

Skyscrapers as a Complex Response to Rising Waters: Resilience and Adaptability



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Mandana Bafghinia is an architect, designer, and artist trained in Milan and Paris. She is a doctoral candidate jointly in architecture at the Université de Montréal, and in geography at Université Lumière Lyon 2. Her dissertation examines the relationship between the skyscrapers and their broader urban context, with a particular emphasis on the effects generated by their summits. Observation decks created on the top of North American, European, and Asian skyscrapers are analyzed in the light of theories of architecture and visuality. Her research is grounded in fieldwork made in New York, Montréal, Paris, and Shanghai.

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Abstract

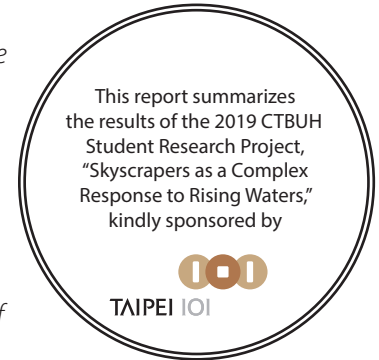
As greenhouse gas emissions continue to rise, the consequences of climate change are becoming more imminent—including rapidly rising sea levels. As a result, many heavily populated coastal cities find themselves at risk. These rising waters threaten not only the populations that live in these cities, but also their skylines, the trademark of the modern city. The purpose of this research is to visualize the effects of climate change and sea level rise on coastal cities, and to establish credible design responses. The foundational analytical work is shown and expanded upon in the companion data study, “Tall Buildings in Numbers: Sea-Level Rise Susceptibility” (see page 50).

Keywords: Climate Change, Resilience, Urban Design

Introduction

This research studies skyscraper typologies capable of responding to the challenges of rising waters, both through an improved resiliency of the lower levels of the buildings, and through the potential adaptations of their upper floors for safety purposes and energy production.

On the basis of a design workshop for architecture students held during the first phase of the project at Université de Montréal, which also included theoretical lectures, the researchers have delineated a series of operative solutions. Using primarily the observations of the workshop, the design solutions suggested mainly deal with the lower floors and the summits of the skyscrapers, considered from the point of view of their resilience and adaptability. The second phase of the research has led to the definition of a benchmarking matrix (see Table 1), and to an inventory of proposals for the different modes of response of high-rise buildings to rising water levels through their architectural design.



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Resilience

First, the basic principles of resilience need to be introduced. Resilience is related to the notion of equilibrium in a single state: the capability of systems to anticipate the threats and recover in a balanced state. Resilience is related to the notion of urban socio-technical and socio-ecological systems. The definition of spatial and temporal boundaries of cities influences decisions regarding climate resilience.

Two questions can be raised:

- a. Is resilience always positive, general or is it specific?
- b. What are the paths to resilience, and the time scales measuring rapid and disruptive events, such as floods, or gradual trends, such as the rising sea level?

In general terms, resilient building systems require four different strategies (Pendall, Foster & Cowell 2010):

1. Persistence or rapid recovery after disaster-induced changes in urban design and/or communication systems.

Typology	Precedent	Location	Year	Architects	Flooding Condition	Precedent Solution	Key Points
Base - Volume - Lift	Re de Boston 2100	Boston	2015	Architerra	Permanent	TECHNICAL: Installation of systems to capture solar energy and rainwater on the roof	Directly linked to sea level rise Hot water retention basins
Base - Connection - Lift						SPATIAL: Regardless of the water level, we have recreational and functional access (circulation on the water)	
Summit - Connection - Lift	City in the Air / Clusters in the Air	n/a	1968	Arata Isozaki	Permanent	Entire area is elevated Large amount of vegetation on the facade of micro-dwellings	New way of living
Summit - Aperture - Collect	Smithsonian National Museum of African American History and Culture	Washington DC	2003	Adjaye Associates, Freelon Adjaye Bond, Smith Group	Occasional	TECHNICAL AND SPATIAL: Natural transverse ventilation accentuated by the shape of the building envelope	
						SPATIAL: Projects city into the air Vertical elements of movement that serve as ground anchors Space that is built progressively according to its needs	
						SPATIAL: Creation of an introverted place Contemplative view of the water in the center of the room	Recreational use of water

Table 1. Selected precedents used in the derivation of high-rise building typologies for response to sea-level rise. More than 30 typologies were developed; a limited selection is shown here.

- Transition, or changes in governance practices to ensure justice in decision-making, and the implementation of legal responsibilities by private and public actors.
- Transformation or local innovation challenging the status quo and producing changes in political-economic systems.
- Knowledge development through education relative to socio-economic inequalities. Community education and self-organization are needed here.

Jean-Jacques Terrin and Jean-Baptiste Marie (2014) outlined several archetypes of flood-resilient solutions in architecture:

- The "Ark," which is a floating, unsinkable city.
- The "Wall," which is a barrier erected between the waves and the city – which seems ever-destined to increase height and thickness.
- The "Sponge," as featured in projects in Seattle or the gateway to Alaska. It deals

with the absorption and retention capacity of the city when the banks welcome the rising floods.

- "Staging," in which the city is elevated by means of stilts or plinths. Water is integrated into the city as a profitable substance, allowing for alternative agriculture and natural air conditioning.
- "Deviation," or the division of the flow of water to reduce its strength and the collateral damage.

In the same publication, three types of technological solutions are suggested, namely the protection of dikes, the development of retention areas, such as basins, canals or artificial lakes, and the implementation of techniques for evacuating water by drainage and pumping.

Among more recent studies dealing with flooding, resilience, and the adaptation of buildings, joint research published in 2016 by a Harvard University team and the Boston Planning & Development Agency is one of the most stimulating (Boynton 2016).

Regrettably, the solutions suggested for contemporary high-rise buildings are limited to four pages of illustrations. In contrast, our approach to this complex problem aims at generating structures that promise resilience (see Figure 1) by rethinking the solutions, not only in terms of the building's lower floors, but also the summit as a catalyst that helps support survival during floods.

As revealed by the cases considered in our research, many cities have started to take action on the challenge of climate change. One important aspect is the understanding that water can become an invasive force. However, these steps towards resistance or adaptation often reach their limits in terms of spatial design. One such example is the [American Copper Buildings](#), a luxurious residential scheme erected in New York in the aftermath of Hurricane Sandy. Five electrical generators have been placed on top of one of the two towers, meant to be active in case of emergency (Warakar 2017). In contrast to the quality and sophistication of many tall buildings' architecture, no

particular design strategy has been dedicated to their summits. As a result, the citizens looking at them cannot grasp, even less so understand their significance, in a time in which humankind is at risk and in search of a new emotional relationship with its dwellings. Previous research by our team has shown how crucial “eco-didactic” strategies can be to complement technical approaches to sustainable design (Chupin, Hazberi & Pelchat 2021).

In addition to the identification of buildings threatened by rising waters, we have suggested design solutions that mobilize both technical and eco-didactic strategies. In the case of the crowns, we introduce the concept of a nest of generators, which would provide a refuge, a place of contemplation as well as a device to produce energy from rainwater and solar energy. Such an attitude requires an aesthetic uplift, as well as a creative state of mind. As The New York Times architecture critic Herbert Muschamp perceptively phrased it in 1994: “Instead of burying a city’s vital organs out of sight, design could visualize a place for them on the cultural landscape. Into sight, into mind.”

Adaptation

The research defines perspectives for a strategy of improved adaptability, thanks to design solutions adjusted to small and micro scales, rather than to large ones. It is first important to clarify whether we are developing strategies of avoidance, resistance, or accommodation (AI 2018).

As for the buildings themselves, we consider resistance and accommodation strategies, as well as measures such as sustainable drainage systems, widened drains to increase capacity, improved flood pathways, flood-resilient materials and raised floor levels (Shaw, Colley & Connell 2007). For public spaces, we consider the strategy of “avoidance.”

Among the categories, and types of flood adaptation measures that could be applied

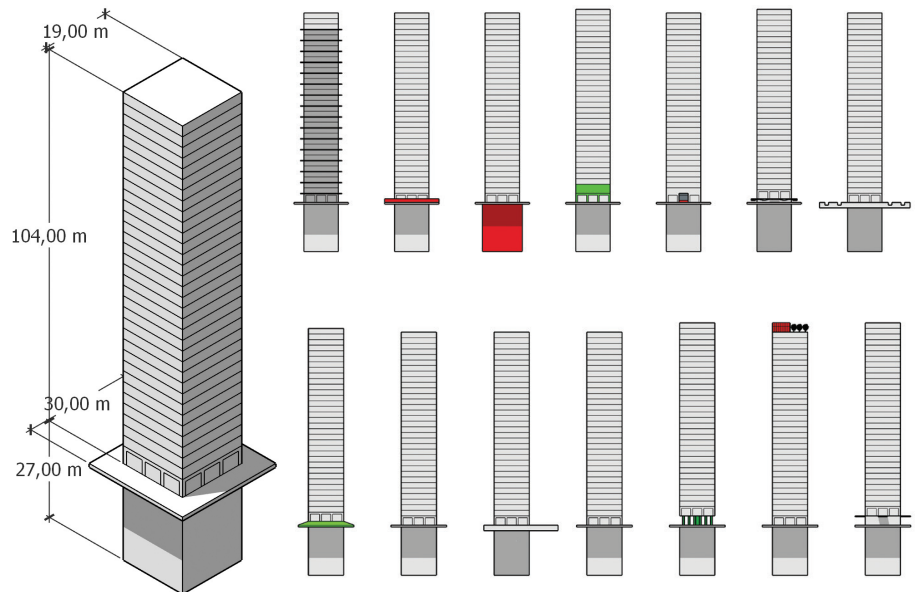


Figure 1. Initial generic model (left) and modeling of spatial (green) and technical (red) solutions (right).

to the design of public spaces, mentioned by Maria Matos Silva (2019), we could mention:

- Plants/green walls, reverse umbrellas (a new precedent), art installations, green roofs, and water (blue) roofs.
- Artificial retention ponds, underground tanks, cisterns, dry or wet bioretention basins.
- Porous paving, floating structures, elevated passages, coastal barriers, blade breakers, glass walls, lifting.

A relevant example is the “BIG U” project, a 10-mile (16-kilometer) loop around Manhattan, designed by Bjarke Ingels Group and One Architecture, with various types of designed resiliency protecting the island from floods.

Two main questions can be raised at this point:

- a. What are the main design strategies that can be deployed by architects to transform the buildings’ lower levels in the event of submersion?
- b. How can the upper levels be rethought, in order to generate a new scenario for the users?

Precedents and Scenarios

In this research, we have developed a matrix and a basic methodological protocol to respond to these questions with a benchmark of precedents. First, a list of precedents which have a direct relationship with the water crisis has been defined (refer back to Table 1). This category considers water damage in two conditions: a temporary condition, dealing with rain or snow, and a permanent condition, dealing with floods. Then, the approach used in terms of spatial or technical devices is analyzed according to the three constitutive tiers of the building: the summit, the shaft, and the base.

We underline in this respect the usefulness of the notion of the “device,” which allows a reappraisal of the issue of resiliency at the micro-scale of the summit, the shaft, and the lower floors, rather than treating a tower as a unified entity. These devices include “technical” devices, referring to engineering or to detailed technical solutions, and “spatial” devices, referring to the livability of the spaces. For each precedent, the elements defining a specific character related to the spatial or technological devices have been identified.

The precedents featured in the second category are not necessarily related to the water crisis. Nevertheless, they help to expand and develop the design scope of the research. For each type of precedent, we have identified its status as adaptive “resilient,” or both. Then, we extracted a solution adapted to our typological design purpose. The results vary from detailed technological solutions to architectural and landscape solutions.

The definition of the design strategies suggested is inspired by the method proposed by Anthony Di Mari in *Conditional Design* (2014). As a generic model, we have used a simple 100-meter-high tower. This model provides the base for our inventory of designs. When multiplied, it generates clusters of towers. The tower is subject to a tripartite division: the summit, with the crown and the upper floors; the shaft—or the body, and the first floors—or the base, which includes the underground floors. Each tier is divided into three groups: Connection, Volume, and Aperture. (see Figure 2).

The Connection corresponds to modes of accessibility to the building, the system of elevators, or elements that extend from bottom to top. The Volume relates to a series of conditions in which the three-dimensional entity is modified. And the Aperture refers not only to the windows or apertures, but to the building’s envelope at large. A series of spatial verbs has been suggested on the basis of these divisions. These verbs help to invent a series of operations dealing with form, eventually leading to spatial solutions responsive to water inundation.

It is obviously necessary that devices be adaptable and transferable to other contexts. First, a series of primary samples were delineated. Since the shaft is not the primary concern in the condition of the water crisis, two solutions have been privileged. The zone of refuge in the time of crisis was precisely developed during the workshop held in Montréal. As for the base, which includes the lower floors, the basement levels, the elevator shafts, the parking spaces, and the

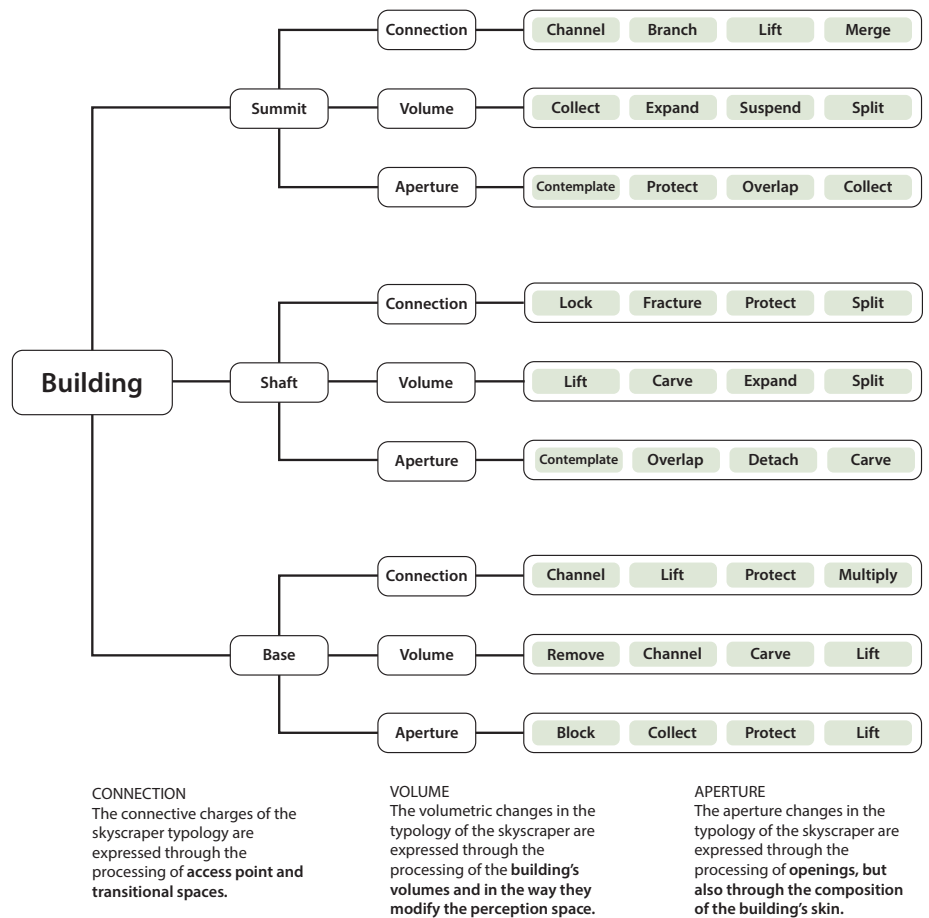
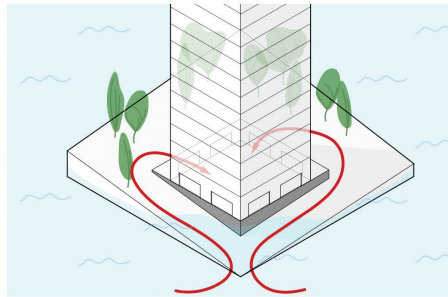
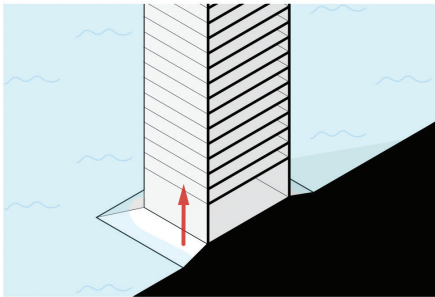


Figure 2. Operative verbs used to develop high-rise building typologies that would be responsive to sea-level rise, combined with precedents and study data.

“In contrast to the quality and sophistication of many tall buildings’ architecture, no particular design strategy has been dedicated to their summits. As a result, the citizens looking at them cannot grasp, even less so understand their significance, at a time in which humankind is at risk and in search of a new emotional relationship with its dwellings.”

BASIC STRATEGY



EXTRAPOLATED TYPOLOGIES

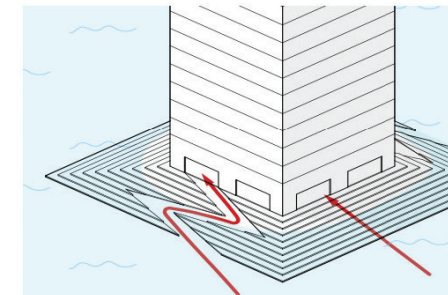
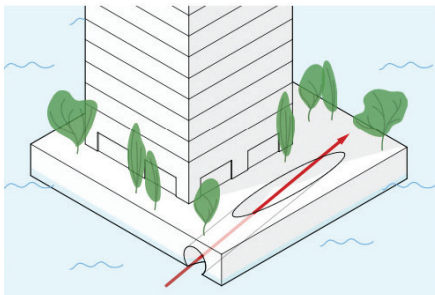
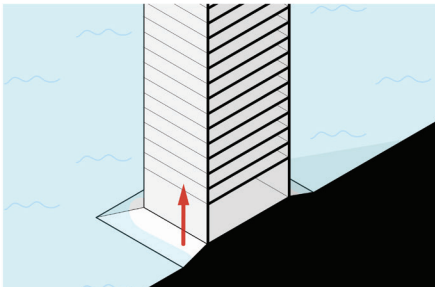
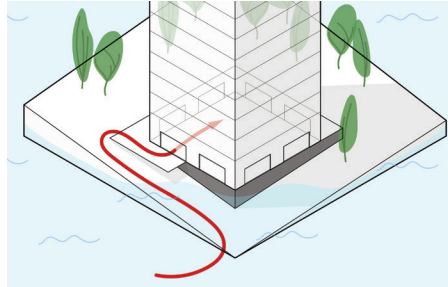


Figure 3. Base - Volume - Lift protects itself by lifting the building onto an elevated base volume.

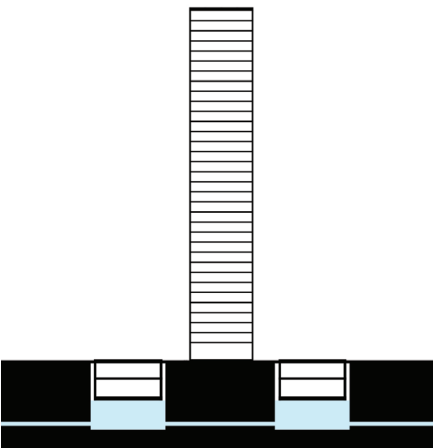
BASIC STRATEGY



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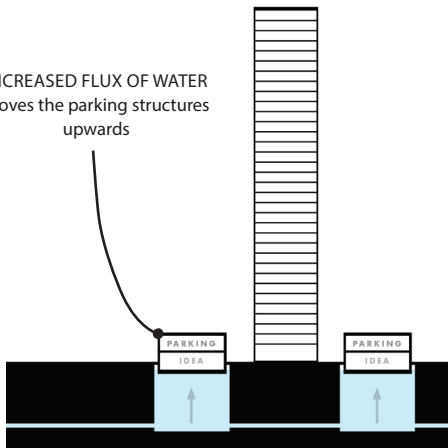


Figure 4. Base - Connection - Lift includes potential for parking garages to be lifted atop channelized rising waters.

accessibility areas to the building, 14 solutions have been defined.

Each solution has the potential to point at various strategies for collecting water and the accessibility to the building; the goal is to activate the building's envelope, provide a variety of access points, and increase usable spaces. One of the main emphases in dealing with the water infiltrating the building is to create a series of different networks to generate water cycles. This method is repeated at every stage, even for the summits. Fourteen solutions were also proposed for the summit. Most of them collect rainwater and circulate it throughout the building. The operational verbs lead us to develop such features as "hard infrastructure," "resilient landscape design," "protection for entrances," and "scope of accessibility."

Project Evaluation

The main issues identified in the development of strategies focused on the base of the building deal with the coordination between the building's and the city's infrastructure, the building's envelope, and the isolation of its users in times of crisis. This means a redefinition of the performance of structural materials to respond to the challenge of water. The management of pedestrian and vehicular traffic before, during, and after rising water levels is also considered. Within the limited space of this article, only some of the 30 projects ultimately developed through our research can be briefly presented.

Project 1: Base - Volume - Lift

The lower floors can be protected from rising water levels by lifting the building via an elevated base volume. It is also an excellent opportunity to create outdoor public spaces, but considering pedestrian and car traffic is at a lower ground level, it creates a spatially isolated project within the city (see Figure 3). One way to remedy this problem could be by ensuring that multiple programs are incorporated into the building to reduce the need for street traffic.

Project 2: Base - Connection - Lift

The second strategy may be particularly intriguing when considered part of the city's long-term development, given a gradual abandonment of the road network in favor of a raised pedestrian network. Existing projects can be inspired by this solution to develop secondary reception spaces on the upper floors, which would become the main spaces once the water level rises (see Figure 4). A series of individual actions can contribute to creating an all-pedestrian network, linking all the buildings in the city. The third strategy is based on the principle of "living architecture." This architecture would reflect visually and spatially the processes in the city's infrastructure during floods. In times of crisis, the building is isolated and protected, and the movement of the parking floors plays an informative role for users.

Project 3: Summit - Connection - Lift

Creating a new roof volume connected by an elevator shaft gives a unique quality to the space at height, which takes on the character of an observation tower (see Figure 5). The technical qualities of such a volume, such as water recovery and the greening of the surfaces, are enhanced by spatial qualities.

Project 4: Summit - Aperture - Collect (Embed, Suspend, Extrude, Channel)

The four strategies suggested all reflect a variation on the classical vision of the top floors of skyscrapers, to create spatial devices that capture rainwater and, at times, redirect it to the ground (see Figure 6).

These devices combine practical effects, water recovery, and aesthetic effects with an integrated contemplative aspect. In contrast with a purely utilitarian view of architecture, the use of the building is included in the reflection and conceptualization process. Roof spaces are made to be visited and appreciated by all, and not relegated to utilitarian functions or reserved for a few, as is the case with most skyscrapers.

EXTRAPOLATED TYPOLOGIES

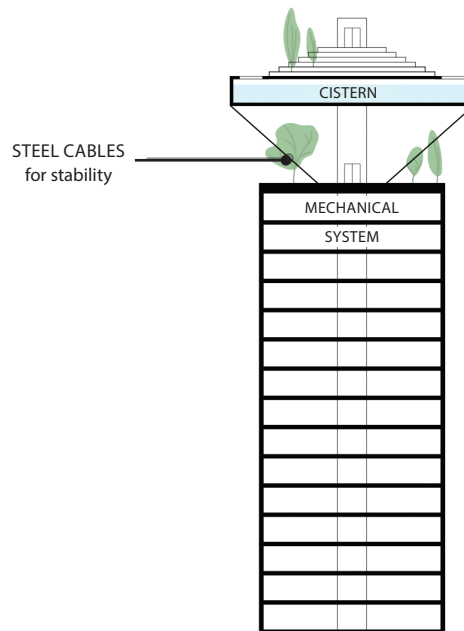


Figure 5. Summit - Connection - Lift would place a cistern atop the structure, buoyed by steel cables for stability.

EXTRAPOLATED TYPOLOGIES

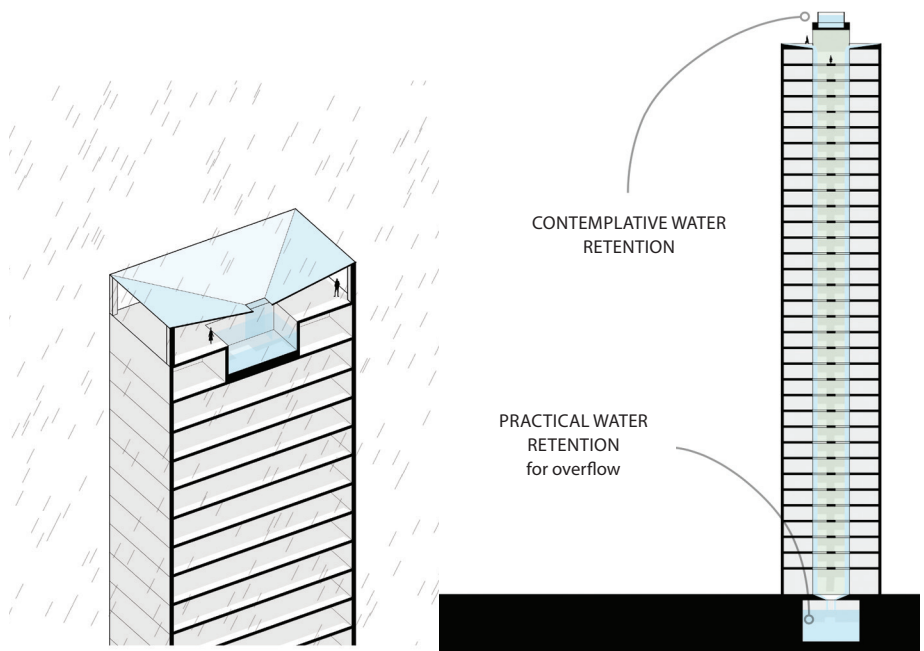


Figure 6. Summit - Aperture - Collect proposes two versions of water retention at the summit of a tall building. "Embed" (left) involves a dimpled roofline that feeds a large pool on the top floor. "Channel" (right) proposes releasing some of the retained water down through dedicated channels adjacent to the core, into a subterranean overflow pool.

“The notion of the ‘device’ allows a reappraisal of the issue of resiliency at the micro-scale of the summit, the shaft, and the lower floors, rather than treating a tower as a unified entity.”

The main proposals identified in the development of strategies dealing with the top of the building can be ordered into five categories:

1. The creation of refuge spaces that can be used in times of crisis, or become new community hubs throughout the building.
2. The protection of users from bad weather conditions.
3. The invention of new modes of rainwater harvesting and conveyance to the ground.
4. The positioning of the mechanical elements so that they are protected from rising water.
5. The redefinition of the role of the top floors as a new energy catalyst, rather than a center of leisure and luxury.
6. The reconceptualization of the top when traffic nodes and street patterns change on the first floors of the tower.

Rising water is a unique opportunity to reconsider how water is used outdoors and inside the building. Notions of adaptability are particularly relevant when dealing with the top floors, which have the potential to become new social and economic hubs in the flooded cities of the future.

Conclusion

The unfolding of the research has allowed for an understanding of the paramount value of the architectural holistic dimensions of a project in rethinking high-rise structures facing the challenge of rising waters, all too

often seen exclusively in technological terms. Considering the corpus of the research, even when solutions are derived from specific precedents linked to particular situations, they are still adaptable to other contexts.

The schematic design proposals suggested might contribute:

- a. To developing a tool that could be used generally and locally according to the specific context of a given tower.
- b. To defining a tool assisting in the design of preventive strategies and the programming of emergency responses.
- c. To integrating crisis-related accessibility in the design of the buildings.
- d. To better understanding the vulnerabilities and possibilities of resilience and adaptation of every scale, from the summit to the shaft and the base.

In conclusion, we propose to shape new approaches relative to flood protection by showing examples of integrated, collaborative, and adaptive solutions. All point to the potential opportunities related to a global, detailed, and consistent reflection on the risks threatening our built environment. Rising waters provide a unique opportunity to change the relationship between urban dwellers and the natural elements and rethink the notion of resilience in the cities, too often defined today in terms of opposition to, rather than harmonization with nature. ■

Unless otherwise noted, all image credits in this paper are to the authors.

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