersection upstream and downstream. Visualizing water practices through icons can facilitate conversations about conflicts and possible positive or negative externalities among stakeholders, in space or over time. For example, there may be conflicts involving water quality (e.g., drinking water vs. sewage water) or agriculture (e.g., irrigation vs. drinking water), or water flows (e.g., water retention vs. shipping). Whether or not specific activities can reinforce or impede one another changes over time and across space. Comprehensive discussions based on icons can help visualize value conflicts and their transformation over time.

The vignettes on value grammar presented in figure 6 illustrate the proximity and interconnectedness of water in all its forms and visualize interactions and possible conflicts between different ways of using water. For example, the provision of drinking water in a well, the use of water for irrigation, the storage of water in a retention basin or the use of water for energy generation can take place in proximity; they can even reinforce each other. Analyzing both existing and missing connections among various uses and the stakeholders that engage with them forms a basis for developing long-term solutions designed to address multiple problems and fit the intervention context. In several pilot workshops (about 10) with stakeholders from public institutions, NGOs, as well as with private citizens, these value coins have served to facilitate communication and help promote conversations on how we value and think about water systems, including how we value and protect historic systems and heritage. For the first workshops we used icons only

2. This section can be redrawn and further developed in green or red, depending on perceptions by different actors.

to indicate specific functions; more recently, we have used different colors to show that a value has been compromised (red), or has been promoted (green). A structured and consistent assessment of the impact of the workshop remains to be accomplished.

Conclusion

Understanding, analyzing and connecting existing conditions and the opportunities for co-creation and trade-offs through shared values lies at the heart of the value case approach. The method aims at a comprehensive understanding of the development of natural and cultural landscapes and of tangible and intangible practices through time, which in turn helps inform the formulation of long-term strategies in line with an action-oriented, overarching vision and mission. The value case approach in itself is not political, but it aims to equip policymakers with tools for identifying shared values and establishing processes. The aim is to create solutions that connect societal principles with local interests and values, using long-term thinking and context-sensitive planning. This requires a deep understanding of the historical processes that have shaped the current situation, of the relevant constellation of actors, networks and values and of the surrounding ecosystem.

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Ancient Hydro-Technologies as a Response to Climate and Food Emergencies: The Use of Cultural Heritage to Rescue the Future

Jordi Morató, Olga Sánchez & José Luis Martin

Abstract
The Mediterranean faces escalating climate challenges, including rising temperatures, water scarcity and ecosystem degradation. Projections indicate up to 6.5°C warming by 2100, with reduced rainfall and increased evaporation intensifying water shortages — especially in agriculture, which uses 70–80 per cent of the region's water. Freshwater competition, declining crop yields and coastal aquifer salinization further threaten sustainability. Ancient hydro-technologies — developed by early civilizations — offer valuable lessons for adaptation. Minoan rainwater systems, Roman aqueducts and Iranian qanats emphasized water conservation, efficient irrigation and flood control. Designed in harmony with nature, they embody sustainability, resilience and multifunctionality, supporting biodiversity and adaptation. Scaling up these systems requires integrated governance, legal recognition, capacity building and interdisciplinary research. International cooperation and funding can help preserve and adapt them to modern needs, integrating them into the water-energy-food-ecosystem (WEFE) nexus for sustainable resource management.

KEYWORDS

SETs
WEFE nexus
Climate emergency
Nature-based solutions
Ancient hydro-technologies

WATER ICONS

Policy Recommendations

- Integrate ancestral hydro-technologies into national and regional water policies by promoting them as nature-based solutions for climate adaptation and water security. This can be achieved through regulatory frameworks, incentives for implementation, and alignment with existing environmental and agricultural policies.
- Support capacity building and knowledge exchange.
- Establish financial mechanisms and incentives.
- Strengthen multi-level governance and stakeholder engagement.
- Enhance monitoring and data integration by incorporating ancestral hydro-technologies into water management planning.

< Fig. 1 Zenu ancestral hydro-technology, Colombia (Source: Jordi Morató Farreras, 2020).

Introduction

The accelerating pace of climate change (CC) has exacerbated long-standing socio-environmental issues in the Mediterranean region. These challenges arise from a combination of factors, including shifts in land use, poor management of natural water resources, soil degradation due to erosion, increasing pollution levels and a decline in biodiversity. Today, over 180 million individuals in the Mediterranean region are affected by water scarcity.

Projections based on the latest findings from the IPCC (2023) and MedECC (2020) reports indicate a worsening scenario. Annual mean temperatures on land and sea across the Mediterranean basin are 1.5°C higher than during pre industrial times and they are projected to rise by 2100 by an additional 3.8 to 6.5°C for a high greenhouse gas concentration scenario (RCP8.5) and 0.5 to 2.0°C for a scenario compatible with the long-term goal of the UNFCCC Paris Agreement to keep the global temperature well below +2°C above the pre industrial level (RCP2.6). Without additional mitigation, regional temperature increase will be 2.2ºC in 2040, and for each degree of global warming, mean rainfall will likely decrease by about 4 per cent and evaporation will increase nearly 7 per cent in much of the region, particularly in the south. On land and in the sea, heat waves will intensify in duration, with higher peak temperatures. Despite strong regional variations, summer rainfall will likely be reduced by 10 to 30 per cent in some regions, increasing existing water shortages, desertification and decreasing agricultural productivity, which could be reduced by 17 per cent in 2050 (MedECC 2020).

With agriculture using most of the Mediterranean's water (about 70 to 80 per cent) (Crovella et al. 2021), which is in competition with fresh water, touristic and industry sectors in a very volatile equilibrium, and climate change impacting water reserves, several challenges arise, including less runoff and groundwater, poorer water quality, more conflicts among stakeholders, ecosystem damage, coastal aquifer salinization and fewer nutrients for sea organisms, which affects fishing, one of the most important sources of protein in parts of the region.

Demand for irrigation is expected to increase by 4 to 18 per cent by 2100, although demographic change, including the growth of large urban centers, could enhance this demand by 22 to 74 per cent. Most significant climate risks are related to a shortage and excess of water, as shown in recent analyses of the Nationally Determined Contribution (NDCs) for the Paris Agreement, at the global level and for Africa specifically (Tollin et al. 2022). However, the NDCs are only defining actions to certain degree, and in only a few cases through an integrated, cross-sectoral and multi-risk approach.

Despite challenges, the Mediterranean region has significant potential for adaptation by improving water use efficiency. Human societies have historically demonstrated resilience by developing socio-technical, cultural and environmental systems (SETs) that integrate traditional knowledge, cultural practices and technologies. These adaptive systems, recognized by scientists as SETs (Grimm et al., 2017; Reyers et al., 2018; Preiser et al., 2018; Nguyen et al., 2023), have enabled communities to endure and respond to environmental challenges while maintaining ecological balance. They reflect centuries of sustainable resource management and a deep connection between people and nature.

Ancient Hydro-Technologies: Lessons from Water Heritage

Ancient hydro-technologies are a key component of adaptive strategies developed by ancient civilizations to manage water sustainably. Designed in harmony with natural hydrological cycles, these systems ensured water conservation, efficient irrigation and the regulation of floods and droughts, serving as nature-based solutions to climate variability.

These traditional water management systems and engineering practices were developed to harness, store, distribute and regulate water resources while maintaining ecological balance. By integrating traditional knowledge with ecosystem management, they supported long-term water availability for agriculture, domestic use and biodiversity preservation. Rooted in nature and adapted to local environmental conditions, ancient hydro-technologies exemplify NbS, demonstrating how human societies have historically leveraged natural processes for resilience and sustainable development.

Water management has played a crucial role in the development of civilizations across the Mediterranean, shaping their resilience, sustainability and prosperity. Over time, societies adapted and improved water infrastructure to address the challenges of arid climates, urban expansion and agricultural needs. Each period contributed to the evolving water heritage of the Mediterranean, demonstrating how civilizations adapted to environmental challenges through technological ingenuity and sustainable water management practices.

Egyptian water culture (c. 3150–31 BCE), was deeply connected to the Nile River, which served as the foundation for the development of sophisticated irrigation systems. The Egyptians implemented basin irrigation, canals and reservoirs to control seasonal flooding and sustain agriculture. They also constructed nilometers to measure water levels and predict harvests, demonstrating early hydrological expertise (Gad 2008; Driaux et al. 2016). In the Minoan civilization (c. 3000–1100 BCE), water management systems became highly advanced, with the construction of complex drainage and supply networks. The Minoans engineered underground clay pipes, terracotta aqueducts and multi-tiered cisterns to ensure a steady water supply. They also developed sophisticated rainwater harvesting techniques and built some of the earliest known flushing toilets, particularly in palatial centers like Knossos (Angelakis et al. 2013; Crovella et al. 2021). The Etruscans (c. 800–500 BCE) in central Italy contributed significantly to water infrastructure by constructing tunnel aqueducts, drainage canals and artificial reservoirs to manage water for both agricultural and urban use. The Romans (c. 100 BCE–476 CE) perfected aqueduct technology, enabling them to transport water over long distances with precision-engineered arches and tunnels. They constructed extensive public infrastructure, including baths, latrines, fountains and sewage systems, setting a foundation for modern urban water management. In the medieval period (fifth–fifteenth century CE), water management practices evolved differently across regions. While some areas experienced a decline in infrastructure following the fall of Rome, others flourished under Islamic and Byzantine influences. Islamic engineers in Spain and North Africa refined irrigation networks, introduced qanats and waterwheels (*norias*), and enhanced agricultural productivity through sophisticated water distribution techniques.

Without a doubt, the Minoans can be regarded as pioneering architects of many advanced water management techniques that continue

^ Fig. 2 Water heritage cultures of the Mediterranean and convergent evolution in other world areas (Source: Jordi Morató Farreras, 2023; Background map: Nzeemin, 2012. CC BY 3.0, via Wikimedia Commons).

to influence modern systems today. Important aspects of this water heritage include the following:

- They recognized the vital role of sanitation, water supply, and drainage systems in human survival and well-being, integrating these elements into urban planning to ensure the sustainable management of water resources.
- Water quality and safety were key considerations in the design and construction of their water supply systems, reflecting an advanced understanding of hydrology and public health.
- They employed a balanced approach, combining small-scale solutions like cisterns for rainwater collection with large-scale infrastructure such as reservoirs to store and regulate aqueduct flows.
- Their water technologies were characterized by their simplicity, efficiency and ease of operation, requiring minimal maintenance and complex controls while effectively meeting the needs of growing urban populations.

Parallel developments occurred among various civilizations, each geographically isolated from the Mediterranean, yet independently devising comparable water management strategies to sustain their communities. This phenomenon of convergent evolution, where different societies develop similar solutions in response to shared environmental challenges, was particularly significant in the Indus Valley (Pakistan) during the Bronze Age (c. 3200–1100 BCE), the Zenú society in Colombia (c. 600–400 BCE), and the Pre-Hispanic Amunas in Peru (twelfth–thirteenth century). These civilizations engineered sophisticated water systems tailored to their landscapes, demonstrating a deep understanding of sustainable resource management.

Key Properties of Ancient Hydro-Technologies

These water management systems and agricultural conservation practices, guided by traditional ecological knowledge and community-based governance, have shown centuries-long sustainability and resilience, enduring

extreme events while efficiently utilizing resources. Good examples of such systems, including some still in use today, can be found all over the world: the acequias de careo in Spain, the zenu channels or camellones in Colombia, the Aflaj and Zajirah in Oman, the traditional stone weirs in ephemeral streams in Greece, the Persian qanat in Iran and the drystone walls in many parts of the Mediterranean region such as in Catalonia (Spain) and Cinque Terre (Italy) to name a few, but also the terraces built on sloping terrain in many Mediterranean areas to help level the land, making it more suitable for agriculture, while also reducing soil erosion caused by rainfall.

If properly managed, these technologies could become an effective solution for CC adaptation and mitigation related to flood and drought control and disaster risk reduction, water regulation, ecosystem services and biodiversity conservation, among other challenges. They also provide multifunctional co-benefits for the management of pollution, food production, health security and economic development. From a cultural perspective, these technologies represent a wealth of ancient local and traditional knowledge that should be preserved and valued as cultural heritage. In summary, key properties of ancient hydro-technologies, which provide valuable insights for modern water management and climate adaptation strategies, include:

1. Sustainability and ecological integration. Ancient hydro-technologies have a low footprint in terms of energy, resources and carbon. Designed in harmony with natural water cycles, these systems minimized environmental disruption and ensured long-term resource availability.
2. Adaptability to local conditions. Tailored to specific geographic and climatic contexts, ancient hydro-technologies optimized water use in arid, mountainous, and flood-prone regions.
3. Efficiency in water conservation. Many techniques, such as terraced irrigation, qanats and amunas, prioritized water infiltration, storage, and controlled release to reduce losses and maximize usage.
4. Decentralized and community-based management. These systems operated through local knowledge and collective governance, ensuring equitable distribution and maintenance.
5. Resilience to climate variability. Designed to mitigate droughts, floods and seasonal changes, these technologies provided stable water access in extreme conditions.
6. Beneficial for biodiversity restoration, ancient hydro-technologies can be instrumental in preserving and restoring biodiversity and strengthening ecosystem services' provision.
7. Low-tech, high-impact design. Simple yet effective engineering principles made these systems durable, cost-efficient and easy to maintain over centuries.
8. Integration with the WEFE nexus. Ancient hydro-technologies serve the further integration of the WEFE nexus at the local and regional scale as a result of their transfunctionality and their contribution to the Sustainable Development Goals (SDGs).
9. Multifunctionality. They often served multiple purposes, such as irrigation, drinking water supply, flood control and soil conservation, contributing to overall ecosystem stability.

Ancient Hydro-Technologies as a Solution to Climate and Food Crises

Ancient hydro-technologies should be recognized not only as historical infrastructure and

cultural heritage but also as viable models for sustainable water management, adaptable to present and future challenges. Their effectiveness can be further enhanced by integrating innovations from social, ecological and engineering disciplines.

Many of these systems have significant potential for recovery and scaling, offering solutions for the transformative changes needed to address global challenges within the broader framework of sustainable development. Their value in tackling current crises – climate change, biodiversity loss, water scarcity, health and food security – has been well-documented with extensive evidence, case studies and the identification of best practices.

The implementation of ancient hydro-technologies today faces legal, economic, technological and governance challenges. Regulatory frameworks often fail to support traditional practices, while knowledge gaps, financial constraints and the erosion of traditional expertise hinder their revival. Additionally, urbanization, land use changes and competing water demands limit their applicability. Addressing these barriers requires policy reforms, institutional support, capacity building and interdisciplinary collaboration. Multi-level governance, financial investment and integrated planning are essential to effectively reintegrate these sustainable water management systems into modern contexts.

In summary, successfully scaling up ancient hydrohydro-technologies requires addressing the following critical challenges:

- Multi-level governance to align national policies with local practices and integrate sectoral policies on climate, water, energy, food, biodiversity, health and development.
- Legal recognition and protection of ancient hydro-technologies at risk of loss.
- Capacity building for policymakers, practitioners, researchers and communities to advance theoretical and operational knowledge.
- Multidisciplinary research integrating low- and high-tech solutions, scientific, socio-cultural and traditional knowledge, and the role of eco-museums.
- Awareness and advocacy to highlight the value of ancient hydro-technologies in resilience transitions.
- Financial support for large-scale demonstrations of these technologies that can inspire transformative change.
- Global networks for knowledge exchange, project development and implementation.

Despite these challenges, ancient hydro-technologies are gaining renewed interest. Cities and rural communities are integrating traditional systems like qanats, acequias and stepwells with modern innovations such as remote sensing and decentralized water governance. These hybrid approaches offer scalable, nature-based solutions for enhancing water resilience and sustainable management in a changing climate.

Conclusion

Ancient hydro-technologies represent nature-based solutions rooted in traditional knowledge and ecosystem practices, offering sustainable approaches to water management. These systems are characterized by low energy requirements, resource efficiency and minimal carbon footprints. By integrating ecological principles, they not only restore biodiversity but also enhance ecosystem services, such as hydrological regulation, artificial aquifer recharge and soil moisture retention. These

benefits, in turn, improve carbon sequestration, soil fertility and local temperature regulation, making them invaluable for climate adaptation and resilience.

These time-tested systems provide critical insights for addressing contemporary environmental challenges. Their ability to optimize water conservation, enhance irrigation efficiency and mitigate the impacts of floods and droughts has been proven over centuries. By reintegrating ancient hydro-technologies into modern water governance, new research opportunities emerge, highlighting their potential to strengthen sustainability and resilience in the face of climate change. However, realizing their full potential requires embedding them in modern policies through multi-level governance, robust legal frameworks, capacity building and interdisciplinary research.

As global water scarcity intensifies, combining these traditional practices with modern innovations can foster adaptive, nature-based water management strategies. Their multifunctionality supports biodiversity conservation, food security, and ecosystem services, aligning with the WEFE nexus and the SDGs. Scaling up these technologies demands financial investment, cross-sector collaboration and awareness-raising initiatives to ensure their preservation and adaptation to future challenges.

By bridging traditional wisdom with modern innovation, ancient hydro-technologies can play a pivotal role in advancing climate resilience and sustainable water management, not only in the Mediterranean but globally. Recognizing their value and integrating them into broader strategies will be essential for building equitable and resilient water systems for the future.

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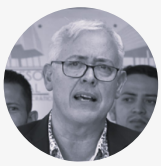

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Qanats: Ancient Innovations Nurturing Sustainable Futures in Water Management

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Abstract
The qanat, a timeless testament to human ingenuity, emerged on the arid Persian Plateau around three millennia ago as a sustainable solution to water scarcity. This technique channels water from aquifers using gravity through gently sloping sub-horizontal tunnels, avoiding over-extraction and ensuring a delicate balance between human needs and environmental preservation. By naturally regulating water flow according to aquifer levels, qanats prevent excessive depletion, serving as a model for sustainable water resource management. This study explores the fascinating journey of qanats, their geographical spread, historical evolution and enduring relevance. We highlight their adaptability to diverse environments, their role in fostering cultural continuity and their potential to address contemporary water challenges. By revisiting this ancient marvel, we uncover valuable lessons for contemporary water management systems worldwide.

KEYWORDS
Oases
Qanats
Groundwater
Resource management
Ancient hydro-technologies

WATER ICONS

Policy Recommendations

- Enhancing and safeguarding the heritage of qanats in their various territorial forms by preserving not only their historical legacy but also their functionality and efficiency as integral components of an integrated water management system.
- Prioritizing groundwater extraction through technologies like qanats, which operate without energy use and prevent aquifer depletion, ensuring sustainability and long-term functionality of water resources.
- Promoting the tangible and intangible heritage of qanats as a catalyst for dialogue and cultural and political exchange in addressing future challenges.
- Revitalizing and strengthening administrative and democratic bodies to supervise regions where qanats are present, ensuring a shared vision beyond individual interests.

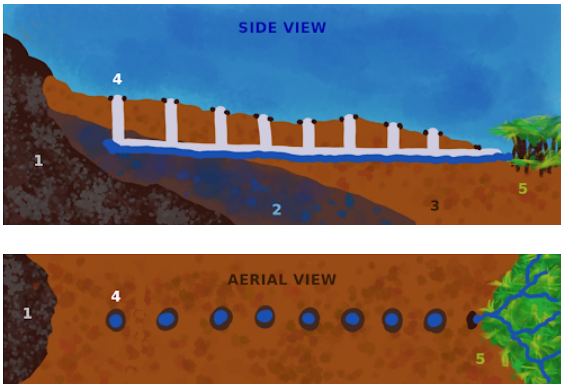
< Fig.1 Qanats of Bam (Source: S.H. Rashedi, 2014. Nomination File, © S.H. Rashedi, whc.unesco.org/en/documents/141554).

Introduction

Qanats, a cornerstone of traditional irrigation systems, exemplify a profound understanding of the harmonious relationship among humans, technology and nature. Originating on the arid Persian Plateau approximately 3,000 years ago, qanats addressed the challenge of water scarcity in arid around semi-arid regions (Barontini et al. 2018; English 1968; Lightfoot 2000, 2024; Remington 2018). These systems consist of gently sloping underground tunnels that transport groundwater from aquifers to surface areas using gravity alone. Qanats operate passively, delivering water sustainably. When aquifer levels are high, qanats yield more water, while during droughts, their output naturally decreases, preventing over-extraction and preserving long-term aquifer health. This self-regulating mechanism aligns qanats with natural groundwater cycles, supporting human activities such as drinking water supply, agriculture and horticulture. The ingenious design of qanats minimizes evaporation losses, allowing water to be transported over long distances in harsh climates. This sustainable approach has endured the test of time, inspiring numerous adaptations in diverse regions (Ashraf et al. 2016; Barontini et al. 2018; Barontini et al. 2017; Chunliang et al. 2014; Himat and Dogan 2019; Khan and Nawaz 1995; Martínez-Medina et al. 2018). This study examines the evolution and diffusion of qanats, tracing their development in ancient Persia and global spread, while emphasizing their contemporary significance in sustainable water management.

Historical and Geographical Diffusion of Qanats

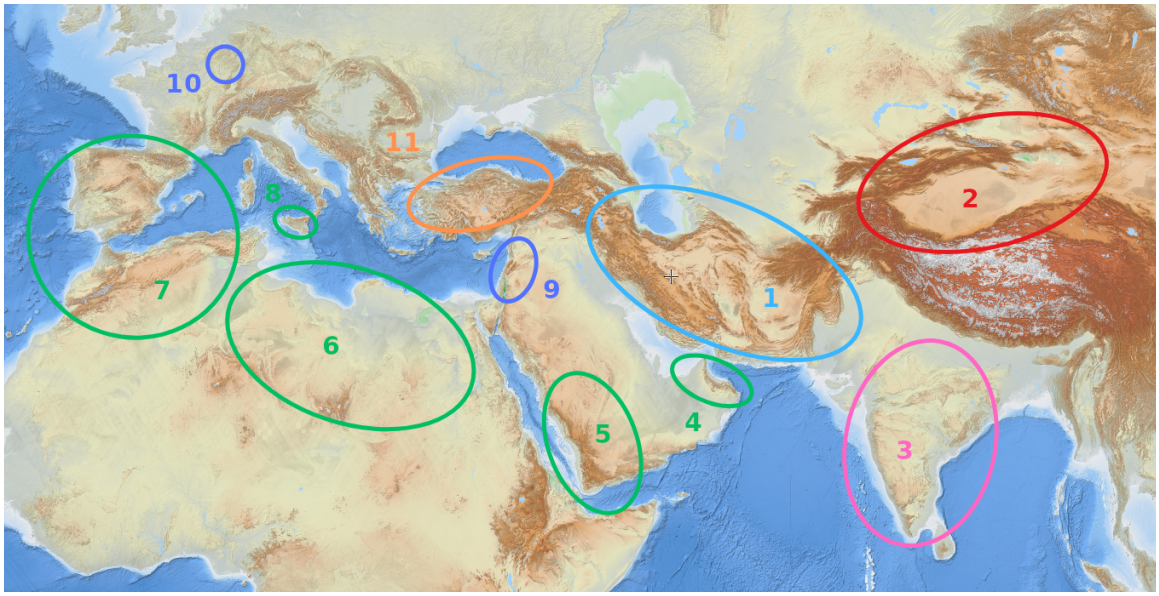
The qanat system, originating in the heart of the Iranian Plateau along the internal fringes of the Zagros Mountains, likely emerged during



^ Fig. 2 Scheme of a qanat section: 1 Bedrock; 2 Water table, saturated zone; 3 Alluvium, unsaturated dry zone; 4 Mother well; 5 Outlet. The qanat drains water from the water table (Source: Massimiliano Borroni, 2024).

the early first millennium BCE as an innovative response to arid conditions and the scarcity of stable, high-quality surface water. The period before the advent of qanats saw advancements in metalworking, which in turn drove progress in mining technologies. Early Persian farmers and miners, noticing water seepage in mining tunnels, adapted this knowledge to channel groundwater for irrigation. By connecting aquifers to farmland through gently sloping tunnels, they developed a reliable and sustainable irrigation system.

The rise of the Achaemenid Empire (550–330 BCE) coincided with the early diffusion of qanats. Ancient sources link the establishment of this imperial power to the extensive use of cavalry, which required substantial agricultural surpluses to sustain the animals. The dissemination of qanat technology made it possible to cultivate arid plains and expand agricultural areas, generating the surpluses needed to support the cavalry. Recognizing the strategic value of this innovation, the Achaemenids actively promoted the spread of qanats, creating a positive feedback loop that reinforced agricultural productivity and military strength (English 1968; Massoud 2022).



^ Fig. 3 Diffusion of qanats: 1 Iranian Plateau, place of origin; 2 Xinjiang region; 3 Deccan Plateau; 4 and 5 Oman, Yemen and Saudi Arabia; 6 Egypt and Libya; 7 Algeria, Morocco and Iberian Peninsula; 8 Sicily; 9 Syria, Jordan and Palestine; 10 Luxembourg; 11 Anatolian Plateau and Greece (Source: Vladimiro Andrea Boselli, 2024).

In summary, the agricultural surpluses generated by this ingenious irrigation system were instrumental in the empire's rise, supporting the development of a formidable cavalry that became a cornerstone of its military power. However, two centuries later, Alexander the Great's introduction of the Macedonian phalanx rendered cavalry tactics ineffective. This shift in military strategy contributed to the empire's downfall, culminating in Darius III's assassination by his own generals following their defeat in Bactria in July 330 BCE.

Persian rulers incentivized qanat construction by granting builders land and water rights for multiple generations, leading to the widespread adoption of this technology across their vast empire. Qanats initially spread westward to Mesopotamia, the Levant and Egypt, and eastward to Afghanistan, Central Asia and the Turpan Basin in western China (present-day Xinjiang) (Chunliang et al. 2014; English 1968; Lightfoot 2024; Massoud 2022). Administrative oversight during imperial expansions further facilitated the dissemination of this ancient system. The system was adapted to suit the specific environmental, hydrogeological and cultural contexts of various regions, reflecting the technique's intrinsic flexibility.

During the Roman-Byzantine period (64 BCE–660 CE), qanats were introduced to parts of Europe, including the Iberian Peninsula and the region of present-day Luxembourg. In the Levant, encompassing Syria, Palestine and Jordan, qanats were integrated into Roman aqueduct systems. However, during this period, Roman aqueducts remained the dominant form of water infrastructure. In Roman Gaul, qanats extended as far as present-day Luxembourg, where the Raschpëtzer qanat, dating to around 150 CE, operated for approximately 120 years (Govindan Kutty 2020; Kayser and Waringo 2000).

A second major wave of qanat diffusion occurred during the rise of the Islamic caliphates in the seventh century and beyond. This expansion brought qanat technology to coastal areas of North Africa, the Iberian Peninsula and Sicily. During this period, the deepening of hydraulic knowledge over the first five centuries of the Islamic era led to significant advancements in qanat construction and maintenance techniques. With the establishment of Islamic sultanates in northern India (eleventh–thirteenth centuries) and later in the central Indian subcontinent (fifteenth–eighteenth centuries), qanat technology spread across the Deccan Plateau (Barontini 2017; Govindan Kutty 2020). The diffusion of qanats during the Islamic period is well-documented, highlighting the existence of skilled labor teams, with each member specializing in a specific aspect of construction or maintenance. These teams, benefiting from the hydraulic knowledge accumulated during the early Islamic era and equipped with technical manuals in Arabic and Persian, further refined qanat technology (English 1968; Lightfoot 2000; Madani 2022; Malik et al. 2021; Martínez-Medina et al. 2018; Remington 2018). They likely facilitated the spread of qanats along trade routes connecting Central Asia and North Africa, particularly in regions with high demand for sustainable irrigation systems. These trade routes often strengthened oasis centers, enabling the expansion of irrigated agriculture and reliable water supplies in arid regions (Madani 2022; Massoud 2022; Messous 2024; Strava 2024). Later, Spanish colonists, familiar with qanat systems from their homeland, introduced variants of the technology to Latin America. They established qanats in regions such as Mexico, further extending the global legacy of this ancient innovation and enriching similar Indigenous pre-Columbian techniques, such as the *puquios* of Peru and northern Chile (Barontini et al. 2018; English 1968; Martínez-Medina et al.).

Localization, Adaptation and Regional Names

The diffusion of qanats followed ancient trade routes and the expansion of empires. This fact allows us to highlight the deep connection between centralized administration and qanat construction. The building and maintenance of qanats, like Roman aqueducts, could be managed by tightly organized local communities without extensive centralized authority, like oasis communities, or by labor groups directed and financed by central authorities or owners of large amounts of land. After the construction of a qanat, the relatively simple maintenance required was often left to the population occupying the area it served to irrigate. This was unlike the great architectural structures of Roman aqueducts, which required highly skilled and specialized workers for upkeep and resulted in the conservation of many functional qanats and the progressive abandonment of the big Roman aqueducts. This can also be observed in oasis regions of North Africa, the Persian Plateau, and the Deccan Plateau of India, where local communities maintain and modernize qanat networks (Ashraf et al. 2016; Govindan Kutty 2020; Himat and Dogan 2019; Khan and Nawaz 1995; Malik et al. 2021; Massoud 2022; Messous 2024; Taghavi-Jeloudar et al. 2013; Weingartner 2007).

Local conditions and cultural influences shaped unique adaptations and regional names, reflecting the integration of qanat techniques into local knowledge systems (the variety of languages involved leads us to abandon any claim to uniformity in romanization). While the word *qanat* is common in the Arabic speaking world (e.g., Iraq and Syria), in Sicily they are called *canate arabe* ("Arab qanats"). In Northern Iraq, Central Asia and parts of India, the Iranian word *karez* is commonly used (sometimes transcribed as *kareez* or *kariz*), and in India we

find terms such as *kharejari*, *surang-bawdi, surangam, nahar* and *kundi bhandara*. In China's Xinjiang region, the system is known as *kanjing* or *kanerjing*, or again *karez*. The *dawudi falaj* (pl. *aflaj*) is another name for these underground tunnels, a term that we find in Oman and Saudi Arabia. In Southern Jordan, the name *dhwawi* may be used. In North Africa, specifically in Libya and Algeria, the system is known as *foggara*, and in Morocco, as *khettara*. In the Iberian Peninsula these systems are known as *galerías* ("tunnels"), a term carried to Mesoamerica and South America during the Spanish conquest (Barontini et al. 2018; English 1968; Martínez-Medina et al. 2018).

Contemporary Relevance and Future Sustainability

Qanats transcend mere technological innovation: they embody cultural and ecological heritage. Their construction and maintenance required communal effort, fostering collaboration and governance practices. Rituals and traditions surrounding water distribution underscore their central role in desert communities' social and spiritual lives, creating a shared sense of responsibility toward water as a precious resource.

In Spain, the *galerías con lumbreras* system in the southeastern region provides a striking example of qanat-inspired adaptation to address local challenges. One notable example is the Caño-Contracaño in Murcia, a qanat-like system designed to manage water efficiently. Beyond irrigation, it plays a vital role in mitigating eutrophication in saline lagoons, demonstrating how traditional techniques can be repurposed for modern environmental management strategies. The Caño-Contracaño's use of interconnected channels and ventilation shafts exemplifies the adaptability of qanat systems to local hydrological and ecological conditions. This harmonious blend of old and new highlights how heritage preservation can coexist with contemporary utility to create sustainable resource management frameworks (Martínez-Medina et al. 2018).

Oman offers another inspiring case of qanat revitalization. In the 1980s, government-led initiatives restored *aflaj* systems, ensuring the preservation of traditional practices while enhancing water accessibility. This effort underscores the potential of qanats to bridge the gap between heritage conservation and practical resource management, particularly in arid regions where water scarcity is a pressing issue (Remington 2018).

Similarly, the Naubad Karez in Bidar, India, has recently undergone conservation efforts, illustrating the ongoing relevance of qanats as decentralized water sources. These ancient systems offer viable solutions for sustainable urban and rural water supply, especially in areas grappling with dwindling aquifers and the adverse effects of over-extraction (Govindan Kutty 2020).

These contemporary applications highlight the enduring relevance of qanats, demonstrating how ancient wisdom can inspire innovative solutions for modern water challenges. Beyond their practical applications, qanats hold untapped potential as cultural and ecological tourism assets. Their unique design and historical significance captivate the imagination, transforming them into compelling attractions that celebrate human ingenuity in water management. From Spain to Oman, Iran, India and beyond, qanats can serve as focal points for heritage tourism, fostering economic opportunities while raising awareness about sustaina-

^ Fig. 4 Example of recent maintenance of a khettara near Ait Zeggane (Morocco) with modern techniques and materials. On the left, the systems for moving the material along the wells; in the center, two wells renovated with stone and bricks respectively; on the right, the maintenance work, during and after, in a slightly kilned well (Source: Mhammad Houssni, 2024).

ble water practices. By seamlessly integrating traditional knowledge with modern needs, qanats stand as enduring symbols of resilience and innovation. Their lessons, deeply rooted in harmony with natural resources, offer a timeless blueprint for the sustainable development of water systems worldwide (Barontini et al. 2018, 2017; Massoud 2022; Messous 2024; Taghavi-Jeloudar et al. 2013; Weingartner 2007).

Conclusion

The historical evolution and geographical diffusion of qanats underscore their enduring significance. By bridging diverse cultures and enabling sustainable resource management, qanats exemplify the potential of traditional knowledge to address modern challenges. Reviving this heritage not only honors its cultural legacy but also inspires innovative approach-

es to water resource management, blending ancient techniques with modern technology. This fusion can help mitigate issues such as groundwater depletion and inefficient irrigation practices. Moreover, it encourages global cooperation in water management, fostering knowledge exchange and intercultural collaboration to combat the growing threat of water scarcity worldwide.

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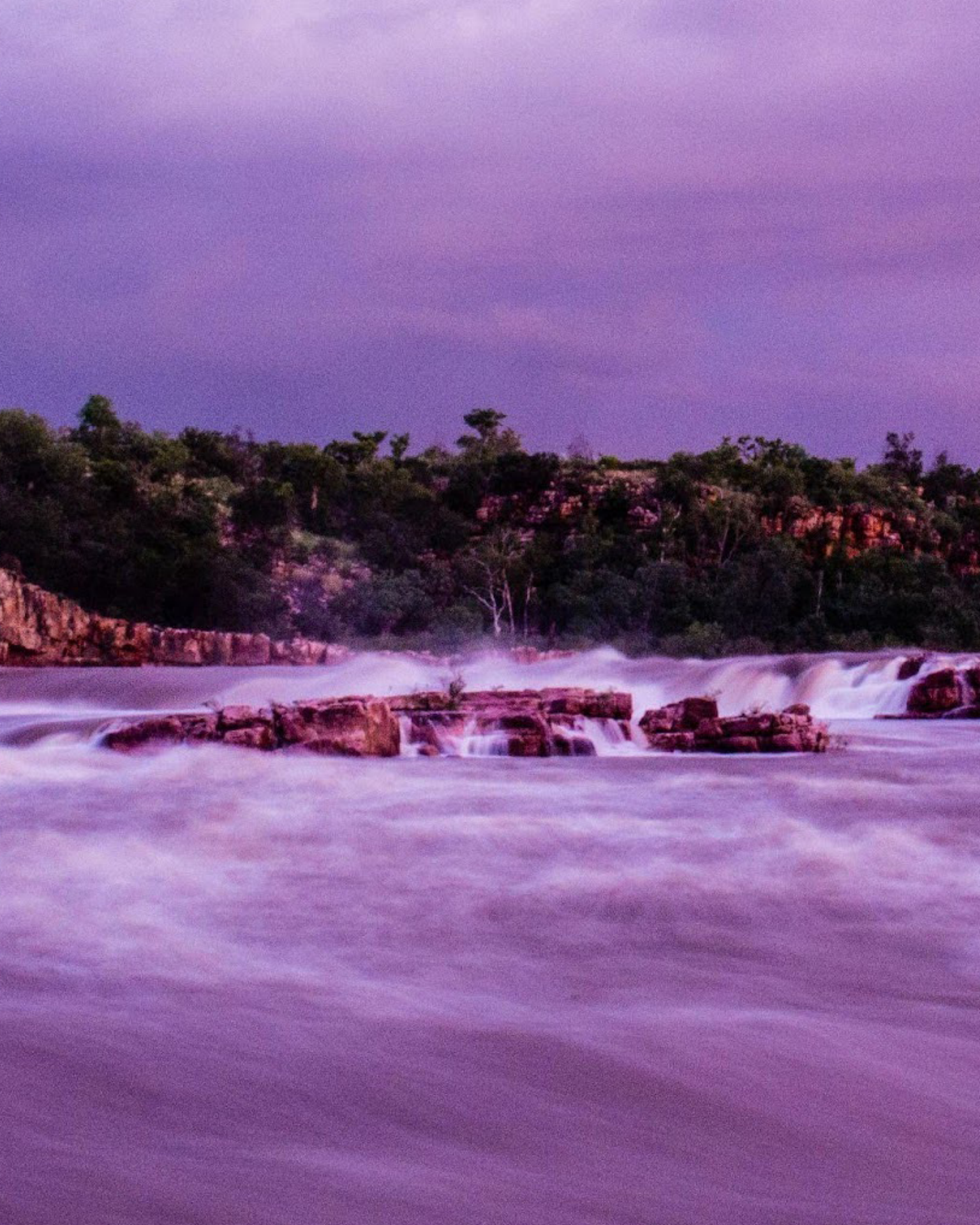

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Interview with Anne Poelina | Sustaining Intergenerational Guardianship and Equity for the Martuwarra Catchment

Interview with Anne Poelina
By Carlien Donkor

Abstract
The Martuwarra (Fitzroy River) Council has been established by senior elders, including Anne Poelina, to represent different parts of the river. The interview explores the history of the Council and its goals for holistic development based on what they call "forever" economies. Dr. Poelina explains the Council's diverse ways of promoting intergenerational equity through the Youth Council, their conservation plan with the nine native title groups and the reason the Martuwarra (Fitzroy River) Council joined the Global Network of Water Museums (WAMU-NET) as a living museum. This interview also serves as an introduction to the Living Water Heritage project discussed in this issue of *Blue Papers* by Lachie Carracher.

Policy Recommendations
- Local leaders should champion intergenerational laws of equity that guarantee the well-being of young people with a holistic approach to the watershed.

KEYWORDS

Martuwarra
Governance
Ancestral personhood
Indigenous knowledge
Sustainable livelihoods

WATER ICONS

< Fig. 1 The Martuwarra (Fitzroy River) embodies ancestral knowledge of water, land and people (Source: Lachie Carracher, 2017).

Introduction

INTERVIEWER | Carlien Donkor: Welcome Anne Poelina, chair and professor of Indigenous knowledge at the Nulungu Research Institute. Thank you for agreeing to this interview; we are privileged to have you here with us. Can you please give us an introduction to your community and also to your work?

INTERVIEWEE | Anne Poelina: The Martuwarra (Fitzroy River) Council was set up because all the Indigenous nations that are connected to the sacred river came together in 2016 and drafted what we call the Fitzroy River Declaration. Within two years, there had been quite a lot of development and conversation between the state government and people in the region about the potential for a water plan for the Fitzroy River watershed, and that required a whole lot of stakeholders to come together. One of the things that Indigenous people have been doing since the beginning of time in this region is coming together in a bicultural model to talk about how we share information, how we cooperate and how we are organized to be able to look after this magnificent system for the greater good of all, particularly our nonhuman kin (fig. 1). In this case, we came together under one of the senior elders who said, importantly, "We need to stand in unity and be organized" – to speak with one voice and one mind. Together, we formed the Martuwarra (Fitzroy River) Council made up of the native title, traditional owners and diverse Indigenous groups. We co-developed the Fitzroy River Catchment Management Plan (2020) for this system, which then made us consider the need to be united in our position about the development of our lands, water and resources going forward. As the group started to grow, we decided that we needed to follow a model of bottom-up governance, especially in terms of representing the voices of the people. The Martuwarra (Fitzroy River) Council is led by very, very senior elders of high degree, but at the same time we formed a young leaders council to ensure that our knowledge is transferred to young people and that we are investing in intergenerational equity, love and care.

Sustainability, Knowledge and Global Dialogue

Carlien Donkor: How do your activities as river custodians relate to the Sustainable Development Goals (SDGs)?

Anne Poelina: The SDGs are benchmarks but one of the things that we are saying as Indigenous people is that for us, it's not just about sustainable development. It's about sustainable lifeways and livelihoods. We want to expand the definition of sustainability because we come from a holistic society, and we've always governed under the principles of land, water and people being intrinsically entwined. Our priority is ensuring that our work captures and protects the lifeways and livelihoods that we have pursued from the beginning of time.

This includes governance, leadership and starting to build what we call "forever" industries: economies based on culture, conservation science, regeneration and healing of the land and the waters, not extraction. So from that perspective, it's really a bottom-up governance mechanism that we have used from the beginning of time that has always been managed on scale because we need not separate land, water and people. Today that conversation includes settler society, so we are very much concerned about articulating our approach in a way that shows it is in the broad public interest. And we want to make sure that the evidence that we generate of the need for

just development is accessible and of peer review quality. So we're producing very high-caliber reports. We're working with multiple universities to make sure we have the evidence base to position ourselves as experts in how to sustain this river system for generations to come.

Carlien Donkor: That's very impressive. You mentioned the river management plan. Can you expand on that? Does it involve a collaboration with the government, or who are the contributors besides the elders who are involved in this?

Anne Poelina: When we wrote a conservation plan with the nine native title groups, which are the very big nation groups that really connect all the rivers, we looked at the whole of the catchment from scale including the diversity of our cultures and the cultural landscape as well as biodiversity. We asked, "What are the multiple values of preserving what we have now to ensure that this biodiversity is here and able to benefit the region and different economies, but in a sustaining way, not just for extraction purposes?" The government funded the development of the plan because at a commonwealth level, the value of the river was recognized under national heritage. And in fact, this river system is globally unique. One of the things that we are working on with the Commonwealth Government and the Indigenous leaders on the ground is looking at how we can showcase and spotlight this watershed as being globally unique and of World Heritage value, specifically through the Living Water Heritage project. This project includes an interactive map to show the biodiversity that's here so that we can value it and protect it; as biodiversity diminishes around the world, it becomes more and more valuable. What we refer to as the economics of well-being is sustaining what we have rather than destroying it.

Carlien Donkor: Okay, so my next question relates to the Global Network of Water Museums (WAMU-NET). How did you hear about them? And why did you choose to join?

Anne Poelina: I was introduced to WAMU-NET by a professor in Australia who spoke to us about this concept of a living water museum and asked if we want to build a living water museum to showcase this globally unique system and the diversity of cultures and biodiversity here. I didn't even need to think about it because what is here is so globally unique and so diverse. The valley tracks are uplifted, and they're folded and fractured, and they're diverse. This gives us an opportunity to showcase what Mother Earth has provided as a sacred and significant place. And so we were able to come together and say that we really need to showcase what is here and help to preserve what we've got through this opportunity to share it with the world. Even though we're way off here at the top of the northwest of Australia, we see ourselves as global citizens, and we see this watershed as having value to Mother Nature, to humanity and to Mother Earth.

Carlien Donkor: What are some of your expectations for this network that you've joined?

Anne Poelina: I think it is really to learn from each other about how to be brave, how to be creative and how to think outside the box in terms of how we showcase these globally unique bodies of water and what the relationships between human and nonhuman can be in the context of these magnificent waterways. Culture plays an important part in that because culture includes the stories from the past, the context of what we are doing now in the present, and serves as a basis for looking to the future in terms of how we can preserve

these global assets not just for the short term, but for generations to come.

Climate Justice, Water Rights and Systemic Threats

Carlien Donkor: Can you tell us about the current relationship between water management and heritage management in Australia? And then coming back to your context, how does your work bridge the two sectors?

Anne Poelina: I think this is a really interesting question. At the beginning of this year, I was a commissioner for water rights across this country as part of the National Water Initiative. So, I was able to look at how water engagement was happening across this whole nation, in the different jurisdictions, in the different place-based areas of Australia. I was able to see how we were working together to ensure we had water security. We come from the driest continent on the planet, where water is so scarce that it is now being seen as the new gold, but for Indigenous Australians, it has always been valued as more important than gold. I am the first inaugural Indigenous scientist appointed to the Murray-Darling basin. I was looking at that situation in terms of how we learn from the Murray-Darling basin: How do we not repeat the mistakes of the South in the North where I live?

All of this information comes together in a way that helps me ground the work that I'm doing in my state-based place of work in terms of the Fitzroy River catchment. What can I learn from the Murray-Darling basin? What can I learn from having a wider lens, looking at our nation and seeing that two of the greatest things missing in this country are trust capital and water security? These are two assets that we don't have very good ways of being able to build on and strengthen. This is a challenge we've got now, and we as Indigenous people are saying, "We need to go back to what we call bottom-up, polycentric governance, governing from a bioregional perspective – governing from a biocultural perspective, where we bring our voices into water management, planning into water management and allocation into water management because we are living on our lands and waters."

As I said earlier, we do not separate land, water, people and the environment. They are all intrinsically entwined. What we are saying to fellow Australians is that we have approached water governance this way from the beginning of time. This ancient wisdom needs to be factored into efforts to ensure water security in this country at a time of great climate change and great uncertainty. What we are advocating for as Indigenous leaders is the need to bring the voices and the wisdom of Indigenous people into better water planning and governance and to look at how we can ensure that these sacred places of water can help us as human beings and our nonhuman kin to survive the challenges of climate change and water scarcity in a just manner.

Carlien Donkor: What are some of the challenges you've been facing? And what are some of the threats to the heritage you're trying to protect?

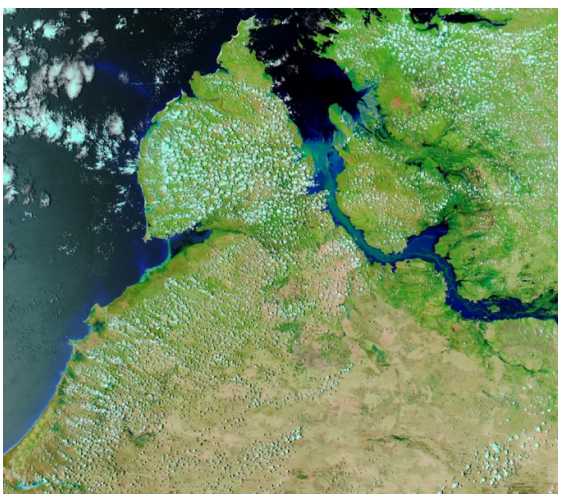
Anne Poelina: One of the things I'm advocating for in our country is that we need to see and value Indigenous knowledge as Indigenous science. We are the first scientists, geologists, anthropologists, archaeologists who built all the systems that we see on Earth. I'm really pushing hard for the recognition of Indigenous and traditional knowledge as multidisciplinary

Indigenous science. Then we can start to have equal weighting and valuing of our knowledge systems, and we can bring that in to deal with the complexity of the current situation. What we're talking about, particularly in relation to sustainable development, sustainable livelihoods and sustainable lifeways, is the importance of ensuring that all of this information comes together so that we can have bicultural governance with Indigenous people that will allow us to get organized, get our systems thinking correct, and then go on to a much bigger bioregional concept. We need to be managing these systems on scale, particularly in terms of the diversity of the systems that we're talking about. One of the things that we are doing is working with very interesting people from different universities on how to really understand the opportunity cost of preserving somewhere, like the Martuwarra (Fitzroy River) watershed as having global value, that it is contributing to the well-being, the planetary health of the Mother Earth and humanity, and that around the world we really need to be spotlighting these places where we have this level of integrity and care and be really understanding that we're really talking about a total systems approach.

Youth, Future Vision and Global Advocacy

Carlien Donkor: I think it's very important, to create a body of young leaders, young movers, who are going to inherit what you leave behind, as you have done. You talked about trying to become a good ancestor more than a good professor. So how are the youth embracing this responsibility that is given them? And how are they also propagating this work beyond the catchment of the Fitzroy River?

Anne Poelina: We have a group of young leaders whom we are investing heavily in by making sure we strengthen their capacity. We transfer this knowledge and give them a greater understanding, even just the understanding of what colonialism is, for our young people need to understand that they were born into a world not of postcolonialism but that colonialism exists today and that these unjust development projects are politically driven by the economics of greed. Another thing to understand about working with our youth is understanding that they have different skill sets than we elders do and valuing them for their ability to bring different forms of media such as Instagram, Tiktok and all of these channels to send our story



^ Fig. 2 Impact of 2023 flood in West Kimberley (Source: Living Water Heritage-Life with Martuwarra, 2024, based on NASA imagery).

out into the world. We want to value our young people. We want to lift them up. We want to hold them and say that we care about you, we love you and we respect you. We understand that you have got skills and knowledge and competence that we don't have as elders.

How do we work together to ensure that this knowledge we create can be shared not only with each other in our nations and tribes, but also with settler society? How do we reach out and look at what young people are doing globally and help them to connect with each other so that they can build and strengthen their capacity to be good storytellers and guardians? How do we connect them with the universities and the conservation and green groups so that they can understand that we need multiple resources to ensure that there is intergenerational equity? As elders and ancestors, we want to leave our region and planet in a better and more fit state than when we inherited it. We rely on our young leaders, particularly if we ever need to resort to strategic litigation, to protect Martuwarra. We would see that this is the due inheritance of our young leaders. They will be the ones who will stand up and provide support in any legal cases. So young people are really the essence of what we are doing, and we are bringing them with us. Their skill sets and technical competence allow ancient wisdom to work with contemporary ways of sharing stories across the globe, and they are really stepping up.

Carlien Donkor: I'm inspired by all the work you're doing, especially in setting an example and taking a lead in discussions about intergenerational exchanges.

Anne Poelina: Yes, and that's because we say young people are living now. Everyone thinks they're the future, but they're living now. They've got big dreams. Our job is to help them reach their full potential as human beings. There's a very interesting paper my daughter and I have written called "Dreaming A Climate Chance," which argues for Earth-centered governance (Poelina et al 2024).

Carlien Donkor: This brings us to my next question. What then is the future that you envision for the Martuwarra (Fitzroy River) Council and the entire river catchment area?

Anne Poelina: We are really spotlighting this globally unique watershed and showing that this system is not found anywhere else on the planet, so the cost to save it, to preserve it and to share the new economies it supports are worth it. We've started to create walking trails along the river to bring people to the river. We can allow them to engage with the river and build their own relationship.

The big, important investment that we are looking to secure is the opportunity to build this bicultural bioregional framework and manage the commons for the greater good of all of us, as we have done from the beginning of time. We support everyone and everything around us. This is not Indigenous versus non-Indigenous. This is all of us as human beings trying to make sense of the world and create a chance to stabilize the climate.

Carlien Donkor: And what do you need to get to this future vision?

Anne Poelina: Like many other Indigenous people across the globe, what I need is serious investment. The nature-repair-positive market, which is different from the carbon trading story, shows that if we regenerate and heal the land and heal people, we can heal the climate. For us, it's about regeneration of carbon, not

extraction. This is a moment in time when we can have the culture, conservation, science and tourism economies as opposed to economies based on oil and gas, destruction of the land, destruction of every living thing around us and potentially creating the largest man-made destruction on the planet. What we're saying in our dream is that we can build forever industries based on the economics of well-being. We understand that we can do this. I'm referring to the conversation that Nelson Mandela started about global geoparks, about biosphere reserves, about walking the country and about the diversity of plant and animal species not found anywhere else. The people here are culturally diverse and great guardians and custodians. We are in a moment in time when we can create and transform and build something beautiful and new based on the rich wisdom of our people; if we don't do this, we will meet our own demise.

Carlien Donkor: You mentioned that Martuwarra is listed as national heritage. How do you plan to get it to UNESCO World Heritage status?

Anne Poelina: The land here in the West Kimberley is 96,000 square kilometers. With the work that Lachie Carracher is doing on the Living Water Heritage project, we want affirmation from the world, once they've looked at our living water museum and the living water maps, that this is a globally unique place. Already world citizens are saying, yes, this should be World Heritage. When people see the work that Lachie has put into this story map, they'll be able to go on to the beautiful films that Mark Coles Smith and Lachie Carracher have created with others and see that we're in a moment in time when these places are rare. They belong to humanity, and we're in a moment in time where we can either choose to love and care for and nurture this place and allow it to do its good work for the planet or to meet our own demise with the destruction from fracking and extraction for oil and gas.

Conclusion

Carlien Donkor: I have one last question. If you could send a message to any leader, policymaker or relevant stakeholder, whom would you choose? And what would you say?

Anne Poelina: There are so many people. My message would be to the leader of Wales to congratulate them on passing an intergenerational law of equity that stipulates that every law and every policy in that country must factor in the well-being of young people and to ask them to demand that it becomes a law for the world.

Carlien Donkor: Well, thank you so much and it's been a pleasure. You've said many things to inspire our readers as they are working in their own contexts.

Anne Poelina: Thank you.

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Useful Links

www.martuwarra.org
www.livingwaterheritage.org

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Making Sustainability Transitions Appealing: The Need for Alternative Narratives in France

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Abstract
Sustainability transitions offer opportunities to rethink and improve society, such as by improving well-being, reducing inequalities and reconnecting with nature. Yet, mainstream political narratives focus on the short-term costs of sustainability transitions and fail to highlight environmental measures that consider people's social and cultural realities. This article discusses the shortcomings of current narratives of sustainability transitions in France and explores alternative approaches. Drawing on water heritage and local values can help shape narratives that resonate with people in their context, and allow them to take a long-term view. The lake and city of Annecy is an interesting example of how water heritage and local values can be used to shape appealing narratives in support of sustainability transitions.

KEYWORDS
Narratives
Climate action
Water heritage
Climate justice
Sustainability transitions

WATER ICONS

Policy Recommendations

- Policy, media and education actors should emphasize the long-term benefits of sustainability transitions and counter the narrative that climate action conflicts with social and economic justice. The initiative of the French Agency for the ecological transition (ADEME) to promote positive narratives through popular culture (Martin 2023) is promising and should be expanded.
- Knowledge institutions should develop and share practical, place-specific, multidimensional methodologies and tools that support political and grassroots actors and foster democratic dialogue.
- The European Commission should continue funding programs that mobilize water heritage for sustainability transitions under the New European Bauhaus, as seen in projects like Bauhaus of the Sea Sails.

< Fig. 1 Climate march in Paris, December 8, 2018 (Source: Jérémy-Günther-Heinz Jähnick, 2018. Wikimedia Commons, CC BY-SA 4.0).

Introduction

"Eco-anxiety is a healthy response to a sick world." With these words, French climate activist Camille Étienne powerfully reframes the narrative on eco-anxiety, which posits that fear of climate change is causing growing mental health issues, especially among young people (Zarachowicz and Couston 2023). Eco-anxiety, she says, is a collective response to a structural issue, not a private matter (Ramsay et al. 2025). And this fear, which affects large parts of the population across countries and regions (Hickman et al. 2021), in her view does not need to be paralyzing. It can spark action and hope for a more sustainable future.

Camille Étienne provides an inspiring vision for climate action and highlights the power of narratives in shaping how we, as members of society, view problems like climate change and the solutions to these problems. The rich literature on narratives (Wittmayer et al. 2019), the way they are framed in a context of climate change (Guenther et al. 2024) and how they influence policy making (see the narrative policy framework approach, Jones and McBeth 2010; Kuenzler et al. 2025) supports this analysis of narratives of sustainability transitions.

This article discusses the shortcomings of mainstream political narratives of sustainability transitions, taking France as an example. It explores alternative narratives that draw on history and culture to appeal to people's sense of identity and enable them to take a long-term view (da Cunha et al. 2020; Abherve 2024; Hein 2022). Water heritage, in particular, highlights how water has shaped the ways humans live and engage with their surroundings across time and space, and the social and cultural conditions that have shaped this process (Hein 2022). Annecy, located in the French Alps and often presented as "the cleanest lake in Europe," provides an example of how water heritage can inspire positive narratives for a sustainable future.

Shortcomings of Mainstream Narratives on Sustainability Transitions in France

In France, like in other countries, mainstream politicians – especially from the center, right and far-right leaning parties that have increasingly shaped government policy since 2021 (Cébille 2021) – frame sustainability transitions as a costly endeavor that requires huge sacrifices (of profits, comfort, lifestyles). They rarely frame them as an opportunity to rethink and improve society in the long term. The sustainability transition is framed as a zero-sum game: if the environment benefits, the economy loses. This narrative fails to envision climate action beyond technical and technological solutions like improving the energy efficiency of buildings and systems of production. It does not recognize opportunities to use transitions as a way to promote environmental, social and economic objectives jointly.

This failure sparks fear and resistance among the population, especially low-income groups who already struggle to maintain their livelihoods. A striking example from France is the "Yellow Vest" movement (*gilets jaunes*), which was composed of largely rural, lower and middle-class citizens who protested against a government tax on automobile fuel, enacted in October 2018 to accelerate the energy transition (Mehling 2018). A key demand of the *gilets jaunes* was territorial and fiscal justice for rural areas that are underserved and overlooked compared to cities and wealthier regions (Bordenet 2024). This crisis revealed the inadequacy of seeing technical solutions as a

panacea for the climate crisis, without considering the lived experiences of the population.

The Yellow Vest movement was a turning point that profoundly changed narratives and perceptions of climate policies in France (Martin and Islar 2021). Indeed, positive and hopeful narratives about sustainability transitions abounded following the signature of the Paris Agreement in 2015 at the United Nations Conference of Parties (COP21), facilitated by French diplomats. Former president François Hollande framed the agreement as a historic moment reminiscent of the French Revolution ("a revolution for the climate") and a mark of national success, universalism and a victory for "the rights of humanity." These frames provided strong historical and cultural references that contributed to a sense of enthusiasm and pride in French society. Yet, only three years later, the Yellow Vest movement turned the narrative around. The carbon tax was the spark and became the symbol of an unequal and polarized French society where "elites are talking about the end of the world" while "we are talking about the end of the month," in the words of a protestor (in Rérolle 2018, cited in Martin and Islar 2020). Reference to the French Revolution was made again, but this time in a depiction of President Emmanual Macron as king committing injustice against the people.

This moment fragmented cultural support for sustainability transitions in France, and altered political narratives, bringing social and economic justice to the forefront of political discourse. However, instead of engendering more holistic climate policies that integrate social, economic and cultural dimensions, mainstream politicians including President Macron have turned to a discourse of "climate relativism," prioritizing (short-term) socio-economic considerations over environmental ones (Dormagen 2024). According to this framing, the sustainability transition is necessary but should not become "excessive" or "a punishment" for citizens (in reference, for instance, to the degrowth movement). The interpretation of the *gilets jaunes* through this frame was the chosen political strategy, instead of drawing lessons from the movement to enact more just, holistic climate policies. This change in narrative concerning sustainability transitions is not unique to France and can be observed in several right and far-right leaning parties across Europe that are pushing back on parts of the European Green Deal, the European Union's main policy framework to tackle climate change (Dormagen 2024).

In sum, mainstream political narratives are using short-term social and economic justice arguments to oppose an acceleration of the sustainability transition in France. Meanwhile the Haut Conseil pour le Climat, a consultative body of scientific experts appointed by President Macron to advise on national climate policy, reports that France is not on track to meet its climate commitments and urges an acceleration of actions in most sectors such as transport, construction, agriculture, energy and waste (Haut Conseil pour le Climat 2023). Alternative narratives are urgently needed to enact the policies and actions to fulfill France's climate mitigation and adaptation commitments, in a socially just manner.

Alternative Narratives to Make Sustainability Transitions Appealing: The Example of Annecy

Alternative narratives could help overcome the perceived incompatibility between sustainability transitions and people's social, economic and cultural realities. A shift in narrative could also send more hopeful, action-oriented

^ Fig. 2 Lake Annecy, by Paul Cézanne (Source: Paul Cézanne, 1896. Public domain, via Wikimedia Commons).

messages to the many people in France (8 out of 10) who report being worried about climate change, according to a recent survey by the Economic, Social and Environmental Council of the French government (Tordeux-Bitker 2023).

History and culture offer opportunities to reanchor climate and environmental policies within longer-term processes, and appeal to people's sense of identity and belonging to a particular place. As shown in the above section, historical references to the French revolution and the values associated with it (human rights, equality) continue to be a powerful political frame in France. Another powerful frame is the relationship between people and their environment. Remembering the different ways we have lived with our environment over time, and how our values have changed accordingly, can help people envision future changes (da Cunha et al. 2020; Hein 2022). In the case of communities living near water bodies like lakes, rivers or the sea, the concept of water heritage can help uncover the memories attached to water and how these can be mobilized for, or against, sustainability transitions. (Re)activating history and culture with a focus on water heritage helps develop future sustainability pathways that are more holistic, place-specific, and rooted in long-term development and sociocultural contexts (Hein 2022).

In the French context, Abherve (2024) investigated how history is used strategically to

^ Fig. 3 View of Annecy from Mount Veyrier (Source: Basteran, 2005. CC BY-SA 3.0, via Wikimedia Commons).

support different political positions on the ecological restoration of the Haut-Rhône River. History and water heritage has also been mobilized to facilitate long-term thinking and foresight (Da Cunha et al. 2020). Using past narratives about the Gulf of Morbihan in workshops with community actors helped these actors to envision future pathways for their region and feel a sense of ownership over them.

The lake and city of Annecy provides an opportunity to explore past, present and future narratives about living with water sustainably. Located in the Alps, the lake of Annecy is the second-largest natural lake in France (Janjua and Gerdeaux 2009). It is famous within the country and beyond for its crystal-clear waters and scenic landscape, which are used strategically by city actors to attract visitors. Terms such as "pure," "pristine" and "dreamy" are commonly used when referring to the lake (e.g., John 2024). The official website of tourism in Savoie and Haute-Savoie emphasizes Annecy's natural landscapes, its rich culture and history and the inspiration the lake has provided to famous artists, including Paul Cézanne, who painted the lake in 1896 (Office de Tourisme Savoie Mont-Blanc 2025). This strategy seems to be effective: the city attracts over 3 million tourists per year, an important source of employment for the city's 135,000 inhabitants, especially during the summer season when tourism accounts for around 35 per cent of the city's employment

(Bianco and Marza 2022). The lake also supports commercial and recreational fishing activities, consisting of more than one thousand recreational fishermen and four commercial fishermen (Janjua and Gerdeaux 2009).

However, the prevalent narrative of the lake's purity and aesthetics might need to be updated to address growing ecological challenges. Indeed, the lake benefits from low levels of nitrate, pesticides and phosphorus, and serves as the main source of drinking water of the city of Annecy (70 per cent) (Agglomération du Grand Annecy 2024). Nonetheless, over-tourism and car traffic close to the lake are bringing other forms of water pollution, like hydrocarbons and heavy metal residues, and non-native species have been introduced via the use of leisure boats (Vinet 2022; Soares et al. 2025). In particular, there are signs that the quagga mussel is present in the lake, a non-native species that poses a high risk of disruption for local ecosystems (e.g., food chains, water deoxygenation) (Syndicat Mixte du Lac d'Annecy 2023; Annecy Ville 2024). Natural ecosystems have also been impacted by water infrastructures like marinas, bridges and sluice gates used for tourism, industry and flood management. Strikingly, 80 per cent of the lake's reed beds have disappeared (Massemin 2018; Nikolli 2022).

In addition, climate change will impact the entire lake ecosystem in the long term, as the Alps will see the melting of glaciers and snow, floods, debris flows and landslides, but also oxygen depletion in the water which threatens fish, as explained in the magazine *Outside* (2021). According to Soares and colleagues (2025), "climate change is the most important threat to the lake [of Annecy] in comparison to other anthropic pressures" and will impact water temperatures and the fish population. These climatic and environmental changes present a complex future for Annecy and its lake, where values and narratives of economic prosperity and leisure will need to be balanced with the imperatives of climate resilience, biodiversity restoration and sustainable livelihoods. Prevalent narratives of the lake could evolve to better highlight the lake's ecological value alongside its aesthetic value.

Annecy's long history of coexistence with the lake can be mobilized to support this rebalancing of values and narratives. Indeed, this history shows how the values and practices around the lake have evolved to meet challenges, and how policymakers have supported these changes. The current uses of the lake for recreation and drinking water would not have been possible if not for key turning points, especially when grassroots pressures and policy changes helped "save" the lake from pollution in the 1950s and 1960s (Barraqué 1986). Local divers, fisherfolks and scientists sounded the alarm and elected officials responded to prevent the eutrophication of the lake (Vinet 2022). In 1957, eight communes around the lake created an intercommunal public body, the Syndicat Mixte du Lac d'Annecy (SILA), to treat sewage water and monitor water quality. This response institutionalized long-term mechanisms that have benefitted the lake environment and public health in the long run, as the SILA has played a key role in the scientific monitoring of the lake's ecological conditions since the 1960s (Barraqué 1986; Conservatoire d'espaces naturels de Haute-Savoie 2016). Today, the SILA has expanded and manages 1,323 km of collectors, 100 pumping stations and 12 wastewater treatment plants, as reported on its website. It is administered by "delegates" appointed by public intercommunal entities. Alongside the SILA, a range of local actors and associations continue to mobilize for the preservation of the lake (Vinet 2022).

^ Fig. 4 Annecy city view (Source: François Goglins, 2007. CC BY-SA 4.0, via Wikimedia Commons).

This memory of the lake's "rescue" is a local success story that can be mobilized in public narratives to highlight Annecy's capacity to adapt to new climate and environmental challenges. It demonstrates what may happen when local actors become proactive stewards of their environment, are listened to by policymakers, and met with meaningful reform (Vinnet 2022). It also sends a positive message, whereby prioritizing health and environmental protection ultimately supported the city's prosperity by boosting the tourism sector for the following decades. As such, a better recognition of the lake's ecological value can be framed as an opportunity to ensure Annecy's long-term prosperity for all inhabitants of the area (humans and other species) in the face of a changing climate. This provides an alternative to the narrative that has emerged after the Yellow Vest movement in France, which pits climate policies against economic justice. For Annecy, this shift in narrative may require rethinking the current tourism model of the city, to consider the lake as a living ecosystem rather than a landscape. The rising ecotourism ecosystem in the area (Office de Tourisme du Lac d'Annecy 2025) can be a driving force in these efforts. In sum, Annecy's water heritage can support inspiring narratives about sustainability transitions and their potential for the advancement of environmental, social and economic objectives jointly, in a way that enhances local cultural identities.

Conclusion

Despite the urgency of accelerating sustainability transitions, mainstream political narratives are spreading fear among citizens and promote a form of "climate relativism," as seen in the case of France. Popular support for values of social and economic justice – as seen in the Yellow Vest movement and its impact

on climate narratives – could foster more equitable climate policies and transform society in the long term. Yet, current narratives focus on the short-term costs of transitions and omit climate solutions that embed technological change within social and cultural contexts. Current political narratives not only generate low popular support and even backlash against transitions in large economies like France. They also fail to inspire and give hope to a population that increasingly feels fearful and anxious about the future – feelings on which far-right populist parties thrive.

Fortunately, narratives are fluid and can be reshaped to support different visions for a sustainable future. History and culture provide many opportunities to make sustainability transitions more inspiring and grounded in local realities. Due to the close relationship between communities and water across history, water heritage offers a unique potential to rethink how we coexist with nature and each other. This is striking in the case of Annecy, where city dwellers have coexisted with the lake for centuries. Powerful narratives around the lake's cleanliness and beauty have taken hold to support a local sense of pride and attract tourists. But narratives should be adapted in the face of climate change and ecological crisis and reflect the values of Annecy's residents beyond the dominant focus on tourism.

French politicians, from the local to the national level, bear a huge responsibility as to what narratives they choose to highlight, in support of which policies, and the long-term costs of inaction for their citizens and humanity as a whole. Remembering and recounting history remains the best defense against populism. Culture and heritage can revive a sense of belonging, community and agency, fostering a shift from hopelessness and apathy to action.

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Water Systems Design: Connecting and Developing Methods for the Value Case Approach

Carola Hein

Abstract
Water uses and practices are typically dissociated and considered separately: drinking water, sewage systems and shipping are often treated as distinct systems. Especially in a time of climate-related water systems change, a more holistic approach is needed. This article explores the background of and inspiration for for the value case approach developed and tested in several workshops for port city territories and water systems under my leadership as UNESCO Chair Water, Ports and Historic Cities and with the PortCityFutures Center of the Leiden-Delft-Erasmus (LDE) university consortium. The article first explores the selection of multiple and diverse methodologies for mapping spaces, stakeholders and cultures over time, and the rationale for the choice of models. It then briefly introduces the reasoning for the various approaches that come together to contextualize current spatial, social and cultural conditions and help guide the development of a shared mission and vision for sustainable and inclusive water futures through hands-on workshops and activities.

Policy Recommendations

- Policymakers and politicians should explore a broad set of contextual tools and diverse practices to fully understand the conditions in which their interventions take place, what the impact is on all stakeholders and to make sure that complex water systems are designed holistically.

KEYWORDS

PortCityFutures
Port city territories
Adaptive strategies
Water system design
Value case approach

WATER ICONS

< Fig. 1 Traditional boat navigating Venice (Source: Carola Hein, 2023).

Introduction

Water systems consist of a complex network of spatial, social and cultural patterns that change over time and across space. Understanding these patterns is an important prerequisite for new interventions. Conceptualizing past developments across multiple scales and stakeholders and in their specific cultural context allows for rethinking future approaches. To understand the role of values concerning water, including ones that have shaped practices of the past, the ones that have catalyzed transformations, and those values associated with material, economic and cultural flows, we need a broader, more contextual analysis, one that makes it possible to identify underlying values in space (landscape, cities and buildings), as part of networks (stakeholders and knowledge holders), cultural systems and values, through time (past, present and future) in an ecosystemic way.

Societies in the past have found ways to balance different needs and interests and get buy-ins. The study of historic buildings, cities, landscapes, institutions, policies and cultures that are the result of decades, centuries or even millennia of development can lead to decisions across multiple scales based on an approach that identifies shared values and brings them to the fore. It can even help to create buy-in from society, including interest groups and taxpayers. Clarifying diverse interests can help us make meaningful interventions regarding the structures that surround us, the ones we decide to preserve and those that can tell us a lot about the complex relationships between humans and water and the shifting roles of places, people and practices; it can also help us protect designated heritage. It can even help us identify the different disciplines and professions that engage with water and heritage themes.

To address contemporary challenges of climate-related water systems change and to preserve our heritage from the past, we need tools that allow new types of analysis across scales, taking into account the diversity of stakeholders and values, over time. Several tools, including some focused on mapping, have recently been developed to gain new insights into multiple scales and diverse stakeholders and to allow culture-led approaches. The article briefly introduces these methodologies. Many of these approaches are based on mapping. The following methodologies have inspired the value case approach presented here. The article briefly introduces these methodologies, including the Canvas tool developed by AGUR, the urban planning agency of Dunkirk, the World Inventory of the Global Network of Water Museums (WAMU-NET), a flagship initiative of UNESCO-IHP (Intergovernmental Hydrological Programme), the UNESCO Heritage Atlas, and the Connected River Flow Forward approach. Building on and connecting these methodologies has led to an advanced toolbox for holistic approaches. Such methods can include both desk research and hands-on workshops to develop new narratives and historiographies for systemic analysis and sustainable design.

Inspiration for the Value Case Approach

Mapping diverse water activities in space allows for a better, more holistic understanding of the spatial, social and cultural conditions of water systems. Several organizations have recently proposed methods focused on connecting isolated structures and identifying flows with the goal of creating new narratives for cross-sectoral and action-oriented approaches to water. These new narratives can enrich projects that are otherwise dominated by a technological and economic focus. They

can make room for social and environmental perspectives that are currently underdeveloped (Hein 2023). Identifying links and reciprocal relationships among different parts of ecosystems can lead not just to new water narratives, but also to new partnerships and sustainable action.

Several institutions have adopted spatial mapping as a tool. WAMU-NET developed an inventory to identify museums located alongside a body of water (Eulisse 2023a, 2023b). As Eulisse explains, connecting various museums, their exhibitions and capacity-building tools along a water body can help raise water awareness. Museums along a river could collectively share knowledge on a shared water-related theme, such as river shipping. Advanced knowledge of the requirements of shipping in terms of water speed and flow, of transshipment from land to sea, or of the impact of maritime flows on quay walls and river edges can help facilitate discussions among citizens regarding other water-related practices, such as swimming, kayaking and canoeing.

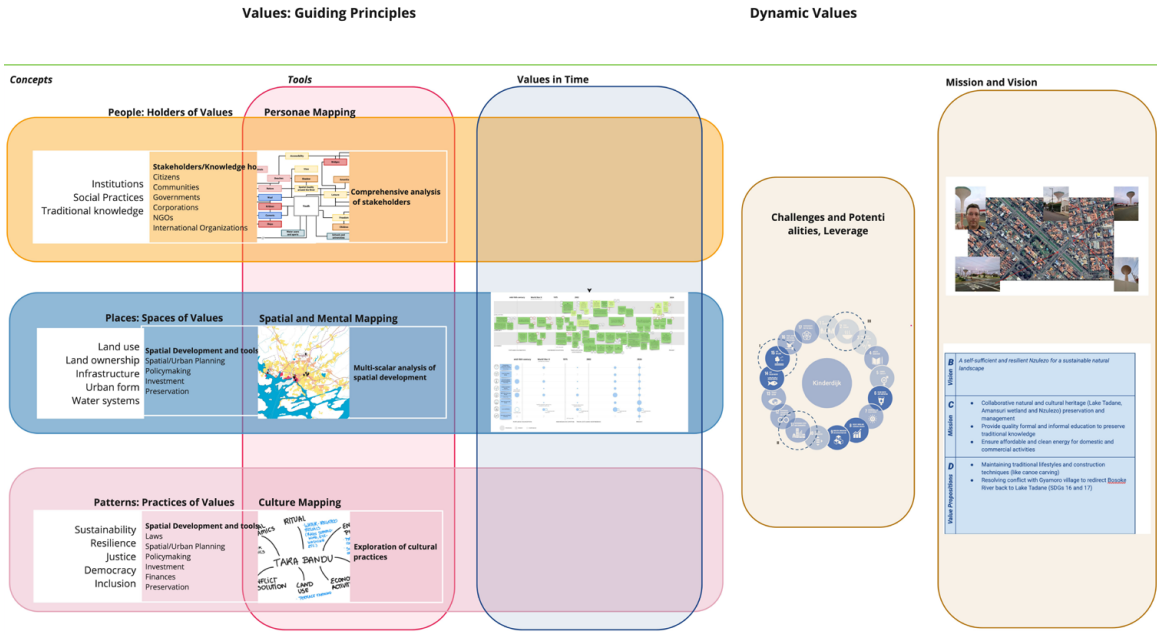
Mapping economic and material flows is another way of contextualizing water systems. The Flanders-Dunkirk Urban Planning and Development Agency AGUR, under the leadership of Jean-Francois Vereecke, developed the Canvas tool to reveal material and financial flows (Vereecke and Hein 2022). The original Canvas focused on the extensive network of the petroleum refinery. AGUR used Canvas mapping to demonstrate the impact of the closure of the refinery on other activities in the region, given that many financial and material streams were fully directed toward the facility. Later Canvas projects identified four different water systems and potentially overlapping systems of use (Vereecke and Deveycx 2022). Such a rethinking of flows and networks can provide insights into the multiscale implications of changing networks.

The UNESCO World Heritage Center has proposed cultural mapping as a tool that allows a more comprehensive understanding of historic cities. The UNESCO Urban Heritage Atlas offers a platform that provides comparable insights regarding traditional building practices, architectural heritage and historical urban forms from around the world.[1] Using analytical maps, the UNESCO Urban Heritage Atlas makes it possible to recognize specific attributes and heritage values in their spatial context. Through the identification of urban heritage characteristics and the Outstanding Universal Value (OUV) of World Heritage properties, the Atlas also allows recognition and better management of historic urban heritage as it positions the heritage sites in their spatial context. The presence of a river in a World Heritage property, for example, invites reflection on environmental and urban dynamics and the potential of applying the UNESCO Historic Urban Landscape Approach.

Other tools can also provide a broad understanding of spatial, social and cultural contexts. The Flow Forward approach, currently under development as part of the Interreg project Connected River, offers a variety of hands-on tools for communication and collaboration with a focus on boosting innovation, user-centric experimentation and fast upscaling.[2] Existing tools can be complemented by spatial, social and cultural mapping to

1. UNESCO World Heritage Convention, UNESCO World Heritage Atlas, https://whc.unesco.org/en/activities/1211/&msg=login_success.

2 Flow Forward: https://flow-forward.eu/.



^ Fig. 2 Visualization of the value case methodology (Source: Carola Hein, 2025).

facilitate the creation of new narratives and the generation of new knowledge. For example, mental maps and mind maps can lead to a better understanding of people's perceptions of space. Such tools have been developed, including ones presented as part of the open, online courses Water Works and (Re)Imagining Port Cities and professional education courses such as Water Systems Design.[3] The making of a serious game, Water Values, which reflects a palimpsestic approach to multiple spatial layers of nature, human interventions, institutions and values has helped refine value deliberation approaches and the value case methodology for water.[4]

I propose creating a toolbox of these approaches, connecting, for example, the World Inventory promoted by WAMU-NET and the UNESCO Heritage Atlas, in a way that can lead to new insights for heritage preservation.

Elements of the Value Case Approach for Water Systems

I have taken the first step toward establishing such a toolbox, working with Matteo D'Agostino, Lea Kayrouz and Bea de los Arcos in the UNESCO Chair Water Ports and Historic Cities and the PortCityFutures Center. We have start-

3. Water Works: https://www.edx.org/learn/water/delft-university-of-technology-water-works-activating-heritage-for-sustainable-development.
(Re)Imagining Port Cities: https://www.edx.org/learn/urban-planning/delft-university-of-technology-re-imagining-port-cities-understanding-space-society-and-culture?index=product&queryID=35a7639331f36b35b9b51c93ed0954e0&position=1/
Water System Design: https://online-learning.tudelft.nl/courses/water-systems-design-learning-from-the-past-for-resilient-water-futures/.

4. Water Values, serious game, https://www.portcityfutures.nl/unesco-chair/water-values-a-serious-board-game.

ed to develop a methodology that consists of five steps, the order of which can be changed, to encourage reflection on water values in institutions, across space and over time. The methodology can be used in desk research and in hands-on workshops that help participants gain a better understanding of their context and encourage the development of a new historiography – or make it possible to read existing histories "against the grain." Initial applications of the methodology in the context of Nijmegen, Timor-Leste and Paris have led to refinements.

Such a broad understanding can help activate values for shared goals (Hein 2025). The value case approach therefore proposes parallel steps that aim at (re)thinking and (re)contextualizing the context of a specific water theme or place, The order in which the steps -specifically related to places (space), patterns (society), and practices (culture) and their transformation over time- are undertaken can vary (see fig. 2 in Hein, "Toward a Value-Case Approach for Designing Sustainable Water Systems," this issue). This approach is intended to serve as a foundation for the development of a vision, mission and strategies for design and interventions.

^ Fig. 3 Paris mapping activity at a workshop of the Connected River project in Nijmegen (Source: Carola Hein and Lea Kayrouz, 2025).

downstream port of Le Havre, from which food is transported to the capital city. Recently, the goal of a swimmable Seine for the Paris Olympics required curtailing water pollution from agriculture, industry and sewage upstream. Applying water icons and discussing them in the context of Paris (fig. 3) as part of a workshop of the Connected River project has helped identify potentially competing and supporting activities.

Step 1: Places – Mapping Spaces of Values

Much understanding can be gained from placing water functions in space. In particular, it makes it possible to see how needs and interests are interconnected. Water is always in movement, connecting different functions and stakeholders. Cities, often located downstream, require access to fresh water, and metropolises like Paris have taken control of river sources. Simultaneously, Paris's interests have long shaped the form and function of the

Step 2: Patterns – Mapping Holders of Value

Changes to water systems are made by people in line with their specific values. Network analysis is a much-used tool to represent this phenomenon, yet it is often framed as part of a "business case" (focused on the pursuit of economic outcomes) rather than a more-encompassing "value case." Placing a person or object – personae – at the center of such a network and exploring specific interests and needs associated with values, and their po-

^ Fig. 4 Mapping of personae for the Seine at a Connected River workshop in Nijmegen (Source: Carola Hein and Lea Kayrouz, 2025).

tential conflicts (e.g., as in the research conducted by Matteo D'Agostino and Lea Kayrouz for Nijmegen with Rijkswaterstaat, the executive agency of the Ministry of Infrastructure and Water Management). Exploring flows and networks among institutions within a water system can help uncover challenges that result from good intentions but conflicting perspectives. This became evident in a hands-on mapping exercise during a workshop for the Connected River project in Nijmegen (fig. 4), where specific water practices were connected to relevant water stakeholders.

Step 3: Practices – Mapping Culture

In any cultural context, there may not be unanimity regarding values, but some can be identified as especially important. Sometimes the importance is prominently underlined in public life –commitments, for example, to the rule of law, filial piety, or in Timor-Leste, the principles of Tara Bandu (see fig. 5). But some important values can be less obvious: consider the role of speed for contemporary design in Europe or the notion of ecological civilization that is currently driving interventions in China.

Step 4: Time and Temporality

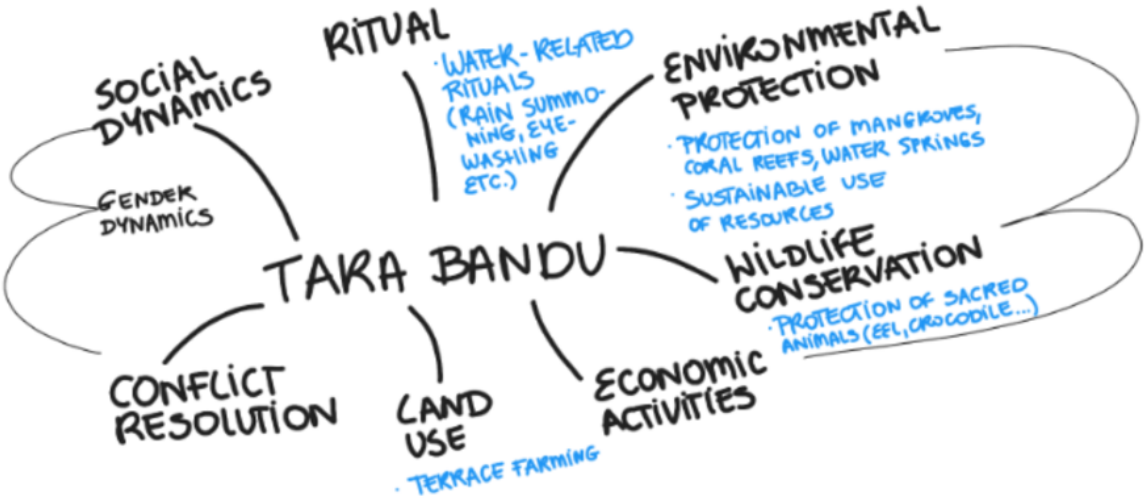
Spatial, social and cultural practices change over time. A fourth line of inquiry is therefore a historical timeline, focused both on time and temporality. There are three important ways in which the past, history and heritage are relevant for the design of the future (Hein et al. 2023):

1. History can serve as a mirror for water system thinking.
2. The past must be recognized as the foundation for future development.
3. Select spaces and practices can be identified and protected as heritage.

Taking a long-term approach requires awareness of water value timelines that capture the predominance of certain values over others where water is concerned: For example, a drinkable river needs to be accessible, whereas an industrial river can disappear underground. The current practice of river daylighting demonstrates the importance of change. Understanding how water bodies were used historically can revive old narratives and generate new ones (see fig. 6).

Step 5: SDGs – A Tool for Identifying and Activating Values

Rethinking the UN SDGs from a holistic, sociocultural, long-term ecosystem perspective can illuminate how water and culture are interconnected and aid the design of a more comprehensive approach to sustainable development (Pellegrom 2023). Considering the SDGs as part of a value case approach to sustainable living can promote transformative actions. Many institutions today refer to the SDGs as part of their environmental, social and gov-



^ Fig. 5 Visualization of Tara Bandu in Timor-Leste (Source: Zuzanna Sliwinska, 2024).

ernance (ESG) agenda. To familiarize learners with the SDGs and their ecosystemic basis, we ask them to first identify relevant SDGs, and then select one SDG that they don't work with and reflect on how their practice would change if they engaged with it. Fig. 7 provides an example of such an approach as used by Rodrigo Manzione, a learner in the professional education course Water Systems Design (Manzione 2024).

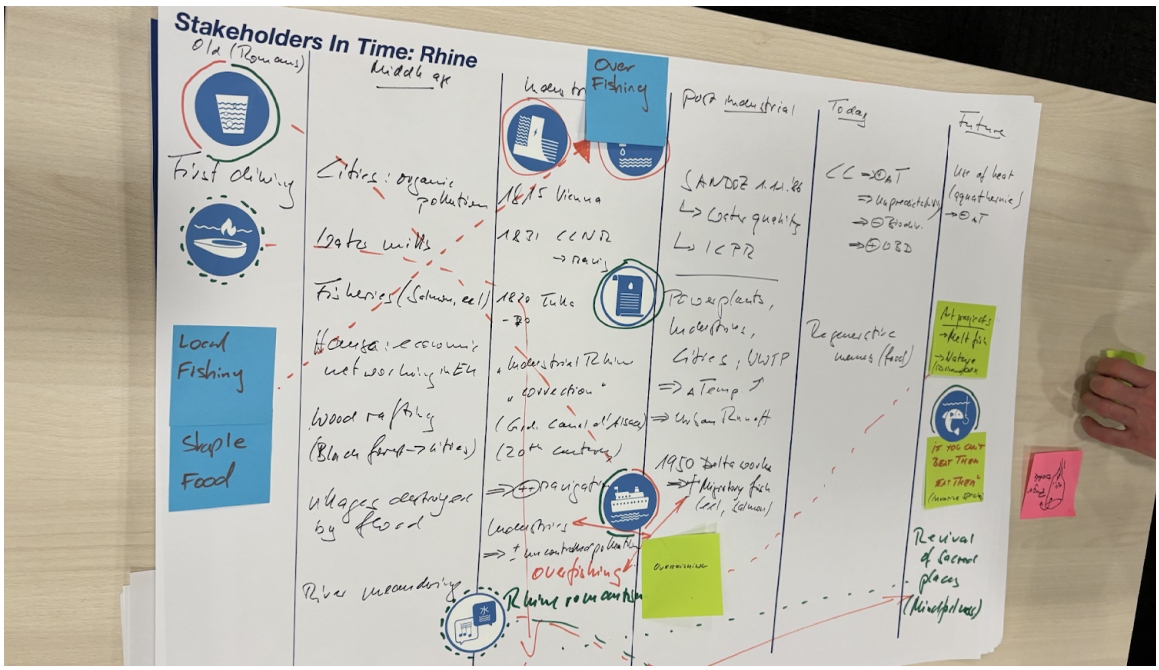
Design Thinking for Future Water Heritage

As a value, in recent years nature has experienced a resurgence. Humans have created water systems, often imposing their own needs and desires, without respect for natural systems. The disconnect between culture and nature has been anchored in institutional frameworks. Recent attention to biodiversity and nature has resulted in activities such as giving voice to a river, as promoted by the group advocating for a Parliament of the Loire.[5] Such attention to nature can conflict with cultural heritage concerns: freeing up rivers to allow for seasonal flooding or to facilitate fish migration may require the removal of historic water mills. The current institutional separation between natural and cultural heritage properties and between tangible and intangible practices can make comprehensive action and protection difficult. Connecting water and heritage can also help integrate nature and culture. Rethinking water systems may provide an opportunity for finding new spatial and organizational models that bring non-human life into governance. The Zoöp concept, which proposes a form of organization that engages human as well as nonhuman life in decision making, can facilitate sustainable development for the benefit of all.[6]

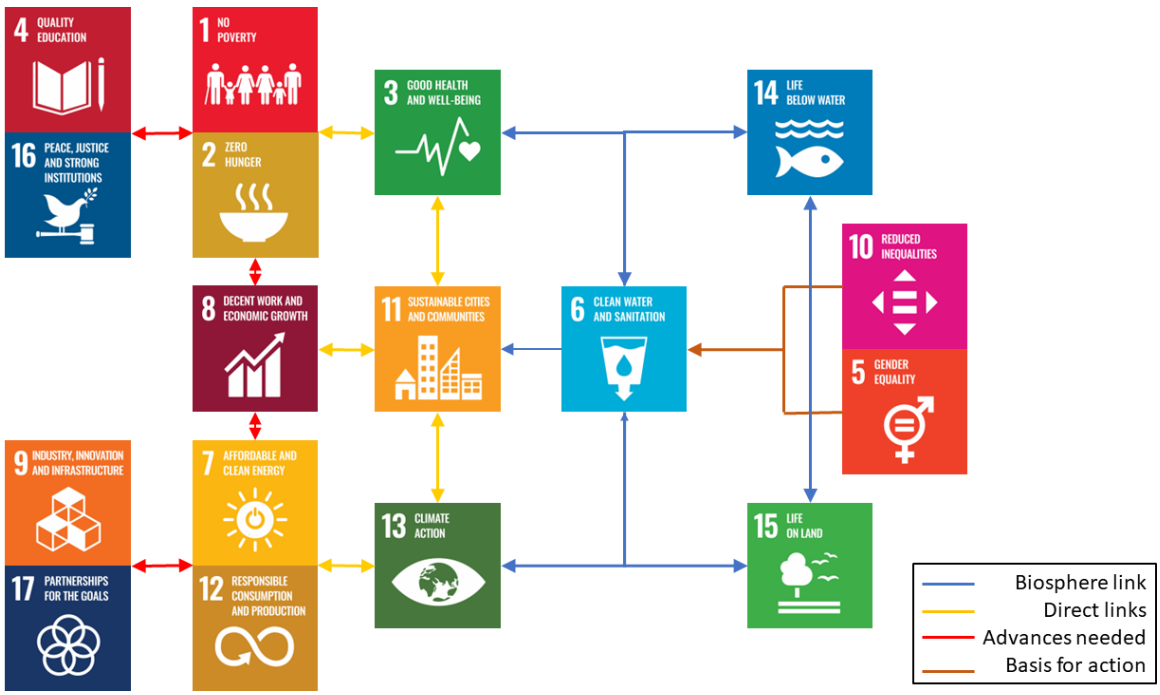
Examples of value-based approaches include the revitalization of the Dutch Waterlinie as a multi-stakeholder endeavor encompassing heritage preservation, nature conservation and spatial development (Netherlands) (Luit-

5. Vers un Parlement de la Loire, https://www.parlementdeloire.fr/.

6. HNI, Zoop, https://nieuweinstituut.nl/projects/zoop.



^ Fig. 6 The historical development of space, society and culture can lead to value conflicts and opportunities as illustrated by a discussion of stakeholders over time on the Rhine, developed at a Connected River event in Nijmegen. (Source: Carola Hein, 2025).



^ Fig. 7 Example of an exercise to activate the SDGs and identify potential values that can inspire design (Source: Rodrigo Manzione, 2024).

en and Kayrouz 2024). An application of the steps of the value case can be seen in a value case proposal for Brazil, where the author used water towers as landmarks and sites for water education (Manzione 2024). Another example of a value case, albeit without the label, is the transformation of the Seine in Paris and the Ile de France.[7] The value case approach provides a methodological framework to consider relevant stakeholders, multiple scales and long-term developments with the goal of establishing a vision and mission for shared approaches to sustainable development. Salzinger (2025) and others have built upon what they learned in the course Water Systems Design.[8] (Re)connecting the isolated elements of water spaces and practices to a larger water body helps us take natural ecosystems into account.

Conclusion

At a time of changing water conditions – more rain, less rain, flooding, drought, sinking and rising groundwater levels – we must think urgently about how water managers and heritage experts, as well as future architects and urban and environmental designers, can collectively shape water systems. We need new tools for capacity building, from serious games to open-access courses. Through conversations and negotiation, we can tease out shared values together. The game Water Values, for example, is designed to help promote understanding of long-term development across scales with a systems approach to design (Hein et al., 2025).

Designers play a key role because they can help sketch potential futures. To develop sustainable water systems, we need to employ system design approaches based on culture and values. Such approaches require multidisciplinary collaboration, connecting water management-related heritage – such as qanats, windmills and dikes – to water-related heritage more generally – including natural heritage sites like the Wadden Sea or even intangible practices like water festivals – to different types of engagement with the past and heritage, including the analysis of historical systems, large-scale territorial changes and the impact of climate change on our historical sites and heritage to encourage greater water awareness in a wide range of disciplines.

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7. (Re)Connecting River and City: The Seine in Paris and the Ile de France, took place March 2025 at the IAS Paris, https://www.paris-iea.fr/fr/evenements/re-connecting-river-and-city-the-seine-in-paris-and-the-ile-de-france-a-model-for-nature-positive-approaches-in-world-heritage-cities-for-climate-resilience?thanks=Inscription_evenement.

8. Water Systems Design https://online-learning.tudelft.nl/courses/water-systems-design-learning-from-the-past-for-resilient-water-futures/.

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PART II Methodologies and Case Studies

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Methodologies for Inspiring, Locally Grounded Sustainability Transitions: The Value Case for Annecy, France

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Abstract
Methodologies that draw on heritage and local values can stimulate new ideas and actions to make sustainability transitions more locally grounded and inspiring. The value case approach is one such methodology that was applied to the lake and city of Annecy, in France, during a course on water systems design. The author describes the steps of the value case and discusses how heritage and local values served as a compass to develop a vision and to propose actions toward an inspiring future.

Policy Recommendations

- Annecy's actors in governance, environment, culture and tourism should explore ways to reactivate local water heritage and draw on shared values to support the sustainability transition. A participatory workshop could initiate this, drawing inspiration from the tools and proposed actions detailed in this article.
- The French government should develop holistic policy responses to the ecological crisis, with greater emphasis on biodiversity restoration and climate justice. The government should be consistent with its long-term climate neutrality objectives by increasing the national budget for the ecological transition (Pisani-Ferry and Mahfouz 2023) and ensure sustained support for the Green Fund (Fond Vert), which provides essential financing to local authorities (Poirier 2024).
- EU member states should use their National Action Plans under the new European Nature Restoration Law (2024) as an opportunity to promote locally grounded approaches that draw on the strengths and heritage of specific territories. Such approaches could foster a reconnection with nature through a combination of spatial, cultural and educational interventions (e.g., "drop" interventions, as featured in a video series produced by the consortium Bauhaus of the Seas Sails [2024]).

KEYWORDS

Water heritage
Climate justice
Value case approach
Sustainability transitions
Climate change adaptation

WATER ICONS

CLIMATE

A B **C** D E

Cfb: Temperate oceanic climate

< Fig. 1 Annecy (Source: Guilhem Vellut, 2020. CC-BY 2.0, via Wikimedia Commons).

Introduction

Sustainability transitions bring opportunities to rethink society and economic prosperity in a way that benefits both people and nature. Yet, current ways of framing and implementing sustainability transitions often do not inspire citizens or resonate with their lived experiences (Salzinger 2025). Predominant political narratives and policy measures present sustainability transitions in terms of short-term losses and focus on overly technical solutions that fail to account for people's social and cultural realities. This has led to low popular support for sustainability transitions, even backlash (Salzinger 2025).

As the ecological crisis continues to deepen (Richardson et al. 2023), there is an urgent need to strengthen alternative narratives and solutions to accelerate a just sustainability transition. However, few know about methodologies that support these pathways. This article explores the potential of the value case approach to make sustainability transitions more inspiring and locally grounded. This methodology is applied to the case of the lake and city of Annecy, in France.

The Value Case Approach

The value case approach was developed by a team from the UNESCO Chair Water, Ports and Historic Cities under the leadership of Carola Hein (D'Agostino and Hein 2024). It recognizes that transitions are never neutral and draw on a set of values or underlying motivations which drive actions and decisions. Values are understood as fluid and context-specific, not as fixed universal moral standards. Considering the existence of many conflicting interests around water systems (especially in the short term) which hinder sustainability transitions, a value-based approach seeks to shift perspectives toward the bigger picture and long-term thinking. This is accomplished by focusing on what shared values exist among relevant actors, and how those could be reinforced in support of sustainability transitions. According to D'Agostino and Hein (2024), "a careful understanding of which values shape stakeholders' logic and interests can shed light on solutions able to address multiple needs and create positive ripple effects for all parties in the context of intervention."

Water heritage refers to ways of living with water that societies have inherited and how they shape cultural identities. Water heritage includes places, structures and objects but also practices, traditions and beliefs linked to water. These are plural and contested, with some practices and identities becoming dominant and others marginalized. Heritage also provides insight into values and how they have changed over time (D'Agostino and Hein 2024). In the case of Annecy, applying a value case approach that draws on heritage seeks to look beyond aesthetic aspects of the lake to examine the dynamic relationship between the lake and the city of Annecy and how different values and interests have been prioritized at different times. It helps to better envision the possibility of change within continuity in support of change for the lake-city system of Annecy.

In the context of the professional education course Water System Design: Learning from

1. Water Systems Design: Learning from the Past for Resilient Water Futures, https://online-learning.tudelft.nl/courses/water-systems-design-learning-from-the-past-for-resilient-water-futures/.

the Past for Resilient Water Futures (TU Delft),[1] I have applied the value case approach to the lake of Annecy. The course guides learners through a series of design steps to explore the water system of their choice, combining long-term thinking with context-sensitive planning to propose interventions that add value for multiple actors (D'Agostino and Hein 2024). The city of Annecy, which was used as a case study, is located in the French Alps. Residents have used Lake Annecy for fishing, commercial navigation, industry, drinking water, tourism and leisure (Barraqué 1986). The history of Annecy, its cultural heritage and its economic prosperity are strongly tied to the lake ecosystem, which is impacted by climate change and biodiversity loss (Massemin 2018; Nikolli 2022; Soares et al. 2025). The process of applying the value case approach to Annecy has helped establish a path forward in pursuit of a sustainable future of the lake and city.

The following sections explain the methodological process and analytical tools. The goal is not to argue for specific solutions for Annecy. The proposed actions discussed below should be seen as possibilities that need to be further discussed and refined with local actors, to reflect their needs and aspirations.

Understanding Annecy's Complex Water System

A holistic understanding of Annecy's context is essential for developing inspiring narratives and pathways for sustainable transitions that are grounded in local realities. This requires considering the set of actors, values, historical legacies and spatial relationships that influence the lake and city of Annecy. The Water Systems Design course devoted ample time to this task, based on the view that connecting past, present and future experiences of living with water would support the development of pathways aligned with local conditions and cultural identities. By highlighting existing strengths and knowledge within the community, this approach can also make challenges of climate adaptation and sustainability transitions feel less daunting.

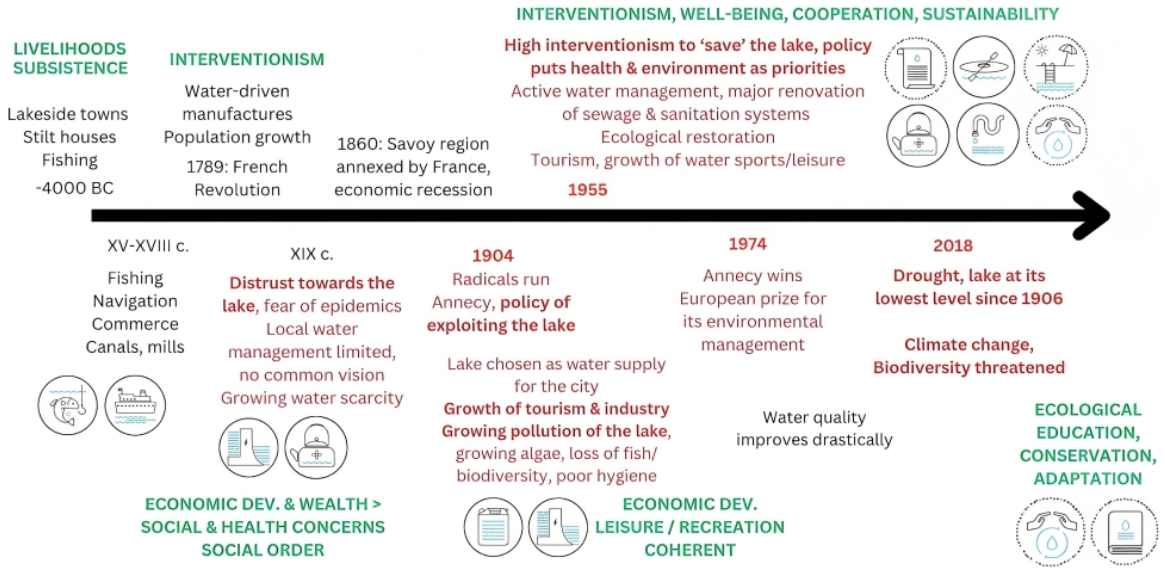
Step 1: Analyzing the History and Evolving Values Underpinning the Lake-city Relationship

The timeline (fig. 2) shows the continued importance of water for the city's development, suggesting that the past, present and futures of Annecy are inextricably tied to the lake. At the same time, it introduces a more complex vision of Annecy's waters beyond the dominant narrative of the lake's beautiful, transparent waters – which mainly serves the city's tourism and leisure sectors (Nikolli 2022; Salzinger 2025). The timeline presents important moments in the lake-city relationship and the main value changes that happened around these moments in Annecy. Key shifts include the move from the use of water for subsistence to economic development, especially for commerce, energy, industry and tourism (Barraqué 1986). This emphasis on economic development has been, and remains, a driving value in the lake-city relationship at least since the fifteenth century. Also, note in the timeline the choice to use the lake as the main supply of drinking water for the city, and the "rescue" of the lake from pollution beginning in the 1950s. Residents, including fisherfolk, demanded better health and environmental protection alongside profits. As a result of this bottom-up pressure and of the strong policy response that met the demands, the quality of the lake waters improved considerably in the following decades (Barraqué 1986).

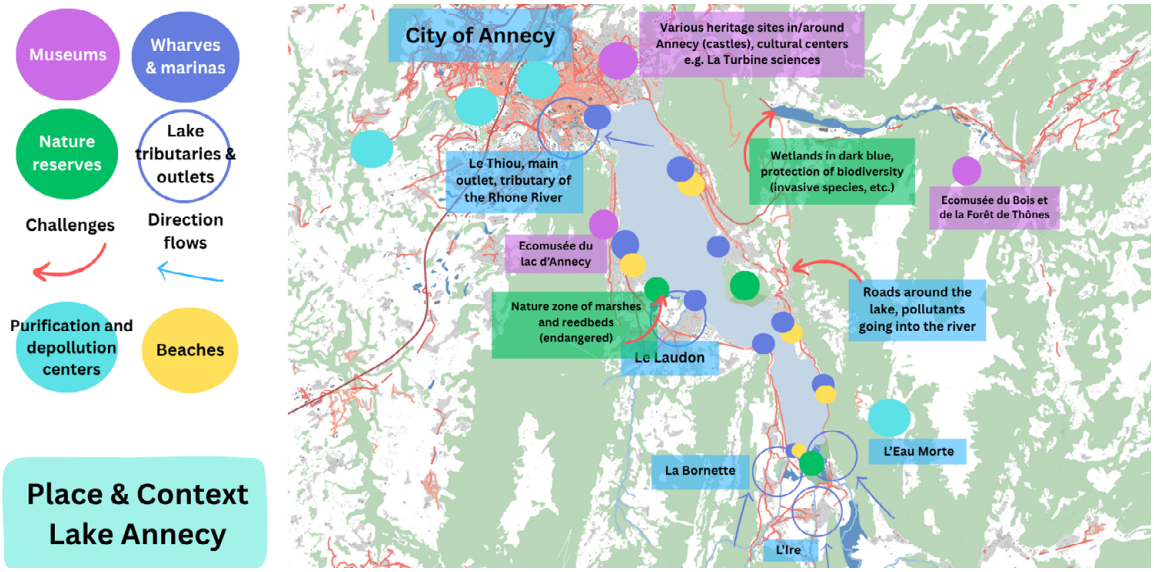
This first step of the methodology led to three important findings regarding the lake-city relationship. First, the combination of bottom-up pressures and effective local governance enabled a value change and its operationalization in Annecy. For instance, the creation of a structure (the Syndicat Mixte du Lac d'Annecy, or SILA) to treat sewage water and monitor water quality not only rescued the lake from pollution but also institutionalized long-term mechanisms that benefit the lake environment and public health (Barraqué 1986; Conservatoire d'Espaces Naturels de Haute-Savoie 2016; Vinet 2022). Second, the prioritization of health and water quality was framed as complementary, not opposed, to the economic prosperity of Annecy. The improvement in water quality would eventually boost the tourism sector and the reputation of Annecy's clear waters. This suggests that, while conflicting values and interests should be considered, grassroots and governance actors can focus on narratives and actions that support shared values and benefits, such as the provision of clean water (benefiting residents, tourism actors, fisherfolk, biodiversity). A third key finding is that widespread recognition of the lake's value beyond its contribution to human activities and well-being has not yet occurred. At the time of the lake's "rescue," values of public health and livability seem to have taken precedence over biodiversity and environmental protection (based on Barraqué 1986). Reciprocity between humans and non-humans (plants, animals, micro-organisms) as part of the lake ecosystem is not yet driving the city's development. Still there are promising developments in favor of biodiversity and climate action, with the election of Ecologist candidate François Astorg as mayor of Annecy in July 2020 (previous mayors were mainly from the center-right) (Hédiard 2020). His current mandate will end in 2026.

Step 2: Mapping the Territory to Reveal Spatial Relations, Challenges and Opportunities

The spatial mapping (fig. 3) helps visualize key local actors, structures and relations around the lake, such as water inlets and outlets, the



^ Fig. 2 Annecy and its Lake, the "Cleanest in Europe". Assignment 1, Water Systems Design (Source: Maëlle Salzinger, 2024).



^ Fig. 3 Assignment 2, Water Systems Design. (Source: Maëlle Salzinger, 2024).[2]

location of touristic and natural areas around the lake, and the presence of water purification centers. Additional research was later conducted to better identify water treatment centers and industries in the area. The process undertaken in the course was useful as a way to locate the lake within its wider territorial context, showing how water flows connect mountains to lakes and cities, and how climate change affecting mountain ecosystems upstream can have far-reaching consequences for people downstream. For instance, the main outlet of Lake Annecy, the Thiou, is a tributary of the Rhone River, which supplies a significant portion of the French population with water for commercial transportation, drinking and agriculture (Les Agences de l'Eau 2019). This suggests an important role for governance actors at various levels, including regional and national, in supporting a sustainability transition.

This step also highlighted challenges and opportunities to consider when developing sustainability pathways for Annecy. The mapping revealed the concentration of structures and activities to support tourism and mobility around the lake (boarding areas and marinas for boats, beaches, hiking paths, roads) and their proximity to natural reserves and vulnerable wetlands, including endangered local species such as reedbeds. Indeed, 80 per cent of the lake's reedbeds have disappeared (Massemin 2018). This suggests a particular challenge in combining economic and ecological values in Annecy. At the same time, the map includes actors and structures that already support, or could support, a sustainability transition in Annecy. For instance, the presence of several ecomuseums offers opportunities for connecting and reinforcing heritage and ecological values in the area. Additionally, the existence of a range of

2. Data retrieved from: Syndicat Mixte du Lac d'Annecy. n.d. "Les infrastructures d'assainissement collectif: Carte interactive – UDEP." Accessed April 23, 2025. https://www.sila.fr/nos-missions/assainir-vos-eaux/les-infrastructures-dassainissement-collectif/carte-interactive-udep/.; and OpenStreetMap contributors. n.d. OpenStreetMap data extract: Rhone-Alpes (Data set). Geofabrik GmbH. Accessed April 23, 2025. https://download.geofabrik.de/

businesses and industries (services, tech, sport, agro-industry, etc.) around Annecy highlights the possibilities for further economic diversification, reducing dependence on recreational tourism (Immobilier Annecien n.d.). However, the map presents the lake as a flat, homogeneous surface, failing to visualize its biodiversity, underwater flows and the spatial relationships between humans and nonhumans (fish, reedbeds, etc.). The use of other types of maps and visualization technologies could be explored to provide a fuller picture of the lake-city ecosystem and its diverse inhabitants.

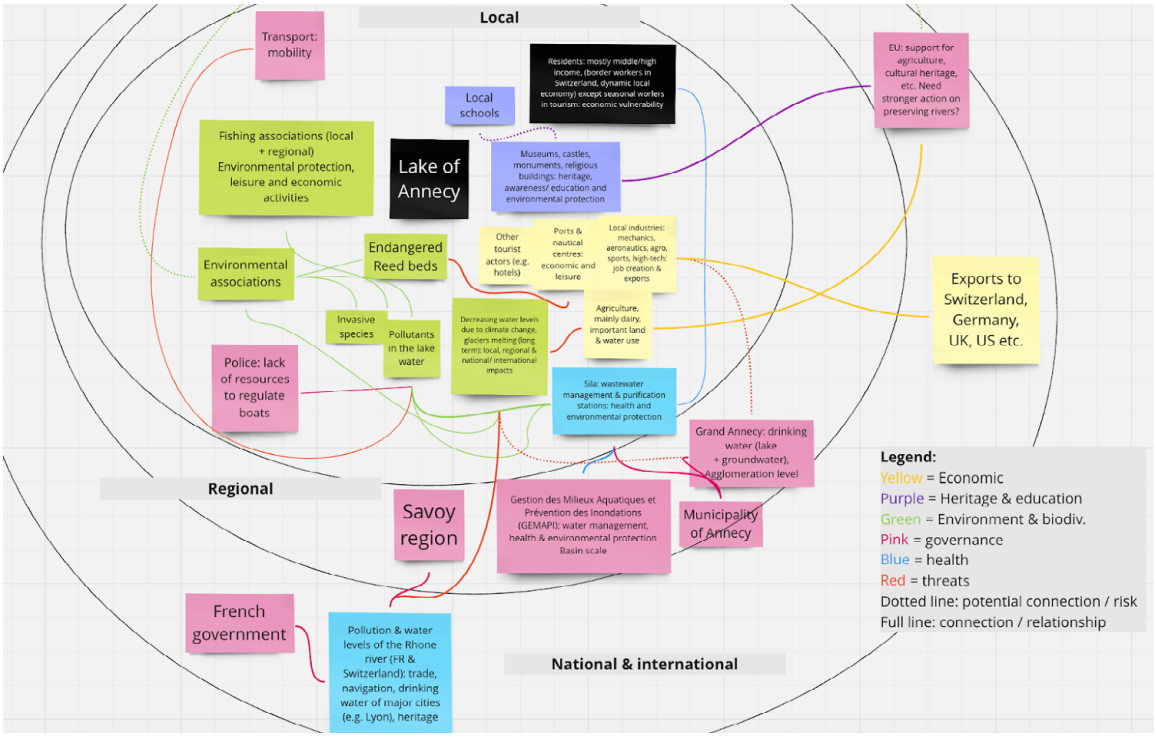
Step 3: Mapping Dynamic, Multilevel Systems to Reveal Potential Alliances

The mapping (fig. 4), developed as part of assignment 3 in Water Systems Design, uses the "canvas" methodology developed by Agence d'Urbanisme Flandre-Dunkerke (AGUR) to visualize complex systems across various scales, from the local to the international (Vereecke and Deveycx 2022). It helps to better represent the cross-border identity of the city of Annecy and its inhabitants. The process of zooming in and out afforded a more diverse picture of who has agency and who has responsibility over the water challenges affecting Annecy. It also helped identify connections within and across scales, which could be used to promote alliance-building between actors (called "agents" in the methodology). This proves particularly useful for the development of a vision and possible actions, which took place later in the course. In terms of potential alliances, local schools could partner with ecomuseums, water engineers and environmental associations to sensitize local children and other visitors to the lake's sustainability challenges. A potential role for the European Commission also appears as part of its implementation of the European Green Deal (2020–2030), in promoting environmental education and the revitalization of water heritage (along with UNESCO) as well as subsidizing cross-border research and innovation regarding, for example, water-systems adaptation to climate change in the Alps, light water vehicles and water-efficient agriculture (European Commission n.d.).

The canvas facilitated lively discussions in the course about which governance actors are better suited to address the sustainability challenges affecting Annecy. For example, while municipal and regional actors are responsible for water management and environmental protection of the lake, the central government can create an enabling environment for sustainability transitions by subsidizing the renewable energy sector (e.g., hydropower plants) and adopting an ambitious nature action plan for biodiversity restoration following the entry into force of the European Nature Restoration Law in August 2024 (Hallosserie and Fofana 2024). Additionally, this mapping tool allows for the integration of nonhuman agents, such as endangered reedbeds and invasive species. In sum, this step helped capture the complex, relational and multi-scalar nature of the water system in Annecy and its crosscutting implications for ecology, culture, education, transport and mobility, agriculture, industry, trade, tourism, leisure, health and sanitation.

Shaping Sustainable Pathways for Annecy Using Local Heritage and Values as a Compass

The methodologies presented in steps 1, 2 and 3 helped capture the complexity of the water system and the lake-city relationship in Annecy. How to move from this holistic understanding to sustainable pathways and actions, however, is not straightforward. This third section pre-



^ Fig. 4 Assignment 3, Water Systems Design. (Source: Maëlle Salzinger, 2024).[3]

sents steps to narrow down possible pathways and target actions that are locally and culturally rooted, thereby offering multiple benefits and hopefully giving the inhabitants of Annecy an inspiring narrative for the future. I drew from the UN Sustainable Development Goals (SDG) framework to shape the long-term vision for Annecy and identify useful synergies. Heritage and values served as a compass to select actions that can reinforce connections which are meaningful for Annecians.

Step 4: Applying the Lens of Heritage and Local Values to Sustainable Development Goals to Activate Synergies and Long-term Impact

The SDGs, adopted by all UN member states in 2015, provide a global framework of goals and indicators to guide sustainable development efforts across multiple sectors and themes until 2030. The framework places a strong emphasis on the interconnectedness of the 17 SDGs. The SDGs have limitations and suffer from reduced political steam in recent years, for instance due to the Russia-Ukraine war and its consequences for the European political agenda (Barchiche 2022; UN 2024; Sherriff and Veron 2024). Nonetheless, the course proposes that they can be used as a tool, rather than a solution, to think about long-term impacts and activate synergies between sectors and themes in support of sustainability transitions (Hein 2022). For the case study of Annecy, the author of this article used the SDGs during the development of pathways and actions based on local heritage and values.

3. "Sila" on the mapping refers to the Syndicat Mixte du Lac d'Annecy (SILA).

Figure 5 shows a selection of related and indirectly related SDGs that were used to refine and enrich the proposed pathways and actions for Lake Annecy and the city of Annecy.

This step had two main benefits for this case study. First, applying the SDG framework supported long-term thinking about the potential cascading impacts of climate change and sustainability transitions on the fulfillment of basic needs like food, drinking water and security. From a long-term perspective, none of the 17 SDGs was deemed irrelevant. Long-term thinking about the disruptive nature of climate change and societal transitions justifies the need for inclusive sustainability transitions to avoid adverse effects on poverty, inequality and social conflict. As a result, the value of inclusion was given more weight in the proposed actions for Annecy, in line with local challenges such as the financial precarity of seasonal tourism workers and economic inequalities between women and men. Indeed, in the Haute-Savoie region, women earn less than men despite better academic performance; female-headed single-parent families are more likely to live beneath the poverty line, according to data from the Département Haute-Savoie and the National Institute of Statistics and Economic Studies known as INSEE (ODS Radio 2024; Delfosse 2024).

Second, the SDG framework helped identify synergies that could be activated by the proposed heritage and value-based pathways for Annecy. For instance, one of the proposed actions to make mobility and transport in Annecy less carbon-emitting and less polluting for the lake (lighter water vehicles, reducing roads close to the lake, improving access by train) supports life below water (SDG 14), climate action (SDG 13) and sustainable cities and communities (SDG 11) but can also

^ Fig. 5 Assignment 4, Water Systems Design. (Source: Maëlle Salzinger, 2024).

support the local innovation sector (SDG 9) if measures to promote water-based innovations are established in Annecy. This was included in the proposed pathways and actions for Annecy, which are detailed in the next subsection.

Another example is the proposed action to revive Annecy's water heritage to promote more culturally rooted, educational and sustainable forms of tourism, which supports SDG 12 (responsible consumption and production) and 4 (quality education) but could also contribute to addressing the local socioeconomic challenges mentioned above. Specific measures to make the local tourism sector more inclusive and attractive year round (rather than only in the summer months) were added to the proposed actions, contributing to reduced inequalities (SDG 10) and boosting gender equality (SDG 5). For instance, women-led small and medium-sized enterprises (SMEs) in ecotourism could be supported by setting up a dedicated incubator in Annecy, launching an outreach program or providing financial incentives (e.g., tax reduction). As shown by the examples in this section, applying the SDGs helped refine the proposed actions by identifying ways to create shared value for more actors and sectors in Annecy.

Step 5: Proposed Pathway and Actions for a More Sustainable Lake-city System in Annecy

Applying the value case approach highlighted the possibility of change within continuity and continuity in support of change for the lake-city system of Annecy. Industry and tourism have played an important role in the economic prosperity of the city but pose long-term risks for human and nonhuman inhabitants around the lake by contributing to CO2 emissions, environmental degradation and biodiversity loss. Rather than seeing industry and tourism as homogeneous sectors that should be abandoned, there is an opportunity to rethink their economic model to identify a more inclusive and regenerative pathway with multiple benefits for human and nonhuman inhabitants living in and around the lake. This proposed pathway seeks to take advantage of and reinforce the long-standing relationship between the lake and the city. It brings together existing values of economic prosperity and innovation, health and well-being as well as environmental quality (natural environment and clear waters as a source of local pride), with new values of ecological regeneration and inclusion, to support a thriving lake ecosystem in the long term.

To achieve this alternative pathway, I propose the following two actions. These should be further refined by the inhabitants of Annecy and implemented in a phased approach to produce incremental, mutually reinforcing effects. The pathway and actions assume a strong governance role for local authorities, accompanied by policies and financial incentives, which are deemed possible based on past governance achievements (e.g., the rescue of the lake) and the city's wealth.

Proposed pathway: A Thriving Lake Ecosystem in the Long Term, Underpinned by Values of Regeneration, Heritage and Innovation

Action 1: Shaping an alternative economic model of tourism around the lake via ecotourism.

The ecotourism sector in Annecy could be centered on the idea of co-living with water, based on Annecy's historical and cultural heritage as well as objectives of ecological regeneration. In the short term (0–5 years), an enabling environment can be set up to support the transition to ecotourism[3] and disseminate regenerative approaches:

- Create a committee or other structure with local actors (e.g., environmental associations, ecomuseums, fisherfolk) to inform city decision-makers about local biodiversity and promote regenerative approaches. Consult the models of the Zoöp and Multispecies Assembly (Bauhaus of the Sea Sails 2024; Zoöp n.d.).
- Set up financial incentives (e.g., tax cuts) or an incubator for SMEs in ecotourism, especially for women-led SMEs.
- Provide training and financial support for "traditional" tourism businesses to transition to ecotourism.
- Create and disseminate a blue-green label for ecotourism around water bodies to sensitize consumers.
- Support the protection and restoration of endangered reedbeds and wetlands with additional resources and actions.
- Promote the use of "light" watercraft (e.g., canoes) on the lake.

3. Stimulating ecotourism poses the risk of advantaging external investors over local actors. City decision-makers should ensure that residents benefit from ecotourism and that taxation to finance this new model is progressive, avoiding a burden on disadvantaged residents.

In the medium term (5–10 years), spatial changes and new experiences can be developed to further transform Annecy's tourism sector, from leisure/recreation to an immersive, educational dive into Annecy's cultural and natural heritage, peace and beauty:

- Develop immersive experiences for locals and tourists in partnership with local schools, ecomuseums, restaurants and ecologists that promote respect for the environment and reconnection with nonhumans around the lake – these might include ecolodges (e.g., stilt houses), educational dives and hikes, nature observatories, ecofood menus/restaurants with local products (e.g., fish), regenerative suppliers (e.g., permaculture) and plant-based options.
- Restore historical waterworks to promote the water heritage of Annecy and sensitize visitors to past, present and future water-related challenges, for instance reviving the memory of the successful de-pollution of the lake.
- Gradually implement stricter regulations to limit recreational boats on the lake and reinforce monitoring and enforcement.

In the longer term (10+ years), more extensive transformation of infrastructure and mobility can be imagined to support the shift to a more regenerative local economy:

- Gradually replace the roads close to the lake with a green belt (for pedestrians, bikes and nonhumans) to protect the lake from car pollution.
- Densify the public transport network, especially the railway; increase accessibility measures for users from marginalized groups (disabled, elderly, low-income).
- Disseminate the blue-green ecotourism label throughout the Savoy region, and hopefully, beyond regional and national boundaries.
- Reduce the number of marinas or create a system of alternating use so that all marinas cannot be used year round. Gradually increase mixed spaces around the lake where informed visitors and nonhumans cohabit and respect one another.

Action 2: Positioning Annecy as a regional and international hub for innovation and knowledge exchange on climate mitigation and adaptation, with a focus on mountain lake ecosystems.

This can draw on the already dynamic economic sector (tech, innovation, industry) and knowledge centers (e.g., universities) and the cross-border identity of Annecy. In the short term (0-5 years), key partnerships can be set up:

- Build partnerships between local/regional innovation, business and knowledge actors to: (1) promote blue-green innovations for mountain lake ecosystems, e.g., development of water-efficient systems for water mobility (joint objective with action 1), hydraulic energy, industry and agriculture in the region; (2) based on climate change scenarios, develop adaptive systems to ensure long-term availability of water for drinking, agriculture, industry, etc. Social scientists should be included to ensure socioeconomic and cultural implications of innovations are considered.

In the medium term (5-10 years), Annecy can be promoted as a business destination for innovators and investors in blue-green innovation, with an emphasis on travel by train:

- Densify the train network (joint objective with action 1) in France and incentivize

cross-border train travel (e.g., fast speed trains, night trains) from Switzerland, Italy, Germany and Austria, which face similar challenges around mountain lake ecosystems.
- Invest in communications to attract national and international businesses, investors and researchers in blue-green innovations for mountain lake ecosystems.
- Use tourism services (ecolodges, eco-food restaurants, etc.) to accommodate business travel, ensuring more stable revenues for ecotourism actors year round (joint objective with action 1).

In the longer term (10+ years), Annecy could become a true international hub for knowledge and innovation on mountain lake ecosystems and contribute more actively to global climate justice:

- Build long-term partnerships with companies and universities from countries hard-hit by climate change (e.g., melting glaciers in the Himalayas, South Asia) to share knowledge around mountain lake ecosystems. Prioritize long, qualitative trust-building and knowledge-sharing visits between partners over short regular trips, to limit carbon emissions from flying.
- Seek European Commission funding to guarantee the durability of international knowledge-sharing and innovation programs.

The two actions aim to create mutually reinforcing systems (economy, infrastructure, mobility, education) in support of shared values of regeneration, heritage and innovation for the long-term benefit of human and nonhuman inhabitants in Annecy. The infographic (fig. 6)

^ Fig. 6 Assignment 5, Water Systems Design course. (Source: Maëlle Salzinger, 2024).

summarizes the impacts that could be derived from the two actions and their joint effects in the short, medium and long term.

Conclusion

This article has explored how methodologies that consider heritage and local values can be applied to a complex water system – specifically, the lake and city of Annecy – to help shape inspiring and locally grounded pathways that support sustainability transitions. These methodologies can help reframe the dominant narrative about climate action, from a costly burden to an opportunity for communities to revive cultural heritage, advance shared values and reap benefits across sectors and stakeholder groups.

Rather than proposing singular solutions for Annecy, the article has guided readers through the process of analyzing the history, evolving values, spatial relationships and multi-scalar dimensions of the lake and city, as undertaken in the Water System Design course. From this complexity, local heritage and values served as a compass for identifying a sustainable pathway for Annecy's future. In this pathway, technical or technological innovations (e.g., light water vehicles) are not viewed as a panacea. Instead, they are part of a broader effort to rethink Annecy's economic model, promoting more responsible resource use and regenerative approaches that support biodiversity.

The proposed pathway for Annecy also recognizes that sustainability transitions are inherently political endeavors, requiring grassroots and governance actors, including municipalities, to play an active role and negotiate competing priorities. As such, the methodologies discussed here should be implemented as part of a participatory process involving local stakeholders like residents, grassroots organizations, business owners in the tourism sector and city decision-makers. Such a process might be facilitated by local universities or policymakers in Annecy, with careful attention to power dynamics among participants (e.g, differences in mandates, resources, abilities to exert influence, confidence and ability to cooperate with others) (Delgado-Baena and Sianes 2024; Hiemstra, Brouwer and Van Vugt 2012; Huttunen et al. 2022). Facilitators may consider tools like co-managed workshop agendas to help less powerful actors promote the values that matter to them (Delgado-Baena and Sianes 2024). In sum, sustainability transitions can become more compelling to citizens when grounded in local cultures, responsive to socioeconomic realities and shaped through inclusive engagement.

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The Peshwa Nahar System: Sustainable Water Management in the Past and for the Future

Radhika Mulay & Pallavee Gokhale

Abstract
Urban water infrastructure in India is currently focused on technocratic solutions, often disregarding sociocultural and environmental values. This article examines the eighteenth-century Peshwa-period *nahar* (aqueduct) system in Pune, within the broader context of three centuries of urbanization. Developed as part of the 2023 professional education course Water Systems Design: Learning from the Past to Design Resilient Water Futures, it employs the value case methodology and the framework of the UN Sustainable Development Goals (SDGs) to highlight ecosystem-based thinking reflecting traditional knowledge systems. Although today the *nahar* system is no longer functional, the authors argue that it can inform future design thinking and offers an important example for initiatives like India's Smart Cities program, offering a sustainable water management approach by integrating ecological and sociocultural values in infrastructure planning.

Policy Recommendations

- Safeguard the Peshwa *nahar* system, a sustainable and highly advanced traditional water technology and heritage infrastructure, in the context of the government of India's Smart Cities Mission.
- For future water system designs, understand and implement the core values of the Peshwa *nahar* system articulated here: (i) adapted to the local environment, (ii) sustainable and cost-effective, (iii) socioculturally inclusive and (iv) decentralized and reliant on climate resilient infrastructures.

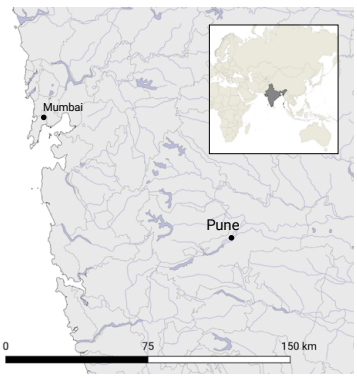
KEYWORDS

Pune
Heritage
Aqueduct
Smart systems
Water management systems

WATER ICONS

CLIMATE

Aw: Tropical savanna climate



< Fig. 1 Panoramic view of Katraj Lake, which waters serves the Katraj aqueduct (Source: Pallavee Gokhale, 2025).

Introduction: Temporal and Spatial Context

Inspired by the tradition of *karez* or *qanāts* from the Persian Gulf, the Deccan sultanates (from approximately the fifteenth to the mid-seventeenth century) built a number of important water systems using underground networks of aqueducts that sourced water from aquifers. In India, such systems are found in the cities of Ahmednagar, Bijapur, Burhanpur Chhatrapati Sambhajinagar and Daulatabad. Inspired by these systems, in 1750, Balaji Bajirao alias Nanasaheb Peshwa, who was the prime minister of Maratha Empire under the rule of Chhatrapati Shahu of Satara, began constructing a *nahar* system to supply drinking water to the city of Pune.[1] Two masonry dams were built on the southern outskirts of the city at Katraj on the Fadtari and Navlaicha streams, respectively (Palande-Datar 2021). Water was led by gravity through a 20 km-long network of aqueducts, masonry pipes, dipping wells, cisterns and joints, with more than 200 outlets in the city (fig. 1). The new aqueduct system thus supplied drinking water to the most densely inhabited parts of the city and almost every neighborhood. When the city of Pune grew, three new *nahar* were built, the Nahar-e Ambegaon,[2] Raste and Chaudhari, which became part of the Peshwa *nahar*.

This system is now recognized as heritage because of its eighteenth-century technology and architecture, understanding of hydrology, and central role in the growth and development of the historic city. However, this transformation from utility to heritage is complex: in the same period that it has been designated heritage, the local population has become apathetic toward the *nahar*. There is also a perception that if something is official "heritage," it has lost its function.

Changing Spatial and Social Contexts

The Peshwa *nahar* system, a testament to exemplary engineering, administration and city-planning, consisted of several cisterns/reservoirs (*haud*), dipping wells (*uchvāsa*) and underground man-made aqueducts (*nala*/*nahar*) (fig. 2). This system provided water to the core city areas as recently as the mid-twentieth century, but it was neglected thereafter and damaged during years of rapid residential and infrastructure development.

Since its creation in the 1750s, this system that provided for primary needs slowly transformed into an abandoned historical structure. Eventually, the Peshwa *nahar* became recognized as heritage by local communities and administrative authorities. This transition from "core utility" to "heritage" can be linked to contemporary social and political upheavals. The feelings of "belonging" and "pride" that citizens had toward this system changed over time (fig. 3). Through the intricate design adapted to the landscape and employing traditional water management communities such as the Beldars and Mehars, the Peshwas had ensured that the system ran effectively and efficiently (Mathur et al. 2022). By building new aqueducts and expanding the overall network in the 1790s, their court created a conducive environment for the growth of new areas of the city. Into the nineteenth century, regular maintenance and usage of the Peshwa *nahar* system ensured its operation. Then, in the late 1870s, the Bombay Act No. VII led to its gradual degradation.

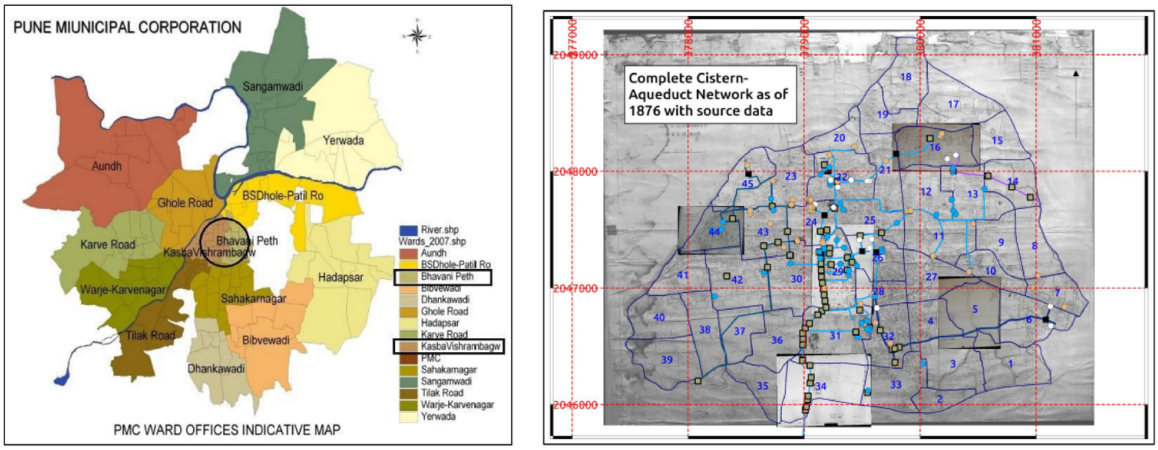
During the early colonial period, the East India Company (EIC) continued to ensure the system was being used and maintained. However,

1. As necessary, non-English words have been Romanized using the Library of Congress romanization tables.

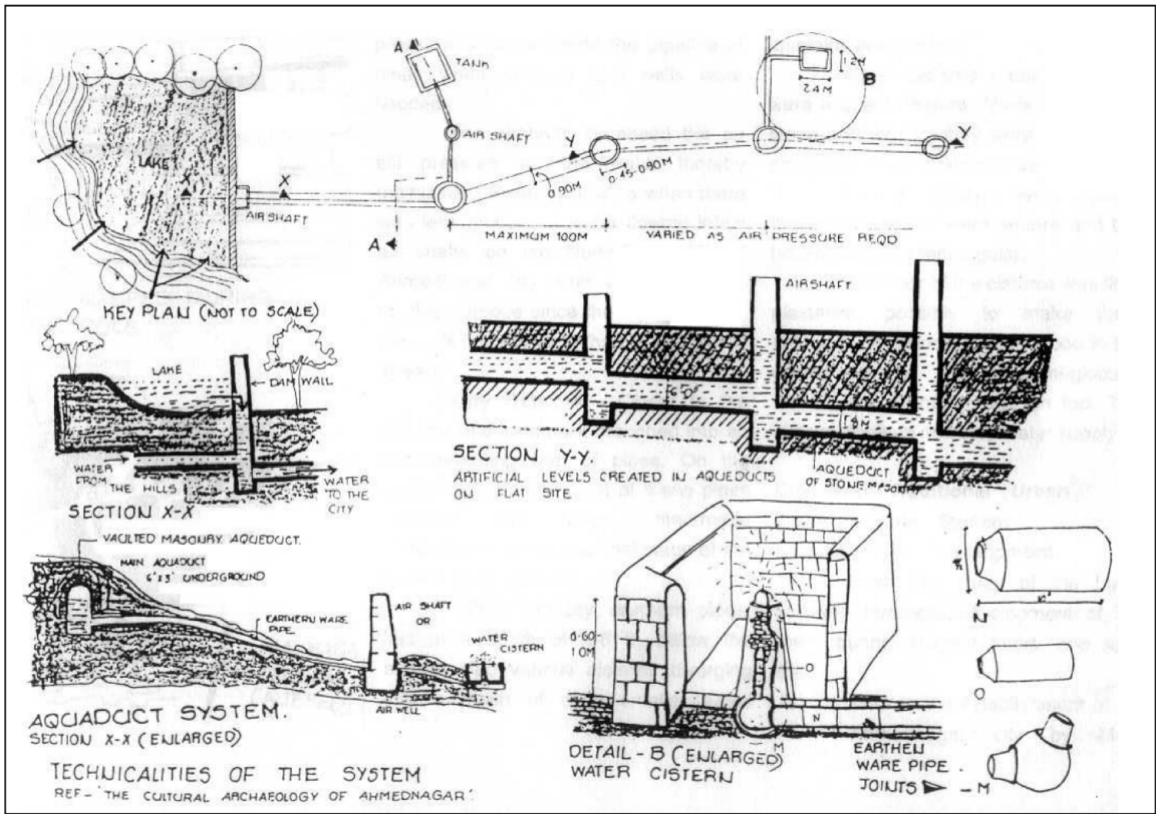
2. The Nahar-e Ambegaon was also known as the Nana Phadanavis system, after the patron.

A Old Pune - Encircled in Centre; Outlined Areas in Legend

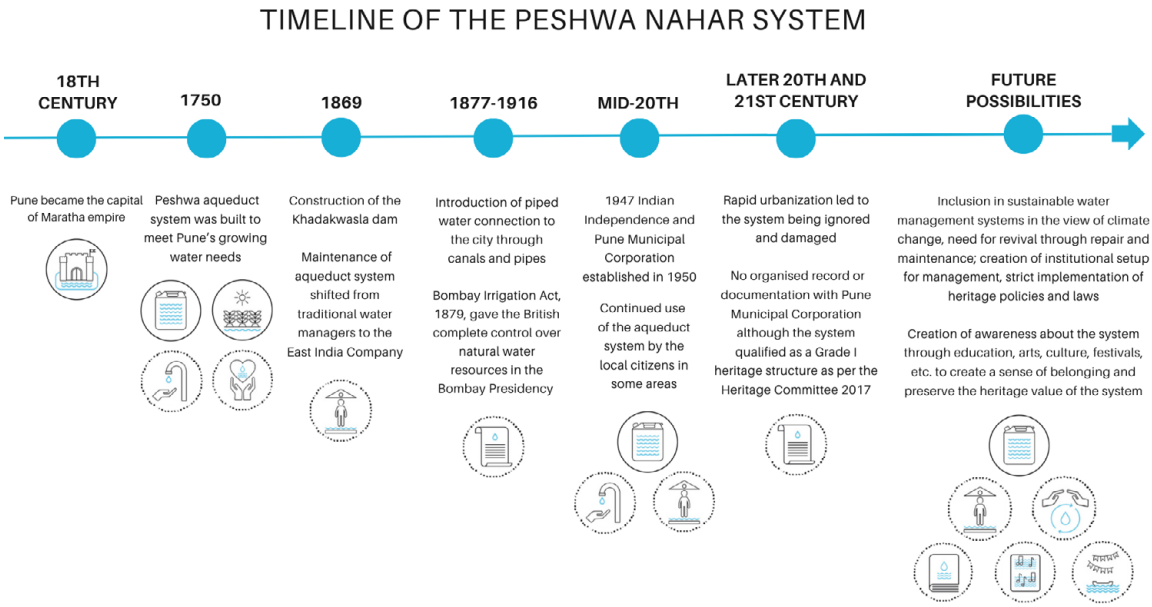
B GIS Data Creation From Old Maps and Texts



^ Fig. 2a Map showing the location of core city areas (*peths*) in the city of Pune (Source: Pune Municipal Corporation, 1987). Fig. 2b GIS data creation of the Cistern-Aqueduct Network as of 1876 from old maps and texts. The blue line identifies the aqueduct network; dipping wells by yellow squares; joints in the system by black squares; cisterns by blue and yellow circles (Source: Gokhale and Deo, 2016).



^ Fig. 3 Section drawings and technical components of the aqueduct system (Source: Kamalapurkar, 2006).



^ Fig. 4 Timeline showing the chronological development of the Peshwa *nahar* system in Pune since its inception and showing link with associated tangible and intangible water categories based on an assignment of the 2023 professional education course Water Systems Design: Learning from the Past to Design Resilient Water Futures (Source: Radhika Mulay, 2023).

instead of employing local caretakers, the EIC hired prisoners from Yerawada jail to maintain the infrastructure (Mathur et al. 2022). This was in line with the systemic disruption taking place in management practices of local and traditional water management systems across India as maintenance was outsourced to those who were not the beneficiaries of the system. This resulted in a declining sense of stewardship toward the *nahar*. At the same time, the increasing reliance on dams, canals and piped water systems introduced by the British as modern sanitation made decentralized water management systems such as the *nahar* appear obsolete.

In 1879, the Bombay Irrigation Act (Bombay Act. No. VII of 1879) permitted the construction and maintenance of any water systems in the broader public interest and gave the British complete control over natural water resources in the Bombay Presidency. This legal change caused new planning practices in water infrastructures and the city water supply began to be provided through canals and pipes. There was no attempt to incorporate traditional water systems in the new water management practice.

Once the centralized water supply was established, the aqueduct system was never formally recognized as a reliable alternate source of water. However, the Peswha *nahar* system continued to be used as an informal water supply until the second half of the twentieth century, even providing potable water relief during the infamous 1961 Panshet floods.[3] During the post-flood period, core areas of the city un-

3. On July 12, 1961, its first year of storing water, the Panshet dam on Ambi River near Pune burst, causing massive flooding and huge loss of life and property in the city (Brahme and Gole 1967).

derwent an intensive process of rehabilitation and redevelopment and the Peshwa *nahar* was physically disrupted and polluted; eventually its integrity was permanently damaged. Despite these events, some of the cisterns continued to receive water from the fragmented segments of the system.

Work to get the system recognized as heritage only began in the 1990s, after years of urbanization. Before then, there was little conception of "heritage" as an entity of administrative interest (Madan 2011). It was only in the twenty-first century that the idea of "heritage" was formally accommodated in the bureaucracy of the Pune Municipal Corporation (TNN 2018). The association of this water system with Peshwa rule, its significance in the growth of the city, and tangible remnants (in the forms of Katraj Lake, dipping wells and a few abandoned cisterns) qualified it as a Grade I heritage structure (Heritage Committee 2017).

Lost Opportunities

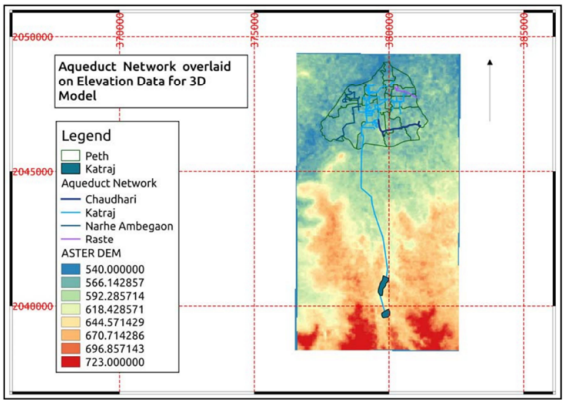
Although different values of water such as utility, purity and life, and sacrality have persisted in societies since antiquity, the concept of "water heritage" and its appearance in discourse concerning local histories is relatively recent (Goralnik et al. 2022), and the theoretical and administrative frameworks are still evolving. Awareness of the notional and archaeological value of the *nahar* system has also only recently developed. Although for some people, the system has long evoked a sense of belonging and pride, it is only recently that there have been organized efforts at preservation, documentation and conservation. We are now at the stage of preserving this system only in memory. Even that is challenging when there is no official record of this system – even of occasional encounters of the remnant infrastructure during construction activity – and there are no initiatives to conduct salvage archaeology or even hasty documentation. There have been no initiatives to sensitize people in the relevant areas or train them for the possible preservation or documentation of this system. Except for the lakes, almost every tangible form of this system has been erased from the landscape with no comprehensive record left by the administrative authorities. The existing documentation of its expanse and complexity consists of colonial maps from the 1870s and local surveys carried out as part of *Pune Nagara Samśodhana Vrtta* (vols. 2–4) in the 1940s, and then by M.S. Mate in the 1990s. Gokhale (2016) has used these archival materials to experiment with the possibilities of virtual reconstruction and digital experience.

Value Proposition for Sustainable Urban Water Infrastructure and Heritage Conservation

A heritage structure such as this aqueduct system becomes especially relevant at a time when cities like Pune are facing water scarcity problems. Employing the SDG framework in retrospect, it is possible to use the value case approach (D'Agostino and Hein 2024) to examine the Peshwa *nahar* system as an example of water system design thinking which integrates environmental, social, economic and cultural aspects of traditional water knowledge systems with advanced technology.

Extrapolating Sustainable Development Goals from the Past: Sustainable Gravity-led Technology

The Peshwa aqueduct system is an example of a highly advanced water management tech-



^ Fig. 5 Aqueduct network overlaid on elevation data. The coordinates are in a WGS 84 UTM 43N projection system. Katraj masonry dam lakes can be seen towards the south. The tentative alignment of Katraj aqueduct can be seen flowing north to the core, i.e., the *peth* area of Pune (Source: Gokhale and Deo, 2016).

nology that combines traditional knowledge systems and was designed in accord with the local geohydrology. The dams built at a higher elevation accumulated rainwater runoff from the hill slopes and from freshwater springs (fig. 4). Due to the natural gradient in the topography of the land, water percolated into the first tank, allowing silt to settle down before flowing into the second tank. Water then flowed into masonry aqueducts (*nala/nahar*) where airshafts or dipping wells (*uchvāsa/ooswas*) were built at intervals of approximately 90 to 100 meters. These prevented the obstruction of air, along with manual desilting, and allowed water discharge to be monitored. The aqueduct also received an additional supply of water through many springs, and in some cases from independent adjoining wells. For the discharge of excess water, the network was finally connected to Mutha River through an underground channel at the Omkareshwar and Amruteshwar ghats on the riverbanks (Palande-Datar 2021). Although highly advanced, this gravity-led network demanded little energy and was therefore sustainable and affordable.

Linking Technology and Traditional Knowledge with Sociocultural and Historical Legacy

Although the *nahar* system of Pune was built by the rulers and their nobles for their residences, historical records indicate that the system was also designed to support the water demands of local people (Diddee and Gupta 2000). Around the core city of Pune, several cisterns, both public and private, were built on the dense network of aqueducts, making drinking water available to neighborhoods. These cisterns, popularly known as *hauds*, were also places of daily public interaction, ritual, social gatherings, and aesthetic displays in the form of fountains (Kamalapurkar 2006). The water system, with its combination of traditional knowledge, newer technology and intricate understanding of complex surface and groundwater interactions, was therefore a symbol of sociocultural and historical achievement.

However, it is also crucial to note that, similar to other water sources, all the cisterns were not accessible to the lower castes, who were assigned separate wells in the low-caste neighborhoods. Historical anecdotes mention a movement led by reformer Mahatma Phule, which demanded equal access to these systems for all the communities in the core city areas (Joshi and Paralikar 1976, Damle 2023). Thus, the history of the Peshwa *nahar* involves social justice dimensions involving access to fresh water. When analyzed through the prism of the SDG framework, these aspects point to various goals, including reduced inequality, access to clean water and sanitation, and sustainable communities and cities, all of which were addressed in the design and implementation of the Peshwa *nahar* system.

In retrospect, another important social aspect to consider, as an externality of the tradition-

al patriarchal family system, is gender inequality. The burden of fetching water typically fell on the women of the household, and was thus unequally distributed. When seen through the lens of the gender equity aspirations of the SDG framework, this aspect would have needed strategic sociocultural intervention.

Local and Decentralized Management

Apart from the tap water system, the rapid rise in the dependence on groundwater and mobile water tankers in Pune is an outcome of unprecedented rise in demand for water year round. The unregulated tanker services acts as an alternative water supply and distribution system to the municipal water supply due to the nexus between the tanker lobby, builders and politicians. There are no strict regulations regarding the recharge of aquifers, daily extraction rates or the number of wells permitted, if any, in designated areas. In this context, the aqueduct system, which was still functioning and in use daily in some parts of the city until the mid-twentieth century, is an example of an alternative, environmentally sustainable, cost-effective and decentralized water supply, especially valuable during periods of water scarcity.

Surveys conducted by Bhagvat and others (2004) from 1992 to 2004 noted that some *wadas* (large mansion or house), especially in the core city areas of Budhwar, Guruwar, Shukrawar and Shaniwar were still using the water from the cisterns (fig 5). In areas expanding beyond the core city, it was observed that a few dipping wells were still in use for drawing water and that few water tankers were filled by pumping out water from these (Bhagvat et al. 2004; Gokhale 2016). It has been observed that local residents have been aware of the connection of these water outlets to Lake Katraj and aware of

Fig. 6 Images of the aqueduct system, including the underground network (*nala/nahar*), dipping wells (*uchvāsa*), and cisterns/reservoirs (*haud*) being used for daily activities and for rituals taken from an archival video highlighting the documentation work undertaken by Shrikrishna Bhagvat, Shriram Bhagvat, Nandkumar Bangude and Sharad Lonkar from 1992 to 2004 (Source: Personal collection of photographs, sketches, videos, notes and news articles by Shrikrishna Bhagvat and Shriram Bhagvat, 1992 to 2004).

their antiquity and origin in the Peshwa period (Gokhale and Deo 2016). The density of this network in the core city areas reveals the potential of this system of uninterrupted potable water supply in the densely populated areas and points to the relevance and utility of these structures even today.

The Creation of an Ecosystem of Flows and Networks

Pune's historic *nahar* system has the potential to exemplify and shift our understanding of "smart cities," which need sustainable, affordable and socially just systems that address climate change challenges and provide water in urban areas. Making use of ancient methods of sustainable water resource management

and consumption could be appealing to city dwellers as well as urban planners. This would be compatible with the Indian government's Smart Cities Mission commitment to innovation, while making it possible to conserve a sustainable and highly advanced traditional water technology and heritage infrastructure (Ministry of Housing and Urban Affairs 2024).

Within India, Smart City goals often focus on globally inspired, world-conjuring projects. For these projects to be sustainable in the long term, they need to be based on an awareness of local ecosystems and an ability to adapt to them. In this context, the *qanāt* or the *karez* system that was adopted from the Gulf of Persia and moulded to the local context of the city of Pune, is in fact a testament to the possibilities of a globally inspired water management system. Unlike the original design from central Asia, where the water was being sourced from aquifers, due to the presence of abundant monsoon rainfall, the Peshwa aqueducts collected surface water runoff (used as a water source), along with base flows from natural springs. The rest of the system relied on fundamental principles of gravity and pressure, in line with the local topography.

It is worth pondering that in many similar cases of water management, opportunities and outcomes have often been constrained by technology and communication. However, the competent use of available resources resulted in systems that continue to sustain communities and if maintained, can be functional even after centuries.

Conclusion and Future Possibilities

Today, the heritage and cultural value of the partially remaining structure of the Peshwa *nahar* persists. The associated pride and sense of belonging felt by citizens of Pune should be tapped as a force for the system's conservation and preservation. It is also important to demystify people's absolute dependence on centralized water supply systems and supplementary unorganized systems like tankers, which exist due to political patronage and not necessarily because of any benefit to society. It is important to diversify water supply sources by moving toward local and decentralized systems. In times of climate change, using already existing decentralized water systems will help make it possible to adapt to the water stresses of the future. In the present case, though the historic system cannot be fully recovered, its core values can be borrowed and implemented to create a sustainable water infrastructure. The aqueduct system is a perfect example of a "value case," since it combines climate resilient infrastructure, effective partnerships and innovative water management along with the potential for heritage preservation (D'Agostino and Hein 2024). In addition to water's obvious value as a utility, it is important to consider how local stakeholders may see opportunities for job creation and education in the need to create local bodies and institutions for maintenance and management of the system.

The existing research, data and documentation concerning the Peshwa *nahar* system can aid the development of educational museums and historical, recreational and cultural tours, which could involve local citizens, student bodies and university departments. Because this is a Grade-I heritage structure, implementation of these strategies would require a robust framework at the municipal corporation level (Heritage Committee 2017). This could be achieved with a successful bid for Corporate Social Responsibility funding to preserve the last remnants of the water system and by

connecting with programs such as “Adopt a Heritage" proposed by the Ministry of Tourism (2020).

The Peshwa *nahar* system merits a cohesive and collaborative approach that not only safeguards the historic structure but has the potential to become a model for future water system design.

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Parched Paradise: Building a Common Future Amid the Crisis of Modern Water in Mexico City

David Sauer

Abstract
For more than a century, the *ejido* system, a historic water and land management system in rural areas of Mexico, has provided a spatial and social context for long-term, sustainable water distribution. The advent of public water distribution under the paradigm of so-called modern water has led the authorities of Mexico City to over-rely on a supply-side approach. As a result, the hydrological boundaries of the local and neighboring watersheds have been stretched to a dangerous degree. Furthermore, many residents experience limited access to clean water. Today we need to rethink the role of state, society and the environment to inspire future community practices in the urban context. This article proposes a location and design for a community building in an irregular neighborhood in the western hillslopes of Mexico City, which could function as a platform for collective action, inspired by *ejido* elements.

Policy Recommendations

- Establish the political framework for a decentralized water governance model and its protection from external actors. Allocate structural funding for this type of local management.
- Develop educational programs to raise awareness about the importance of water conservation and the benefits of community-led water management. Encourage the adoption of a "water culture" that promotes visibility and respect for water as a shared resource.
- Recognize and integrate the principles of traditional water management systems and technologies.

KEYWORDS

Ejidos
Mexico
Modern water
Water commons
Local governance

WATER VALUES

CLIMATE

Cwb: Subtropical highland climate

< Fig. 1 Inside view of a 118-inch HDPE pipe used in stormwater and sewer systems (Source: Tomas Castelazo, 2017. CC BY-SA 4.0, via Wikimedia Commons).

Introduction

In the twentieth century, the natural water system was systematically overexploited to sustain the expansion of Mexico City. Lakes and rivers were altered to meet the city's needs. What used to be an almost "paradisic" area, described by the American writer Brantz Mayer in 1847 as "filled with such variety of land and water" developed under Indigenous leadership, had eroded under colonial rule. Modernization efforts erased the remainder of the hydro-social equilibrium by transforming the conception of water from a shared resource into a strictly utilitarian one, spurring massive infrastructure projects like the Water Works, Lerma-Cutzamala System and the Deep-Drainage System.

Societal developments in modern Mexico have been fueled by what geographical philosopher Jamie Linton (2013) christened the "paradigm of modern water." The inherent contradiction of the "utilitarian" perspective of water birthed many social and environmental distortions. Water was abstracted from socio cultural contexts, becoming a universally exploitable resource. Specialized, technocratic water authorities were commissioned to consolidate power and expertise over the resource, creating the state-hydraulic paradigm (Bakker 2003).

In Mexico City, symptoms of the problem vary. Affluent residents shield themselves from most ailments while the poor suffer. The inherent power balance of the modern water system and widespread corruption (Eakin et al. 2016; Vitz 2018) have left those suffering the crisis without a platform for agency. This article first contrasts modern water's role in Mexico City and compares its (dis)functionality with the historic rural water management of the *ejidos*. It then advocates for translocating the *ejidos* to Mexico City, promoting communal water narratives and urban emancipation. The final section presents the author's design for a translocated *ejido* water complex in an irregular settlement of Mexico City.

The Mexican Commons

Under President Porfirio Díaz, Spanish settlers expropriated large swaths of Indigenously owned lands. The process led to strong rural discontent and fueled the Mexican Revolution in the 1910s. In response to revolutionary demands for land and liberty, the 1917 Constitution's Article 27 introduced the *ejidos*, a communal land management system inspired by the Aztec calpulli (Kourí 2015).

While the technical definition of *ejido* territory and its governmental structure are contested, "in terms of its performativity [...], *ejidos* are neither public nor private, but 'social property'" (Flores Hernandez 2020, 184). Central to its functionality is the Asemblea Ejidal (General Assembly), composed of all ejidatarios. Elections form the Ejidal Commissary and a surveillance council. The former coordinates the daily operations, organizes meetings and communal works, addresses conflicts and communicates with authorities. The latter intervenes in cases of Commissary misconduct. Ejidatarios also have the option to introduce Internal procedures and regulations (Codigo Interno). Members meet regularly in the General Assembly in spaces like school buildings or specially built *ejido* houses (Schroeder and Castillo 2013). Attendance is compulsory and absence is financially penalized. Collective matters are decided by majority vote.

Spatially, the *ejido* territory is divided into housing lots, private farming and communal use. Collective governance and action occur in communal

areas. These areas usually constitute resources best exploited communally, such as pasture or forest. The assembly ensures fair distribution of tasks and benefits. Fraud by members is generally punished internally (Barsimantov et al. 2010). The earnings are partially collected in *ejido* funds. Published sources highlight significant variation among *ejidos* in their collective vision and capacity for action, reflected in either large communal lands or predominantly private ones. The political economist Elinor Ostrom attributes these differing outcomes of collective action to the respective resources and social attributes of the particular resource system operating in a specific socio-spatial context (Ostrom 1990). However, solid cases for successful collective management exist for forest management and water supply (Schroeder and Castillo 2013; Hausmann 2014; López-Villamar et al. 2013).The map in figure 2 explores one such case study. Reduced government support in the 1970s and 1980s led to neoliberal reforms in 1992 under President Salinas de Gortari, before NAFTA (Barnes 2009). These reforms aimed to open the Mexican economy to global markets, privatizing *ejido* lands through the PROCEDE scheme. By 2006, about 93 per cent of *ejidos* were certified, allowing them to decide on privatization (Escobar 2006).

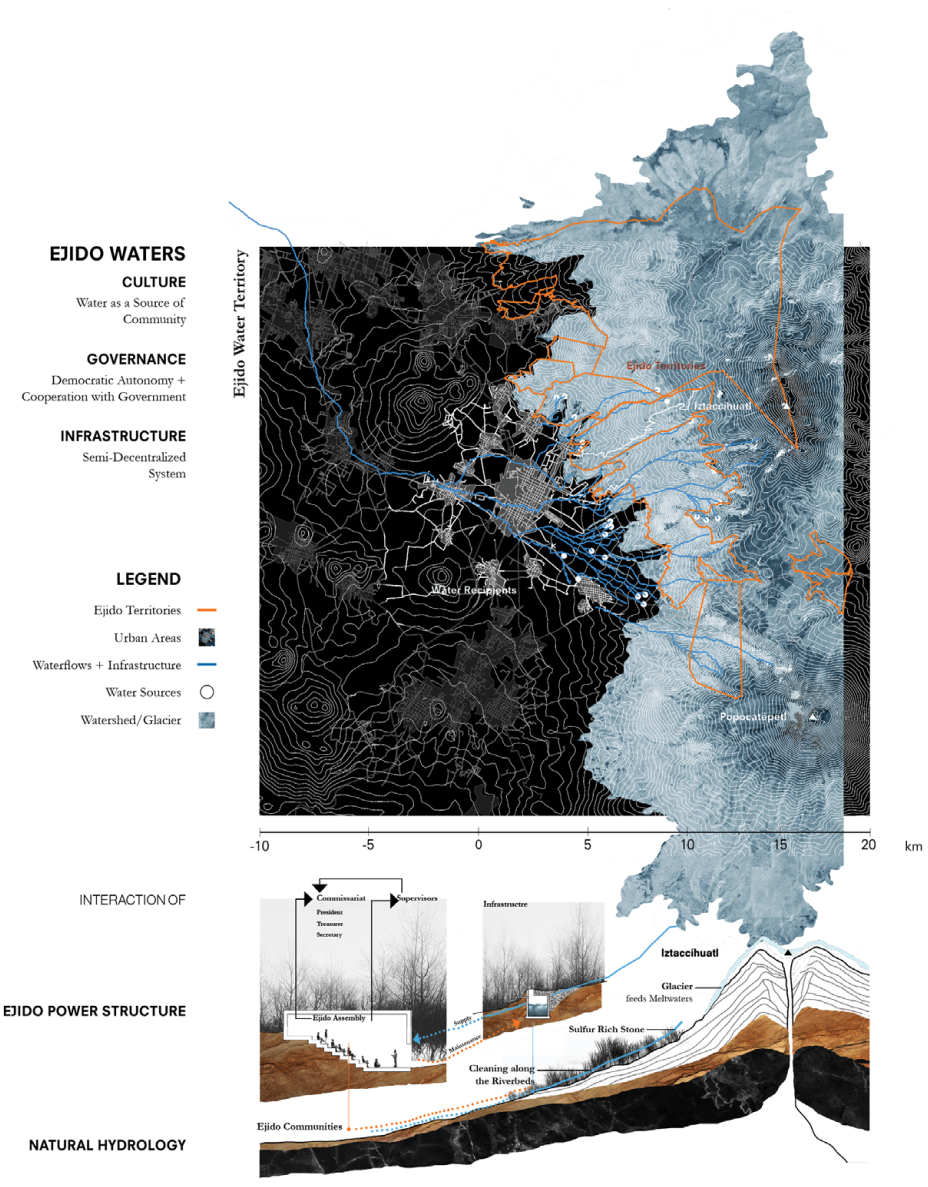
Despite the pressures, the system largely proved resilient to land privatization and the allure of external claims. This resilience suggests that translocating the *ejido* system from rural to urban areas offers an alternative to the subverted role of the state, society and water in Mexico City.

The Crisis of Modern Water

The crisis of modern water is rooted in the profound transformation of Mexico City's environmental and political landscape. By the late nineteenth century, unsanitary conditions, including inadequate sewage, polluted supply systems, and floods from the contaminated Lake Texcoco, prompted the first large-scale modern projects. These were only the beginning. They reshaped the city for capitalist urbanization and industrialization efforts, commodifying water and consolidating state power in newly formed authorities as the sole providers of water (Vitz 2018).

Central to modern water is the promise of universal access to modern residents. Access, however, has been systematically impeded for marginalized residents. This has been the case regardless of time frame or spatial configurations like for the rent strikers of the 1920s (Vitz 2018), the self-help housing settlers until the 1990s (Ward 1990) and working-class neighborhoods under the neoliberal *tandeo* system (Eakin et al. 2016; Schwarz 2021). Water access was thus politically weaponized to keep receivers in line with the benefactor's interests (Eakin et al. 2016; Vitz 2018; Ward 1990). State interventions under the paradigm of modern water have reshaped the hydrological landscape (fig. 3). As the omnipresent lakes were gradually drained for a "smog-infested desert of concrete sprawl," the "Paradise" of past centuries was parched. These transformations complicate a revival of traditional practices, as Matthew Vitz (2018) argues.

Environmentally, the supply and drainage systems heavily strain the hydrological limits of the basin and beyond. Local aquifers are exploited at an unprecedented rate, leading to subsidence and infrastructural failure (Tellman et al. 2018). The interbasin water transfers plunder water sources of neighboring watersheds. Full operational capacity is restricted, destroying local agricultural livelihoods (Perló and González



Source:

Lopez Villamar, Silvia Marlen. *"Sistemas de deshielo para abastecimiento de agua potable: Organización comunitaria y multicomunitaria en la región de los volcanes" (Meltwater Systems for Potable Water Supply: Community and Multi-Community Organization in the Volcano Region).* Master's thesis, Colegio de Postgraduados, Programa de Estudios en Desarrollo Rural, 2012.

^ Fig. 2 The Popocatépetl Ejidos manage water through glacier-melt capture infrastructure, showcasing local governance for sustainable hydrological livelihoods (Source: David Sauer, 2024).

2009). Surface sealing from unplanned urban expansion causes severe rainy season flooding. Sewage waters are only partially treated and transported to the Mezquital Valley, where the unfiltered water is used in agricultural production (Carrera-Hernandez 2018). In light of the myriad of social and environmental distortions, it is undeniable that modern water is in crisis and has been for a long time.

Climate change and inadequate infrastructure threaten to worsen the existing distortions. Continuing the current system increasingly becomes a Sisyphean task with dire consequences for over 20 million inhabitants. Nevertheless, systemic asymmetry incentivizes the continuation of modern water adaptations as a means to sustain political power, an "immediately viable and familiar way to increase robustness," which might jeopardize long-term sustainability (Tellman et al. 2018).

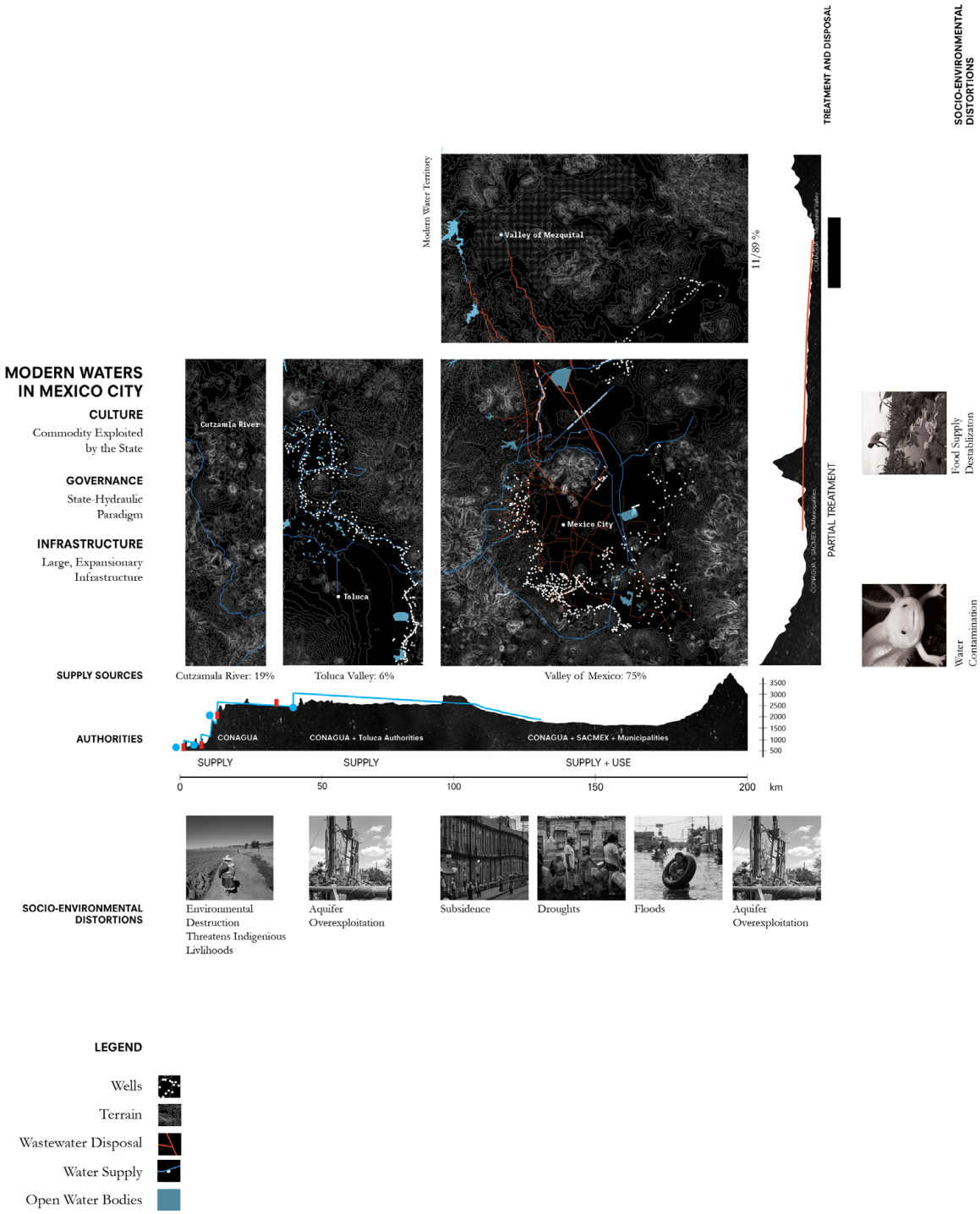
Decentralized water practices have emerged as an alternative to the classic state provisions. The NGO Isla Urbana has installed rainwater systems for about half a million people in cooperation with the Secretaría del Medio Ambiente (Isla Urbana, n.d.). In theory, constructed wetlands will lower water vulnerabilities on a large scale in the city (Barkwith and Godoy-Lorite 2021). However, if left to individuals these solutions may become just another form of capitalist "exploitation". As Peter M. Ward vividly depicts in his analysis of self-help housing developments in the last century, the absence of systemic solutions forced working-class residents to endure exploitation both in the workplace and during their limited free time by constructing their own homes (Ward 1990). The fragmentation of communities and their interests has been a fundamental factor in shaping the exploitative nature of modern water in Mexico City.

The Need for Local Governance and *Ejido* Translocation

As socio-environmental pressures mount on an inadequate water system, many of modern water's inherent distortions are in danger of being reproduced. Researchers warn that a crisis "may not be very far off" (Tortajada and Castelán 2003). The specific configuration of systemic corruption and the inherent power asymmetry of the state-hydraulic paradigm has left little hydrological agency, as evidenced by numerous political dealings surrounding water. Here Linton's (2013) "recombination of water and society" with "people at the center" becomes imperative. *Ejidos* could inspire a future platform for such a "people-centered" and local governance. With decentralized hydrological technologies, such a translocation could create a distinctly Mexican "water-sensitive community" (Chadfield et al. 2022), addressing:

- Participation and collective governance – Unlike modern water's individualization, an *ejido* structure emphasizes community participation and collective decision-making. The General Assemblies would form the backbone for residents to address social and environmental needs in an inclusive and crucially accountable fashion.

- Ownership and "water culture" – Under modern water, residents are relegated to being water consumers while relying on public servants to speak for their interests. The *ejido* mixed-ownership model of communal, private and social parcels fosters a platform for collective emancipation and equitable resource use. Collective governance and ownership ensure the "visibility of water," fostering



^ Fig. 3 Modern water has altered watershed boundaries, causing interconnected socio-environmental distortions. The map explores these issues' multi-dimensionality and relationships (Source: David Sauer, 2024).

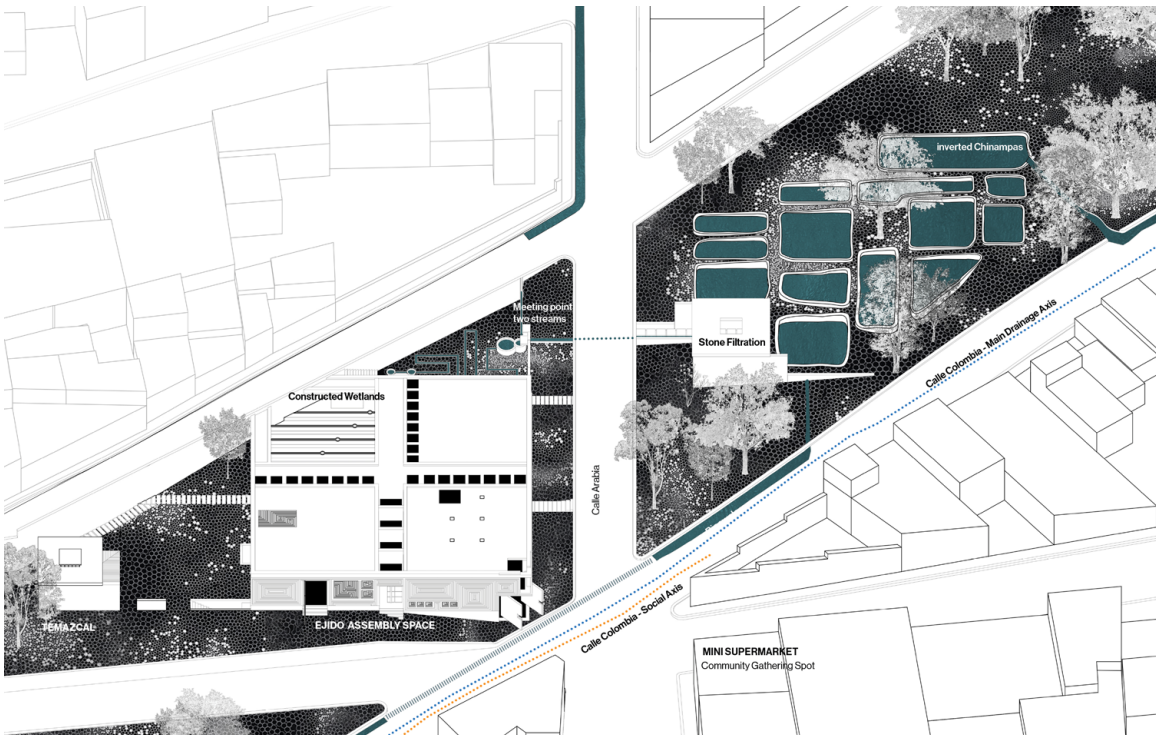
a stronger water culture and conservation (Brown 2017).

- Autonomy and external relations – *Ejidos* derive much of their agency from their well-defined territoriality. Like self-help housing, this could limit external actors' power while establishing a direct identity. However, this does not need to be an exclusive interpretation of autonomy. Some *ejidos* show that relationships with external actors can be based on sustainable cooperation with authorities and other *ejidos* (López-Villamar et al. 2013).

A Proposal for an *Ejido* Community Building

Due to the lack of economic alternatives in the post-war boom, urban working-class residents were pushed to self-build their houses on land with precarious titles, so-called irregular settlements. Limited institutional involvement required the population to organize and advocate for infrastructure provisions. While an important precedent for collective action, the process should not be romanticized, as "self-build can increase labor exploitation and contribute to capital accumulation" (Connolly 1982). Nevertheless, the resulting close-knit character of these communities provides a favorable foundation for an *ejido* translocation. I chose one of these former settlements, Mexico 68, which is a parched area for weeks at a time, as a site for my intervention. To this day, water access in the neighborhood remains limited, with residents sometimes not receiving water for days on end. Paradoxically many streets flood during the rainy season.

The proposed *ejido* is structured around the central role of the assembly space (fig.4), like



^ Fig. 4 The building complex is situated in an underutilized green space along the main drainage and social axis. Its components (right to left) – bioswales, inverted *chinampas*, stone filtration systems, constructed wetlands and an underground cistern – are designed to reengage the public with water while transforming the neglected area (Source: David Sauer, 2024).

^ Fig. 5 The facade plays upon the rich architectural heritage of Aztec temples. It interprets the cultivation of water streams/ripples through human intervention, publicly displaying a narrative even in the absence of water in the dry period (Source: David Sauer, 2024).

its rural counterpart. The density of the urban context allows reimagining the governance spaces and hydrofunctional components to be intertwined. This combination spatializes water's social, political and cultural proximity to the social fabric around it. The site is on a lively street, also serving as the neighborhood's key drainage axis. The expressive façade (fig. 5), referencing Aztec temple exteriors, is a visual attraction for visitors and *ejidatarios*. Water ripples cultivated by human intervention are artistically interpreted. The relevance of water even in its absence during the dry period is publicly and visibly celebrated.

The interior contrasts the busy exterior with a quiet atmosphere, operating similarly to religious facilities. Functionally the building captures, cleans and stores urban water runoff from the street using eco-technologies. The individual components (fig. 4), such as bioswales collecting water in an artificial riverbed at the street edges, a series of water ponds in the park to store the unfiltered water, a stone garden filtering large debris, a constructed wetland patio (fig. 7) and the underground walk-in cistern, are atmospherically "charged" to visibly and sensually engage the *ejido* with water in a positive manner (fig. 6, 7). The material pallet of plants, rammed earth walls, volcanic stone elements and underground water storage mirrors the geological conditions that would "naturally" clean rainwater (fig. 7).

The proposed hydrological interventions aim to establish a platform for further local transformation. This process is defined through social components, specifically democratic deci-

sion-making through the *ejido* institution and engagement through education. These intangible components are spatialized through the *ejido* assembly space and a hydrological library. Both spaces are typologically bound to water but also physically, as openings in the roof allow filtered rainwater to enter. The combination of social and hydrological interventions aims to establish a prototype for urban hydrological *ejidos*. This process imagines the hydrological landscape of Mexico City as a myriad of distinct local conceptions, a condition long lost to the abstraction of modern water.

The design of the building complex reflects on the use of heritage in a severely altered context, specifically which aspects ought to be continued, how and by whom. It achieves this through typological innovation by recombining the governance and infrastructural spaces of an *ejido* case study, referencing and further developing vernacular architectural heritage by incorporating Aztec elements such as aqueducts and stone masonry traditions and promoting a collective water culture through the visible and artistic spatialization of water infrastructure.

The proposal does not recreate what has been lost. It integrates traditional and modern approaches to collectively living with water in a distinctly Mexican interpretation. Nevertheless, the proposal carries implications for other water heritage projects. Heritage is not a static concept; it is locally developed and fluid, shaped by the values and contributions of communities. The approach challenges top-down interpretations of heritage, embracing a distinctly bottom-up perspective that empowers communities to define and develop their collective narratives.

^ Fig. 6 The building is not a fully enclosed space sheltering against the elements. Water permeates the exterior, creating points of interaction between people and water (Source: David Sauer, 2024).

^ Fig. 7 The vernacular patio purifies water with constructed wetlands (Source: David Sauer, 2024).

Conclusion

Modern water in Mexico City replaced Indigenous collective ownership with the state-hydraulic paradigm. Central to this transformation was the promise of universal access for its modern residents, a promise yet to be fulfilled. The consequent transformations of the twentieth century have overstretched hydrological limits. Climate change threatens to further destabilize an already unstable water system, with serious implications, especially for marginalized communities

Hope remains, as modern water's technological lock-in has overlooked decentralized solutions. Adopting eco-technologies could tap underutilized water sources such as rain and grey water. However, the decentralization of supply, use and treatment will only amount to a solution with a parallel decentralization of power. Without this, it risks becoming another avenue of capitalist exploitation, as self-build housing has proved to be. Nevertheless, these technologies offer a foundation for implementing decentralized water governance.

Over the past century, *ejidos* have proven resilient in governing common resources and ensuring equitable, sustainable distribution in cooperation with the state. Thus, translocating the *ejido* system to the urban landscape of Mexico City could offer a platform to address many of the distortions of modern water. Corresponding

interventions, like the proposed *ejido* complex in Mexico 68, must celebrate a positive relationship with water by making it visible in its infrastructure and governance spaces.

Despite modern water's destructive history over the past century, the future of Mexico City remains to be determined. The relentless demand for increased water supply is deeply tied to the inherent power imbalance. Authorities "choose what environmental signal or threat to respond to, when it matters and for whom, and how to respond" (Tellman et al. 2018). This selective response has clearly favored those close(r) to power. Therefore, the continued expectation that the state will act as the ultimate authority on water must be questioned. Water is a human right, but like many rights before it, it is to be collectively upheld. Only then does Mexico City stand the chance to "unparch Paradise."

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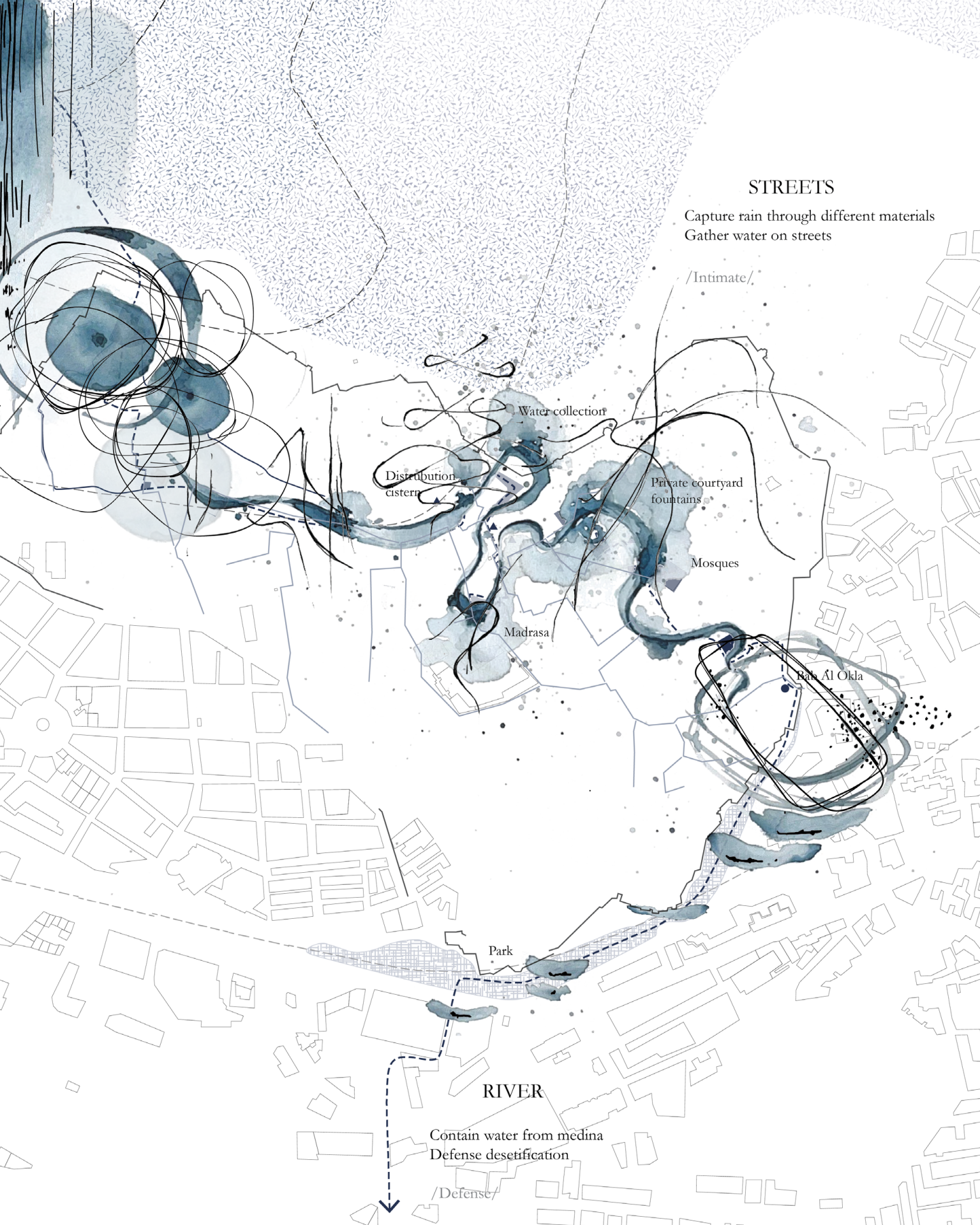
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Capture rain through different materials
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Private courtyard fountains
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Designing with Sound as a Methodology to Reconnect Water, Culture and Heritage in Tetouan, Morocco

Regina Klinger, Nicola Vollmer & Aylin Yazici

Abstract
This paper explores the use of soundscape design to reconnect the people of Tetouan, Morocco, with their cultural heritage as embodied in their historic *skundo* water system. Our understanding of soundscapes within this context was developed through an in-depth soundscape analysis within the medina of Tetouan that identified how the *skundo* system and its audible sounds are still present. To amplify the presence of the *skundo* system and raise awareness of the value of water, we used the system's traditional clay pipes, with their audible and tactile qualities, as focal elements in our design interventions. Through the soundscape analysis, we designed interventions in several unique spaces that highlight the value of water within two possible future climate scenarios: one involving an abundance of water and the other its absence. Through these sound interventions, we aim to reconnect residents with their water and cultural heritage and emphasize the importance of sustainable water management while integrating local traditions.

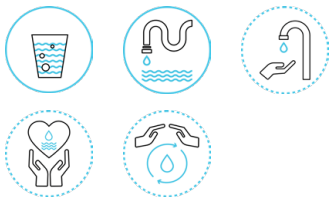
Policy Recommendations

- Prioritize the preservation and integration of traditional water systems to maintain cultural heritage while addressing contemporary water management challenges.
- Encourage local communities to actively participate in the preservation of water heritage through initiatives that raise awareness of the historical and cultural importance of water systems.
- Promote the use of innovative methodologies, such as soundscape design.

KEYWORDS

Skundo
Medina
Morocco
Soundscape
Water and cultural heritage

WATER ICONS



CLIMATE

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Csa: Hot-summer Mediterranean climate

< Fig. 1 Masterplan soundwalk (Source: C. Chang, 2024).

Introduction

Tetouan is a historic city in northern Morocco located between the Mediterranean Sea, the Martil River and the Rif Mountains. This geographical setting creates an interconnected natural water system that has played an important role in shaping the city's development. The *skundo* system (fig. 2), a native network for transporting water, originates in the mountains to the north of Tetouan, where water is gathered and funneled underground through clay pipes, relying solely on gravity. These pipes not only transport water but also naturally purify it, making it a key resource in urban life.

The cleaned water flows first into general reservoirs and distribution points before reaching public taps, fountains, mosques, madrassas and hammams. After serving these critical communal spaces, the water continues its journey to the river and finally northward to the sea. The system exemplifies Tetouan's long-standing heritage of managing natural resources efficiently while connecting its people with the surrounding landscape, from mountain to sea.

Water, both physically and symbolically, plays a significant role in the local culture. In Islamic tradition, water represents purification, spiritual renewal and sustenance. Not only has the *skundo* system served the city's water needs, but it has also helped to create traditional and cultural places, meaning it is the literal embodiment of heritage. Traditionally, these waters and the rituals associated with them had audible qualities that were experienced as part of locals' everyday lives—they were seen and heard as the water sprang from the depths of the mountains, through the *skundo* clay pipes and out of the fountains into the medina, the "old walled core" of the city center.

^ Fig. 2 *Skundo* distribution system (Source: N. Vollmer, 2024).

However, the heritage and the presence of the *skundo* system have faded due to the dilapidation of this traditional water supply network and the commodification of water. The question that motivated our soundscape project was "What if you could hear the water of Tetouan again?"

For residents of the medina, water still shapes everyday life, whether it is part of preparing meals, brewing mint tea or performing ablutions. The communal act of collecting water from the public basins of the *skundo* system creates a sense of community. In addition, some individuals continue to embody the traditional relationship with water, preserving its significance for future generations. One such figure is "The blind plumber of Tetouan," whose unique ability to hear the water flow enables him to maintain the hidden *skundo* pipes behind walls and under the ground (Calder-

wood and Attwell 2010). His work is not only a practical necessity but also a reminder to the people of their historical ties with water and the importance of preserving their cultural identity. Even though the cultural significance of water remains through individuals like the blind plumber, as well as through common religious practices and daily routines, the system that connects people to their history has faded into the fabric of the city, due to the lack of water availability (New Arab Staff & Agencies 2022) and the modernization of the local water supply system (Strava 2024). This research-by-design therefore prioritizes the preservation and integration of traditional water systems to maintain cultural heritage while addressing contemporary water management challenges.

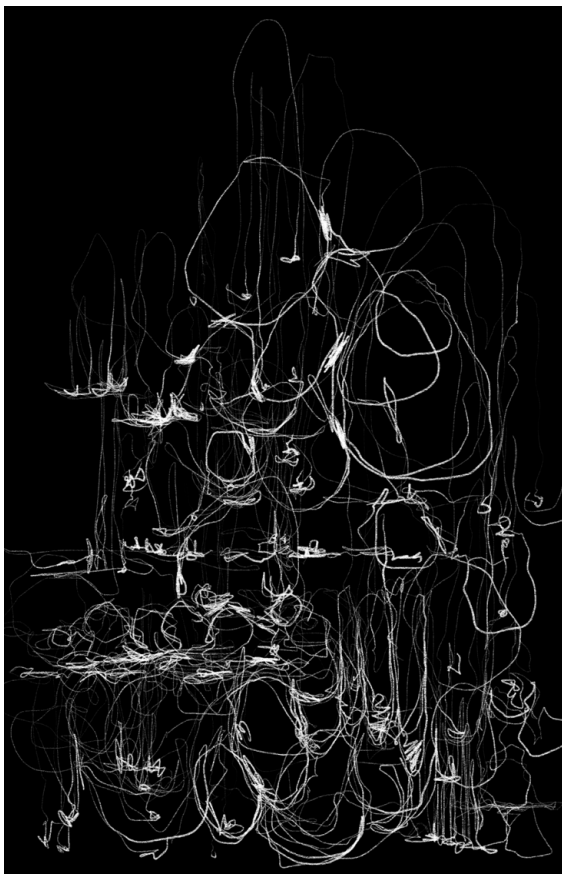
Like many places around the world, Tetouan is facing the urgent issue of climate change. Water scarcity is a growing challenge that raises concerns about how people will sustain their daily lives and traditions (El Bouenani et al. 2020). The region has already seen a decline in rainfall, with some studies predicting a reduction of up to 20 per cent in annual precipitation over the next few decades, which exacerbates the strain on already limited water resources (World Bank 2022). In addition, rapid urbanization and population growth in Tetouan are further increasing the water demand, making traditional systems like the *skundo* less effective (Alzahid 2024). In response to these pressing issues, the Moroccan government has announced plans to introduce modern technologies to improve the water infrastructure. However, these projects risk endangering the heritage of Tetouan by potentially replacing the traditional system with new piping (Arab Fund for Economic and Social Development 2024). This potential creates tension between modernization and the preservation of Tetouan's cultural heritage.

The soundscape methodology that we developed in this project was designed to address these issues by enhancing existing sounds of water and introducing additional audible elements within the city, thus encouraging local communities to actively perceive the relationships between water, culture and heritage. Through our sound design initiatives, we aim to raise awareness of the historical and cultural importance of the traditional water system. Furthermore, we want to promote the use of innovative methodologies, such as soundscape design, to reconnect Tetouan's residents with their water heritage on a perceptual level and foster climate awareness.

Analysis and Tools

To apply the concept of soundscapes as a method to reconnect water-culture-heritage in the medina of Tetouan, we used sound as a tool to explore the existing traditional *skundo* system that bubbles its way to the surface of the city. In May 2024, the Urban Archipelago studio briefly visited Tetouan. The experience of the audible waterscape revealed a force that lives in the Tetouan soil, connecting the residents with the workers, shops and mosques and the tourists with the locals and the animals. Listening closely to the sounds of water gave the impression that this lively water is a dynamic but often invisible driver that feeds the city and its workings. These existing soundscapes provided the foundation for our design interventions, which seek to make water's abundance or absence tangible through auditory experiences.

The *skundo* system is a carrier of stories, history and life from the mountain, through the city and out into the landscape of Morocco—an infrastructure that has shaped the medina (Benaboud 2024). The method of listening and

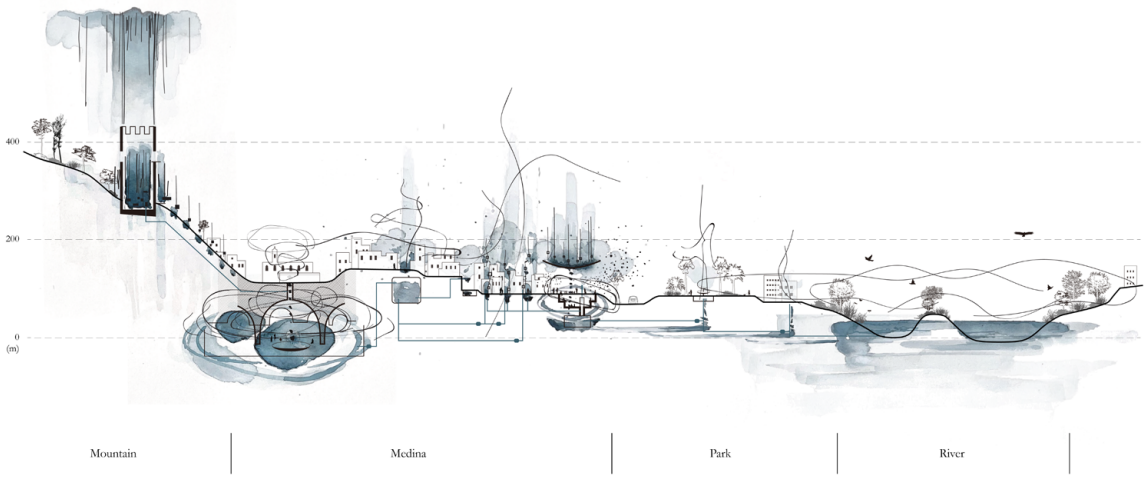


^ Fig. 3 Etchings and markings of a soundscape (Source: N. Vollmer, 2024).

tracing the sounds from the *skundo* became the lens of our exploration of the medina, including its people, practices and spaces, rendering the heritage visible and newly imagined within the city. We further linked the non-audible and audible flow of water to the existing and future climate conditions of Tetouan. Through an analysis of how the current climate conditions affect water availability in the medina, as well as a workshop on imagining extreme possibilities for the Moroccan climate, we developed two possible climate scenarios that we used to explore the experiences of the designed soundscapes. The first involves the abundance of water, which means long and extreme periods of rain and flooding. This climate exploration strengthens the connection between people, water and culture by allowing water (the abundance or lack thereof) to be the voice. Consequently, the second involves a lack of sounds (in this case related to the lack of water sounds), which means a condition of drought, lack of rain and possible sandstorms, as well as extended periods of heat.

Exploring soundscapes can be a daunting approach within a city with an unfamiliar language and practices and a potentially overwhelming blur of sounds, but our approach was to focus on the universal and familiar sound of water. For the first analysis layer, we were guided by the help of experts and locals to find where the *skundo* system showed itself through openings in walls, taps, fountains and private gardens and under the drains in the streets. In this way we were able to record the bubbling, trickling and plopping of the existing water that we found in the narrow streets of the medina.

The second layer of sounds that we extracted were the noises of people and activities within the context of the water source. What were people doing? Was it loud or silent? Was this a place of refuge or activity? A place of gathering, resting or working? By paying attention to the multiple layers of forces creating the existing soundscapes, we developed not only sections that visualized the physical creation of sounds, but also abstract drawings, etchings, scratches and markings, which represent our individual experiences of the city's sounds (fig. 3). These methods of extracting and interpreting the sound components made it possible to develop sound typologies that eventually sculpted our spatial design interventions.
Discovering the soundscape of Tetouan made us aware of connections that we did not origi-



^ Fig. 4 Longitudinal sequences of the soundwalk from the mountain to the river connecting to the subterranean *skundo* system (Source: C. Chang, 2024).

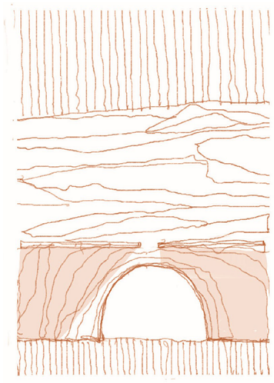
nally see or notice; it made us sensitive to what was creating these sounds and why. Through this analysis, we spatialized our findings into a tangible sound design representing the (non-) audible sounds of water flowing that inherits the narrative of the existing *skundo* system and aims to reinforce the water-culture-heritage relation as a circular system (once again).

Creating Audible Awareness

We translated our findings, represented by drawings, sketches and recordings of the voice of the water, into spatial expressions along a longitudinal sequence of public urban places. We created a soundwalk that narrates the journey of a drop from source (mountain) through the human scale (medina) to the outskirts (riverscape) (fig. 4).

We spatialized this narrative into a design based on the subterranean *skundo* system. While working with the existing sounds we mapped out, we then imagined new sounds according to the two scenarios of flood (presence of water sounds) and drought (absence of water sounds). The new sounds would then encounter the irregularity of urban sounds and the distant, passive bubbling of water sources that currently characterize the lively streets of Tetouan. Before and during the creation of a soundwalk design, several guiding questions helped shape our design approach: Which sounds will our design create in both scenarios, we wondered? How many design interventions should we include along the long line from the mountain to the river? How can we transmit a sense of climate awareness through the sounds we design? Which materials are suitable to create a sustainable and inclusive sound design that resonates with the people encountering it? And finally, how can we materialize these designed sounds in a way that they can be experienced alongside our recorded soundscapes?

These questions were answered in different design locations along the soundwalk: The Dersa Mountains, the ruined barracks and former prison (fig. 5), the houses and ritual places of the people, the streetscapes (fig. 6) and the new marketplace (fig. 7). The journey of the water



^ Fig. 5 Concept mountains and barracks (Source: N. Vollmer, 2024).

^ Fig. 6 Concept streetscape (Source: N. Vollmer, 2024).

^ Fig. 7 Concept market space (Source: N. Vollmer, 2024).

continues then toward the outskirts of the city, where, after having collected enough memories and wisdom to access the outside world, it ends up in the river landscape that leads it toward the sea.

Part 1 of the soundwalk starts with the area of Tetouan that we experienced as "other-worldly" and distant, yet vital to the heritage—the Dersa Mountains (fig. 8). The first design intervention is located within the old ruins of the Jebel Dersa Tower (fig. 14), which will be reused as a water storage cistern that fills up during events of prolonged rainfall.

Through this design intervention we aim to make the water readable for residents: Once the tower has filled up to a certain height, the water will overflow through the existing openings and become visible on the outside in the form of a waterfall-like dripping and splashing. The sounds created will spread with the wind and the abundance of water will be audible and visible from the city. The water will then disappear underground and connect via pipes to the *skundo* system.

Further along the water's path, it seeps into the area of human settlement, crossing the boundary into the space where the people of Tetouan originally started to manage their surroundings and livelihood. Here the mysterious quality of the mountain meets the historically rich, robust and functional infrastructures that served the growth of the city of Tetouan (fig. 9). The design intervention for this area is located within the ruined barracks and former prison, which are currently hidden under the city (fig. 16).

In our design, the water drips into these caves and fills the new proposed water tanks located under the barracks, after which the water flows into the *skundo* distribution system (fig. 17).

^ Fig. 8 Proposed sound drawing of the mountain, with sounds characterized as "unearthly, echoing of rain, crashing and dripping, gushing, thunderous wind" (Source: N. Vollmer, 2024)

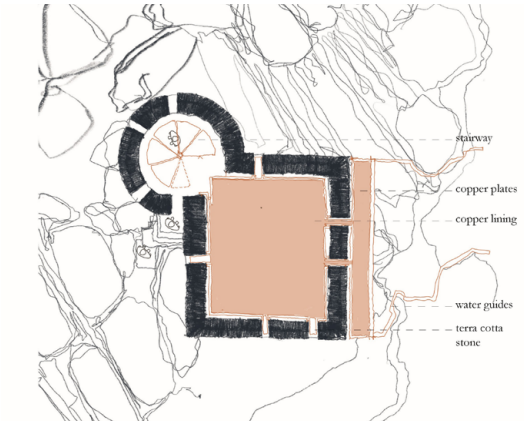
^ Fig. 9 Proposed sound drawing of the cave and barracks, marked by near silence and a heightened awareness of one's own heartbeat, with sounds characterized as "dripping of water and echoes" (Source: N. Vollmer, 2024).

^ Fig. 10 Proposed sound drawing of the communal street, filled with social activity and interaction, with sounds characterized as "gathering, eventful, gushing and plopping, water on water" (Source: N. Vollmer, 2024).

^ Fig. 11 Proposed sound drawing of the distribution cistern, establishing a sense of belonging, with sounds characterized as "rhythmic, moving, trickling from one to the other" (Source: N. Vollmer, 2024).

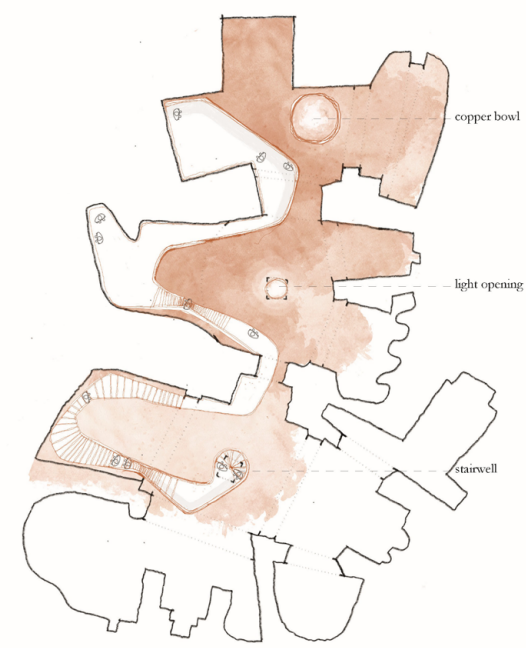
^ Fig. 12 Proposed sound drawing of the residential street, with sounds characterized as "rustling wind, movement of people, wind and water on fabric" (Source: N. Vollmer, 2024).

^ Fig. 13 Proposed sound drawing of the market square, with rich sounds representing people, market animals, talking, living, relaxing, overflowing water (Source: N. Vollmer, 2024).



^ Fig. 14 Floor plan of the Dersa Tower (Source: N. Vollmer, 2024).

^ Fig. 15 Dersa Tower in different scenarios (Source: N. Vollmer, 2024).

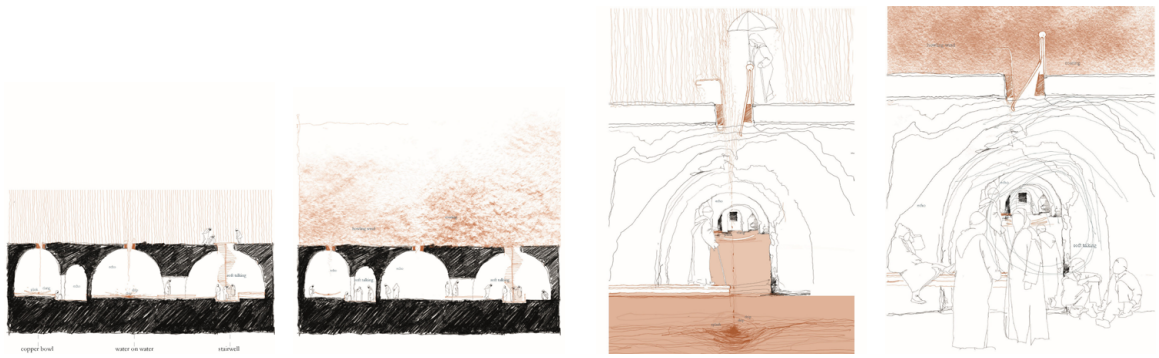


^ Fig. 16 Floor plan of the cave (Source: N. Vollmer, 2024).

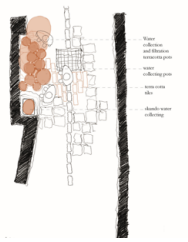
The purpose of the design intervention is to bring people back into this abandoned heritage space by making the caves accessible as cool spaces in times of extreme heat. The entire underground space is transformed into a water monument that captures discrete drops of mountain water and displays them as the central audible element. The sounds of the drops bounce off the resonating walls of this cave and form a gentle echo. The spatiality can also be experienced by listening to the drops crashing into a copper basin, which overflows with an abundance of water. The perceived sounds represent the solitude with which the prisoners lived within these caves and the hydrological stress of no – or little – rainfall.

In the second part of the soundwalk, the drop of water enters the human scale: the houses and cultural institutions. The water becomes part of personal narratives and rituals and therefore embodies the familiar and intimate sounds of the city (figs. 10, 11, 12). The water bubbles into the streets (figs. 18, 20, 22) and, together with proposed design interventions (figs. 19, 21, 23), it will make a valuable contribution to a rich sensory environment in which the inhabitants and visitors of Tetouan listen to the water with more awareness.

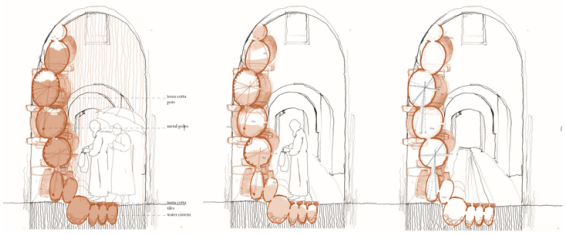
Our design makes visible springs and distribution systems that are currently hidden from the locals and passersby through small interventions such as tiles on the floor and openings in the wooden doors that allow people to find and listen to the water elements, while still restricting access to the critical infrastructure (figs. 20, 21). Along the streetscape, three spatial interventions will contribute to the sensorial experience of the sounds of water. Here, clay pots, tent fabrics and copper linings will mark existing places where these materials were once used, inspiring remembrance of their function



^ Fig. 17 The cave in different scenarios (Source: N. Vollmer, 2024).



^ Fig. 18 Floor plan of the communal street (Source: N. Vollmer, 2024).



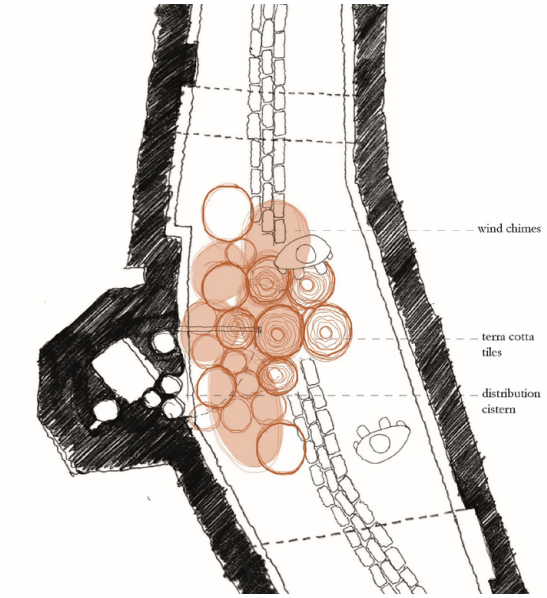
^ Fig. 19 The communal street in different scenarios (Source: N. Vollmer, 2024).

and meaning. Working with these materials in each of the locations, we create spaces for communal water collection (figs. 18, 19), spaces to gather around the distribution cistern and collect drinking water (figs. 20, 21) and spaces that work with the rainfall and wind, like the fabrics that give a rustling sound to the city's streets (figs. 22, 23).

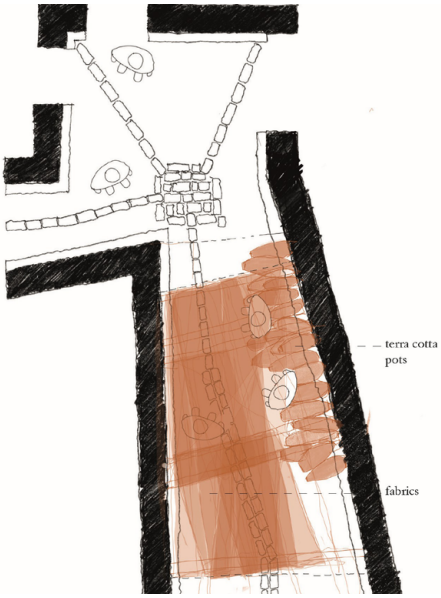
Toward the end of the medina, the water enters the third part of the soundwalk, the newly developed market square. This location resembles an accumulation of the sounds that we heard and gathered throughout the various medina streets (fig. 13). Here the pipes of the *skundo* system bring the water into a large overflow basin, which cools the square and brings the residents together (fig. 24). An overarching roof of fabric reaches over the square, letting light through but also directing water into clay pots, creating a place for locals and visitors to collect water. From here, the water exits the medina, ready to face the outside world of Tetouan (fig. 25).

The water gained knowledge, experience and stories by flowing through the sequences of the design, encountering people and their cultural practices. After this, it can enter the big natural reservoir – the river. From here it becomes part of the big sounds, exposed to flood and drought and going on a journey to tell the stories of the future. Our final step in designing the soundwalk was to make the intangible tangible by translating the sensorial designs, each with its own distinct spatial form and atmosphere, into clear architectural floor plans, sections and conceptual drawings.

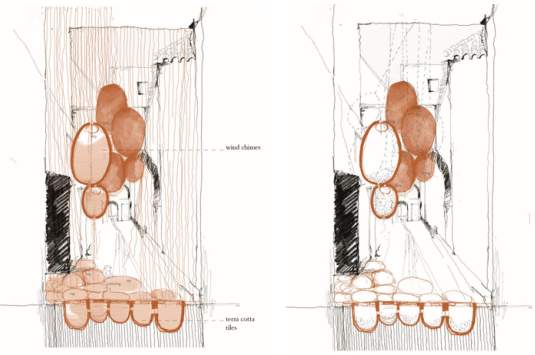
To make it possible for people to experience these architectural sound designs, we used sound creation software to design two versions of sound sequences and drawings that repre-



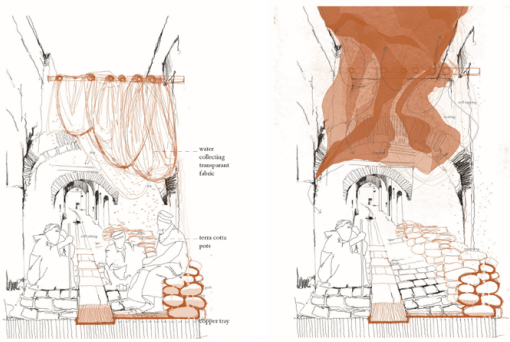
^ Fig. 20 Floor plan of the distribution cistern (Source: N. Vollmer, 2024).



^ Fig. 22 Floor plan of the residential street (Source: N. Vollmer, 2024).



^ Fig. 21 Distribution cistern in different scenarios (Source: N. Vollmer, 2024).



^ Fig. 23 Residential street in different scenarios (Source: N. Vollmer, 2024).

sent the audible features of the new spaces created. The first sound sequence represented the sounds of the soundwalk for the flood scenario, adding to the existing soundscape of Tetouan we recorded on the field trip. The second sound sequence represented the audible elements of the soundwalk during a period of long drought during which the sand of the Sahara takes over the city and creates sounds when encountering our designs.

After the two sequences were set up, we then recorded a video of the sounds being drawn by hand while simultaneously listening to our created audio recordings. Sound and sound drawings were then combined into a final video which represents the intangible.

In our design, the water-culture-heritage relation becomes circular again through the binding force of audible water flow between the people,

the abundance or absence of water and the heritage of the *skundo* water system. The residents become the stakeholders who function as "value-keepers," remembering the importance of the existing and perceivable *skundo* system.

Sound design video link: https://youtu.be/J37so_IdN88 (Source: R. Klinger, 2024).

Conclusion

While water remains vital to daily life, its direct connection to heritage has diminished in the present day. Modern interventions often disregard cultural and historical dimensions of water, such as Tetouan's *skundo* heritage. By analyzing the historical significance of the *skundo* system and employing sound as a tool for spatial design, our exploration of the *skundo* system's role in the city has demonstrated how traditional water infrastructure can be revitalized through design, reinforcing the importance of preserving and integrating such heritage within contemporary water management strategies. Through our engagement with Tetouan's urban and social infrastructure, we observed how community-driven participation strengthens the cultural connection to water, emphasizing the need for awareness initiatives that involve local stakeholders. Additionally, our methodology highlights how soundscape design serves as an innovative tool for making water heritage tangible, fostering a renewed sensory and spatial understanding of its presence in the city.
We recommend that any use of soundscape design to make water heritage visible, should focus on sustainable practices by utilizing local materials, such as clay in the case of Tetouan, while addressing contemporary challenges. Engaging with stakeholders and the local community is essential for fostering a renewed appreciation of the system.

Our approach faced limitations: Specifically, time constraints prevented in-depth engagement with the local community. Future research should incorporate participatory methods to ensure residents are involved in the conversation and decision-making processes. The integration of their perspectives ensures that the cultural significance of water is preserved and celebrated in the face of changing environmental conditions.

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Designing For Extremes: Heritage Strategies for Rising Sea Level Adaptation in The Hague

Marlies Augustijn, Mila Avellar Montezuma, Beate Begon, Jean-Paul Corten & Carola Hein

Abstract
This article presents insights gained from an international research-by-design workshop on the future of the historic harbor of Scheveningen, its heritage and the districts surrounding it in The Hague. The workshop – part of long-standing cooperation between Brazil and the Netherlands on heritage management – explored how and to what extent historic features can accommodate adaptation to rising sea levels. The results of the workshop provide insights for coastal cities worldwide and show that historic features can support nature-based and adaptive strategies for climate resilience and that it is possible to integrate heritage into spatial planning for sustainable urban futures.

Policy Recommendations

- Heritage conservation is important for addressing societal needs through climate adaptation. It should be relocated from the cultural domain, where it has traditionally emphasized history, identity and aesthetics, to the spatial planning domain.
- The Municipality of The Hague should continue taking a "research-by-design" approach while taking sea level rise into account regarding long-term maintenance projects along the coast and in the harbor, including landscape design projects, maintenance of the harbor quays as well as redevelopment projects such as the pier and heritage buildings.
- Local stakeholders should collaborate with local museums, events and outreach programs to disseminate innovative proposals and raise awareness.

KEYWORDS

Sea level rise
Urban resilience
Coastal protection
Heritage management
Designing for extremes

WATER ICONS

CLIMATE

Cfb: Oceanic climate

< Fig. 1 Spatialization of the design principles applied to the city and port scales (Source: NXR, 2024).

Introduction

Heritage holds significant potential as an asset in sustainable development and climate adaptation, as demonstrated globally by numerous urban revitalization efforts. However, this asset is often underutilized and neglected in discussions of development and the climate crisis. Heritage is often considered a vulnerable element in need of protection. For instance, UN SDG 11.4 focuses on the need to "protect the world's cultural and natural heritage" rather than on its ability to contribute to urgently required resilience (Van Oers and Pereira Roders 2014). The New Urban Agenda (Habitat III) takes a more practical approach to heritage, but it has not routinely included heritage in planning (United Nations Conference on Housing and Sustainable Urban Development Quito, Ecuador 2016). The Intergovernmental Panel on Climate Chance (IPCC), in a new report, Climate Change and Cities, also leaves little room to recognize the potential of (and threats to) the historic urban landscape (Special Report on Climate Change and Cities — IPCC). The n x r 2024 | Designing for Extremes research-by-design workshop held 17–21 June 2024, part of a long-standing collaboration between the city of Recife in Brazil and the Netherlands, explored this issue, focusing on the Dutch case of Scheveningen.

The Hague and Scheveningen Harbor

The Hague, the biggest Dutch coastal city in the densest river delta of northwestern Europe, provides an important case study regarding the impact of climate change and sea level rise on coastal cities – and the need for long-term adaptation and mitigation strategies (Kopp et al. 2017; Meulen et al. 2020). The sea has played an important role in shaping The Hague's identity. The sea, beach, dunes, port and boulevard

^ Fig. 2 Urban evolution (1665–1975) and contemporary spatial exploration of Scheveningen (Source: Gemeente Den Haag, DSO and Haagse Kaart (Gemeente Den Haag and Haags Historisch Museum).

offer both residents and visitors to Scheveningen opportunities for rest, recreation, sports, entrepreneurship and a lively environment (Morris et al. 2018; Harris et al. 2014).

Scheveningen is The Hague's seabound city quarter. Although administratively bound to the city since its origins, Scheveningen only merged gradually with The Hague's urban conglomerate in the twentieth century (fig. 3). Originally a small fishing village that began in the fourteenth century, Scheveningen saw its harbor formally constructed in 1894 after a heavy storm wrecked many fishing boats; subsequent expansions in the twentieth century took place to accommodate fishing, transshipment, and later, yachting, shaping its current maritime character.

^ Fig. 3 What if? In the unlikely event of a 2–5 meter sea level rise in the long term, this image visualizes an extreme scenario of flooding for Scheveningen (Source: NXR, 2024).

The Challenge of Sea Level Rise

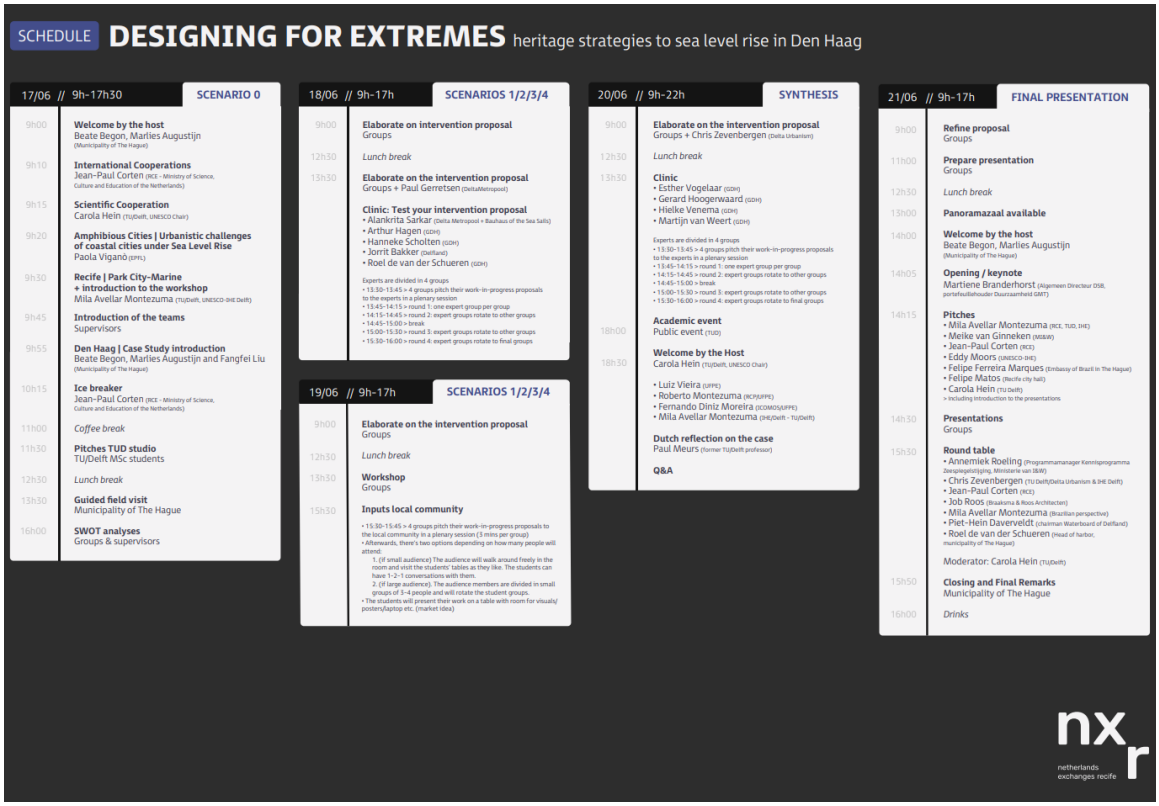
Scheveningen's seaside location makes it especially vulnerable to sea level rise. The latest projections from the Royal Netherlands Meteorological Institute (KNMI) estimate a sea level rise of up to 0.4 m in 2050, up to 1.2 m in 2100 and up to as much as 2 m in 2150. If the Antarctic ice sheet melts at an accelerated speed and greater intensity – which has been the case – sea level rise may be much higher (Kopp et al. 2017; Taherkhani et al. 2020). This poses challenges for Scheveningen's 11-kilometer-long coastline, which can be intensified by compound extreme events (fig. 3). Eight kilometers of this coastline consist of sandy dunes and three kilometers of hard protection measures. The dunes offer solid coastal protection and grow with the rising sea. However, the solidified coastline in front of Scheveningen Bad and Scheveningen Dorp is vulnerable. Here, coastal protection consists of a hard barrier, which cannot adapt to the rising sea without technical interventions. There is no space in the urban landscape for raising and widening the barrier in the long term. Moreover, there is a coastal squeeze in Scheveningen: the beach here is the narrowest one in the Netherlands and the sea is already extremely close to existing infrastructure and buildings. Finally, part of the coastline falls outside the inner-dike protection area and is therefore not protected by the flood defense barrier. This includes Scheveningen Harbor, the Havenkwartier, Norfolk and parts of Scheveningen Bad, which feature important heritage sites.

The national government has developed long-term scenarios for adapting to sea level rise through the Deltaprogramma/Kennisprogramma Zeespiegelstijging, each providing a different perspective of coastal adaptation. These strategies are respectively characterized by "protection," "moving along" and "seaward expansion." The protection strategy continues and optimizes current Dutch water management relying primarily on hydraulic engineering measures such as dike improvements, sand replenishments, sluices and pumping stations. The "moving along" strategy envisions living more with the water and adapting to expanding water bodies. However, it is explicitly stated that fully adopting this approach in the Randstad (the western part of the country, including the city of The Hague and Scheveningen) is unfeasible due to the economic importance of the Randstad area for the whole country. The "seaward expansion" strategy proposes creating a large storage lake along the southwestern coast of the Netherlands (from the head of Walcheren to the head of the Maasvlakte) to accommodate fluvial flooding from the rivers.

All the national strategies impact coastal cities and frame the site-specific interventions for the plans in Scheveningen:

1. The "City by the Sea" scenario aligns primarily with the protection strategy. The city will undertake local prevention and adaptation measures. As a preventive measure, weaker spots in the primary barrier would be strengthened through small-scale interventions such as retaining walls and floodproof buildings. To limit the consequences of flooding, adaptive measures could be undertaken, such as the designation of flood zones.

2. The "City Behind the Dunes" scenario complements both the protection and seaward expansion strategies. In this scenario, the city will focus on creating sandy dunes along the coast along the entire coastline of The Hague. This new row of dunes along the coast can be built in phases over a period of decades and may eventually con-



^ Fig. 4 Overview of the workshop process: Day 1 focused on immersion in land-sea interactions and urban vulnerabilities. Day 2 involved analysis and ideation, with teams proposing adaptation interventions. Day 3 tested these proposals through expert and community feedback. Days 4 and 5 refined strategies, culminating in public debates with authorities (Source: NXR, 2024).

nect the dune areas to the west and east (Westduinpark and the Oostduinpark). The row of dunes would be placed in front of the boulevard and harbor. The beach will then shift seaward.

Ultimately, a combination of these scenarios can be a solution. So far, the national strategies and local solutions have not explicitly considered the historic features of Scheveningen Harbor. For that reason, The Hague municipal government supported the workshop n x r 2024 | Designing for Extremes, which aimed to refine the urgently needed strategies and solutions The Hague is preparing and help to include heritage perspectives.

The Workshop n x r 2024 | Designing for Extremes

The Scheveningen Harbor in The Hague is a historic port and city, but what is the future of its historic features in light of expected climate change? How can these historic features be protected or adapted? How and to what extent can they accommodate Scheveningen's future water challenges? These were the key questions addressed during the workshop, which employed research-by-design as a tool to develop and test adaptive and protective strategies.

The n x r 2024 methodology is rooted in a long-term and fruitful collaboration between Reci-

fe and the Netherlands on heritage management. Students from the MSc 2 course Building Green, taught at TU Delft, developed a detailed analysis of the challenges faced by The Hague, setting the stage for the intense, hands-on workshop that provided the foundation for the creation of a shared database. Together, the Municipality of The Hague, the Cultural Heritage Agency of the Netherlands, the Chair History of Architecture and Urban Planning (TU Delft), the PortCityFutures Center, the Federal University of Pernambuco and professionals from the Netherlands and Brazil then hosted a workshop that involved diverse governmental, academic and non-profit organizations and approximately 100 participants representing 6 out of 7 continents. The outcomes have since been presented as policy advice to the Municipality of The Hague on formulating a long-term strategic vision for Scheveningen's future.

The five-day workshop adopted a hybrid methodology, on site with practitioners, specialists and local community decision-makers co-designing and debating large-scale printed maps – spanning the Netherlands' continental and maritime territory, its delta, Zuid-Holland, The Hague and the port of Scheveningen – with computational drawing software for digital modeling and visualization and an online Miro platform to share the database and to record and receive feedback on daily progress. These tools facilitated a multi-scalar approach, integrating spatial analysis with existing and proposed regulatory frameworks, historical features, biodiversity assessments and floodplain mapping.

Participants engaged with diverse urban and coastal settings, including key local sites and institutions, ranging from Scheveningen's coastline to institutional sites such as the JachtClub, TU Delft and Muzee, facilitating context-driven analyses (fig. 4). The group studied the two scenarios of "protection" and "moving along" as complementary pathways for the port and the larger urban and coastal areas, respectively developing an amphibious infrastructure, and reimagining the city as a resilient "archipelago territory," embracing water as part of the urban fabric and dynamics, with the second approach potentially complementing the first in case of system failure.

Outcomes of the Workshop

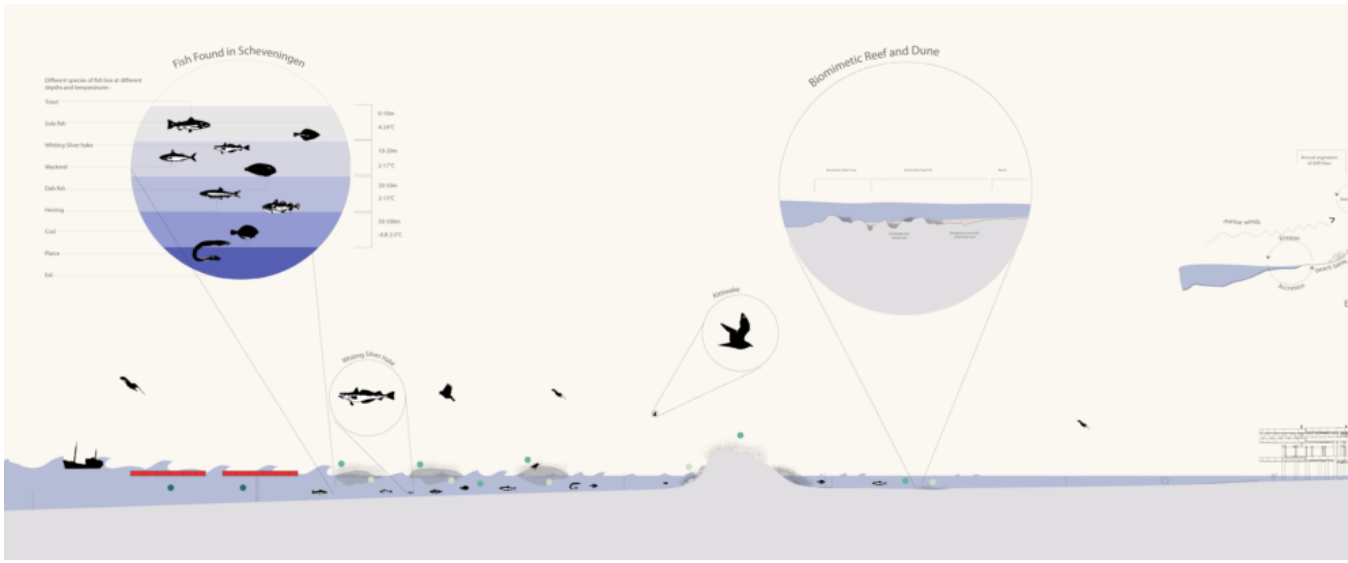
The workshop findings were presented at Muzee — Scheveningen's local museum, rooted in its sea-born culture — to a diverse audience that included local, national and international authorities, involved stakeholders and committed residents (fig. 5), leading to a lively discussion with a panel of experts.

The main conclusion drawn from the workshop was that necessary measures anticipating sea level rise and extreme floods and droughts may be accommodated by Scheveningen's historic features. The workshop distinguished between protective strategies and adaptive strategies, which are not mutually exclusive (fig. 6).

The protective strategy, aimed at keeping the water at bay from the coastal "city behind the dunes," is predominantly nature-based. Expanding the dune landscape westward into the North Sea, along with blue-green network buffers inland and amphibious infrastructure, will provide protection by using existing features. This represents a continuation of a long-standing Dutch struggle against an intruding sea. Historic coastal features such as coastal and marine ecosystems, the open sea, tidal dynamics, extensive beaches and hilly dunes, along with related flora and fauna, will be enhanced

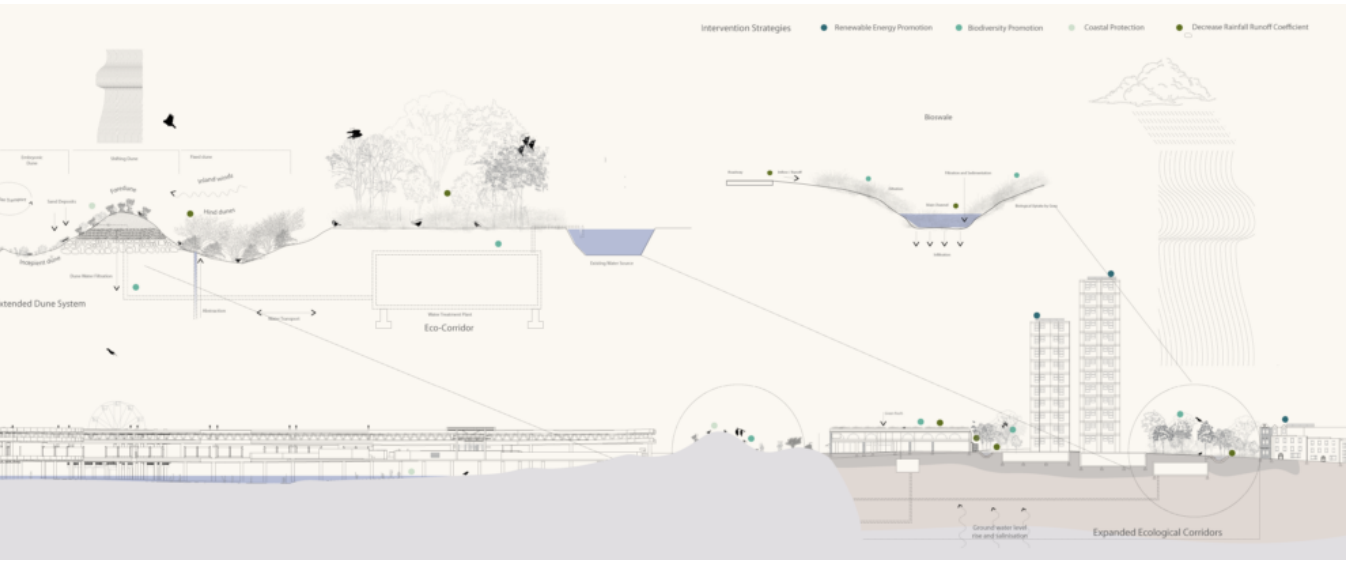
^ Fig. 5 The participatory methodology of research-by-design: technical visits, co-design sessions, testing with multiple stakeholders and public debates (Source: NXR, 2024).

and deployed as protection. Proposed interventions include the restoration of seagrass meadows and biomimicry reefs and the creation of artificial islands to absorb the energy of waves to protect the coastline from erosion. Thus, use of these historic features will restore biodiversity, creating a more resilient coastal ecosystem, while also generating new opportunities for leisure, recreation and sport activities. In pursuing this strategy, we should also anticipate that some species may disappear and others arrive as a result of climate change.



^ Fig. 6 Spatialization of the design principles applied to the city and port scales (Source: NXR, 2024).

The adaptive strategy, on the other hand, focusing on "living with water," largely concerns the urban context. It requires reimagining urban spaces by integrating water-based solutions into existing features. The workshop concluded that the historic urban spaces offer opportunities to accommodate blue-green networks, sponge territories and (semi-) wetland zones. Meanwhile, urban infrastructure requires adaptation to fluctuating water levels with flexible and modular constructions. These include floating platforms, movable bridges and modular building materials that can adapt to changing water conditions. The future use



of the port for the fishing industry will be a challenge, as vessels need access, raising the question of a possible fourth port-basin. Rather than viewing the port as a fixed structure, the participants imagined it as a dynamic space, where different uses and structures could evolve alongside the changing environment. Such adaptive solutions not only support the port's economic functions but also transform it into a resilient, future-ready urban space.

To further develop these strategies, the workshop proposed establishing a living lab, a real-world environment where researchers, users (including citizens and other community members), businesses and public authorities can collaboratively develop, test and refine new solutions, services and policies. This lab would serve as a center for responding to sea level rise, researching future needs, leveraging heritage assets to address these needs and fostering public awareness. For The Hague, such a lab could ensure climate adaptation measures remain flexible, responsive and tailored to Scheveningen's unique context.

Takeaways and Next Steps

The workshop revealed that Scheveningen's historic features, as a dimension of the city and coastal territory, can substantially accommodate much needed climate measures across multiple spatial scales through dual strategies: a nature-based protective approach that involves expanding the historic dune landscape seaward, and an adaptive approach reimagining historic urban spaces through blue-green networks and flexible infrastructure. The workshop outcomes demonstrate that heritage-sensitive climate adaptation can enhance rather than compromise historic coastal landscapes, contributing to multiple SDGs: protecting cultural heritage (11.4) and advancing climate action, while using blue-green infrastructure for adaptive urbanism, scaling up nature-based protective strategies (13) and water management with innovative sponge territories and wetland zones (6) and developing resilient infrastructure using amphibious and modular solutions (9). The decade-long Netherlands-Brazil collaboration, uniting diverse academic, governmental and local stake-

holders, exemplifies the power of international partnerships (SDG 17) in fostering knowledge exchange, capacity building and the generation of new insights and creative ways of meeting global challenges. The findings also highlight the potential value of establishing a permanent living lab, an idea supported by project participants, to foster continuous innovation in heritage-based climate solutions. The n x r 2024 workshop demonstrates that heritage conservation is no longer solely a cultural pursuit but has become a spatial endeavor that is important for addressing societal needs through climate adaptation. It should be relocated from the cultural domain, where it has traditionally emphasized history, identity and aesthetics, to the spatial planning domain – where it can actively contribute to resilient and sustainable urban development. Furthermore, the workshop's findings and takeaways are relevant to port city territories worldwide, including partner city Recife.

Acknowledgment

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Finally, thank you to everyone behind the scenes, from coordinators to facilitators, who made this event a meaningful step toward resilient futures for coastal cities.

The full list of participants, experts and support team members is available here: https://recifeexchanges.com/netherlands/.

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Digital Terrain Models from Historic Data Sets: The Case of Land Subsidence, Water Management and Sustainable Land Use in the Dutch Lowlands

Roeland Emaus & Sylvia Leenaers

Abstract

The region surrounding Gouda, in the middle of the Dutch Delta, is one of the lowest-lying areas in the Netherlands. The historic inner city is situated at the current high-water mark (Amsterdam Ordnance Datum, or NAP). In contrast, the surrounding landscape lies between two and six meters below that due to subsidence as a result of draining the land and making it available for urbanization and agriculture. The original factors that caused the land to subside are still at play here, while relative sea level rise adds to the problem by making these areas prone to flooding. In this region, accurate digital terrain models make an invaluable contribution to data-driven governance and decision-making. These models can illuminate how changing conditions affect heritage sites and the cultural landscape. We propose and evaluate a methodology for developing accurate terrain models from historical aerial photographs. The method provides high-density, high-precision data for the past half-century. This data can provide insight into the long-term effects of local interventions on local subsidence, making the method a valuable tool for developing risk inventories for proposed interventions.

Policy Recommendations

- Establish detailed risk inventories based on historical digital elevation models to evaluate long-term land subsidence. These inventories will prepare policymakers for potential challenges in spatial planning, water management and heritage management.

KEYWORDS

Data
Land use
Land subsidence
Photogrammetry
Water management

WATER ICONS

CLIMATE

Cfb: Moderate sea climate

< Fig.1 Structural damage in a Dutch farmhouse caused by land subsidence (Source: Roeland Emaus, 2024).

Introduction

The region surrounding Gouda lies within the Rhine-Meuse delta and can be characterized as cultivated clay and peatland. The land is mostly flat, with minimal natural differences in height or slope, and soils that are either loosely packed (unconsolidated) or more compacted (consolidated), containing a high percentage of organic matter (>15 per cent) (fig. 2). The first settlements in the area appeared during the early Middle Ages when the area was colonized and used for arable farming. Currently, the level of the groundwater is artificially kept just below the ground surface. Since the landscape is situated below sea level, the surface water must be pumped continually from the canals between the agricultural fields up into the rivers flowing at a higher level. Consequently, the landscape is peppered with canals, rivers and dikes. The historic fight against the water is deeply embedded in the built environment and the general appearance of the landscape.

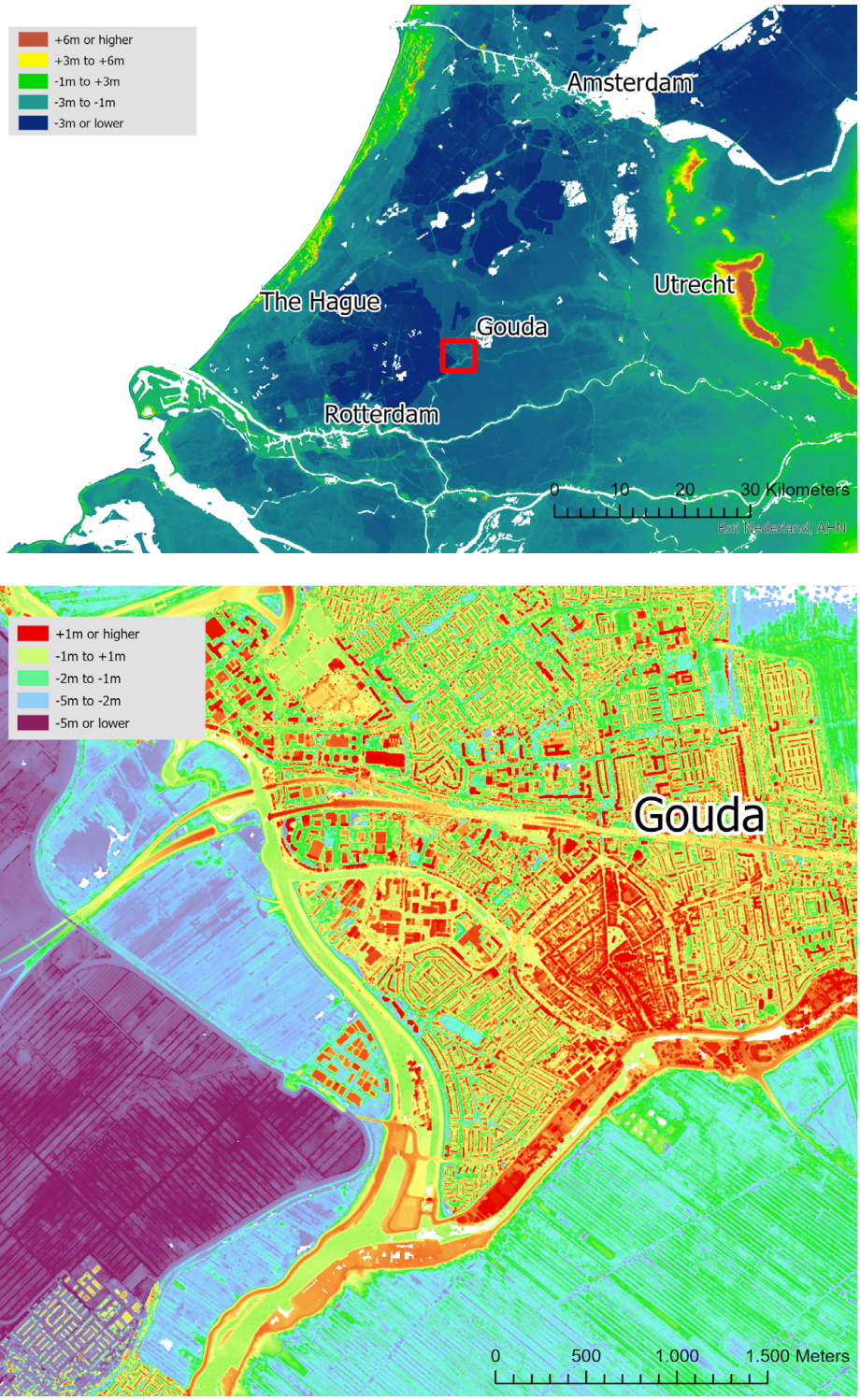
Dairy farming currently dominates land use in the region, as the high groundwater level makes arable farming impractical. The soil, primarily composed of organic matter, faces inevitable subsidence wherever it is not waterlogged. Subsidence occurs due to both consolidation and, more significantly, the oxidation (or decomposition) of the organic matter. Even pasture-based agriculture requires relatively dry soil, which depends on maintaining a relatively low groundwater level. However, the drying process accelerates the loss of the soil's top layer. To sustain healthy pastures, further lowering of the water level becomes necessary, creating a "land use trap."

This trap is rooted in historic land use decisions, which continue to shape contemporary challenges by deeply influencing current agricultural practices and the local economy. It is important to recognize the historical and social complexity of the situation, in which any technical intervention is inherently a socio-political act, as it directly affects peoples' daily lives. In this context, high-accuracy elevation data from the past half-century are crucial for revealing the effects of past interventions and for developing effective governance strategies. Without this data, detecting local and sometimes delayed responses to certain changes – such as those reported by Locher and De Bakker (1990), who observed effects taking place up to 30 years after 1960 – would be nearly impossible.

Socioeconomic Context

Land subsidence began occurring as soon as farmers colonized the region and began draining the land, during the ninth and tenth centuries. Although conditions were relatively wet, once drained, the soil was also relatively fertile. Ditches were easily dug in the soft peat, and arable farming was possible. Over time, the drained soils began to oxidize and subsided. However, in locations on top of the bog, well above groundwater levels, this problem was quickly addressed by digging deeper ditches and moving further into the bog, where the surface level was still unaltered.

This process has continued into the current era. All the land has been exploited and it has subsided to a level lower than the original water table. Ditches cannot be dug any deeper unless the water table is artificially lowered. In its basic form, the process of land subsidence due to agricultural practices is already some eleven centuries old. The current agricultural practice resulting from this centuries-old process is uniquely tied to the land and part of the local



^ Fig. 2 The research area in relation to regional elevation (Source: Roeland Emaus and Sylvia Leenaers, based on AHN-data, 2024).

way of life. The problem is, therefore, a technical one with a significant socioeconomic component. This context highlights the importance of governance based on empirical data, rather than conjecture or economic interests. Well informed, long-term and data-driven technology governance is essential to signal the need for local interventions in water management, land use planning (Stouthamer et al. 2020). Data provides a valuable empirical foundation, however, it must be interpreted and contextualized to ensure that policies are comprehensive and address the complexities of real-world issues.

Current Practices

To allow for the precise modeling of areas prone to flooding, the Dutch water authority has commissioned an integral laser-altimetric-derived digital terrain model for the entire Netherlands, the AHN (www.ahn.nl). Since the production of the first AHN in the 1990s, the data set has been renewed with increasing resolution over the years, leading to the current preparation of the fifth updated version, the AHN5. For the last 25 years, we have been able to monitor landscape change at increasing levels of precision. Not only are anthropogenic changes such as urban sprawl and infrastructural developments visible, but the more natural processes of fluvial dynamics and dune formation can also be quantified. In many cases, changes in surface elevation can be followed precisely.

Over the last 25 years, Dutch agriculture has become increasingly industrialized, leaving its mark on the landscape. While remnants of the cultural landscape formed over the past eleven centuries were still visible in the relief of a quarter-century ago, many of these elements have since eroded or vanished. The loss of heritage sites and historic landscape features from this period can now be studied using historic digital terrain models.

The rate at which land subsidence occurs can be estimated in millimeters per year. Since accurate monitoring has become available, the total amount of land subsidence that has taken place is therefore low and difficult to measure in a high-density grid. Therefore, land subsidence changes cannot be substantiated yet for a continuous surface over a more extended period, although short-term monitoring is taking place (van Asselen et al. 2018; van Asselen, Erkens and De Graaf 2020). Long-term processes are, therefore, only modeled and not measured (e.g., Koomen and Exaltus 2003; Van der Meulen et al. 2020). Local and historical changes in the built environment and the landscape have, until now, only been modeled rather than directly measured. As a result, governance and decision-making have relied on generalized data, potentially overlooking or misapprehending local and long-term phenomena. Using the new methodology, we can check the models on which governance is based.

New Methodology

Recent developments in computer science have led to the wide scale availability of powerful computers that can handle large data sets and perform complex tasks. At the same time, software developers have integrated the classical principles of aerial photograph triangulation into modern end-user software packages, specifically designed for drone-based surveying and remote-sensing practices.

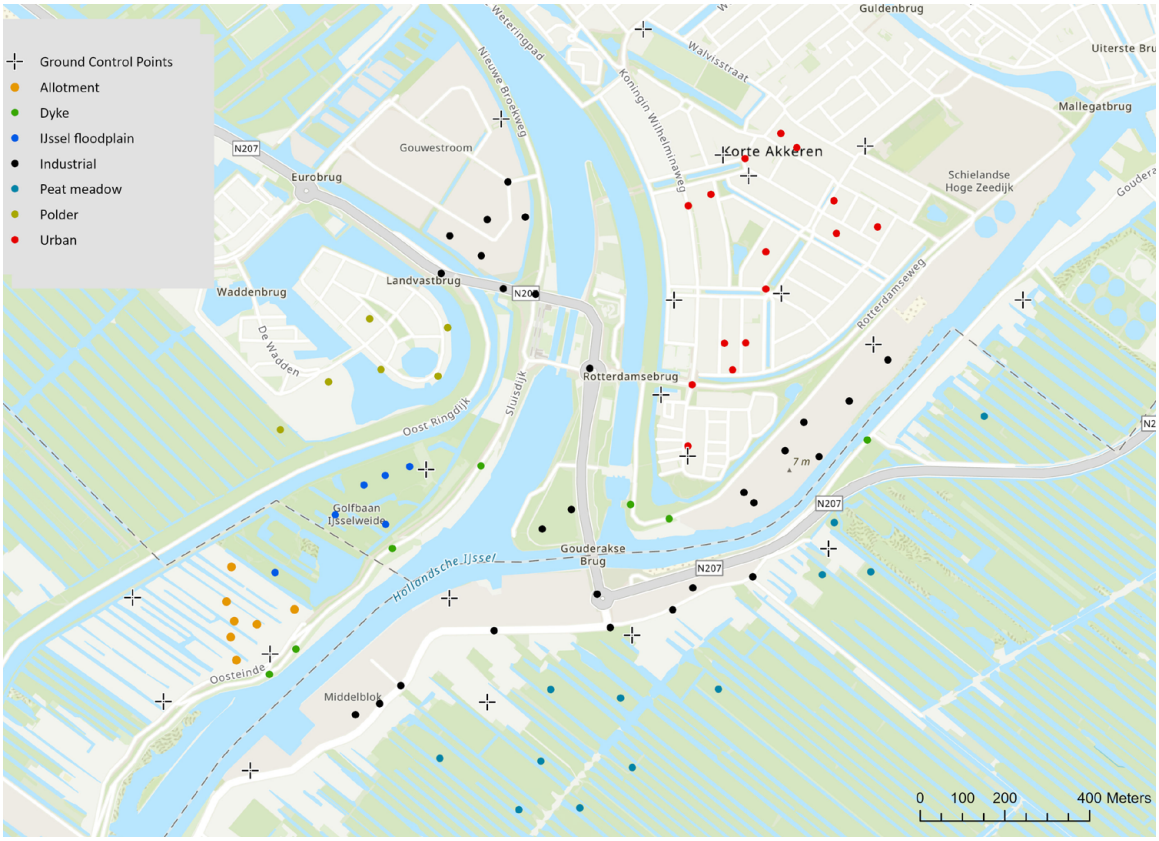
The principle of photogrammetry involves extracting 3D information from a series of overlapping aerial photographs (Avery 1968).

As the software described above is a further development of manual aerial triangulation techniques, it can generate digital terrain models not only from modern drone imagery but also from any set of overlapping aerial photographs. In this project we will use this technology to analyze historical images.

Since the Second World War, practically every national topographical service worldwide has produced its topographic cartography through manual aerial photogrammetry (Cosgrove and Fox 2010). The historical aerial imagery that formed the basis of this cartographic production is often still available as hard copies in national archives. However, in some countries, it is still regarded as military intelligence even though the imagery is over 50 years old.

Our research was based on the premise that these legacy data sets, produced for manual processing, can now be digitally processed to the same standards we produce terrain models today. Legacy data coupled with new technologies have more potential than was conceived at the time of its original production.

To test our premise, we acquired a set of overlapping aerial photographs from the region of Gouda made in 1999. Older imagery is available in this region. However, as we are dealing with a dynamic landscape, we would have no way of estimating the accuracy and precision of the digital terrain model produced with our new methodology. If we want to determine the quality of a data set, we need to compare it to another data set from the same period with



^ Fig. 3 Ground control points (GCPs) used in the photogrammetric production process, and sample locations for the statistical accuracy analysis of the historic elevation models comparison with the AHN1 (Source: Roeland Emaus and Sylvia Leenaers, readapted from the map by ESRI, 2024).

known accuracy. The oldest appropriate available data set is the first national digital terrain model from the late 1990s, the AHN1, which has an accuracy of 0.2 meters. This way, a direct comparison can be made between the terrain model produced with legacy data and a contemporary LiDAR data set.

We selected 20 distinctive landmarks in the area. Through cadastral databases and historical data, we were sure these landmarks had remained unaltered by land subsidence in the last decades, or at least to a negligible degree. We determined the coordinates of these landmarks through a topographic survey with GPS and Total Station which we could use as ground control points for the photogrammetric restitution (the plus signs in fig. 2). Since this is a novel application, we chose three software packages to process the historical photographs and compare their performance: Pix4D, Agisoft Metashape and ERDAS Imagine. Within these packages, we ran multiple models with varying settings regarding triangulation, automatic (tie) point extraction, point cloud production and filtering. This resulted in a total of 16 digital terrain models. These digital terrain models were then compared with the AHN1. To analyze the results, we divided the region into seven distinct areas based on their land use types and morphology. Within these seven groups, we located control points that are the most meaningful for this kind of landscape. For instance, we only used rooftops and street level locations for comparison in the "urban" category since facades of houses are always challenging to model with conventional aerial photogrammetry. In the same fashion, we excluded waterbodies and high-rise vegetation. In the final analysis, we calculated the performance of each terrain model for different terrains at a total of 80 locations (the dots in fig. 3).

Software	Pix4D	Agisoft	ERDAS
Model no.	18	232	3-0047 (7)
Overall	1.54	0.62	2.81
Allotment	1.81	1.47	1.06
Dike	0.4	0.41	0.76
IJsselweide	1.36	0.4	1.61
Industrial	0.84	0.23	0.94
Polder	1.8	0.27	2.74
Urban	1.42	0.9	4.85
Veenweide	2.52	0.39	1.38

^ Table 1 Comparison between the results with the lowest RMSE of each software package in this study. The values are the calculated error (RMSE) of the photogrammetric models compared to the contemporaneous LiDAR elevation model (AHN1).

Results

Since all measurements can contain errors, we first filtered the sample points for outliers. We used a statistical measure to reject measurements from the comparison that seemed stable in our legacy data sets, having a high RMSE compared to a relatively low standard deviation, but that did not correspond well to the AHN1. The assumption is that our legacy measurement at some locations might be more accurate than the AHN1.

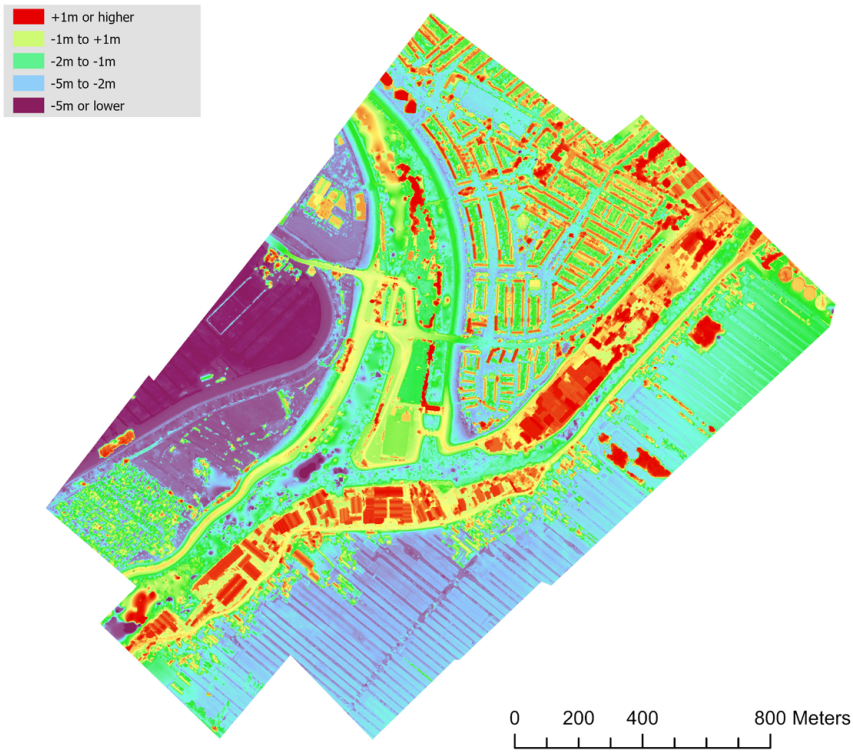
All software packages performed well in industrial and rural terrains, but relatively poor results were obtained in residential areas (table 1). Overall, the Agisoft Metashape package performed well on most terrains with a consistent error (RMSE) of 0.6 meters in general but between 0.4 and 0.2 meters in agricultural and industrial areas. The ERDAS package performed relatively well in one type of terrain but poorly in others. The Pix4D package performed poorly on all terrains, with an overall RMSE of 1.5 meters. This means that the landscape and (historic) buildings can be measured and monitored retrospectively, with an accuracy be-

tween 0.2 and 0.4 meters or larger and the effects of local (construction) interventions and even general impacts of climate change can be detected and monitored.

Conclusion

Combining advanced computer technology with historical imagery makes it possible to produce historic digital terrain models with an accuracy of 0.2 to 0.4 meters for most types of terrain (fig. 4), comparable to the accuracy of AHN1. This approach allows for the creation of digital terrain models from the 1950s on, providing an accurate model of the terrain before extensive urbanization, land consolidation and industrial agriculture changed the landscape beyond recognition and impacted local hydrology and land subsidence. This way, the original cultural landscape, with all its (historical) buildings, waterworks and hydrological installations, can be studied as it was in the 1950s and more recently.

Furthermore, the methodology will allow us to monitor changes through time accurately since a terrain model can be produced for every decade or even every year from the 1950s to the present. Landscape changes can be linked to hydrological interventions, urban planning and land use practices. We can now offer accurate historical context and show trends in how the landscape has changed. This is potentially valuable input for decision-making, as we can understand how original hydrological processes functioned before large-scale industrial interventions changed the landscape. However, it also enables us to learn from the often-invisible long-term effects of local interventions and the gradual impacts of global climate change.



^ Fig. 4 Result of the photogrammetric production of a historic elevation model from 1999, model no. 232 (Source: Roeland Emaus and Sylvia Leenaers, 2024).

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Human-Nature Relations in the Urbanizing Landscape of the Deep Bay Wetlands, Hong Kong

Zuzanna Sliwinska

Abstract
Traditional activities, including aquaculture, of communities living on the edge of the Deep Bay Wetlands in Hong Kong transformed the landscape into a semi-artificial ecosystem that supported local wildlife, briefly enhancing its ecological value. However, since the 1970s, rapid urbanization has disrupted these human-nature interdependencies through habitat loss, fragmentation and the decline of traditional occupations. Today, the Northern Metropolis Development Strategy (NMDS) further threatens this unique eco-cultural landscape. This article considers how village-based practices have contributed to the wetland's biodiversity over time. It argues that Deep Bay should not be seen as a passive ecological site but as a dynamic cultural landscape where human activity has historically sustained ecological functions. Wetland protection requires more than ecological conservation – it demands an integrated approach that values cultural heritage as a vital component of ecological sustainability.

Policy Recommendations

- Wetland conservation strategies should include local voices and offer culturally grounded economic alternatives to reduce land conversion pressure.
- Wetland conservation strategies should integrate cultural heritage into ecological planning by recognizing and supporting human practices that contribute to biodiversity in dynamic wetland landscapes. To do that, a comprehensive assessment of historical water management, land-use patterns and socioeconomic transitions should be conducted, with findings integrated into environmental impact assessments – particularly in light of upcoming NMDS development.

KEYWORDS

Wetland
Cultural landscape
Urbanization
Socio-ecological system
Fishponds

WATER ICONS

CLIMATE

Cwa: Humid subtropical climate

< Fig. 1 Nam Sang Wai, part of the wetland looking east toward Lam Tsuen Country Park (Source: 姒姓賢寧 2023. CC BY 4.0, via Wikimedia Commons).

Introduction

The Inner Deep Bay catchment is a low-lying area in southern China. Located in the northwestern New Territories (NT) of Hong Kong, across the Yuen Long and North districts, it comprises marshlands, mudflats, mangroves, fishponds and 6,640 ha of peri-urban estuarine wetland (Agriculture, Fisheries and Conservation Department 2023; figs. 1–3). This includes 1,540 ha designated as the Mai Po Inner Deep Bay Ramsar Site, collectively known as the Deep Bay Wetlands (DBW). Hong Kong's DBW exemplify a relatively short but dynamic transformation of the landscape and evolving human-nature interactions, reflecting a broader global pattern in which nearly three-quarters of terrestrial ecosystems have been altered by human activity (Ellis et al. 2021; Perry 2021).

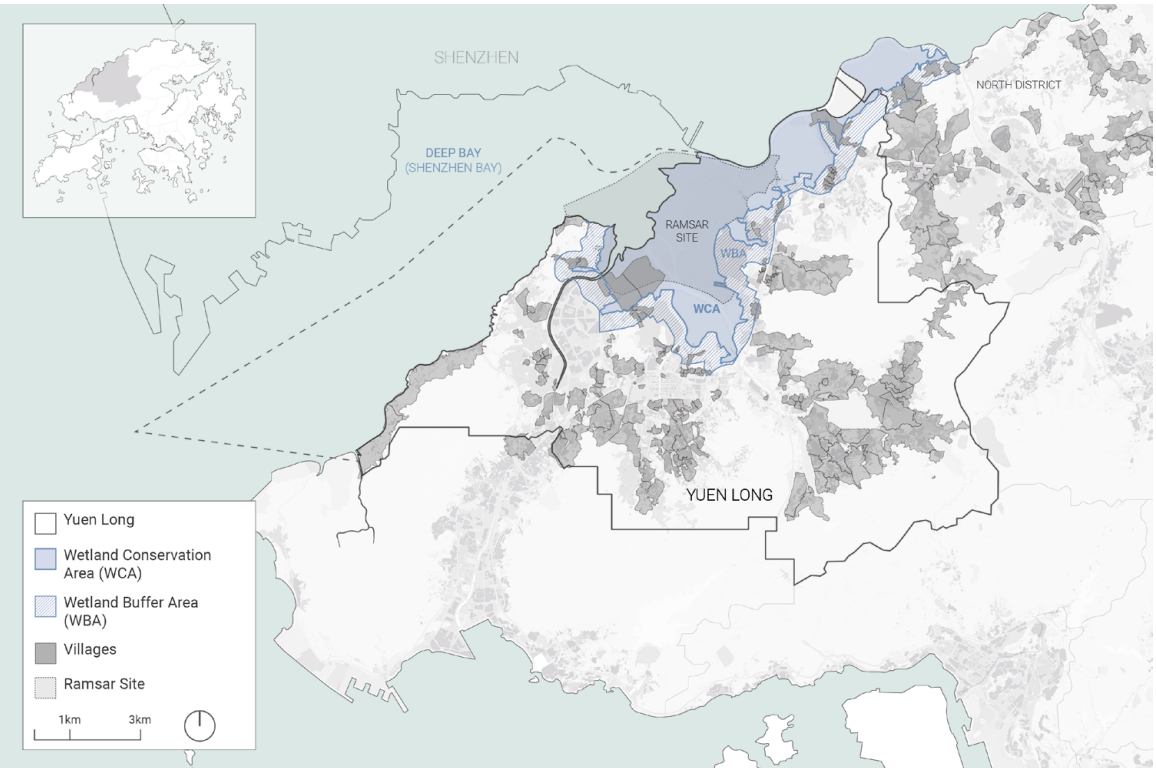
The first inhabitants arrived in the Deep Bay area in the late tenth century; however, significant landscape modifications did not begin until the twentieth century, when local communities introduced aquaculture ponds that eventually became part of the region's cultural heritage (HKICHDB 2021). These ponds enhanced biodiversity by attracting both migratory and resident birds, fostering a distinctive interdependence between human activity and ecological support and contributing to the formation of an ecologically and culturally unique landscape. However, since the 1970s, rapid urbanization and socioeconomic changes in the NT have altered land cover, reduced the distance between wetlands and urban zones (fig. 7) and contributed to the decline of traditional livelihoods.

This article identifies two layers of human-nature engagement in the DBW: a traditional, livelihood-based relationship and a more recent urban-driven one that has reshaped local industries and practices. While conceptually distinct, these layers are historically intertwined. The study explores how overlapping ecological, cultural and urban development forces have shaped the wetland and advocates conservation strategies that integrate historical land-use practices and cultural heritage into sustainable planning. The analysis draws on historical and socioeconomic data supplemented by anecdotal insights from local residents.

Ecological and Cultural Importance

About 75 per cent of Hong Kong is undeveloped or natural land, including mainly woodlands, shrublands and grasslands (65 per cent). Only a small area is covered by an estuarine ecosystem – such as mangroves and swamps (0.5 per cent) and aquaculture (1.4 per cent) (Planning Department 2023). As the largest remaining tidal mudflat and mangrove habitat in the Pearl River Estuary, the DBW represent a rare and ecologically significant example of this ecosystem type in Hong Kong, helping to stabilize shorelines, reduce coastal erosion, and contribute to carbon sequestration.

The area includes 1,135 ha of fishponds (as of 2016) (Hong Kong Bird Watching Society, n.d.) – man-made aquaculture sites now integrated in the wetland landscape. The ecological value of fishponds in Hong Kong began to be recognized in the 1990s due to their flood mitigation and habitat-support functions (Planning Department 1997), and their importance has grown with rising sea levels and shifting hydrological patterns linked to climate change. Extreme precipitation events in the Pearl River Delta are expected to increase significantly under high-emission scenarios (RCP 8.5); meanwhile, flood risks in low-lying urban areas like Hong Kong's northwest NT are also growing (Chen et al. 2021). In this context, fishponds serve as



^ Fig. 2 Yuen Long district, including wetland conservation and buffer areas, village outlines and Ramsar Site (Source: Zuzanna Sliwinska, 2024).

buffers that retain stormwater and reduce runoff, helping protect adjacent residential areas (Hong Kong Bird Watching Society n.d.).

Well-maintained fishponds contribute to the wetlands' ecological value. Seasonal practices like pond draining during harvest create nutrient-rich environments that benefit migratory and resident birds. Each winter, 40,000 to 90,000 birds along the East Asian-Australasian Flyway stop here, including 35 globally threatened species (Leung et al. 2023). These birds rely on organic matter — fish feed, waste and silt – accumulated in and around the ponds (Leung et al. 2023). However, fishponds function as an interconnected system and require active management to maintain their ecological value (Planning Department 1997). Abandonment leads to stagnant water, habitat degradation and their eventual drying up. When they lose their ecological function, it becomes more difficult to advocate their conservation, increasing the risk of urban encroachment (Bolchover 2016). This illustrates the link between declining cultural practices and environmental degradation.

Recognizing the ecological value of these semi-artificial landscapes, in 1999, the Town Planning Board[1] established the Wetland Con-

1. The Town Planning Board in Hong Kong is a statutory body responsible for developing and implementing urban plans to ensure the orderly and sustainable development of the territory.

^ Fig. 3 Mangroves exposed along the Kam Tin River's muddy edges on the Nam Sang Wai's east side (Source: Zuzanna Sliwinska, 2023).

servation Area (WCA) and Wetland Buffer Area (WBA) to regulate land use and development around Hong Kong's DBW. WCA covers existing fishponds within and around the Ramsar Site[2] together with the 500 m WBA along the landward side of the WCA (Agriculture, Fisheries and Conservation Department, and Environmental Protection Department 2019). Today, several peri-urban villages still exist in the WBA area (fig. 4), remnants of Hong Kong's traditional society – lineage villages established by Indigenous inhabitants of the NT – with ancestral halls, burial grounds and shrines.

The fishponds demonstrate that human-shaped landscapes are not inherently ecologically inferior and that cultural engagement with land and water can support ecological health. Wetland protection, therefore, requires an integrated approach that values cultural heritage as part of ecological sustainability. While some local initiatives acknowledge this, the decline of traditional practices continues to threaten the landscape.

Historical Transformations of the Wetland

The Tang clan, from southeastern China, arrived in the Kam Tin area (today the district of Yuen Long) in the late tenth century. They planted freshwater rice on slopes near the marshes and mudflats. Over the next four

2. In 1995, the 1,500 ha of Mai Po wetlands, including the neighboring Inner Deep Bay area, were designated Wetlands of International Importance under the Ramsar Convention.

centuries, several other major clans settled nearby, attracted by the fertile land surrounding the wetland and the interaction between freshwater streams and tidal saltwater inflows (Bolchover 2016). As the fertile grounds inland became occupied, some farmers moved closer to the bay's edge and reclaimed mudflats by separating them from the tidal zone (Bolchover 2016). These practices allowed water to drain through the soil until it became less salty. Alternatively, residents planted red rice, which could grow in brackish water. This, in turn, led to the intake of estuarine water containing shrimp larvae, later harvested for food on a subsistence level (Bolcholver 2016).

In the NT, the local lifestyle has remained unchanged for several centuries. Farmers altered the landscape to some extent to create paddy fields and support agricultural practices; however, it wasn't until the British takeover in 1898 that substantial changes occurred.

In the early 1900s, fishponds emerged around the Tung Tau village cluster and slowly expanded in the following decades; however, agricultural practices still dominated throughout the first half of the century. In 1953, rice fields covered 9,466 ha (70 per cent) of Hong Kong's farmland. At the same time, *gei wai* – a traditional shrimp farming technique practiced in intertidal zones near mangrove stands – was introduced by migrants from mainland China in the 1940s and initially coexisted with other agricultural activities in the wetland landscape.

In the 1950s, a trade embargo led to shifts in farming policy, promoting vegetable farming, livestock rearing and fish breeding. This shift led to a decline in rice production in the NT. By 1988, rice cultivation had nearly disappeared, with less than one ha dedicated to it (Lee and DiStefano 2002).

^ Fig. 4 Shan Pui Tsuen, with a few preserved ancient buildings (forefront) and modern architecture typical of today's peri-urban villages (background), is an example of a village within the Wetland Buffer Area. The first fishponds in this area were established around the Shan Pui and the Tung Tau village cluster to which this village belongs (Source: Zuzanna Sliwinska, 2023).

During the second half of the twentieth century, the economic context and the establishment of "New Towns" in the 1970s and 1980s by the Hong Kong Planning Department greatly changed the morphology of the NT landscape. New Towns were part of a strategic government initiative to decentralize the population and develop self-contained residential and industrial hubs. While effective in accommodating urban growth, their construction significantly altered rural landscapes.

Beginning in the 1960s – and especially during the early 1970s – many of the *gei wai* systems, along with surrounding farmland and mudflats, were converted into freshwater fishponds,

^ Fig. 5 Fish are collected, weighed and sold in the Yuen Long and Kowloon local markets by farmers near Shan Pui village (Source: Zuzanna Sliwinska, 2023).

which eventually covered 2,255 ha to meet the rising demand for food from Hong Kong's growing urban population (Lau 2022; fig. 6).

The construction of New Towns and the development of neighboring Shenzhen in the 1980s, while initially increased the demand for fishpond cultivation, later triggered the expansion of urban boundaries into the wetland and a fast decline of fishpond cultivation and the ecosystem (Leung et al. 2023) through habitat destruction and fragmentation, and sociocultural changes.

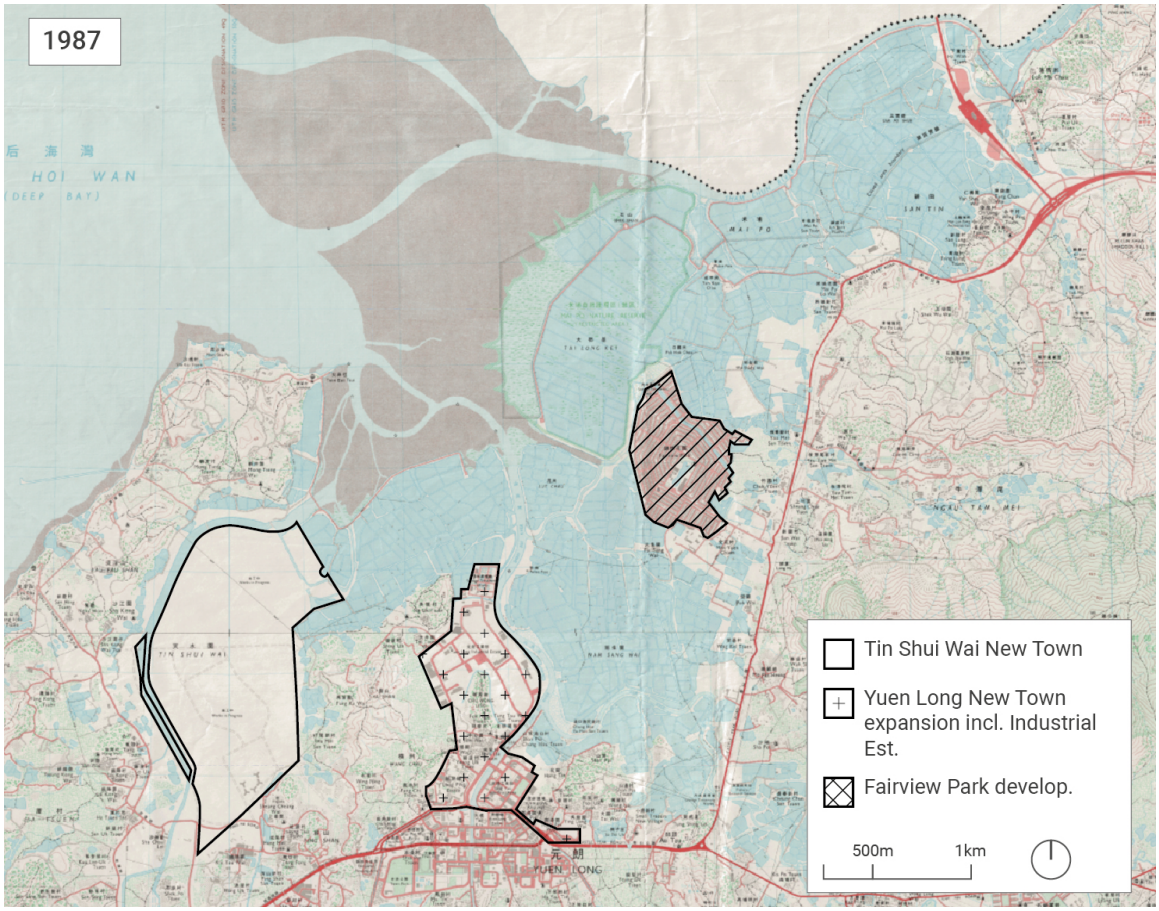
Yuen Long, originally a market township, was formally expanded through government planning, and Tin Shui Wai developed primarily onto reclaimed marshes and fishponds. Designated as New Towns in 1972 and 1987, respectively, both areas grew rapidly, further encroaching onto the wetland (fig. 7). Apart from habitat destruction, urbanization has impacted wetlands through changes in the hydrological regime and interventions to the morphology of the land. For example, the designation of the Shenzhen Special Economic Zone and New Towns in the DBW area impacted the estuary through mud dredging to infill fishponds to allow for development and the increasing amount of construction waste deposited in the river and the sea (Bolchover 2016); it also pushed the urban edge further toward the coast with projects like Fairview Park (1970s) and Palm Springs (1990s). In the 1990s, studies conducted by the Planning Department confirmed that land use changes leading to the loss of fishpond

^ Fig. 6 Marshes and fishponds seen from the border between Hong Kong and Shenzhen, 1978 (Source: Urbain J. Kinet. Flickr.com, no known copyright restrictions).

habitat were likely to be detrimental to birds (Planning Department 1997). Leung and colleagues (2023) found that these large-scale landscape alterations in the last forty years in the Deep Bay area have led to significant changes in water quality, hydrodynamics and the loss of wetland habitats.

Beyond their physical development, the creation of New Towns also triggered socioeconomic and political changes, including the relocation of villages from areas designated for development to newly built settlements on the fringes of the New Towns (Hayes 2006). Policy changes – such as the introduction of the Small House Policy in 1972 – further increased demand for land and contributed to the expansion of village boundaries, often in the direction of the wetland. Together, these dynamics brought what Lee and DiStefano (2002) describe as "gradual but irreversible changes to local society" in the northwestern NT.

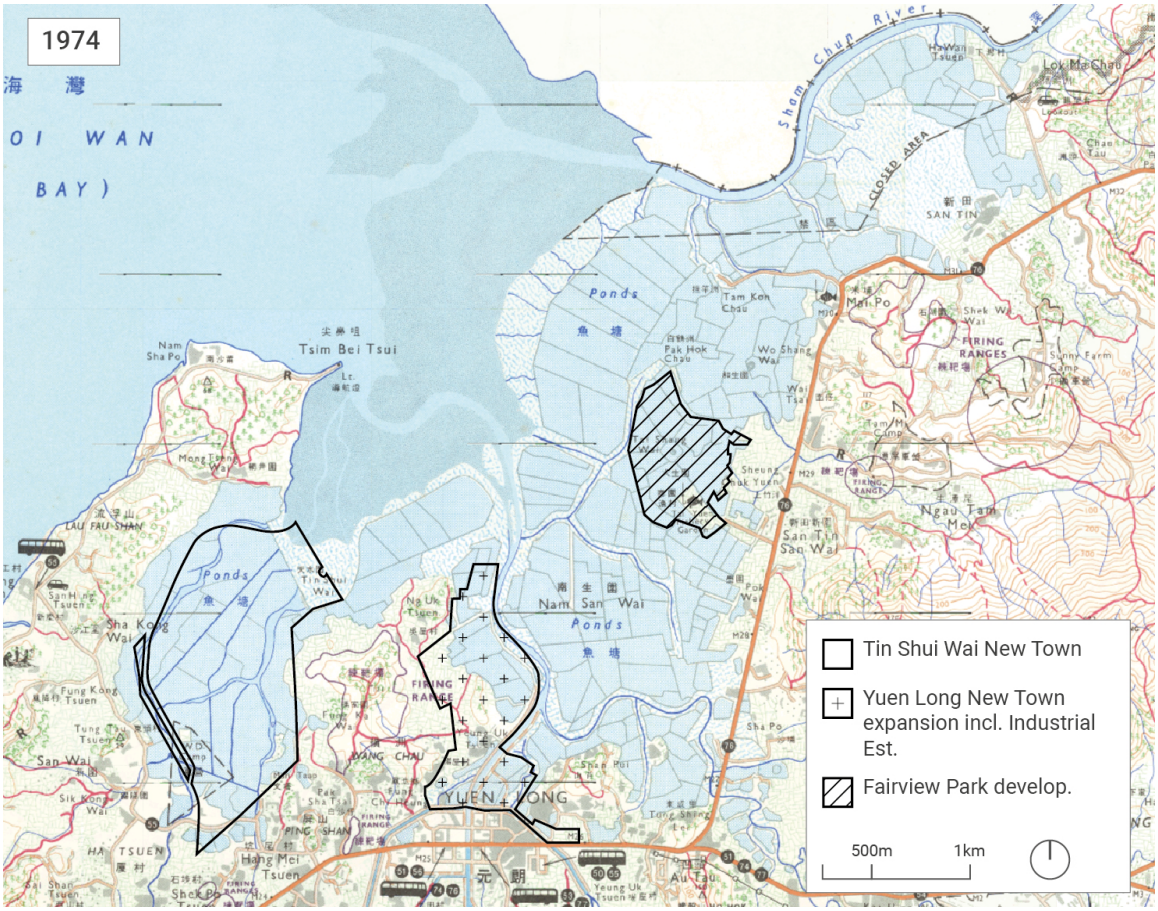
By the 1970s, local village economies could no longer rely solely on traditional resources. The opening of factories in Tuen Mun, Yuen Long and Tin Shui Wai offered alternative livelihoods, leading many to abandon fishpond cultivation. Some pond owners informally repurposed their land into container yards, storage sites or housing, fragmenting the wetland and weakening ecological connectivity. Today, an estimated 200–300 ha of ponds lie inactive or abandoned (Lau 2022), with most remaining ponds managed by elderly fishers averaging 60 years old. The lack of regular maintenance



^ Fig. 7 The wetland area near the Yuen Long township (today Yuen Long New Town) in 1974 (left) and 1987 (right) after the expansion of Yuen Long New Town with Industrial Estate and construction of Tin Shui Wai New Town (Source: www.hkmaps.hk, modified by Zuzanna Sliwinska, 2025).

leads to stagnant water, reduced biodiversity and eventual ecological degradation, raising concerns about the long-term viability of the practice (Lau 2022).

Globally, cultural change threatens wetland biodiversity, particularly the decline of traditional aquaculture and land stewardship practices. These threats have increased significantly in the latter half of the twentieth century (Rotherham 2013). In Hong Kong, land use shifted from subsistence, and emerging economic conditions in the DBW prompted a decline in traditional jobs associated with the wetland ecosystem. As fishpond cultivation is increasingly seen – especially by younger generations – as a less viable economic option, the practical knowledge required to manage these systems is no longer being passed down. This has led to the erosion of local expertise and a decline in interest among village residents in activities on the village periphery. Without cultural incentives to maintain these landscapes, conservation efforts depend entirely on regulations rather than community participation. Hence, integrating cultural heritage with wet-



land conservation is crucial to avoiding further land fragmentation and ensuring that conservation efforts are holistic rather than purely regulatory.

New Development Plans - Northern Metropolis

The DBW represents Hong Kong's largest remaining flat land. Today, this region sits at the heart of Hong Kong's development agenda, particularly within the Northern Metropolis Development Strategy — a large-scale urban expansion plan encompassing the Yuen Long and North districts. The NMDS envisions New Development Areas matching existing New Towns with an expansion of urban centers and major public transport infrastructure. The project covers an estimated 600 ha, extending up to the edge of the wetlands.

Within the San Tin Technopole boundary alone – the first phase of the project – 150 ha of fishponds are included, raising concerns. First, converting fishponds into urban land reduces habitat connectivity for migratory birds and disrupts wetland hydrology. Further fragmentation, already an issue, weakens the ecosystem's ability to sustain biodiversity, as isolated wetland patches are more vulnerable to degradation. Second, the announcement of this project in 2021 has already led to the relocation of

several villages and could further affect the use of the wetlands. Therefore, the project raises the potential for consequences similar to those experienced during the 1970s and 1980s when New Towns were constructed in the NT.

Past developments in the area show that once development reaches wetland boundaries, land speculation and informal urbanization often accelerate – undermining not only ecological integrity but also the cultural practices that sustain the landscape. Such pressures will likely intensify without proactive conservation strategies that account for environmental and cultural value, weakening long-term efforts to protect the DBW.

Discussion

Fishponds lose ecological function when the cultural and economic incentives to manage them disappear, increasing their vulnerability to development. This is particularly evident in villages within the WBA, which sit at the boundary between the wetland and expanding urban zones. Perspectives on conservation in these communities are not uniform: while some residents and environmental groups resist further development due to concerns about ecological degradation and cultural loss, others see urban expansion as an economic opportunity – especially amid rising land values. Informal conversations revealed that not all villagers feel a strong attachment to the wetland landscape. Some appreciate aspects of recent development, such as the shade cast by nearby high-rise buildings, making outdoor areas more comfortable for elders. These differing views show that conservation must be ecologically sound and socially grounded in peri-urban realities. Effective wetland conservation requires engaging local communities, especially landowners, and providing culturally rooted alternatives that reduce pressure to convert wetlands into urban or commercial developments.

Although wetland conservation policies exist, they often separate ecological protection from cultural continuity. For instance, the WCA and WBA offer physical boundaries (ecological zoning) but do little to address the cultural and economic disconnection from the land. Additionally, mechanisms like the "no-net-loss"[3] principle have encouraged the creation of artificial mitigation zones treating fishponds as interchangeable units, lacking the cultural and ecological depth of real aquaculture systems, and failing to address the underlying sociocultural and ecological dynamics that sustain wetland biodiversity. This principle also facilitates building more in areas suitable for development while promising to compensate in other areas, with ecological effects that are not the same. The NMDS is an example of this, as is Hong Kong Wetland Park, originally built to offset Tin Shui Wai, which now serves more educational than ecological functions.

Future conservation efforts need to move beyond viewing wetlands as static ecological assets. Instead, they should be recognized as dy-

3. The "no-net-loss in wetland" principle was introduced by the Hong Kong Town Planning Board as part of its planning guidelines in response to growing concern over wetland degradation in the Deep Bay area. It was formalized in the 1997 Town Planning Board Guidelines (TPB PG-No.12B), which apply to the WCA and the WBA. The policy stipulates that any development proposal that involves a loss of fishponds or wetland area must demonstrate ecological compensation of an equivalent or greater value, often through habitat creation or enhancement.

namic cultural landscapes where human activity can – and has – contributed positively to biodiversity. Such an approach can move beyond the binary of development versus biodiversity and toward more holistic, sustainable planning.

Conclusion

Lung and colleagues (2005) note that the NT's heritage value as a cultural landscape is declining. The evolution of the NT landscape across the twentieth century reveals how cultural priorities, driven by socioeconomic changes and developmental pressures, can influence wetlands' health. The case reveals two intertwined dynamics: traditional aquaculture supporting biodiversity and more recent urbanization and cultural detachment. Initially, traditional fishpond activities supported the wetland's ecosystem, which became partially dependent on their continued use. However, as urban expansion accelerated, pollution increased, economic realities shifted and traditional occupations declined, land-use priorities changed, leading to wetland fragmentation and lower ecological value.

This study demonstrates that the DBW are not passive ecological sites but dynamic cultural landscapes. While minimizing the level to which the NT is urbanized would benefit the wetland, limiting that process is probably unrealistic. Without addressing the cultural disconnection accompanying physical development, conservation efforts will remain reactive and fragmented. The example of DBW shows that sustainability cannot be achieved through zoning alone – it requires the reintegration of cultural values into land use and conservation to move beyond a binary of development versus biodiversity. This is especially important amid ongoing climate and biodiversity loss.

Ensuring the long-term viability of the Deep Bay Wetlands requires policy approaches that acknowledge and support the interplay between ecological functions and cultural practices. Wetland conservation strategies should include local voices and offer culturally grounded economic alternatives to reduce land conversion pressure. They should also integrate cultural heritage into ecological planning by recognizing and supporting human practices that contribute to biodiversity in dynamic wetland landscapes. To achieve this, a comprehensive assessment of historical water management, land-use patterns, and socioeconomic transitions should be conducted, with findings integrated into environmental impact assessments — particularly in light of the upcoming Northern Metropolis Development Strategy.

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Interview with Lachie Carracher: Living Water Heritage, a Digital Platform for Indigenous Knowledge Valorization of Martuwarra

Interview with Lachie Carracher
By Carlien Donkor

Abstract
The Martuwarra (Fitzroy River) in the Kimberley Region of North West Australia is a National Heritage site, recognized for its cultural and biodiversity values. This interview explores the conceptual and ethnographic process of creating Living Water Heritage, an online exhibition showcasing the catchment and First Australian Traditional Owners. The project showcases how Indigenous communities are making their voices heard in a modernizing and extractive world faced with climate challenges, and are working to protect their cultural and natural heritage in line with sustainable development.

Policy Recommendations

- The Western Australian government should take action to promote and protect the Matuwarra watershed.
- Ban fracking across the state of Western Australia.
- Invest in conservation economies rather than extractive ones.

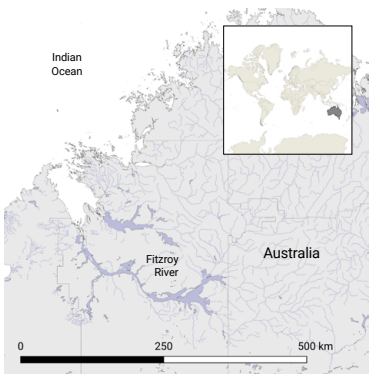
KEYWORDS

Digitization
Martuwarra
First Australians
Living water heritage
Sustainable development

WATER ICONS

CLIMATE

Aw: Tropical savanna climate



< Fig. 1 A section of the Martuwarra (Fitzroy River) Catchment (Source: Lachie Carracher, 2017).

Introduction

INTERVIEWER | Carlien Donkor: Welcome Lachie Carracher. Thank you for joining me today for this interview for *Blue Papers*. Can you give us a brief summary of the project you've been working on for the last three years?

INTERVIEWEE | Lachie Carracher: The Martuwarra (Fitzroy River) is a catchment in the northwest of Australia. First Australians, Australia's "first people," or Traditional Owners have been managing the River since the beginning of time. In 2016 a group of Traditional Owners, came together and signed the Fitzroy River declaration, which was agreed upon as a code of practice for the management of the River. From that, the River Council was formed, which is an alliance of elders and senior knowledge holders from the catchment, which encompasses 10 different Indigenous languages. The Martuwarra Council consistently works to ensure the health and well-being of the river and its people.

As a project manager working for the Martuwarra Fitzroy River Council, I have just completed working with the Council on the Living Water Heritage virtual exhibition, which was set up to improve access to and awareness of heritage values associated with the Martuwarra.

Community Engagement and Governance

Carlien Donkor: Since the Martuwarra Council was set up, has there been more interest from people participating and from the community?

Lachie Carracher: The amazing thing about the Martuwarra Council is that people want to be there. It's different from other organizations in the region. People are on the Council because they are speaking up for the future of the River, they choose to be there. There is also the Youth Council, which represents the young leaders, the next generation of senior people, and they engage in projects throughout the nation, improving awareness and understanding of the River. I am incredibly privileged to work with such an inspirational group of people.

There are a few people working in the organization, two working full-time. Support is growing, and a lot of people are taking interest in the River and the work the Council does. Many people are wanting to get involved and come to Martuwarra to experience this amazing place and to work in any capacity with the council.

Carlien Donkor: How do you support the projects and activities you're working on?

Lachie Carracher: The organization runs on philanthropic donations and is not government funded, with the exception of major projects like the Living Water Heritage virtual museum. The Martuwarra Council also engages with academic institutions. For example, there are currently three PhD candidates working with the Council on their doctoral research. From the beginning of my time with the Council the door has been open for support from people who come with good ethics and the intention of broadening understanding and appreciation for why the Martuwarra needs to be protected.

Carlien Donkor: That's great! We noticed that you're part of the Global Network of Water Museums (WAMU-NET). Why did you choose to join?

Lachie Carracher: I was put into contact with Eriberto Eulisse from WAMU-NET two years ago. The reason to join was to improve awareness, engagement and the visibility of this amazing part of the world that we call the Kimberley and Martuwarra.

Carlien Donkor: Has it helped your objectives so far? And what are your expectations from your WAMU-NET membership?

Lachie Carracher: It's good to be part of a global community of people working in the water sector. The opportunity to attend the 10th World Water Forum in Indonesia was fantastic, to be able to connect with various inspirational, powerful leaders in the water sector. So that was a really good result from being part of the network.

Challenges, Protection and Cultural Continuity

Carlien Donkor: You've said a lot about raising awareness and visibility. Don't you feel there may be some threats in that? Because sometimes, when heritage sites and communities become exposed, let's say to the outside world, there's a risk of infiltration of foreign values and cultures, especially with tourism. So how have you also tried to keep your community "untouched"?

Lachie Carracher: The Kimberley is constantly under threat. The saving grace for the region has been its remoteness and the lack of economically viable transport for extractive industries. But now that those factors are changing, the main challenges that we're facing are the threats to the river and its environmental well-being. Fracking is banned in 98 per cent of Western Australia, but the remaining two per cent, which isn't banned, is right in the middle of the Martuwarra watershed. So, we are constantly working to ensure that fracking doesn't destroy the River and fracture the backbone of the Country. Water extraction is another ongoing threat. The proposal to dam the River was put forth in 2017 by a New South Wales agricultural company, KIMCO. Nowadays, people are considering floodplain harvesting, groundwater extraction.

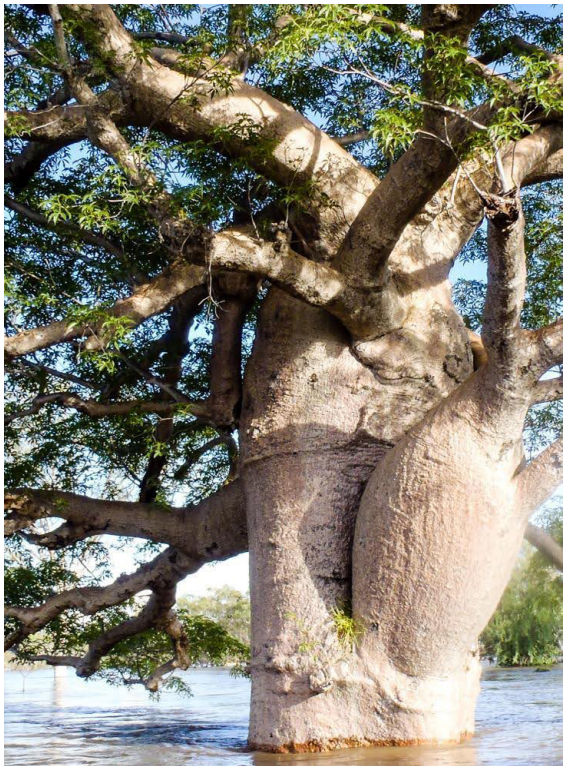
^ Fig. 2 Painting of Ancestral Serpent Beings (Artist: Llyod Kwilla; Source: livingwaterheritage.org, 2024).

You also mentioned threats of cultural discontinuity. With its work, the Martuwarra Council aims to safeguard cultural and traditional knowledge. For instance, the Council engages with various groups on cultural mapping exercises and to ensure that information is kept safe for generations to come.

Carlien Donkor: Has national heritage inscription helped? And how does the water heritage you're trying to protect and promote also help address other challenges?

Lachie Carracher: Martuwarra and the West Kimberley was listed as a National Heritage Site in 2011. The inscription put together multifaceted heritage values associated with the catchment, precisely its connection to the Ancestral Serpent Beings. There's a lot of rock art here, arguably, some of the oldest in the world. Just down the road there's an archaeological site which has been dated to 48,000 years old. However, the River would also qualify as world heritage for its ecological value alone. For example, it has the largest population of freshwater sawfish, *Pristis pristis*, on Earth which is number one on the EDGE list as an evolutionary, distinct, greatly endangered species. And this is the last stronghold for them, here on Martuwarra.

National heritage inscription helps to raise awareness and to bring people along on the journey. It has offered elements of protection for the river. Protection of the river is very complicated and there are many layers needed to protect the place. The Living Water Heritage exhibition aims to improve engagement with – and understanding of – this globally unique watershed. The area is vast and remote, and not many people are as fortunate as I am to experience being with the River, and to feel the power of that place.



^ Fig. 3 The Martuwarra has many endangered plant and animal species (Source: livingwaterheritage.org, 2024).

Digital Heritage, Future Visions and World Heritage Aspirations

Carlien Donkor: You just mentioned the Living Water Heritage virtual museum. Can you tell us a bit more about the idea behind it, what it entails, how long you've been working on it for and so on?

Lachie Carracher: The project was funded by the Federal Government of Australia, and it aims to improve access and engagement with the national heritage values associated with the West Kimberley. We include the River as the narrative to weave all these values together under three themes: Culture, Country and Truth. Each theme has its own simple introduction which is very visual and easy to digest. But then you go

deeper and get into full articles and exhibits. There are many topics covered including biodiversity, river ecology, geology, saltwater, the Devonian reef, fire and water, and archaeology.

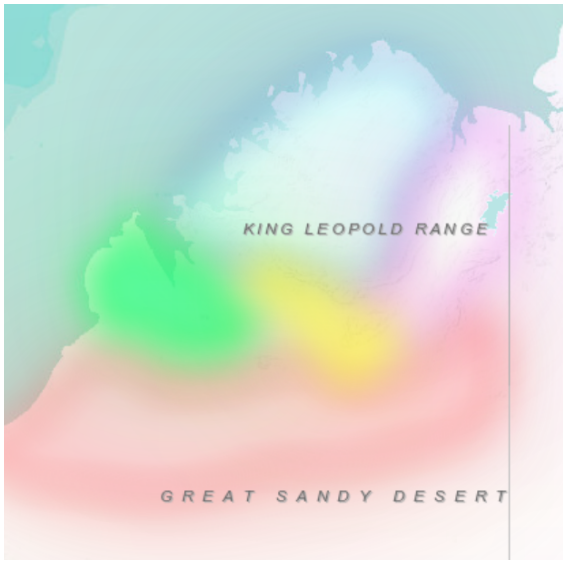
Throughout 2024, my dear friend Mark Coles Smith and I travelled around the catchment, speaking with various communities and groups, trying to find a way to articulate why the area is globally significant. The project champions the need for just development on just terms in line with both the National Heritage criteria and Traditional Owners' voices, while prioritizing the voices of the First Australians of the region.

Talking about Indigenous language within the region, the Kimberley is one of the most linguistically diverse in Australia. The idea was to make something map-centric to explain to someone, perhaps from another country, that with language comes highly specific bio-regional knowledge, which has evolved over thousands of years of intimate observation and landscape-scale sustainable management. But how can we visually articulate this? As an idea, I grouped the First Australian languages by family (there are five different language families in the catchment) and then I overlaid that on top of the Interim Biogeographic Regionalisation for Australia (IBRA) dataset which classifies Australia's landscapes into geographically distinct bioregions based on common climate, geology, landform, native vegetation and species information. Guess what? It was a perfect match! This is nothing surprising when you listen to Indigenous Knowledge Holders but it is another prime example of how significant Indigenous knowledge is. I wonder how much the Australian Government spends on its national bio-regional mapping project when it was already completed thousands of years ago by Traditional Owners.

The National Heritage inscription was in 2011, meeting every possible criterion, but when I would speak to Traditional Owners and say, for example, “There are fossils from your Country, which are of national significance," the response was, “I don't know anything about fossils. But I can take you to my Country, and I'll show you why it's important." I did not make the mistake of starting a conversation with “Why is the specific area of National Heritage value?" I just followed and listened. The road was longer but the result was much richer and more authentic than we could have initially dreamed.

For instance, the “Truth" theme came out loudly as a unified narrative throughout the catchment, although it was not as prolifically mentioned in the National Heritage description. As a result, we discovered some incredible media deep in the national and state archives concerning colonization in the Kimberley, the arrival of the pastoral industry, Indigenous resistance to European invasion, and what I call colonial institutions: missions, stations, police and ration camps. We commissioned archival films to be digitized and repatriated to Community, some of which are included in the exhibition.

So it was a massive undertaking and we compiled some incredible material and worked tirelessly on the research, digging through the archives and putting together a virtual exhibition which is heavy on visual media and map-centric elements. It's aimed at a broad audience but also has enough detail that if you want, you can really take a deep dive into various values which have been highlighted both for National Heritage and by First Australians. It is about 38,000 words, with 20 two-minute videos that are very visually focused and it's publicly available for you.



^ Fig. 4 Map showing overlay of the Bunuban, Nyulnyulan, Jarrakan, Pama-Nyungan and Worrorran language families (Source: livingwaterheritage.org, 2024).

Carlien Donkor: You mentioned you want to get a broad audience. What does promotion look like locally and globally? Are community members aware of this platform that has been created? And how are they interacting with it?

Lachie Carracher: It's just gone live. We are working with state libraries from around Australia to feature the projects and also working with educational institutions so they can use it as a tool and get people to engage with all the gathered material. We are always open to ideas so let people know they can reach out if they would like to learn more or engage with the exhibition and Martuwarra in general.

Carlien Donkor: Congratulations! What would you like to see in the future of your museum?

Lachie Carracher: It would be great to see the conversation with Traditional Owners continue on the theme of World Heritage listing for the River because it is an incredibly rich, globally unique, interconnected heritage landscape that I believe should be protected and enjoyed by future generations.

Carlien Donkor: We noticed that the UNESCO site Purnululu National Park is also in your vicinity. Do you currently have relations with the site managers or do you see possible connections? For instance how can it help to promote Martuwarra?

Lachie Carracher: Yes, it's just outside the Martuwarra catchment. It's great that Purnululu is inscribed on the UNESCO World Heritage list and is a site that is globally recognized in the Kimberley. This is good to raise awareness for the region. We'd like to see more of that in the future and I hope that Martuwarra can join the ranks of Purnululu.

Carlien Donkor: And what would Matuwara need to become listed as a UNESCO World Heritage site?

Lachie Carracher: In my opinion, we need to improve engagement with – and awareness of – the area, especially to help decision makers. For small organisations, funding is always needed and more human capital to help bring everyone along.

Conclusion

Carlien Donkor: Last question. If you could send a message to any leader or policy maker or relevant stakeholder, either locally or internationally, who would you choose and what would you say?

Lachie Carracher: I would like to see the Western Australian government take action to protect Martuwarra and the catchment for future

generations, so that would mean banning fracking for starters, protecting Martuwarra and investing in economies that are not based on extraction, but conservation. I believe the current federal government agrees, as do local people and a large community abroad, so the message would have to go to Roger Cook who is the premier of Western Australia: protect Martuwarra.

Acknowledgment
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Useful Links
www.martuwarra.org
www.livingwaterheritage.org

Lachie Carracher has always centered his life around wild rivers. He has worked in conservation economies throughout Canada, Uganda, Nepal, Sumatra, Laos and Colombia. This unique life experience has provided a valuable depth of knowledge which he now brings to the West Kimberley and specifically the Martuwarra Fitzroy River. Lachie continues to build his relationship with Martuwarra Fitzroy River Country by hearing, feeling and learning from everyone and everything around him.

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Carlien Donkor is a PhD candidate at the African Studies Centre Leiden (ASCL), interested in traditional ingenuity and historical practices of living on and with water, and their positioning in inclusive development frameworks. Her experience as an architect and project manager, combines research, design and construction for climate-resilient and context-sensitive solutions. She was among the winners of the EU Sparks hackathon in which The Nettuniani proposal was awarded the best solution for climate adaptation. Other interests include community collaborations and multimedia installations.

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Interview with Alioune Dème | Uniting Riverine Cultures through the Regional Water Museum in Senegal

Interview with Alioune Dème
By Carlien Donkor

Abstract
In March 2022, the Ninth World Water Forum, focusing on the theme of "Water Security for Peace and Development," was held in Dakar, Senegal. Responding to the recommendations of the Forum and sanctioned by the Dakar Declaration, "A Blue Deal for Water and Sanitation Security for Peace and Development," Senegal's Ministry of Water and Sanitation, Minister of Culture and Communication, the Cheikh Anta Diop University of Dakar and the Organization for the Development of the Senegal River (OMVS), in partnership with the UNESCO Regional Office for West Africa in Dakar, met twice to consult and reflect. Through this process, they decided to combine their efforts to create a regional water museum in Senegal. This initiative is the result of the recommendations of the World Water Forum, several sessions of Action Group 4E "Increasing Water Efficiency and Sustainable Management through Science, Technology, Innovation and Education," and various activities of UNESCO, one of the Forum's strategic partners.

Policy Recommendations

- A strong and smooth cooperation among national institutions and countries combined with an approach that gives voice to Indigenous groups is the way forward for the whole of humanity.

KEYWORDS

Senegal River
Water museum
Hydro-technology
Hydro-diplomacy
Anthropology of water

WATER ICONS

CLIMATE

BSh: Hot semi-arid climate

< Fig. 1 Water as an economic and a liminal space in the Salum Delta of Senegal (Source: Moussa Wele, Layepro/UNESCO Dakar).

Introduction

INTERVIEWER | Carlien Donkor: Good morning, Dr. Alioune Dème, professor at Université Cheikh Anta Diop in Senegal. Can you tell us about what is tentatively called the West Africa Museum of Water?

INTERVIEWEE | Alioune Dème: It is a pleasure to discuss the regional West Africa Museum of Water. This was an effort by the Secretary of Hydrology and Water Sanitation of the Senegalese Government, undertaken through a regional organization called Organisation pour la Mise en Valeur du Fleuve Sénégal (OMVS; Senegal River Basin Authority). This organization included all the countries crossed by the Senegal River: Guinea, Mauritania, Mali and Senegal. These countries share an interest in better management of the water coming from the Senegal River in terms of hydrotechnology and irrigation and in addressing issues related to water policy, hydrology and technology. And then there is UNESCO, which is the technical arm of this endeavor. OMVS and UNESCO started discussions after the World Water Forum (WWF) in Dakar in March 2022, and the idea to have a regional water museum emerged. After many discussions, they both decided that it was time to go beyond talk and try to make it happen, and that is when I was contacted by UNESCO to lead the effort.

This regional water museum is very important and different from other museums because it is not a museum for one country. This is really a museum for five to seven countries, and it may eventually include all the members of the Economic Community of West African States (ECOWAS), which would amount to more than 15 countries. In fact, the museum is a contribution Senegal is making to all of West Africa in terms of water anthropology, policy, technology and diplomacy. It is also a way to educate the public on water preservation, conservation and sanitation.

Institutional Partnerships and Museum Development

Carlien Donkor: Can you name the West African countries that are involved in the West Africa Museum of Water?

Alioune Dème: Currently, it's Senegal with input from Guinea, Mali, Mauritania (through OMVS) and OMVG (Gambia River Basin Authority).

Carlien Donkor: How are you funding this initiative? You mentioned the Senegalese government, UNESCO and possibly ECOWAS. Are they your main donors, or do you have other sources?

Alioune Dème: So far, the main donors are the Senegalese government and UNESCO, which has a small budget for these kinds of programs. However, when we go from just an exhibition to opening the space, we have to find additional donors. We are considering the Senegal River Basin Development Authority (OMVS), cooperation with other countries and funding agencies, so that's where I think the main funding will come from.

Carlien Donkor: To follow up on the 2022 WWF event, I wanted to ask how you found out about the Global Network of Water Museums (WAMU-NET) and how you became a member.

Alioune Dème: When I was chosen to lead the regional water museum project, UNESCO put me in contact with WAMU-NET. During the 10th World Water Forum in Bali, I met the director, Eriberto Eulisse, and that's when he invited

me to their Porto conference and also invited the Regional Museum of Water to become a member of WAMU-NET.

Carlien Donkor: Why did you chose to join WAMU-NET, besides being recommended by UNESCO? Do you see it aligning with some of the objectives of the regional water museum?

Alioune Dème: WAMU-NET is the "place to be" in this field. It is a benchmarking space for all these world museums to come together to share experiences and ideas. There are so many ways that we will benefit by being a member of WAMU-NET, so that's why I fought hard for us to join. For example, the organization can help us understand how to design an online museum, how to use new technology and how, in a broad comparative approach, water is constructed in other cultural settings.

Water Heritage and the Role of Community

Carlien Donkor: And as a new member, what are some of your expectations?

Alioune Dème: Because our museum is in progress, it's always good to share experiences and expertise, discuss and innovate and incorporate new ideas while still ensuring that each water museum is different from the other. Networking events like conferences and potential international collaborations will be helpful. Of course there are things that all water museums share, and by having these kinds of interactions, we go through these shared processes more easily and can have a better institution.

Carlien Donkor: You haven't started operation yet, but there are some heritage elements you identified as very important to protect in the West African region. Can you mention some of these initial submissions that will be showcased in your museum, including heritage sites, systems or practices? Can you also talk about some of the threats to water heritage and the potential challenges the new institution may be facing?

Alioune Dème: You know West Africa has a lot of waterways and around those, you have a lot of fishing communities. These fishermen and shell collectors don't use water only for economic and food-related activities but they also have cultural relationships with the water and with the aquatic fauna. That is why the ethnographic side of this water museum is very important; it exhibits what West Africa will bring to the world (fig. 1).

We have started an inventory of all these "people of water." In French, we call them *peuple de l'eau*. So, there are fishermen and shell collectors with a lot of symbolism and a cultural memory of water. We have made a unique survey of each culture and group, but the challenge now is that for some countries, it will be very difficult to go there. For countries like Mali, Niger and Burkina Faso, the violence and warfare going on there causes us to think twice before going. That's the biggest threat. But we already have a lot of information and can rely on some native colleagues who are there to help us gather information about those parts of the region. It would have been easier or better for us to be there, but because of the political situation now, we cannot do that.

And of course, the second challenge is mobilizing money. We might rely more on some countries than on others, but that's how we can deal with the economic situation in West Africa.

Carlien Donkor: You mentioned how connected people are to their water in West Africa, espe-

^ Fig. 2 Manatali Dam as source of water sharing among OMVS member states (Source: OMVS, 2014).

cially in non-urbanized areas. You also made some very valid points about the political tensions within some West African states, hindering access to these heritage communities, and you also mentioned the problem of funding.

How can the water heritage that you plan to protect and exhibit in the museum be activated on the ground to address these challenges and others within the different participating countries, for instance, in Senegal?

Alioune Dème: We hope that the water museum will boost tourism and economic development in all participating countries. The idea is to get museum visitors excited enough to say, "Okay, I will go and see this place for myself." Also, such challenges can be solved using diplomacy. Through OMVS and ECOWAS, this museum can bring more peace and solidarity across the region and more cooperation among countries. Topics such as water and cooperation, water and peace, water and inclusion, water and diversity, and hydro-diplomacy will be highlighted. OMVS has a lot to showcase. In areas such as East Africa, water is a cause of conflict. In West Africa, OMVS has used water to strengthen peace and cooperation among member states (fig. 2).

Innovation, Inclusion, and the Museum's Future

Carlien Donkor: Using museums for water diplomacy and advocacy is an inspiring idea. Earlier, we discussed innovations you want to introduce in your museum. You spoke about artificial intelligence (AI) and how you are targeting the younger generation using this tool.

Can you say a bit more about how AI forms a part of the museum? And what are some difficulties you're facing introducing and funding that aspect of the museum, if any? Have you already identified some partners?

Alioune Dème: Actually, we don't have partners yet. But the good thing about being poor is that it makes you more innovative and better at finding solutions. I have colleagues in the computer science department who specialize in AI, so they help me in this endeavor.

When I was thinking about education, my question was, "For whom is this museum?" And I said, "More than 60 per cent of the African population is less than 25 years old. To be a successful museum, you have to target this age group." Then the question became, "How can we communicate with them? By which means?" Well, this is a very savvy generation, and their time is about high-speed communication. They are all very excited about AI, so let's use generative AI to reach and attract them to come so they can learn and spread it elsewhere. I think this tool and strategy is more important than staying with the ways we are used to seeing museums — as walls, paintings, boats and so on.

Carlien Donkor: This integration of advanced technology with traditional knowledge sounds very promising. However, people sometimes talk about how the digital era threatens the continuity of Indigenous knowledge. How do you

plan to keep the use of new technologies from interfering with, let's say, the integrity of whatever water heritage you're protecting?

Alioune Dème: Well, the way I see it, all the data we have is a result of co-construction. I talk with local people, and I'm always being guided by them to get the information that we want. We tell them why it is important, but when we need to spread that information to a broader audience, we use technology. So I don't see a conflict between local culture and technology. Rather I see them as complementary. The information remains local but to squeeze and speed that information, we use technology. In terms of public education, technology allows us to reach a wider audience. It allows Africa to have a voice in this digital age.

Carlien Donkor: Can you elaborate on the impact you're trying to have on Africa and beyond through this water museum?

Alioune Dème: I've been outside of Africa for 20 years and that has shaped my conception of Africa today. Africa is not just the continent. You have the diaspora of Africa, the friends of Africa and the public who want to learn about Africa. So, you have to take all these people into consideration and see what strategies you can use to teach them, and that is how I plan my activities. Everybody wants to learn, and new technology is so important in addressing this broad need for education because it allows us to do a lot of work with less money.

Carlien Donkor: Coming back to the topic of technology and cultural communities, how do you plan to relay this digital interface to people who perhaps don't know how to handle it?

Alioune Dème: I question this notion that (local) people don't know how to handle technology. Look at how smartphones have changed Africa. Africans have not rejected technology but have always embraced it to fit their own needs. What is important for us as curators is to investigate the kinds of technology available and how to use them to fit the contextual needs. And it's not that local people don't want to learn about new technologies; instead, there are situations where they have not been exposed to it. Once they are, if they see that it's important for them, they'll adopt it. That's my philosophy, and that's how I've been doing this so far.

Carlien Donkor: How does the West Africa Museum of Water align with the UN SDGs?

Alioune Dème: As I mentioned earlier, this idea started with the UN at the 2022 World Water Forum. Everything related to the protection of culture, to inclusion, to development, to diversity and to the protection of cultural minorities is connected with the work of the West Africa Museum of Water. So, it is really part of the UN agenda to #leavenoonebehind.

Carlien Donkor: Are there other specific SDGs that your museum will also help achieve besides SDG 4 on education, which you have highlighted a lot?

Alioune Dème: Local development is a priority because we hope that this museum will help the cultural communities in terms of revenue generation. We also deal with diplomacy between and within West African countries.

Carlien Donkor: What would you like to see in the future of your museum after it opens?

Alioune Dème: This is really up to the government, but when we open, I would like people to see it as their own museum and not as a museum of the elite nor as a museum of the gov-

ernment. That's why I said it has to be a product of co-construction: a museum created in collaboration with the local population for the general public because it's the local population who are going to tell the story, and I'm here just to help make the connection. If the local population see themselves in the museum and members of the public enjoy the museum, if the museum helps OMVS and the Senegalese government advance their public education objectives, then, yes, I would be happy and will be able to say "mission accomplished."

Conclusion

Carlien Donkor: Last question. If you could send a message to any leader, policymaker or relevant stakeholder, whom would you choose? And what would you say?

Alioune Dème: If I had the power, my message would be addressed to the UN, but I'm sure that they already know and that's why we have WAMU-NET. Then I would address the African Union and the European Union.

We have to think about water, or water will make us think about it. We see what is happening all around the world. Climate change is destroying a lot, and not just lands. Cultures and memories related to water have been destroyed. So, it's really important to salvage all these ideas and cultures for the sake of humankind. Stories from a particular culture are not just for their people; they hold some cultural values that are relevant to all of us, and it's important to tell these stories.

Carlien Donkor: Thank you for taking time to talk with me.

Alioune Dème: Thank you for giving me that opportunity.

Acknowledgment
This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein.

Useful Links
https://www.omvs.org/

Alioune Dème is Assistant Professor of Anthropology, Cheikh Anta Diop University (Senegal). He earned his PhD from Rice University in Houston, Texas, in 2004. His dissertation is entitled "Archeological Investigations of Settlement and Emerging Complexity in the Middle Senegal Valley." A member of the World Water Academy, Dème has authored many published works including "Ancient Developments in the Middle Senegal Valley and the Inland Niger Delta," in *Oxford Research Encyclopedia of African History* (2018); "Pêche et interactions entre la Moyenne Vallée du fleuve Sénégal et le littoral atlantique Sénégalo-Mauritanien durant le dernier millénaire BC," in *La mer dans l'Histoire: l'Antiquité* (2017).

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