Liquid Borders: (re)claiming the coast through resilient urbanism

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Liquid Borders
(re)claiming the coast through resilient urbanism

Natasha M. Valldejuly
Contention

Infrastructure, architecture, and landscape have been commonly understood as three different entities within the urban fabric. Nevertheless, climatic uncertainties such as rising sea levels have proven that the division between these systems needs to be re-thought. How can this boundary be transformed into a more flexible urban development in which the water is seen as a habitat rather than a threat? The project I am proposing will use the Caño Martín Peña in San Juan, Puerto Rico as a testing ground to re-think how these systems can come together to form a more holistic architecture of resilience. By building for disaster instead of against it, this project will re-envision infrastructural means to rebuild a new coastal texture in which water becomes the framework of a more economically, ecologically and socially sustainable development.
Can buildings find a *liquid* (adaptable) state in which they can transform based on their climatic condition?

How can the combination of these three systems work together to create a resilient form of public space?

Is it possible for an institutional building to take on the same responsibilities as landscape and infrastructure?
Rising Sea Levels
Recent evidence summarized by the National Research Council indicates that the rate of sea-level rise is accelerating. As the tides continue to rise more people are becoming aware of the risks coastal cities are facing around the world. Global warming is causing thermal expansion and the melting of ice caps, which are the two main factors of the increasing rate of the rising sea levels. Evidence shows that from 1970 to the present, the sea level has risen at a rate of about 29 centimeters per century on Puerto Rico’s north coast. As the diagram on the right illustrates, the rate of rising sea levels has risen dramatically. In 1880 the sea level rate ranged from 1.3 to 1.7 mm/year. By 1930 the rate increased to 1.7 to 2.0 mm/year. And, by 2000, the rate ranged from 2.4 to 3.7 mm/yr. The rate of rising sea levels tripled in only a century and will continue to accelerate. According to the U.S. Environmental Protection Agency (EPA), the sea level is expected to rise 2 meters by 2100, more than seven times the current rate. Some geologists believe the sea level may rise even more than 2 meters in the next century. In “Climate Change and World Cities”, Michael Oppenheimer states that estimates of the rising sea level are enough to permanently inundate a 300-foot width of Atlantic coast beach before the next century. However, these projections are relative because they depend on the amount of additional gas people emit and the inability to accurately predict the response of the polar ice sheets to global warming. The important thing to note is that water is coming back into the city. As a result of climate change, it rains often and harder; sewers can no longer handle the load of heavy rains and streets are constantly flooded. While many people worry about the oceanfront, the biggest threat can be found along rivers because they swell and overflow the quays along their banks with increased frequency. While eroding coastlines are a risk in the near future, overflowing rivers are a risk now due to increased flash floods. It is imperative that this issue be taken seriously and addressed promptly because the acceleration of rising sea levels will ultimately result in loss of lands, properties and even lives. Cities need to find new ways of treating rising sea levels because keeping the water out is no longer a viable option.


20,000 years ago, the sea level was 100m lower, and Puerto Rico's shoreline was several kilometers seaward of its present position. The sea level was so low that the broad Puerto Rico-Virgin Islands Platform was exposed and one could walk to Vieques, Culebra or St. Thomas.¹
The Puerto Rico Trench

The deepest point in the entire Atlantic Ocean (84,000 meters) is found in the Puerto Rico Trench, an east-west-trending depression located about 125 kilometers off the northern coast. The Puerto Rico Trench is located between the Caribbean plate and the North American plate. It formed thousands of years ago when the continents moved apart and outpourings of lava accumulated to form the floor of the Caribbean. The undersea volcanoes and lava flows built up and accumulated through time to form the chain of islands that includes Puerto Rico. Throughout time, rivers carried millions of tons of sediments from the mountains into the oceans and, as the weight of the sand and mud was removed, the island gradually rose upward.

The National Oceanic and Atmospheric Administration states that “the geologic settings of Puerto Rico and the Virgin Islands have created or contributed to several pressing societal issues related to human safety, environmental health, and economic development.” Puerto Rico’s location on an active plate boundary makes the island prone to earthquakes and killer tsunamis.

Numerous tsunamis have struck the coast of Puerto Rico, but one of the most memorable hit on October 11, 1918. In that date an earthquake of magnitude 7.5 occurred about 15 kilometers off the northwest coast, generating a large tsunami that advanced (from its highest levels near the northwest corner of Puerto Rico) along the coast to the south and east, killing 91 people. Other historical catastrophes include a magnitude 7.5 earthquake centered northwest of Puerto Rico (1943), and magnitude 8.1 and 6.9 earthquakes north of Hispaniola in (1946) and (1953), respectively.

In summary, all the known causes of tsunamis are present in the Caribbean. These include earthquakes, submarine landslides, submarine volcanic eruptions, subaerial pyroclastic flows into the ocean, and major tsunamis called teletsunamis. If a tsunami were to hit the island today, the north-eastern part of Puerto Rico would be the most affected area due to its high population density and its extensive coastal development.

the ocean's surface: temperature and salinity

the ocean's surface: temperature and salinity

what causes sea levels to rise?

The Greenhouse Effect
Some believe this effect is caused by the accumulation of carbon dioxide, methane, and other exhaust gases in the atmosphere. The greenhouse effect is expected to increase the frequency and intensity of hurricanes, thus magnifying the threat from all coastal hazards, not just rising sea levels.

Seismic Faults
Earthquakes are one of the greatest concerns to coastal dwellers because they can also lead to the formation of Tsunamis.

Storm Surges
During storms, waves pile so much water up against the coast that the local sea level is temporarily raised.

Climatic Uncertainties
Climatic uncertainties can include flash floods, tsunamis, earthquakes and hurricanes.

Melting of glaciers
Global warming is causing the glaciers to melt. Evidence shows that, if all the glacial ice melted, the sea level would rise by more than 135 meters.

Water's temperature and salinity
Warmer temperatures cause water to expand, thus increasing its volume. Non-uniform changes in salinity levels as well as currents and local wind patterns can also lead to rising sea levels.

Land subsidence and uplifts
Land surfaces tend to rise or drop due to tectonic plate movements. How often these occurs can have a short or long-term impact on the sea level datum.
What are the effects of rising sea levels?
Flooding

Flood-prone areas are identified by maps conducted by the National Flood Insurance Program (NFIP). The NFIP is part of the Federal Emergency Management Agency (FEMA). The purpose of this program is to provide affordable flood insurance to the public through a federal-private industry program, and to encourage land-use planning in flood-prone areas. This way, the need for disaster relief is minimized and everyone in the community has equal opportunity for flood insurance.

Participation in the NFIP is voluntary. Nevertheless, if a community decides to participate and receive federal funds, they must adopt certain floodplain management regulations and meet minimum criteria set by the Federal Insurance Agency (FIA).

Puerto Rico is treated as one single community participating in the program because authority is centralized in the Puerto Rico Planning Board. The planning board is thus the state-coordinated agency for flood insurance.

Flood-prone areas are identified through flood insurance rate maps (FIRMs). They are categorized into V-Zones, A-Zones, B-Zones, C-Zones etc. V-Zones are defined as high-hazard areas. They can also be understood as floodplains subject to storm-driven waves. A-Zones are 100-year flood zones that have a 1% or better chance of having flood (from tides) in any given year. B-Zones are 100-500 year flood zones and C-Zones are greater than 500 year flood zones.

A great part of San Juan’s coast (about 3-4 miles) is considered as high-hazard areas. These types of maps are also useful to predict the height and penetration of waves above the still-water surge elevations for the coasts.

Fig. 2.2 FEMA V-Zone and A-Zone criteria for coastal flood zones (after ref. 164, appendix C).

Fig. 2.3
Hugo 1989

Fig. 2.4
San Juan’s Flooded Streets

Fig. 2.5
Hortense 1

Fig. 2.6
Hurricane Hugo damage to Parque Barbosa
Erosion can be understood as loss of land due to changing water levels. In Living with the Puerto Rico Shore, erosion is described as the moment when the amount of sand lost from the beach exceeds the amount of new sand entering the beach. During a storm, waves temporarily transport sand offshore, flattening the overall beach profile. The sand later migrates back onshore during fair weather. If uninterrupted, the natural process of erosion would not be a risk to coasts around the world.

Nevertheless, humans tend to build too close to the water’s edge, meeting head-on with eroding shorelines and exposing themselves to hurricane winds and storm-surge flooding. Similar to many coastal cities around the world, Puerto Rico’s shoreline is a constant battle zone between waves and terra firma. By building so close to the water’s edge, the natural process of erosion is interrupted and sand cannot migrate back onshore. Therefore, human disruption is one of the main causes of beach erosion.

Furthermore, erosion not only affects the beaches and properties along the coastlines but it also affects the country’s overall economy. For example, many islands in the Caribbean such as, Puerto Rico are highly dependent on the tourism industry as their main economic driver. These tourist developments are usually located along the coasts, affecting the overall morphology of the beaches and further increasing the risk of erosion. Therefore, since having a beach front is what attracts tourists to stay in such hotels, an eroding beach defeats the purpose of having an oceanfront development in the first place. In other words, coastal developments ultimately lead to empty hotels, disappearing beaches, and economic risks.

03_Stabilization Techniques
### Hard-Stabilization (structural)
Shore erosion control practices using hardened structures that armor and stabilize the shoreline landward of the structure from further erosion.

**Benefits:**
- Slows erosion rates landward
- High energy environments

**Drawbacks:**
- Alteration of natural shoreline
- Alteration of water dynamics
- Maintenance

### Soft-Stabilization (non-structural)
Shore erosion control and restoration practices using only plantings or organic materials to restore, protect or enhance the natural shoreline environment.

**Benefits:**
- Natural buffer
- Traps sediment
- Increases vegetation
- Preserves habitat
- Maintains shoreline dynamics

**Drawbacks:**
- Low-energy environments only
- High Maintenance

### Hybrids
Shore erosion control and restoration practices that are a combination of structural and non-structural techniques.

**Benefits:**
- Similar to soft stabilization
- Wider variety of habitats
- Higher-energy environments

**Drawbacks:**
- Alteration of natural shoreline
- Alteration of water dynamics
- Maintenance
Seawalls: A wood, steel, rock, or concrete structure separating land and water areas, designed to protect the land and buildings behind it from the impact of waves.

Bulkheads: Prevent the land from eroding into the sea. Commonly used in quiet-water areas such as lagoons but, they can also be found on the upper part of beaches.

Rip-rap / Revetments: They consist of an armor facing of rocks or construction debris. Similar to a seawall, their role is to act as a buffer to the waves.

Breakwaters: Structures specifically designed to block wave energy, thus sheltering a portion of the shoreline. Usually, but not always, built parallel to the shore.

Groins: Low walls perpendicular to the shoreline. They are designed to trap sediment flowing in the long-shore current, and thus to rebuild an eroding beach.

Jetties: Their purpose is to maintain harbor entrances and channel depth. They are not meant to protect open-ocean shorelines.

Hard Stabilization (structural)

**Soft Stabilization (non-structural)**

**Beach Replenishment:**
Artificially rebuilt beaches. The process usually consists of pumping offshore sand to the shoreline.

**Construction Setbacks:**
Planning ahead to build structures with a specific setback from the shoreline. In PR, a 60-meter setback is usually enough.

**Relocation:**
Moving the structure back from the shore. The costs & benefits must be weighed when considering this alternative.

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**Hybrid Stabilization**

**Groins + marsh:**
Combination of low structural walls with a type of wetland found at the edges of lakes and streams, where they form a transition between the aquatic and terrestrial ecosystems.

**Rock sills + marsh:**
Combination of low walls made from rocks with a type of wetland found at the edges of lakes and streams, where they form a transition between the aquatic and terrestrial ecosystems.

**Oyster Reefs + Vegetation:**
Combination of a three-dimensional structure created by oysters growing on a firm substrate such as shell, while subsequent generations attach to the older oysters, often forming clusters.

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Hybrid Stabilization (Estuaries)

Bank shaping & vegetation:
Removal of soil to reduce the slope of very steep banks to achieve a more stable angle. Costs range from moderate to high. Stabilization techniques have proved to be more successful.

Branch Packing:
Live branch cuttings incorporated into compacted soil. Used to fill depressions in soil. Moderate costs.

Vegetated Geo-grids:
Alternating layers of live branch cuttings and compacted soil layers wrapped in geotextile fabric to rebuild and vegetate eroded banks. Usually used for steeper and higher slopes. Very costly.

Tree Revetments:
Rows of cut trees (usually cedar trees) anchored to the toe or the bank. Often used for toe protection with other bioengineering techniques.

Live stakes:
Branches of rootable plants inserted into the bank. This technique is very flexible, low cost and has many applications.

Live Fascines:
Bundles of live branch cuttings that are burlapped into the bank and staked in place. This technique enhances conditions for colonization with native vegetation. Often used in combination with other bioengineering techniques.

Brush Mattress:
Live branch cuttings covering entire stream bank and secured in place. Provides immediate complete cover and long-term stabilization. Moderate cost.

Coconut fiber rolls:
Flexible rolls made from coconut hull fibers, staked at the hull of the bank. They are used in conjunction with native plants to trap sediment and encourage plant growth.
why stabilize the unstable?
which stabilization strategies does Puerto Rico use?

Puerto Rico’s shoreline is littered with “low-cost hard stabilization structures that do nothing more than give property owners a false sense of security.” Most of these structures are sea walls and they can be found along the entire perimeter of the island.

Each of the four coasts of Puerto Rico faces different climatic conditions. The northern coast faces warm, humid trade winds and the rough, open waters of the North Atlantic Ocean. As a result, this coast can receive waves that exceed a 3 meter rise during storms.1

Each type of shoreline responds differently to storm waves, sediment supply, and a gradually changing sea level.1 The east and west coast are the steepest coasts while the north and south coasts are the shallowest. Since most currents come from the north-east, the northern coast, specifically the metropolitan city of San Juan, is the most affected by rising sea levels.

Fig. 3.21 Diagram highlighting location of P.R.’s sea walls
Two scales of shoreline exposure exist in Puerto Rico. One is islandwide: north shore versus south shore and the other is individual embayments such as the San Juan Bay Estuary System. The Cordillera Central is the main mountain range in Puerto Rico. The Cordillera has an average elevation of 3,000 ft. and it crosses the island from east to west, becoming the main dividing factor between two very different coastal conditions.

As shown in the diagram, the northern coast of Puerto Rico has a greater width than the southern lowlands. The northern rivers are of greater length as well. This means that when sea levels rise, the most affected area would be the north because water will penetrate further inland through the northern flat coasts.

In the diagram above one can see the difference between the wide, gently dipping northern coastal plain and the narrow, faulted and folded, steeply dipping southern coastal plain. Note that the crest of the Cordillera Central is about two-thirds of the way across the island. Steep shoreline retreat, like the rocky portions of the Puerto Rico coast, retreat much slower than a gently sloping shore with the same rise in sea level. Therefore, since Puerto Rico’s northern coast is the flattest of all four, it is the most affected by erosion.
An especially large ridge forms the foundation of the city of Old San Juan. Only the necessary fortifications were built on the shoreline. These include La Fortaleza (1533), El Morro (1539-1586) and San Cristobal (1634). These fortifications were footed firmly on rock and elevated well above flood levels. By developing parallel to the coast, the developed property is exposed to more coastal hazards than if the developments were perpendicular.
What factors define beach size, position and shape?

**Dynamic Equilibrium** means that when one of these four factors changes, the others adjust accordingly to maintain the balance.

When humans enter the system incorrectly—which is often—the dynamic equilibrium continues to function but in a harmful way. For example, unplanned developments that occur along the shoreline impede the natural process of sand migration during storms, resulting in permanent erosion.

“Human interaction with natural processes can sometimes lead to disaster” (p. 16)

Truths of shoreline stabilization:

1. There is no erosion problem until a structure is built on a shoreline. Erosion is a natural and expected event, not a natural disaster.

2. Construction on the shoreline causes erosion.

3. Coastal stabilization structures protect the interests of a very few, usually at a very high cost to taxpayers. They serve the interest of the minority (shore front property owners) rather than the general public.

4. The costs of saving beach property through shoreline engineering is usually greater than the value of the property to be saved.

5. Once you begin shoreline engineering, you can’t stop it.
04 San Juan Estuary System
The Caño Martín Peña is a channel that connects the San Juan Bay with the San José Lagoon. Together, they form part of the San Juan Bay Estuary System, which is the largest and most complex lagoon system in Puerto Rico. The estuary system is comprised of the San Juan Bay, four different lagoons and a series of streams that are all connected to one another.
San Juan’s Lagoons

The Condado Lagoon receives all the fresh water from nearby urban run-off as well as minor amounts of subterranean water from the local aquifer. The connection to the Atlantic Ocean through Los Hermanos bridge and to the San Juan Bay through the San Antonio Canal permits a backflow of saltwater through the Lagoon. The water flow is generally from the Atlantic Ocean, through the lagoon towards the San Juan Bay. The salinity levels in the lagoon are almost equivalent to those of the ocean, with an average of 50,000 µS/cm. This lagoon has the best water quality out of the four main lagoons in the San Juan Lagoon System. Sea grass and a variety of fish and other aquatic life such as Manatees predominate the lagoon.  

The San José Lagoon receives run-off of a 15 mi² (39 km²) urban catchment area, including the discharge of the dewatering pumps of the Baldorioty Avenue. The aquifer of the San José Lagoon discharges around 50,000m³ of fresh water on a daily basis (approximately 20ft.³/sec or 13,000,000 gallons/day). Brackish water flows towards the San José Lagoon via the Martín Peña Channel from the San Juan Bay and the Torrecilla Lagoon via the Suárez Canal. The brackish water flows in both directions depending on the tides and swells. The mixing of brackish water and fresh water from the surface run-off and subterranean run-off result in specific conductivity percentages of 20,000 micro Siemens per centimeter (µS/cm) in flat plains. In the deep areas that were dredged in the San José Lagoon (up to 11m), the salinity levels are up to 40,000 µS/cm since brackish water is denser and it is more likely to accumulate in these pockets. In comparison to these salinities, saltwater from the Atlantic Ocean near the San José Lagoon has salinity levels up to 54,000 µS/cm. Inside the San Jose Lagoon, there used to be a dike that was constructed in the early 20th century.  

The Piñones Lagoon is the smallest of the San Juan Lagoon System. It receives brackish water via the Piñones Canal, maintaining high salinity levels (average: 43,000 µS/cm) most of the time. During severe flooding in Río Grande de Loíza, the run-off floods the Piñones Forest and penetrates fresh water to the Lagoon, reducing salinity levels up to 50%. The subterranean water flow to Piñones is minor. A substantial part of the little fresh water the lagoon receives comes directly from rainfall on the surrounding forests.  

The Torrecilla Lagoon is the second largest in size and volume and the most complex of the system. Its primary source of fresh water is the Blasina Canal. This stream has a catchment area of 8.5 mi² (22 km²). It receives run-off and disperse sanitary waters that vary from 10,000 to 20,000 m³/day (4.2 to 9.0 ft³/sec). The Lagoon also receives storm run-off from the housing developments to the west, north and south of its perimeter. The seawater that flows through Boca de Cangrejos is accumulated in the deeper zones of the Lagoon. The salinity levels in these dredged zones reaches levels of 50,000 µS/cm, almost equivalent to those of the sea. In general, the lagoon’s salinity levels are equivalent to 90% of the ocean’s salinity levels. 

Hydraulically, the level and water flow to the San Juan Lagoon System responds to the surface run-off of the surrounding urban areas, the effects of tides and swells, the subterranean water flow in the Metropolitan Zone, and the major flooding in the Piñones area.
Site: Caño Martin Peña
River flooding is the most menacing natural hazard in Puerto Rico. The Planning Board of Puerto Rico acknowledges the dangers of floods and stresses that they have claimed more lives in Puerto Rico than hurricanes, earthquakes, and landslides combined. The board estimates that 121,400 hectares of land is subject to flooding, 81,000 hectares of which are in the coastal plain. The Caño Martin Peña is a channel that connects all of San Juan’s lagoons and is already facing significant flooding risks that could ultimately lead to a catastrophic annihilation of eight communities.¹

San Juan 2100 (after a projected 2m sea level rise)

Fig. 5.2 FEMA V-Zone and A-Zone criteria for coastal flood zones
Caño Martín Peña (CMP) is a 3.75 miles long channel that connects the San José Lagoon with the San Juan Bay. In the early 20th century, Puerto Rico’s economy started evolving and poor farmers started migrating from the rural to the metropolitan city of San Juan with the hope of finding better job opportunities. Most of these farmers settled illegally along the CMP, hoping to eventually acquire legal titles for the land.

These farmers began to develop their own communities, growing towards the canal throughout the years. Now, eight different communities house around 27,000 inhabitants in the zone. Nevertheless, because this community was founded illegally, the settlers had to build their own houses and roads. As the communities grew, development started growing further towards the canal and the squatters began filling the wetlands at the margins of the CMP with garbage and debris in order to build their homes.

The canal has the capability of providing a waterway for the operation of an aquatic mass transit system. However, the continued practice of filling in the banks of the CMP with trash reduced the eastern half of the CMP depth a few inches in some areas. This has resulted in a severe disruption of the natural water flow and circulation within the San Juan Bay Estuary System. Furthermore, over 3,000 structures discharge raw sewage into CMP through direct pipes, ditches and the stormwater system. Some of the pollutants found in the canal include mercury, lead and PCBs. Residents of the Caño Martín Peña communities, also referred to as G-8 communities are exposed to these contaminated waters on a regular basis due to the frequent flash floods in the area and the clogged sewage systems.

Since the U.S. Environmental Protection Agency (EPA) designated the San Juan Bay Estuary as an Estuary of National Importance in 1992, data has been steadily collected. The creation of The San Juan Bay Estuary Program (SJBEP) has been instrumental in raising awareness among government agencies, communities, and the general public about how the restoration of the CMP could have a positive impact on the whole San Juan Metropolitan Area.

In 2007, the Governor of Puerto Rico, Aníbal Acevedo Vilá, signed a Land Use and Comprehensive Development Plan for CMP. The plan involves the dredging of the canal in order to improve the water flow, reduce flooding hazards, promote biodiversity, and restore the San Juan Bay Estuary System. 1

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Caño Martín Peña

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Fig. 5.3 Aerial View of Caño Martin Peña.
1. Barrio Obrero
2. Barrio Obrero Marina
3. Buena Vista (Santurce)
4. Cantera
5. Parada 27
6. Las Monjas
7. Buena Vista (Hato Rey)
8. Israel & Bitumul
Historical Development

1936

1962

1981

2002
Point A: Intersecting Systems

1. Highways
2. Railway
3. Linear Parks
4. Canal

static vs. dynamic
Point A: Adjacent Districts

San Juan Bay

Financial District
Average Water Flows 1975 vs. present

ATLANTIC OCEAN

- Boca de Cangrejos: Net flow 230,000 m³
- Piñones Lagoon: Net flow 225,000 m³
- Piñones Canal: Net flow 11,000 m³
- Blasina Stream: Net flow 11,000 m³
- La Torrecilla Lagoon: Net flow 290,000 m³
- Suarez Canal: Net flow 60,000 m³
- Rio Puerto Nuevo: Net flow 30,000 m³
- Juan Hernandez Stream & Aquifier Discharge: Net flow 20,000 m³
- Baldorioty de Castro Pumping Station: Net flow 25,000 m³
- Boca del Morro: Net flow 1,200,000 m³
- Las Cucharillas Pumping Stations: Net flow 35,000 m³
- Cooling water discharge from Palo Seco: Net flow 1,000,000 m³
- Las Cucharillas: Net flow 35,000 m³
- Condado Lagoon: Net flow 1,000,000 m³
- San Jose Lagoon: Net flow 1,000,000 m³
- San Juan Bay: Net flow 1,000,000 m³

- Freshwater
- Saltwater
Before 1930, the San Juan Bay was characterized by its balanced tidal flows. Since this estuary system is connected to the open sea, it received tidal flows from multiple directions: from the Atlantic Ocean and from the inner rivers and streams. These reversing tidal flows dominated unidirectional flows because they achieved a natural balance in net flow and salinity levels.\(^2\)

Limestone aquifers beneath the layers of marine sediments south of San Juan fed fresh groundwater to the lagoons. The tidal waves that lash the north coast drive large amounts of salt water to the lagoons. The aquifers contributed to the dynamic balance between salt water and fresh water.

In 1975, the San Juan Bay Estuary had a perfect balance in net flow and salinity levels. The amount of saltwater that came in from the Atlantic Ocean was balanced by the amount of freshwater that came down from the rivers.

Nevertheless, this equilibrium was destroyed by the landfill that came with the unplanned development of San Juan’s Caño Martín Peña community. The development resulted in contamination of the system’s water and its sediments, the destruction of significant segments of wetlands and mangroves that surrounded them, and the alteration of its water systems.\(^1\)

Today, landfill and waste have blocked the flow of the canal. This pollution interferes the dynamic equilibrium of the mangrove habitat. In order to maintain a healthy mangrove ecosystem, a balance between freshwater and saltwater must exist. Right now this equilibrium has been broken by poorly planned interventions and stagnant water is causing many health risks for the adjacent communities.

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Point B: Two Tensions
Fig. 5.7 Floods in the G-8 communities
In the 1930’s farmers started migrating from the rural to the metropolitan San Juan and settled illegally near the Caño Martin Peña.

As migration continued, unplanned development kept growing towards the channel.

With the lack of sewage systems and the growth of mangroves, pollution started blocking the flow of the channel.

By the 21st century, pollution and landfill blocked the flow of the channel and destroyed the water’s dynamic equilibrium.

If no action is taken to restore the flow of the channel, rising sea levels will continue to flood the G-8 communities with polluted water.
As the communities grew, development started growing further towards the canal and the squatters began filling the wetlands at the margins of the CMP with garbage and debris in order to build their homes. The houses were initially built out of wood but later covered with cement. The practice of this uncontrolled development is what led to the contamination and obstruction of the canal.  

CMP Housing 2000’s

Fig. 5.10 Martin Peña Housing 1970’s

Fig. 5.11 Martin Peña House on piles

Fig. 5.12 Martin Peña House 2000’s
The Mangrove Ecosystem

Mangrove swamps and fringes are common along low-lying shorelines. Mangrove root systems trap and anchor sediment, stabilizing the shore and contributing to shoreline accretion. The removal of these mangroves leads to accelerated rates of erosion. By removing mangroves, areas become subject to flooding and unsuitable for development.¹

Mangroves are an essential part of estuary habitats. They provide an essential nursery habitat for fish, they provide sediment stabilization and trapping, and they act as nutrient filters. They are also a good resource for wood production for building. Finally, they shelter communities from storm winds and help combat erosion. They also process carbon dioxide and other pollutants.²

Vegetation at or near the shoreline may be considered a nuisance when it obstructs the ocean view, but natural vegetation is an asset and it should be treated accordingly. The very presence of well-developed growth of grass, small shrubs and trees high on the backshore of the beach suggests low erosion potential and infrequent saltwater intrusion.¹

Mangroves grow only on very low elevation coasts where salt-tolerant vegetation flourishes. Mangroves hold the shoreline in place. They also indicate past as well as future flood areas. Areas filled with mangroves are not safe for development. They erode very rapidly when destabilized by the death or removal of the mangroves. In other words, removing mangroves guarantees shoreline erosion.¹

Unimpacted Habitat

- Sunlight
- Rainfall runoff (nutrients)
- Leaf litter & decomposer
- Small predators
- Scavengers
- Filter feeders
- Large predators
- Birds
- Humans
“Unless resources are recycled and reused, the island will drown in solid waste long before its shores are drowned by the rising sea.”

This quote by David M. Bush addresses the health hazards of solid waste. In the book, Living with the Puerto Rico Shore, he acknowledges that many parts of Puerto Rico are facing greater risks than rising sea levels. Many of the islands water environments are polluted, causing health hazards to their adjacent communities. That said, rising sea levels may be a greater risk but one that has time to be addressed. Flash floods in rivers, especially polluted ones, are a present risk that needs to be addressed immediately.

The Caño Martin Peña is a perfect example of how industrial progress sometimes causes environmental problems such as polluted rivers, lagoons, and estuaries. In CMP, the unplanned development caused the degradation of the marine ecosystems in the San Juan Bay Estuary System.

Unless resources are recycled and reused, the island will drown in solid waste long before its shores are drowned by the rising sea. In the Caño Martin Peña, water management is the primary concern of all residents adjacent to the channel, the accumulated waste has increased health hazards for every community and, with flash floods and rising sea levels, these residents are constantly exposed to waters polluted with lead and mercury.3

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How to restore salinity levels?

Dividing the channel with water replenishment systems is one way to regain the balance in salinity levels and restore the polluted water to its natural state.

division across border:

division along border:
Re-interpreting Metabolist ideals

From the Second Industrial Age to the Climate Change Generation

"With the shift from the second industrial age to the digital age, the accelerating flows of population, materials, and information within the global network have fundamentally changed conceptions about permanence and transience. As a result, cities are transforming dramatically as the emphasis form urbanism is shifting from concrete structures to more complex and flexible organizations as well as "soft" (digital and ecological) infrastructures." Therefore this new form virtual unity should be studied as a continuation of the Metabolist notion of "city as process".

This quote, written by Zhongjie Lin in her book: Kenzo Tange and the Metabolist Movement: Urban Utopias of Modern Japan, clearly points out the dramatic transformations cities are facing today. The author suggests that metabolist ideals be revisited to address the dramatic transformations cities are currently facing. Nevertheless, she describes these transformations as pertaining to the digital age. While technological advancements have made a dramatic impact in urbanism trends I would argue that other factors such as, climate change will be the main factors defining the new urban fabric.

With global warming, rising sea levels have made a huge impact on coastal morphologies. To many, rising sea levels are a serious threat. Others, see this as an opportunity for design and believe that the city of the future will be on water. The notion of building on water isn’t anything new. In fact, it can be traced back to the Metabolists in the 1960’s who envisioned the sea as an extension of the landscape.

I agree with Koen Olthius and David Keuning, authors of FLOAT!: Building on Water to Combat Urban Congestion and Climate Change, that global warming has made our generation the "climate change generation". Furthermore, it is climate change that will impact the morphology of future cities and technological advancements will be instrumental in proposing a solution.

The project I am proposing will re-visit Metabolist ideals through the lens of climate change and re-interpret the typology of mega-structures to address the issue of rising sea levels in order to re-introduce water as the new infrastructure.

Plan Obus - Le Corbusier

Location: Algiers, Africa  
Year: 1932  
Type: Megastructure  
Status: Unbuilt  
Scale: 180,000 dwellings

Plan Obus consists of three major elements:
1. A business district at the tip of the Casbah, in the Cape of Algiers
2. A residential area on higher land
3. An elevated highway that would connect different cities

Plan Obus follows the ideal of a “viaduct city” a concept later adopted by the metabolists which follows the theme of mobility within the city.

The elevated highway would contain fourteen levels for residential purposes beneath it, and according to Corbusier’s plans, it would be a model for infill housing that would fill in little by little in response to demand. This is an example of the “city as process” that the Metabolists later developed.

Plan Obus’ most interesting feature is how Le Corbusier proposes creating urban space along transportation networks and modes of movement.

This project illustrates the tension between the rigid pre-fabricated and flexible custom designs.

Residents have the ‘freedom’ to choose to make 1-story or 2-story apartments.

Notion of ground plane altered by placing public and transportation space above residential space.

The Plan for Boston Bay, also known as the "Plan for a Community of 25,000 Residents", perfectly illustrates the idea of "artificial land" that was typical of the Metabolists. It consisted of multi-level concrete platforms supported by two triangulated space frames.

"Artificial land" focused on the relationship between the collective and the individual. These relationships were addressed by playing with different levels of land. Different terms such as "multi-level ground" and "vertical ground" stemmed from this concept.

The A-shaped form can be understood as an improvement to Le Corbusier’s Algiers because it allowed more natural light in the residences.

The triangulated interior housed the public amenities of the residents.

Fig. 7.3 Model Plan for Boston Bay

Fig. 7.4 Cross-section Plan for Boston Bay
Plan for Tokyo Bay - Kenzo Tange

Location: Tokyo, Japan
Year: 1960
Type: Megastructure
Status: Unbuilt
Scale: >20,000 residents

The plan for Tokyo Bay can be interpreted from three different perspectives:

1. **Mobility** as the fundamental character of a “pivotal city” (a city meant for over 20,000 people).

2. **Linear axis** as the symbol of an open urban structure as well as an open society (free & flexible).

3. **“City as process”** or through different “Metabolic Cycles”.

Kange addresses the issue of mobility by using the highways as the main framework of the city plan. He designs the plan as a linear development as a symbol of an open society. The metabolists argue that a central regulated system allows for free and flexible development, similar to a vertebrate with a central spine.

The metabolists also added a fourth dimension to city planning: time. Most of the metabolist projects represent the idea of “city as process” or the notion that a city should grow in different phases just like an organism.

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The Plan for Tokyo also proposes building on water to combat urban congestion. As Japan’s population was rapidly growing, the sea was envisioned as a continuation of the urban fabric.

With this project Kange imagined the city as an open complex connected via communication network (transportation system).

Kange used the introduction of the automobile as an opportunity to rethink the way cities are changed. He acknowledged that the automobile demanded a system of transportation which would inevitably affect the relationship between architecture and the street.1

Instead of finding a simple solution such as, widening streets for the automobile, Kange celebrated the new transportation system as the main guiding factor of his proposal. The highways then created the framework for the new city through a system of interconnected loops that framed the buildings.

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Jersey Corridor - P. Eisenman & Michael Graves

Location: New Jersey, USA
Year: 1965
Type: Megastructure
Status: Unbuilt
Scale: 20 sq. mi.

The Jersey Corridor, also known as “Linear City,” was a competition entry to a 1 mile wide and 20 mile long megastructure that ran through New Jersey.

The goal of the project was to house every possible urban function in one building. It consists of two parallel strips:

1. Industrial strip
2. Downtown strip

The industrial strip was the working headquarters of the ‘city’ while the downtown strip was the living and leisure portion. This duality of live-work can be associated with the metabolism ideals of town-country because they aimed to re-unite city functions (work) with those of the country (living).

Another repeating concept is that of mobility and linearity. These can be seen in the overall composition of the megaform and in the highway located in the basement which penetrates the underground landscape.

By going underground, Eisenman and Graves also address the “multi-level” or “artificial land” concept.

The idea of “Linear Cities” was first seen through the work of Edgar Chambless in 1932. Chambless proposed the idea of the linear city in his pamphlet of Roadtown.

Le Corbusier’s Plan for Algiers (1930) The two showcase an inverted relationship with the highway. In Algiers the highway sits atop the residences while in the Jersey Corridor it runs underground.
LOMEX - Paul Rudolph

Location: NY, USA  
Year: 1967  
Type: Megastructure  
Status: Unbuilt  
Scale: +20,000 residents

LOMEX, also known as the Lower Manhattan Expressway, is Paul Rudolph’s proposal for Manhattan. The project was a battleground between Jane Jacobs and Robert Moses because of its rigid monumentality. It recalls Hugh Ferr’s ideas of bridge/buildings from 1929.

The main idea was re-interpreted from Le Corbusier’s Plan Obus to organize a new city core around modes of movement or transportation networks. It was highly criticized because its anti-urban “HUB” at the center, a parking-and-plazas complex, looks like some alien Roomba, sucking up street life.

The ideal was an approach to city planning that would conceive of movement throughout a city as the most common shared experience. The multi-use transportation networks would be integrated into one design that would replace plazas as the prevailing urban design element.

Horizontal Skyscraper - Steven Holl

Location: Shenzhen, China
Year: 2006-2009
Type: Megastructure
Status: Completed
Scale: 1,296,459 sqf.
Program: mixed-use (hotel, offices, serviced apartments, and public park.

The Horizontal Skyscraper, also known as the Vanke Center, is a tsunami-proof 21st century hovering structure that creates a porous micro-climate of freed landscape.

“The Vanke Center or ‘Horizontal Skyscraper’ is a surreal hybrid: part building, part landscape, part infrastructure.”
-Nicolai Ouroussoff

“...the first project that both realizes and expands upon Corbusier’s project in Algiers”
-Thom Mayne

Steven Holl describes four types of architecture: under the ground, in the ground, on the ground, and atop.

In his book, Horizontal Skyscraper, he focuses on the fourth type. Instead of having individual buildings to serve individual purposes, the Horizontal Skyscraper joins them in one single hybrid building and, by elevating the building, the largest possible green and water grounds open to the public are achieved.

Steven Holl talks about four different types of architecture:
1. Under
2. In
3. On
4. Atop

Fig. 7.15 Horizontal Skyscraper collage
The Water Hub

Location: Jordan Valley, UT
Year: 2010
Designer: Fadi Masoud
Type: city plan
Area: 100km
Concept:

A proposal for a regional landscape planning scheme that necessitates an understanding of the landscape's limitations and potentials to create a new agro-urbanization regime for the Jordan Valley. One that is based on more receptive, de-engineered, and decentralized infrastructures involving trans-territories/border regions and organized around a new land use pattern. The project will uncover the underplayed link between water diversion for urbanization and agriculture and the resulting desertification.
The water hubs become production nodes, high-speed rail stops, local markets, and tourist draws that are all organized around water infrastructure.

water collection and treatment as civic architecture
What is needed in the Caño?

Proposal for development:

This project will be developed as a form of megastructure that will span from the northern part of the G-8 communities to the southern portion. It will house all functions that already exist within the community as well as additional functions that relate to the adjacent financial district and tourist attractions. It will be developed in several phases based on program necessity in regards to rising sea levels. Programmatic options include:

- **Housing**
  - Elderly*
  - Temporary
  - Permanent

- **Education**
  - High-school
  - Library*
  - Research Lab

- **Transportation Hub**
  - Bus station*
  - Ferry station
  - Bike Rental
  - Kayak Rental

- **Recreation**
  - Children park*
  - Basketball Court
  - Baseball Court
  - Community Park**
  - Murals for art

- **Commercial**
  - Restaurants
  - Shops

- **Water management**
  - Water treatment plant**

- **Healthcare**
  - Pharmacy
  - Senior Healthcare**

* : priority (these should be addressed immediately)
Is it possible for an institutional building to take on the same responsibilities as landscape and infrastructure?

How can the combination of these three systems work together to create a resilient form of public space?

Can buildings find a liquid (adaptable) state in which they can transform based on their climatic condition?

Is it possible for an institutional building to take on the same responsibilities as landscape and infrastructure?
“The water will break down the boundary again and again. The question is whether we should build faster and harder to keep it out, or find a way to gently merge ourselves with the water once again, transforming the hard boundary into a continuum, a smooth transition, a commingling rather than a battle zone.”

-Michael Oppenheimer

*Rising Currents: Projects for New York’s Waterfront*


