On Groundwater
Invisible Architectural Environments

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The advent of the Anthropocene influenced a new groundwater environment. Agricultural irrigation and urbanization dramatically shifted groundwater patterns globally. Climate change will amplify these shifts. Reduced surface water flows in dry regions, and the resulting increase in groundwater extraction exacerbates drought conditions. Increasing rainfall in regions of moisture convergence, coupled with increased impervious surface in urban areas that impedes groundwater recharge, exacerbates flood conditions. Decreasing groundwater levels in some regions, and rising groundwater levels in others, affect surface and groundwater quality through mobilization of microbes, contaminants, and seawater intrusion.

This rapidly changing, relatively unexplored, and increasingly unpredictable underground environment is inextricably tied to building practices. Yet architects’ contractual responsibilities usually end 5 feet away from the building. The interface of building with groundwater is limited to pumps, barriers, and perimeter drains. The project of extracting, infiltrating, and monitoring groundwater remains at the margins of architecture discourse, despite its role in material preservation, ground plane articulation, and climate modification. This micro-narrative examines remarkable interactions between building and groundwater, exploring the performative and experiential potentials of an invisible landscape.

Ground as Fluid Ecology: (Preserving) Submerged Forests of Venice

Piranesi worked under both “a Venetian preoccupation with foundations and an antiquarian curiosity about the ground upon which he stood,” making unseen geological substrates visible and intelligible, and exaggerating archaeological legacies (Figure 1). Venice often draws attention to the margins, to “the water-steps and the Istrian stone footings of buildings; borne ... on wooden piles driven into the caranto—the compact sand and clay strata of the lagoon.” Piles of larch, oak, and alder, 4–9 inches in diameter and 3–15 feet long, spaced about a foot apart, hold the zatteroni and madieri—the beams and planks supporting the masonry. Millions of trees were harvested to build Venice, although piles became less common after the sixteenth-century expansion, where the caranto was deeper, and buildings

Figure 1. Giovanni Battista Piranesi, Ichnographia of the Campus Martius of the Ancient City (1757). Piranesi’s archaeological knowledge translates into a systematic recording and design experiment with “traces and fragments of the past continually juxtaposed with the process of decay and deterioration.” (Source: Yale University Art Gallery.)
became wood barges. Groundwater preserves piles, which become vulnerable to its changing chemistry, physics, and biology. Researchers recognize the lagoon’s ecosystems by the microorganisms living in the piles, and their changes are bio-indicators of large urban and climatological changes.\(^5\) Natural subsidence, exacerbated by groundwater extraction, loss of riverine sedimentation, dredging, and sea level rise, caused a sixfold increase of *acqua alta* in seventy years.\(^6\) The aesthetic and performative agenda of Carlo Scarpa’s *Fondazione Querini Stampalia* suggests a more nuanced and sensible way to address critical vulnerabilities to this changing environment than attempts at fortifying with urban-scale floodgates and tanks that further alter the physics and ecology of the lagoon. Unlike Venetian construction that “maintains the fiction of the campo’s solidity,” this ground-floor renovation accepts flooding and exudes an aquatic sensibility of “liquefied materials” and “spatial affects that unmoors us from the earth” (Figure 2).\(^7\)

**Ground as Resource: (Extracting) the Swelling Groundwater of London**

Designed collaboratively by Swiss architects Herzog and de Meuron and Chinese artist Ai Weiwei, the Serpentine Pavilion consisted of an excavation five feet into the ground, until reaching groundwater; “a waterhole … to collect all of [the] London rain that falls in the area.”\(^8\) The seemingly floating roof holds and celebrates water, creating a reflective surface below eye level that slowly drains into the waterhole (Figure 3). Incorporating an “invisible aspect of reality in the park”—groundwater—and cleverly revealing remnants of former pavilions, the structure “testifies to the more or less invasive intervention in the natural environment of the park.” But this groundwater perched above the London Clay is a shallow aquifer mostly maintained by leaking pipes (Figure 4). Deeper and denser building construction increasingly limits the aquifer to the gravel base under roads. Future increased rainfall and higher tides in the River Thames will exacerbate flooding, but scarce information and the heterogeneous nature of shallow aquifers are an obstacle to urban-scale management.\(^9\) The deep aquifer, with its deepest levels dating 25,000 years, has also been transformed by human activity. Industrialization exploited aquifers, lowering groundwater as much as 300 feet,\(^10\) resulting in the loss of yield in boreholes, a switch to piped supplies, and saltwater intrusion.\(^11\) Postindustrial decentralization and declining groundwater extractions reversed the trend, causing a rise of more than three feet per year, threatening the swelling of clay, reduction in buildings’ bearing capacity, hydrostatic uplift pressures, and chemical attack.\(^12\) To stabilize groundwater levels, 70 million liters were extracted daily across London.\(^13\) This suggests that, like the Serpentine Pavilion, accommodating flow, holding and slowly releasing water, becomes a critical program for architecture.

**Ground as Sponge: (Infiltrating) Water Squares in Rotterdam**

The delta city of Rotterdam lies below sea level, challenged by sea level rise and extensive impervious cover. Recently, the dramatic increase in rainfall created a bigger challenge than the sea—needing a retention capacity of 160 million gallons or a 200-acre underground lake.\(^14\) Large retention projects under a limited number of large structures prove insufficient and unfeasible in the dense city center; thus, rainwater needs to be collected across a wide
Groundwater network, preferably closer to where it falls. Current strategies operate on a range of scales, transforming a network of buildings and public spaces into sponges—legibly absorbing and retaining rainwater and giving it time to slowly infiltrate into the ground—animating public space. The Benthemplein Waterplein (Water Square) by De Urbanisten became a model for the city’s master plan, transforming the center of a block into a hyperproductive public space for groundwater infiltration. Collecting water from green roofs and impervious surfaces of adjacent buildings, this constructed topographical hardscape made up of concrete basins playfully painted blue, rain gardens, and stainless steel gutters makes the path of water and hydrological cycles visible (Figure 5). Water floods two of the three multiuse basins during storms, overflowing into the deepest basin after heavier storms and infiltrating into the ground within 36 hours (Figure 6). The design embraces temporality, integrating recreational public space with infrastructural function.

Ground as Artifice: (Monitoring) Traces of Landmaking in Boston

Boston’s nineteenth-century neighborhoods were built predominantly on fill. Wooden piles support most buildings, driven to clay under the rubbish filling former marshes and coastal waters. These piles were to be preserved by groundwater, assumed a constant, without anticipating the landscape of leaking tunnels, pipes, and foundations that draw down groundwater. The scarce knowledge of this underground environment makes the movement of groundwater unpredictable. The low cost of abundant water in the region encourages unsustainable solutions. The Metropolitan Boston Transportation Authority injects over 70,000 gallons of potable water into the ground each day to maintain the foundations of historic buildings near Back Bay Station. Threatened by dropping groundwater levels, flooding,

Figure 4. Section of the 2012 Serpentine Pavilion, showing historic groundwater levels in Kensington Gardens. (Image © Michelle Laboy.)
and sea level rise, the city council enacted policies for groundwater monitoring and recharge, slowly implemented one new building or renovation at a time. A project of public installations attempts to make groundwater legible with a constellation of glowing objects; ranging in scale from new sidewalk caps for existing groundwater monitoring wells, to urban furniture that celebrates green infrastructure, and atmospheric installations that reveal where the path of surface water has been hidden below ground. The well cap concept leverages more than 800 existing groundwater-monitoring wells, fitted with new digital displays connecting sensors to a mobile app for crowdsourcing data (Figure 7). Interactive mapping of historic data, and crowdsourcing real-time data, make this critical architectural landscape more legible, tracking its vulnerabilities and fluctuations (Figures 8). Design can make citizens aware of the relationship of cultural heritage to groundwater, visualizing the role each individual building’s garden can play in maintaining the groundwater table in a very densely built environment. Engaging city engineers with designers in a public space project can transform a network of small- and large-scale recharge projects into a communicative and performative landscape.

**Design and the Hydro-Social Cycle**

In contemporary culture, water is either utility or nuisance. The science of hydrology turned water into a resource to be managed. Modern technology has resulted in the “metaphorical degradation of water” perceived as a “piped and metered cleaning fluid.” Urban groundwater has less direct utility or visibility, but it is a foundational environment to urban architecture and landscapes, with the potential to surface literally and figuratively in daily life. Efforts to monitor groundwater, research vulnerabilities of building materials, and adjust infrastructure to sinking buildings are emerging areas of urban policy and environmental science in many cities. Design that makes groundwater legible in public space engages with the notion of the hydro-social cycle, which argues for the inseparability of the social and the physical. Like Piranesi, architects can find creative potential in interdisciplinary exploration of the environment found below ground. Increasing social engagement and legibility of this critical environment can expand cultural narratives and performative potential for architectural design.
Author Biography

Michelle Laboy is an Assistant Professor at the School of Architecture in Northeastern University and cofounder of FieLDworkshop, a Boston-based design and research firm that specializes in the design of ecologically restorative architecture, urbanism, and public art. Laboy is trained in architecture, urban planning, and civil engineering, and her research examines the evolution, significance, and practice of architectural ecology, or how architecture is grounded in the urban landscape to actively engage, integrate, and heighten the performance of cultural and natural systems.

Notes


12 Rising groundwater can add significant upward pressure under buildings, a problem if foundations were not designed for it. The chemicals that the water may lift up from lower layers of soil, or from seawater intrusion into the aquifer, may cause deterioration of concrete underground structures. See C. W. Hurst and W. B. Wilkinson, “Rising Groundwater Levels in Cities,” *Geological Society, London, Engineering Geology Special Publications* 3, no. 1 (1986): 75–80.

13 Shama and Johnston, “City of London SFRA Review” (note 9).


