UNDERWATER ASSETS: WASHINGTON DC & CLIMATE CHANGE

STEERS
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Executive Summary

Underwater Assets: Washington DC & Climate Change

T. Jeremiah Healey[1]

Washington, D.C. (also, the District), like many major cities, is subject to significant and growing climate risk.[2] While this reality is acknowledged by many real estate market participants, it has done little to change investor behavior. In part, this is attributable to the challenges of assessing two critical issues:

- **Physical impact:** The projected scale of future climate events, measured both regionally and at the asset level, and how these may change over time, and
- **Post-disaster response:** The potential reactions of key constituents, particularly government decision-makers, and how future responses may differ from prior events.

To address these issues, Georgetown University's Steers for Global Real Estate convened a group of leading analysts and market participants as part of a structured, two-part process to examine a representative test case.[3]

To effect these goals, the Steers Center worked with a range of best-in-class partners to build out a detailed forecast, a realistic event simulation, and a strategic discussion to address three major topics:

- **Modeling:** What tools are available for forecasting inland flood risk, and what do they indicate in terms of asset impact? How do these results vary when sensitizing both event severity and the year of occurrence?
- **Recovery:** How do we simulate post-event response, particularly around prioritizing resource allocations? What implications does this have for institutional investors?
- **Mitigation:** What defensive strategies are available, and are there ways for the public and private sectors to work together to build community resilience? What risks does this create, and what other opportunities will emerge as a result?

Our responses to these questions included the following takeaways:

- **Base Risk:** Inland flood risk, while under-analyzed, is high for certain neighborhoods in Washington due to a combination of natural elements, climate change, and engineering, indicating the need for a reappraisal of physical risk.
- **Available tools:** Most typically used resources and models do not adequately identify these increasing risks, due to overemphasis on historical events at the expense of forward probabilities.
- **Economic costs:** Investors should expect adverse income / value impacts from this growing climate risk, including any or all of reduced revenues, increased expenses, and required capital expenditures.

EXERCISE AIM: QUANTIFY AND ROLEPLAY THE IMPACTS OF INTERIOR FLOODING ON THE WASHINGTON NEIGHBORHOODS OF H STREET NE AND NOMA.

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[1] ESG Fellow, Steers Center for Global Real Estate, McDonough School of Business, Georgetown University.

[2] To cite one study: "The District is already experiencing the impacts of human-made climate change.
… In the past few years, the District has seen: Record-breaking extreme weather (heat waves and snowstorms); Higher tides caused by rising sea level; Record precipitation, including heavy rains and flooding; Warmer average temperatures and two to three times as many dangerously hot days
… The direct impacts of variable weather threaten both the safety and the quality of life of District residents." **Sustainable DC 2.0**, p. 45, formatting altered for clarity.

[3] The reasons for the scenario selected are discussed in detail below, but it is critical to emphasize that we view this analysis as indicative of a growing category of risks, rather than a specific and unique case.

- **Recovery risk:** Well-capitalized private investors are exposed as events become more frequent and expensive, with governments likely to allocate scarce funds to socially vulnerable constituents and owners with few other financial resources.
- **Constrained response:** While tools may diagnose areas of increasing stress, governments are unlikely to prioritize or fund mitigation efforts in many cases, due to limited budgetary resources.
- **Investment opportunities:** New programs are needed to address these issues, although achieving meaningful results from private or public-private action is difficult. These challenges, which may limit holistic solutions, will create opportunities for private investments as a result.

At a high level, our work suggests that investors should adapt their expectations in two primary manners:

- **Asset Underwriting:** Investors should anticipate the effects of increased climate risk on individual assets, adjusting both investment strategies and valuation accordingly.
- **Disaster Recovery:** Investors should expect the resolutions associated with future events, especially from government sources, to be less favorable than they have been to date.

OVER TIME, WE EXPECT TO OBSERVE MEANINGFUL DIVERGENCE IN PERFORMANCE FOR EXPOSED ASSETS, DRIVEN BY THE ASSET-LEVEL IMPACT OF CLIMATE-ADJUSTED CASH FLOWS.

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All photos are courtesy of Kevin Wolf (@wolfkann), Non-Resident Senior Fellow of Georgetown University's Center for Security and Emerging Technology, whose generosity is much appreciated.

Strategic Partners

In order to address the broad range of issues affected by climate change, we worked with a world-class group of external partners both to model the physical risks and to create a realistic simulation of recovery and mitigation considerations.

FORECASTING PARTNERS

To develop our climate projections and damage estimates, the Steers Center partnered with two leading companies in risk analysis and climate forecasting:

- **Gallagher Re:** The reinsurance advisory and risk analytics subsidiary of Arthur J. Gallagher & Co. (NYSE: AJG). Gallagher Re advises over 750 client relationships worldwide and has a history of thought leadership in risk modeling and climate change, including the recent launch of the Gallagher Research Centre for academic collaboration.[4]
- **KatRisk:** An independent modeling firm dedicated to catastrophe analytics, including both flood and tropical cyclone modeling. In addition to their work with insurance and reinsurance providers, KatRisk has served as the risk modeler and calculation agent for all of the FEMA FloodSmart catastrophe bond placements issued to date.[5]

Partnering with this team enabled us to generate an unprecedented level of detail in our analysis, which we believe is distinguished from traditional approaches in three ways:

- **Local specificity:** KatRisk's SpatialKat module combines granular event scenarios with detailed local area topographical modeling, producing flood forecast detail that we then cross-checked against observed physical conditions.
- **Scenario variability:** By modifying key variables, we were able to study how the intensity of hazard and subsequent losses varied based on the simulated weather patterns of later periods (specifically 2025, 2030, 2040, and 2050).
- **Asset detail:** By uploading key building data into KatRisk's SoloKat module, we were able to generate customized building-level damage estimates for each of our sensitivities.

Gallagher Re

KatRisk

[4] Press release **here**.

[5] The **Artemis Catastrophe Bond and Insurance-Linked Securities Deal Directory** provides overview information on "every cat bond and ILS transaction we hold information on"; see their pages for the Series **2018-1**, **2019-1**, **2020-1**, **2021-1**, **2022-1**, and **2023-1** transactions.

SIMULATION PARTNERS

To develop our event scenario, we partnered with two expert teams in experiential learning and wargaming:

- **Booz Allen & Hamilton:** Booz Allen is a global firm that specializes in consulting, analytics, digital solutions, engineering, and cyber. Supported industries include defense, health, energy, climate, and sustainability. Booz Allen's Experiential Analytics team designs research and experiments, modeling & simulation, wargaming, and exercises to empower creativity, test ideas in a safe environment, and discover the solutions that help organizations thrive.[6]
- **U.S. Naval War College:** The U.S. Navy's "Home of Thought", the Naval War College educates U.S. and international military officers, as well as selected civilian executives. The War Gaming Department comprises more than 45 faculty members, with the department's Chair serving as an advisor to our efforts.

This team helped to articulate and effect an approach marked by two goals:

- **Representative asset selection:** A careful selection of real estate for analysis, providing a meaningful cross-section of property and tenant characteristics; and
- **Realistic framing:** The integration of government and investor expertise to create a detailed experiential exercise patterned on existing disaster response mechanisms.

By combining the particular skills of these four groups, along with significant in-house knowledge resident within Georgetown University,[7] we created the structured process described further below.

Booz | Allen | Hamilton

[6] To learn more about Booz Allen's wargames and exercises, please visit **www.BoozAllen.com/experientialanalytics** or email **Experiential_Analytics@bah.com**.
[7] Detailed in Appendix B: Georgetown Resources.

Modeling

Our planning team employed a carefully structured sequence of decisions to hone our focus.

GEOGRAPHIC SELECTION

We elected to study Washington for several reasons, some of which are inherent to the location, and some of which reflect the relationship between Georgetown and its host city.

- **Moderate exposure:** While the effects of climate change are visible in the District, the area is generally perceived to be lower-risk than many other cities.[8] This balanced positioning strengthened Washington's appeal for our purposes, as a conclusion indicating meaningful economic exposure would likely suggest the same to be true in more obviously risky markets, as well.
- **Government presence:** Government is Washington's primary business,[9] with high concentrations of both District and Federal activity. This unique dual role gives Washington an exceptional importance to the nation, particularly relative to its size, and the city receives a high level of planning and risk management focus as a result.
- **Home turf:** Georgetown University plays a major role in the life of the District, particularly in the area of climate change.[10] This role, when combined with the University's breadth of commitment to issues of sustainability, allowed a level of impact that would be difficult to replicate elsewhere.

HAZARD SELECTION

Within the District, while there are many forms of observed physical climate risk,[11] we chose to focus on inland flooding (also known as interior flooding).[12]

- **Clear drivers:** Inland flooding is linked to quantifiable risk sources, with well-tested forecasting tools available to simulate changing climate conditions. At the same time, they are not heavily dependent on certain complex or confounding factors, such as rising sea levels or lunar nodal cycles.[13]
- **Lower focus:** Even groups focused on Washington flood risk acknowledge inland flood to be a less understood phenomenon,[14] increasing the potential contribution of our work to the overall risk assessment conversation.
- **Potential exposures:** Given our focus on neighborhoods outside of the traditional flood zones, we enhanced our ability to evaluate the risk to potentially under-protected assets and infrastructure.

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[8] In one 2018 national study, the **Notre Dame Global Adaptation Initiative** assessed Washington to have the 64th highest overall risk score out of 278 U.S. cities studied.

[9] As one proxy, data from the **U.S. Bureau of Labor Statistics** for October 2022 suggest 30.7% of the District's non-farm payroll was classified as Government (235.6 thousand out of 767.2 thousand in total).

[10] As an example, at the time of the simulation exercises, Georgetown faculty held 3 of the 14 available Commissioner's seats on the District of Columbia Commission on Climate Change and Resiliency, including the role of Chair.

[11] See Footnote 1.

[12] "Interior floods, also known as flash floods, stormwater floods, or urban drainage floods, are caused by heavy rainfall that accumulates too quickly to be absorbed by the ground, or drained by the storm sewer system. … Factors that contribute to interior floods include topography, surface permeability, localized weather, buried streams, high water tables, and the capacity of the storm sewer system." **Interior Flooding in Washington, DC: A first look at where it occurs in the District of Columbia**, p. 3.

[13] For a recent treatment of certain related issues, see **Rapid increases and extreme months in projections of United States high-tide flooding**.

[14] As the DC Silver Jackets Interior Flooding Task Group observed in August 2017, "Riverine and coastal flooding are the subject of many maps and other research in the region, including federally funded mapping efforts such as the Storm Surge Inundation Maps and the Flood Insurance Rate Maps. Interior flooding and where it occurs in the region, however, is not well understood." **Interior Flooding in Washington, DC: A first look at where it occurs in the District of Columbia**, p. 3.

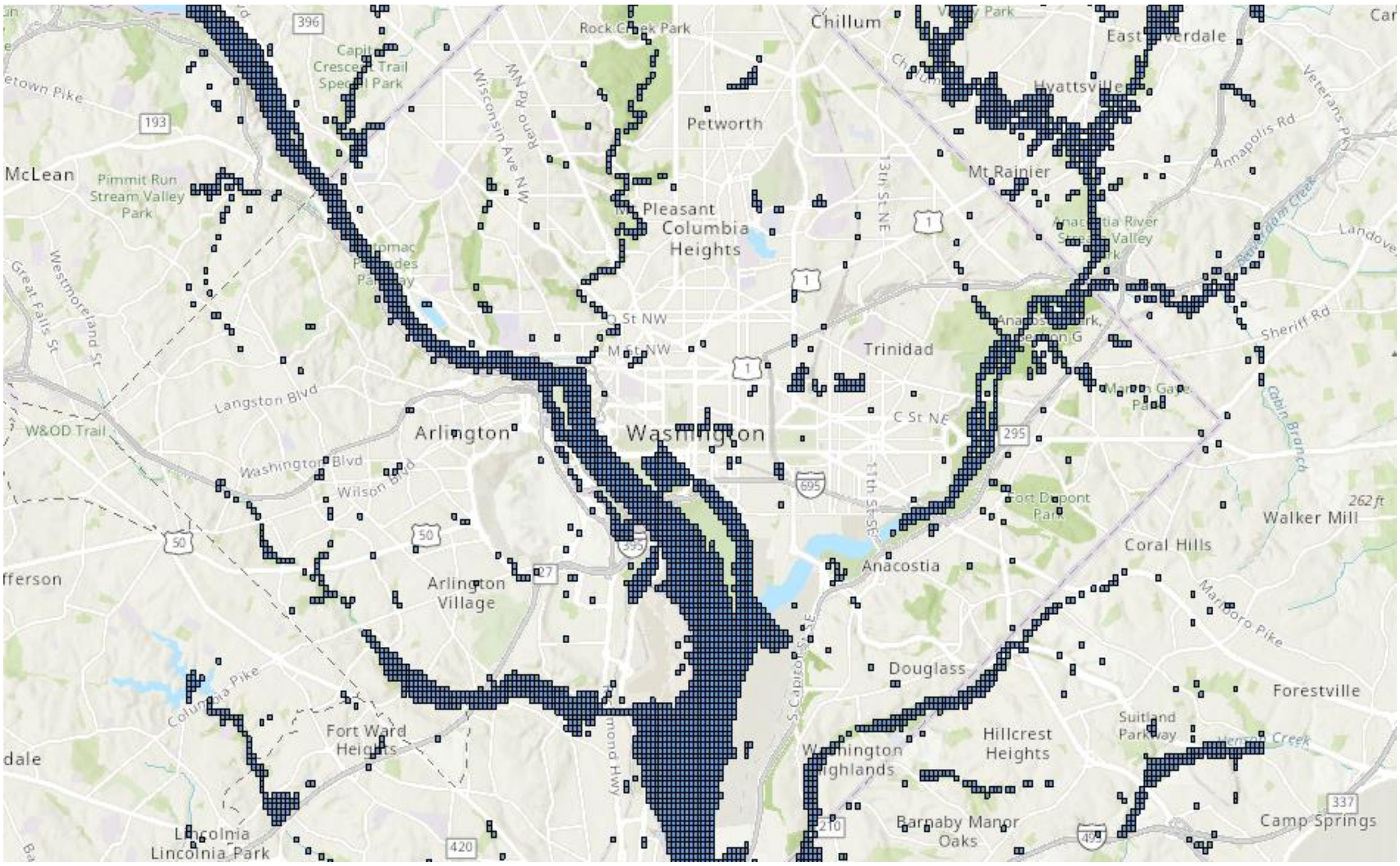
INITIAL CLIMATE MODELING

Our initial efforts drew on KatRisk's SpatialKat module, which we first ran in a base case scenario on a rectangular grid roughly corresponding to the District's borders,[15] along with the following assumptions:

- **Built environment:** As currently constructed, without further development or mitigation.
- **Climate conditions:** Current year, with no impact from additional climate change.
- **Severity:** a 1 in 100 event probability, based on 50,000 years of event simulations.

This grid was then subdivided into steps of .001° of longitude and latitude ("Nodes", each roughly 100m x 100m) with initial individual flood depth projections for each Node. We overlaid this flood output on a more traditional map of the District via GIS visualization tools, allowing us to identify flood areas with significant concentrations of high-value assets and critical infrastructure.

This produced the following visualization, in which every Node with a forecast flood depth of three feet or greater was coded blue.[16]



[15] The measured area was bounded by 39.00° N, 77.15° W at the northwest corner (in the Burning Tree Club of Bethesda, MD, due west of Walter Reed Medical Center), and 38.75° N, 76.90° W at the southeast (on the grounds of Waldron Woods Elementary School of Clinton, MD, south of Joint Base Andrews).

[16] For a high-resolution map presentation, see Appendix D: Alternate Map Format.

NEIGHBORHOOD SELECTION

With our initial analysis complete, we used the results to screen District neighborhoods for further study.

Due to a desire to focus on less-studied geographies, we ruled out a focus on neighborhoods of two differing types:

- **River-Adjacent Flood Risks:** Locations adjoining either the Anacostia or Potomac Rivers with a demonstrated risk history in either riverine or tidal flood scenarios, as seen in the floods of 1936, 1942, 1985, and 2010.
- **Demonstrated Interior Flood Risks:** Locations such as Federal Triangle, which flooded in 2006, and has been the subject of several major prior studies,[17] or Bloomingdale / Ledroit, which flooded in 2012.

From the remaining locations, we chose to focus on the neighborhoods to the east (H Street NE) and west (NoMa) of Washington Union Station, both of which demonstrated elevated modeled flood risk.

The Washington, DC Economic Partnership describes these neighborhoods as follows:[18]

- **H Street NE:** "[The neighborhood] maximizes a 'live, work, play' community philosophy. Historic townhouses and modern apartment buildings surround its flourishing commercial district."
  - Immediate population: 21,198
  - Median age: 36.8
  - Income: $185,948 (average household), $137,694 (median household), and 16% below $50,000
- **NoMa:** "NoMa is one of the city's fastest-growing neighborhoods. The area includes nearly 21.5 million square feet of office, hotel, retail, and residential space, including 30 LEED-certified buildings and revitalized historic buildings."
  - Immediate population: 24,560
  - Median age: 33.7
  - Income: $144,964 (average household), $110,519 (median household), and 23% below $50,000

In their collective combination of Class A Federal tenants, Class B District and commercial tenants, high-income residents, and limited-income residents, these neighborhoods presented a representative sample of key Washington constituencies, creating a strong proxy for the larger city in the context of relevant policy choices.

FLOOD DRIVERS

As H Street NE and NoMa have not shown heavy flooding historically, we worked to understand the reasons for the results calculated by KatRisk.

We identified the following as the primary drivers:

Base Climate: The District evidences a high current level of heat and humidity, which has already risen notably over the years.[19]

Climate Change: Given that temperatures are expected to continue to rise, standard modeling projects[20] a corresponding increase in overall moisture content, often manifesting as more frequent, intense rainstorms.

Topography: H Street NE and NoMa are both significantly graded. Locally, elevations range from highs of over 100 feet just north of New York Avenue to over 300 feet further north in the city, while our focus assets, which are described further below, sit at ground elevations ranging from 26 to 42 feet.

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[17] See **this** page for additional detail on the DC Silver Jackets effort, with extensive coverage of their analysis of Federal Triangle.

[18] From **DC Neighborhood Profiles: 2022 Edition**.

[19] See, for example, this **2019 analysis** from The Washington Post: "It's no secret the world is warming, but thanks in part to climate change, humidity is also beginning to surge. Here in Washington, that means the punishing combination of heat and humidity is becoming more oppressive. … we found that the District is, on average, a little more than 5 percent more humid than it was in 1970, and slightly more than 10 percent juicier than in 1950."

[20] Per the Clausius-Clapeyron equation (CCE), a 1-degree increase in Celsius temperature yields a ~7% increase in atmospheric moisture. See this **article** from Eos for a treatment of both the basic mathematics and of other recently published work testing the CCE in practice, concluding that "as the planet continues to warm, extreme rainfall events will continue to become an increasingly common part of life for many heavily populated parts of the world."

- **Development:** These two neighborhoods have seen an extraordinary amount of development in the past two decades,[21] with significant open space replaced by buildings and pavement, reducing overall porosity and drainage.
- **Engineering:** The waterflow forecast by our model followed channels reflecting engineering decisions, including the design of the H Street (Hopscotch) Bridge,[22] which passes over the Union Station rail tracks, and the interactions among the rail tracks, the Metropolitan Branch Trail, and the Noma - Gallaudet U Metro Stop.[23]

ASSET ANALYTICS

In selecting assets for the simulation exercises, we moved forward in two related directions.

The first was a review of potential anomalies, particularly in locations where the forecast flood depth appeared counter-intuitive based on either asset specifications or local topography.

The KatRisk team reviewed these, correcting a number of geocoding issues by hand that, while correct as of the last map update, were now manifestly incorrect.[24] Based on these updates, we then remodeled our target area.

These projections were then benchmarked against more traditional risk assessments, leading us to find that at least two groups understated what we see as an elevated risk.

- **FEMA:** Neither neighborhood is designated a flood risk by existing FEMA flood maps.[25]
- **Silver Jackets:** Our studied areas were generally categorized as areas of limited concern by a District-led analysis of interior flood risk.[26]

Our team then reviewed all commercial assets in the projected flood zone, employing a variety of mapping tools and databases to review every building in the affected regions to screen candidates for our simulation exercises.[27]

This process yielded a short list of assets for analysis, which we then investigated through an integration of the KatRisk SoloKat (to drive weather forecasts) and SpatialKat modules (to evaluate the specific impact of our forecast on individual assets). These losses were cross-referenced against key property data, including tenancy, history, and available information, allowing us to confirm that these buildings were both economically impacted and narratively engaging.

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[21] The Washington DC Economic Partnership produced a 2021 report entitled "**20 Years of Growth in the District of Columbia**." Of their ten neighborhood groupings, H Street NE, NoMa, Union Station was near the top for growth both historically and prospectively, with rankings of #3 for 2001-2010, #4 for 2011-2020, #1 for Under Construction, and #1 for Pipeline.

[22] While the H Street Bridge is scheduled for replacement, the project's **environmental assessment** provides essentially no analysis of the impact of the bridge on local flood risk. The main report tersely notes that "the Project area is not within or near the base (100-year) floodplain," while the Appendices reference flood zone data, but provide no further analysis.

[23] While largely beyond the scope of our analysis, we observe similar issues with certain critical roadways. Our model forecast significant flood depth in both the New York Avenue underpass along North Capitol Street and in the tunnel entrance to Route 395 south of New York Avenue.

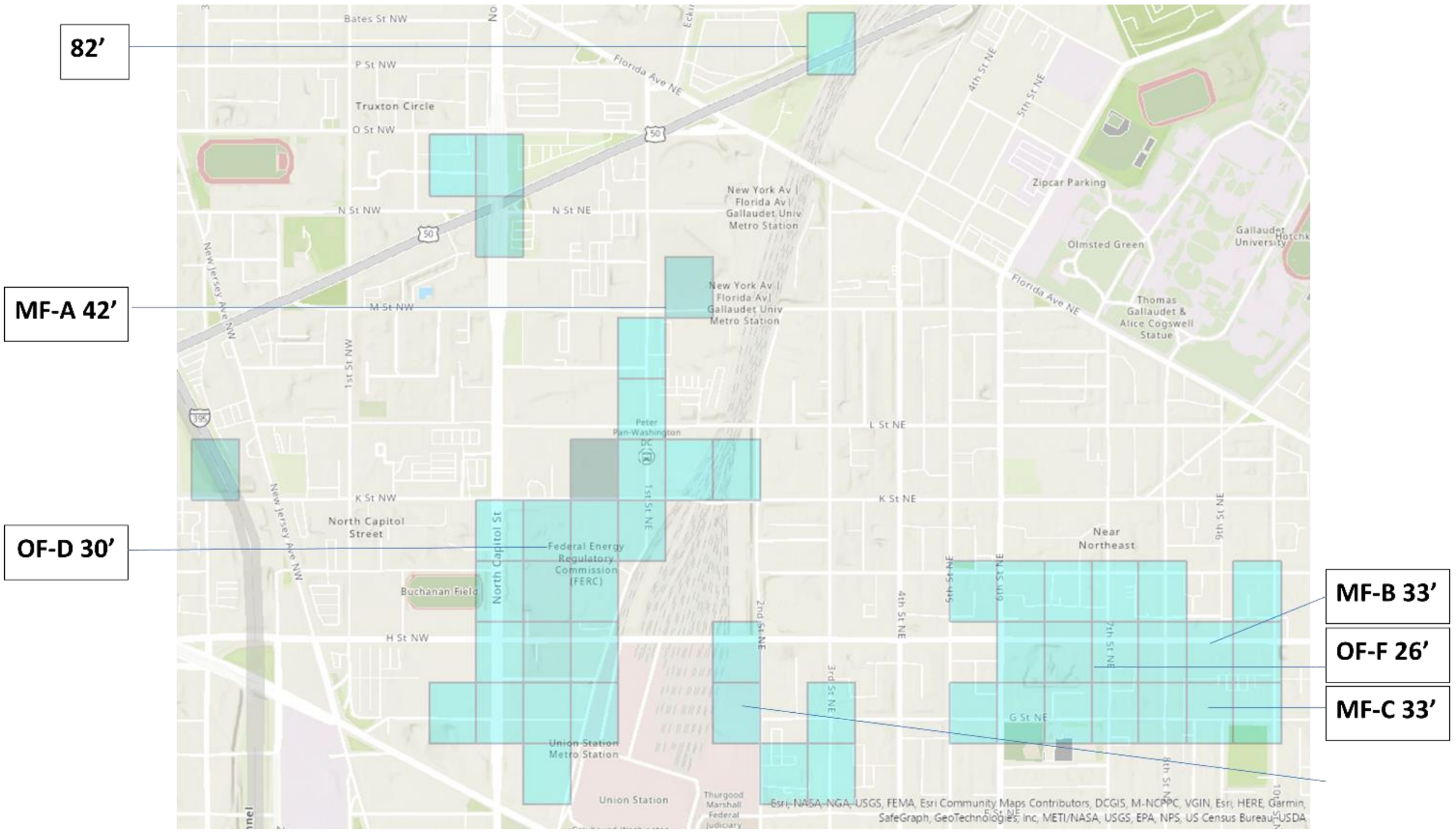
[24] As an example, we noted exceptional flood depths in the location associated with 90 K St NE. That property was under construction when the topographical maps were last updated, so the indicated depth reflects the then current conditions (i.e., a deep hole in the ground), not the current improvements.

[25] See the **FEMA Flood Map Service Center**, maps 1100010019C and 1100010038C.

[26] See Interior Flooding in Washington DC, op cit. The mapping on p. 10 indicates six areas of "Least Flooding" in our studied geography, and one area of "Less Flooding."

[27] Examples include the **DC Real Property Finder**, **HistoryQuest DC**, and the **SCOUT database**,

Six properties (the “Focus Assets”) were selected for the simulation exercises: three multifamily residential properties (MF-A, MF-B, MF-C), and three office properties (OF-D, OF-E, OF-F), as indicated on the following flood mapping (which also indicates approximate property elevations.)



An overview of their key characteristics is below:

Property	Neighborhood	Year Built[28]	Appr. SF / Units	Key Tenants
MF-A	NoMa	2010	450	Market-Rate MF; Grocery Retail
MF-B	H Street NE	2020	425	Market-Rate MF; Mixed Retail
MF-C	H Street NE	1960	200	Seniors / Low-Income MF
OF-D	NoMa	1969/2012	315,000 SF	District Agency (Health-related)
OF-E	H Street NE	2005	360,000 SF	Federal Agency (Regulatory)
OF-F	H Street NE	1987/2015	85,000 SF	District Agency (Welfare-related)

Working from public information, our team generated high-level physical characteristics for each building, including precise location, square footage, floors below-grade, and floors above-grade, allowing us to run loss estimates in SoloKat.

We also made two simplifying assumptions:

- To minimize the influence of asset valuation issues, we arbitrarily set each building’s value to $100,000,000. While the results below are presented in dollars, to maintain consistency with the actual modeled output, they can be treated as effective loss percentages.
- We also focused on damage to the building structure only. While SoloKat is able to account for losses on contents, we elected not to do so, due to our limited information on building interiors and the value of personal contents owned by the underlying tenants.

[28] All data are approximate, and public sources may differ slightly in presentation. As an example, OF-E shows a 2005 year-built in the HistoryQuest DC database and in CMBS disclosure filings, but a 2006 year-built in building owner materials.

MODEL OUTPUT

Integrating all of the above, we combined our climate change projections in SpatialKat with asset-specific detail in SoloKat to generate 10,000 ensembles of five years each (50,000 years in total), from which we sampled loss estimates 10 times per event (for 500,000 years of total modeled losses) and flood depths one time per event (for 50,000 years of total modeled flood depth). Loss estimates were run for each of the six buildings, then stratified by the total loss estimate, allowing us to sensitize losses along two dimensions:

- **Time:** Simulations were run for current day (October 2022), as well as 2025, 2030, 2040, and 2050.[29]
  - Key climate assumptions included an RCP 8.5 CO2 concentration scenario[30] and no development of neighborhood / public / building-specific mitigating engineering defenses over the period studied.
- **Probability:** For all scenarios, we generated:
  - An average annual loss equal to the probability-weighted mean of all scenarios.
  - A 1 in 100 event, which is the loss met or exceeded in 1.00% of all modeled yearly cases.
  - A 1 in 250 event (0.40% of modeled cases).
  - A 1 in 500 event (0.20% of modeled cases).
  - A 1 in 1000 event (0.10% of modeled cases).

As an example, the following summarizes the loss estimates for OF-E over a range of time frames and scenarios:

	Current[31]	2025	2030	2040	2050	Multiple[32]
Average Annual Loss	134,678	136,640	140,881	151,444	168,703	1.25x
1 in 100	1,232,937	1,599,935	2,173,035	3,398,847	5,116,099	**4.15x**
1 in 250	**15,080,935**	15,243,445	15,666,448	16,569,728	17,930,162	1.19x
1 in 500	23,830,332	23,923,904	24,413,482	25,206,644	26,270,474	1.10x
1 in 1000	31,340,278	31,406,798	31,651,318	32,319,114	33,391,998	1.07x

BASE CASE

KEY TAKEAWAY

We highlight two elements of these results:

- **Base case loss:** Our base case assumed a 1 in 250 probability event[33], modeled in October 2022, shortly prior to the simulation exercises.
- **Key takeaway:** The changes in forecast losses over time (as summarized by the Multiple value) highlight a critical element of climate change: the most significant increase in overall risk comes not from making extreme scenarios worse, but rather from increasing the impact of more probable scenarios. This is intuitively clear, as very extreme events (e.g. eight feet of flood depth) do not get significantly more expensive when one more foot is added due to climate change. At the same time, adding one foot of flood depth to an original (pre-climate change) flood depth of six inches produces a significantly greater loss.

  As an example, a 1 in 1000 event is only 7% worse in 2050 than it is today (a 1.07x multiple), while a 1 in 100 event is 315% more costly (a 4.15x multiple).

  While all of the Focus Assets show meaningful risk in the Current scenario, the expected cost of more-likely events rises meaningfully over time due to climate change.

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[29] The modeled losses are expectations for approximately two years after the nominal date, e.g. the period from 2030 to 2032.

[30] As defined in **The representative concentration pathways: an overview**.

[31] All Current calculations were run in October 2022.

[32] "Multiple" is calculated by dividing the 2050 loss forecast by the Current loss forecast.

[33] While many investors are more familiar with a 1 in 100 framing, which we employed in our original neighborhood selection, the disaster planning community has generally moved to a 1 in 500 scenario for their own analytics and mitigation work. We chose to split the difference between the two approaches, in the belief that a roughly 4% cumulative probability, when measured over a 10-year hold, was consistent with the spirit of the exercise design.

ALTERNATE ASSETS

In addition to the work above, we performed another set of checks to review the plausibility of the SoloKat output, by selecting certain out-of-sample assets for review within our model framework to verify that the loss output of our Focus Assets reflect specific and realistic physical model assumptions, and not simply an extreme modeling process impacting all assets equally.

As an example, we benchmarked OF-E, a Focus Asset which is part of a multi-building complex, against the adjoining building (which we designated OF-G), sited immediately uphill of OF-E and built by the same team three years later.

Even after giving full benefit for the impacts of climate change, by focusing on 2050 weather forecasts, we found that OF-G experienced minimal losses in our forecasting, demonstrating an average annual loss level only 4% of its neighbor:

2050 losses	OF-E	OF-G
Average Annual Loss	168,703	6,480
1 in 100	5,116,099	-
1 in 250	17,930,162	19,951
1 in 500	26,270,474	236,628
1 in 1000	33,391,998	1,319,353

While OF-G did show more significant losses in in the most extreme probability scenarios, the differential impact of topography is significant, and consistent with the physical conditions we observed on the ground in our tours.

FORECAST LOSSES

Our forecast loss matrices are included in Appendix E: Loss Sensitivities by Focus Asset.

Recovery

While desktop analytics presented the most rigorous way to model the physical dimensions of an event, we took a different approach to considering the political dimensions of a potential disaster, drawing on the expertise of our assembled teams.

DAMAGE ASSESSMENT

To create a realistic proxy for government disaster response, we designed the first portion of our simulation exercises around the framework of a post-disaster Damage Assessment meeting.[34]

As stated within the District Response Plan,

- Disasters cause injury to individuals and damage to property, the environment, businesses, nonprofit entities, and government-owned assets. Damages must be assessed to determine a priority of response efforts and to determine eligibility for disaster aid.
- An Initial Damage Assessment Report will be completed within 72 hours of the event, outlining the severity of the problems and the determination of need for further assistance.
- Federal- and state-supported damage assessment precedes delivery of a Presidential Disaster Declaration and defines the specific needs for a long-term recovery.[35]

Under those guidelines, the District's Homeland Security and Emergency Management Agency ("HSEMA") is tasked as follows:

"HSEMA will ensure that the following is accomplished:

- Determining **what happened, what the effects are**, which areas were hardest hit, what situations should be given priority and what types of assistance are needed (e.g., local, state, or federal).
- **Public, private, nonprofit, and individual damage assessments should be performed**, because of the corresponding types of federal and/or state assistance available. Each type of assessment is designed to quantify the eligible amounts of damages a community incurred."[36]

It is this HSEMA-led process that we replicated in our event.

SIMULATION TEAMS

We sought to combine the expertise of our own team and our strategic partners with several other critical constituencies:

- **Government actors:** a range of District and Federal experts in Washington resilience and climate risk.[37]
- **Private actors:** a range of different investors and capital providers focused on the implications of climate change.[38]
- **Georgetown experts:** a range of climate-related academic and policy specialists from across the University.[39]

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[34] Key elements were taken from the **District's District Response Plan** dated March 2017, primarily "Emergency Support Function #14 Damage Assessment," pp. 381 – 396 of the PDF document.
[35] District Response Plan, p. 385.
[36] District Response Plan, p. 389 – 390, emphasis added.
[37] See Appendix A: External Actors, "Government Efforts" for further detail.
[38] See Appendix A: External Actors, "Private Efforts" for further detail.
[39] See Appendix B: Georgetown Resources for further detail.

After a several month process of outreach and discussion, we assembled a broad list of simulation participants, who were subdivided into six teams of varied backgrounds.[40] In addition, each group included members of our student research team to assist in processing information and preparing materials.

Each of these groups was assigned to one of the six Focus Assets,[41] and tasked with advocating for that asset in our simulated Damage Assessment meeting. To support their presentation, each group was provided the loss estimates for all six buildings, as well as a dossier of information specific to their asset that included selected publicly available information covering the following topics:

- Maps, in a standardized format.
- Building photos, taken from ownership materials or other sources.
- Building structure and design features, including relevant materials publicly filed with the District.
- Tenant information, including, for offices, lease data sourced via CompStak.
- Marketing materials available for potential office, retail, or residential tenants, where available.
- Ownership information, including publicly available information including news items, website data, and any SEC-filed documents.
- Capitalization detail, where available, including extracts from commercial mortgage-backed securities filings and DC Housing Finance Agency submissions.
- News articles with meaningful historical context, particularly around tenancy, changes in ownership, and development / redevelopment.

Based on these data, the teams were asked to advocate for the priority of their assigned assets in the recovery and repair funding processes.

[40] A list of all participants is included in Appendix C: Simulation Participants.
[41] MF-A, MF-B, MF-C, OF-D, OF-E, or OF-F, as described above.

VOTING AND RESULTS

Following the team presentations, assessment voting was conducted individually using mobile polling technology.

Each of the participants was asked to rank order the Focus Assets on the following criteria, along with a recommended order for asset prioritization. Our written instructions read as follows:

"Rank the following assets on their …

- SEVERITY of damage (with most severe at the top)[42]
- STRATEGIC IMPORTANCE (with most strategic at the top)
- the IMPORTANCE of the population that they serve (with most important at the top)
- own RECOVERY RESOURCES (with highest resources at the top)
- your RECOMMENDED REOPENING (with the first to reopen at the top)"

A summary of the voting is as follows:

Characteristics			Ranking by Category				
Asset	Tenancy	Damage ($)	Damage	Strategic	Population	Resources	Reopening
MF-A	Mkt. Rate MF	$19.102	2	5	4	3	4
MF-B	Mkt. Rate MF	$16.891	5	6	6	2	6
MF-C	Aff. Seniors MF	$11.390	4	3	1	6	2
OF-D	Dist. Agency	$17.824	3	2	3	4	3
OF-E	Fed. Agency	$15.081	6	4	5	1	5
OF-F	Dist. Agency	$18.519	1	1	2	5	1

These results suggest a number of key insights:

- **Damage is subjective:** All participants received loss data for each building, not just their own. Our expectation was that buildings would be ranked on a strictly quantitative basis, which was not the case.
  - MF-A, which was forecast to suffer the highest damage, was ranked second in the voting, while OF-F, which had a lower forecast loss, was ranked higher.
  - More interestingly, MF-C, which was forecast to suffer by far the lowest damage, was ranked fourth in the voting, ahead of two assets that were more economically impacted.
  - Both of the assets ranked above their forecast loss positions were linked to vulnerable populations, as discussed further below.
- **Strategic Importance correlates with vulnerability:** Our rankings asked voters to rank strategic importance, without the benefit of defined criteria.
  - OF-F was an interesting case. While the property provides District-level services to a range of vulnerable populations, its narrow focus made it a surprising choice for top strategic ranking.
  - OF-D hosts a number of key District health functions, while MF-C provides housing for limited-income seniors. Surprisingly, both were ranked higher in the Strategic Importance voting than OF-E, which is part of the headquarters complex for a major Federal agency with an active role in financial sector management.
  - It is less surprising that the market rate housing assets, MF-B and MF-A, were ranked the lowest in Strategic Importance.

[42] The polling software allowed participants to rank order their choices on their screens. In our presentation, the choice "at the top" would equal a score of 1, while the choice at the bottom would equal a score of 6.

- **Importance of Population directly reflects vulnerability:** Even more than Strategic Importance, this ranking directly reflected population vulnerability.
  - MF-C ranked first, potentially reflecting the perception of low-income seniors.
  - OF-F was second, potentially reflecting the high needs of the vulnerable residents served.
  - OF-D was third, potentially suggesting the importance of local health administration.
  - MF-A was fourth, which is difficult to reconcile with its ranking for Strategic Importance.
  - OF-E was fifth, suggesting a low priority for national financial administration.
  - MF-B was sixth, despite a fairly similar tenant profile to MF-A.
- **Recovery Resources combines economics and clout:** The rankings largely reflected owner financial capacity, with some notable exceptions.
  - OF-E, which is jointly owned by two major developers and property investors, ranked first.
  - MF-B, which was a surprising second, may reflect the benefit of having a well-connected local owner.
  - MF-A, ranked third, is owned by a major insurance company directly on balance sheet.
  - OF-D, ranked fourth, was recently acquired by another well-connected local team.
  - OF-E, ranked fifth, was surprisingly low for an asset owned by a property sponsor with $10+ billion in assets under management.
  - MF-C, ranked last, is owned by a specialty investment firm located in another state, and carried potential constraints due to the limitations of public financing on the project.
- **Reopening ranks largely matched Importance of Population:** The first and second place rankings were reversed from that of Importance of Population, but third through sixth were identical.

RECOVERY TAKEAWAYS

Collectively, these results suggest two clear messages.

- **Population vulnerability is the critical determinant:** Vulnerability correlates to almost every ranking, either directly, as in the case of Strategic Importance, Importance of Population, and Reopening, or indirectly, as in the relative assessments of Damage.
- **Priority is given to the lightly resourced:** the top two assets as ranked for Recovery Resources were recommended to be fifth and sixth in Reopening priority, while the bottom two were ranked first and second.

While perhaps not surprising to those with experience working with municipal governments, this message should raise concerns for private investors, especially those who combine traditional tenant bases with high capital resources.

Mitigation

H Street NE and NoMa were selected as our focus neighborhoods, in part, for the degree of new development seen in recent years.

Even more new construction is slated for the years to come.

PLANNED AREA DEVELOPMENTS

- **Union Station:** A full redevelopment, including "[n]ew rail infrastructure … new train hall with new passenger concourses … new bus facility… and [e]nhanced connections to Metrorail, DC Streetcar, local buses, and H Street NE and re-established connections with the surrounding neighborhoods, NoMa and Capitol Hill, via the H Street NE concourse."[43]

- **H Street Bridge:** As part of the Union Station redevelopment, "Amtrak's proposed rail reconfiguration plans … provide the general conditions under which the District Department of Transportation … will design and construct the new H Street Bridge piers and deck."[44]

- **Burnham Place:** Akridge has the rights to develop Burnham Place, "a vibrant and dynamic new neighborhood of shops, residences, offices, and public spaces … the approximately three-million square-foot … project will be built above Union Station's rail yard … in an ideal location at the convergence of the city's Central Business District, Capitol Hill, NoMa, and near Northeast neighborhoods, with unparalleled accessibility."[45]

- **60 New York Avenue:** In 2021, the U.S. General Services Administration announce that "it has awarded a lease for a new U.S. Securities and Exchange Commission (SEC) headquarters … [to] an entity affiliated with the Douglas Development Corporation, which will construct Financial Plaza at 60 New York Avenue, NE."[46]

- **Combined:** As of August 2021, NoMa Business Improvement District estimated the neighborhood pipeline of planned construction of that neighborhood alone at 11.6 million square feet.[47] In another, similar analysis dated April 2021, the combined development pipelines of H Street NE, NoMA, and Union Station were estimated at 15.3 million square feet – the largest pipeline in the District by a significant margin.[48]

PROPOSED STRATEGIES

After reviewing a number of the plans cited above, we asked the same six teams to generate develop non-traditional ideas to use this wide range of economic activity to boost overall neighborhood climate resilience.

Our intent was to benefit from the diversity of each team's experiences, tasking members with exchanging ideas with partners of different backgrounds. Each team was encouraged to start broadly, generating as many potential ideas as possible, and only later narrowing their focus down to a single, primary proposal.

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[43] From Union Station Redevelopment Corporation, "**Status of the Washington Union Station Expansion Project**."
[44] From Union Station Redevelopment Corporation, "**H Street Bridge Project**."
[45] From "**Burnham Place at Union Station**."
[46] From U.S. General Services Administration, "**GSA Announces New Headquarters for the Securities and Exchange Commission**."
[47] From NoMa Business Improvement District, "**Making NoMa Magnetic – 2021-2026 Strategic Plan**," p. 9.
[48] Washington DC Economic Partnership, ""20 Years of Growth in the District of Columbia," op. cit.

While each team highlighted a distinct strategy, they can be grouped within three general themes, as follows:

Category	Target	Description
Data	Flood mapping	Use improved modeling to create forward-looking FEMA flood maps
Data	Improved metrics	Integrate building data and hazards into an improved multi-factor property score
Redevelopment	Resilience hubs	Regulations / subsidies to encourage resilient common areas within buildings
Redevelopment	Street grading	Redevelop local projects to reset street levels, improving flood drainage
Subsidies	Financing	Enhance environmental resilience in lower-cost developments via enhanced benefits
Subsidies	Transit	Incentivize use of public transit instead of personal automobiles

These proposals can be further described as follows:

- **Flood mapping:** All participants, including a representative of FEMA, acknowledged that our modeling work emphasized the need for improved FEMA flood maps.[49] This team proposed tying together the flood maps[50] with a model source such as KatRisk to counteract the historical orientation of existing data, as well as raising the possibility of considering more severe scenarios than the typical 100-year flood approach.
- **Improved metrics:** Several members of this team were actively engaged in developing new asset scoring systems for their own firms, and proposed adopting a variant of this approach for a broader audience to reflect both climate risk and other critical variables. While some elements of these ratings exceed the scope of our exercise, there is clearly room for improved measures, particularly ones that adjust potential hazard scores for the impact of mitigation strategies in place.
- **Resilience hubs:** As climate events worsen, cities increasingly need to develop specialized resources dedicated to mitigating their worst effects, particularly on behalf of vulnerable citizens.[51] This team proposed programmatically developing spaces within new and existing buildings to serve as shelter areas during events, providing both relief from extreme weather conditions and easy locations to deliver services, such as food, hydration, phone charging, and potentially refrigeration for critical items.
- **Street grading:** Our research emphasized the impact of topography on flood paths, particularly in geographies with limited green space. This team proposed a public-private partnership to design and fund improved street layouts, maximizing drainage through a program of alternately raised and lowered roads to create more efficient channels for water flow.
- **Financing:** Over the course of our simulation, many participants were concerned that traditional development projects, particularly of the types currently planned, were insufficient to meet the full range of community needs. This team proposed augmenting other work with a dedicated financing vehicle, driven by some form of subsidized capital, to serve as a source of low-cost financing for projects to complement private development efforts.

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[49] This is widely acknowledged by FEMA management, as well. See, for example, "**Climate Change is Overwhelming US Flood Maps, FEMA Head Says**".

[50] There are several different types of flood maps produced, as indicated on FEMA's **website**. The focus of our discussions were generally on Flood Insurance Rate Maps, which are classified as Regulatory Products.

[51] Examples of this are evident in the efforts of newly-named Chief Heat Officers within cities. See, for example, "**How the World's First Chief Heat Officer Plans to Keep Miamians Cool**" or "**Africa's First Heat Officer Faces a Daunting Task**".

- **Transit:** Travel is the sector with the highest contribution to climate change – according to the EPA, 27% of all greenhouse gas emissions are attributable to transportation, with 57% of that from light-duty vehicles and 26% from medium-duty and heavy-duty trucks.[52] This team focused on addressing this long-term risk through more effective subsidies for public transit, particularly given the access of H Street NE and NoMA to the combination of metro, local bus, streetcar, distance bus, and passenger rail.

MITIGATION TAKEAWAYS

Each of the six teams addressed a different component of our simulated scenario, ranging from the tactical to the fundamental.

Overall, however, we came away from these discussions with the uncomfortable sense that these proposals were too small in scale to address the challenges of climate change suggested by our analysis. As is often the case, the result is likely to be a continuation of increased asset resiliency for those who could afford it, leaving significant residual gaps for the larger communities surrounding those properties.

[52] Taken from "**Fast Facts on Transportation Greenhouse Gas Emissions**".

Investment Implications

Based upon the results of both our modeling work and our simulation exercises, we considered the potential economic impacts for investors in climate-exposed assets.

UNDERWRITING

Our general view is that there is currently no direct premium paid[53] for holding climate-exposed assets within a given market.

This is not to claim that there are no distinctions among markets; rather, it appears that the primary distinction is between "risky" and "unrisky" markets, driven by history, rather than "risky" and "unrisky" sub-markets or assets, based on a forward view, which appears consistent with existing research on the topic.[54]

As a theoretical matter, the easiest way to think about the impact of climate change is to consider its impact on property-level cash flows, which ultimately must have a direct impact on stabilized properties when modeled in a traditional valuation analysis.

We divide these impacts into three key categories:

- **Revenues:** We are at the very beginning of tenant consideration of physical risk and sustainability issues. While a consideration of physical risk is required by government tenants,[55] certain of our event participants highlighted systemic work by private tenants in evaluating leased property sustainability.

  As tools to measure forward climate risk become more accessible, we expect that the most sophisticated tenants will avoid exposed areas, reducing demand for at-risk properties. This may manifest in the form of lower nominal rent levels, higher vacancies, longer downtimes, or some combination thereof, but we expect to see a meaningful potential impact on the asset-level top line.

- **Expenses:** We see three major categories of expense risk, listed from most direct to least direct.
  - **Repairs and maintenance:** These costs are clearly expected to rise due to increased climate change, many of which may not be covered under relevant insurance provisions, or which may not meet policy deductibles for the given event. In flood-exposed areas, these items include some combination of water removal, remediation of mold and/or contaminants, common area expenses such as drywall repair or replacement, repainting, carpet cleaning, and repairs to exposed building components, including electrical systems, elevators, landscaping, and exterior elements.

[53] A premium may be more accurately characterized as a pricing differential, observable in the form of an increased return, assuming no change in cash flow; a reduction in cash flow, with no change in return; or some combination of the two.

[54] In one review of the UK market, the authors found that "[c]ommercial owners/investors in some geographies are placing a higher risk premium on all properties in metro areas affected by climate events, regardless of whether their individual properties have been directly affected." **Climate Risk & Commercial Property Values: A review and analysis of the literature**, p. 6 of the PDF document.
Similarly, the same authors cite "Pottinger and Tanton (2014) [in finding] evidence of increasing flood risk due diligence among major UK investors when making acquisitions, driven by tightening regulation and the occurrence of major flood events. The availability and accessibility of insurance were also identified as issues for occupiers. Yet, the authors found no evidence that valuers were making rent or yield adjustments to reflect changes in investor and occupier sentiment." Ibid, p. 23.

[55] As an example, the General Services Administration is bound by EO 11998, dating from 1977, which prohibits "most projects … [from] occurring in the 100-year floodplain." **Executive Order 11998, Floodplain Management**, p. 1. In their most recent policies, however, a more forward-looking view is highlighted: "Historic climatic design data is becoming less illustrative of the current and long-term climate conditions that federal buildings endure. GSA must integrate both the observed and expected changes in climate and extreme weather for the asset service life when planning and designing their capital investments." **Facilities Standards for the Public Buildings Service**, p. 41, emphasis ours.

- **Insurance:** Some climate-related costs will be covered by insurance, which has caused property and casualty insurers to raise rates in anticipation of further climate-related payouts. While the mechanics of this adjustment are controversial,[56] some combination of higher rates and/or lower willingness to provide coverage will impact owners, due to the combination of increased cost or higher levels of self-insurance.
- **Property Taxes:** There is also a link between climate change and property tax increases, as physical risk creates costs for not only property owners, but the municipalities in which the assets are located. Ultimately, these municipalities will either preemptively address these issues through mitigation strategies, bear additional costs due to post-event cleanup, or a combination of the two. Given the limitations of municipal budgets, property owners are an obvious target in jurisdictions where taxing authorities are not otherwise constrained.[57]

- **Capital Expenditures:** Owners have taken on a range of investment strategies in anticipation of climate change. Within the context of flood risk, we are aware of several distinct approaches to the issue:
  - **Dry Floodproofing:** These are techniques that may include backflow values, impermeable walls, internal drainage, interior flood resistance, opening flood shields, and/or opening sealants.[58]
  - **Systems Protection:** This work generally focuses on both electrical and mechanical systems, which are heavily exposed to flood damage. Typically, this is accomplished either through dry floodproofing techniques such as impermeable walls, or through elevation of key systems components above expected flood levels.
  - **Barriers:** For flood risk, some owners of exposed properties have invested in a range of barrier technologies. In the District, Georgetown's Washington Harbour floodwall system famously experienced issues in the floods of 2011,[59] while in Boston, BXP has invested in an AquaFence system to address potential flooding at Atlantic Wharf.[60]

    Over time, we expect many of these expenditures will become more common, whether driven by owners, insurers, or tenants.

Ultimately, we expect that the market will develop in a tiered manner, with a more modest adjustment for issues tied to city-level changes (e.g. real estate taxes and, to some degree, insurance) and a more significant adjustment for heavily exposed submarkets.

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[56] See, for example, this Wall Street Journal account of a dispute between insurers and regulators on the mechanics of pricing coverage. "Some insurers are frustrated that California regulators require them to set home-insurance rates based on their historical loss experience, not projections of future losses that are determined by catastrophe modeling. Such models can reflect detailed, location-specific data that the insurers feel they need amid escalating wildfire activity tied partly to climate change." The result of these restrictions? "Worried about wildfire exposure and frustrated by state regulations … two of the biggest firms offering protection for multimillion-dollar properties end coverage for some customers." **Wildfire Risk in California Drives Insurers to Pull Policies for Pricey Homes**.

[57] **Climate change will increase local government fiscal stress in the United States**, from Nature Climate Change.

[58] This list is taken from **Floodproofing Non-Residential Buildings**. As our work concerns existing buildings, we have not focused on wet floodproofing, which is less common for existing commercial structures.

[59] See **$5 million lawsuit filed after Georgetown flooding**.

[60] See **New Barriers Protecting Some Boston Property From Flooding**.

RECOVERIES

In pre-event discussions, one of our participants observed that their overall experience with climate events such as floods were actually positive, as the impact of area rehabilitation spending and net recovery payments ultimately accrued to the benefit of their owned assets.

This seems to us an unsustainable view, driven by a recent history of relatively few climate events, and colored by the response to a small group of visible events such as Superstorm Sandy (2012).

More recent U.S. data[61] indicate a quickly growing physical risk problem, with the last 10 years of national economic losses estimated as follows:

Year	Economic Loss ($bn)
2013	$57.05
2014	$49.58
2015	$53.32
2016	$82.35
2017	$284.55
2018	$138.16
2019	$88.53
2020	$148.79
2021	$184.79
2022	$205.73

The three years from 2013 to 2015 averaged $53.32 billion in economic losses; by contrast, the three years from 2020 to 2022 averaged $179.77 billion – an average increase of over 200%, and the highest three-year cohort on record (in constant dollar terms).

Given both the increased losses over the past decade, and the forecasted increases in our loss scenarios going forward, we believe that future events will become increasingly zero-sum for asset owners.

In that context, we believe that our simulated results, which suggest the likely prioritization of vulnerable populations at the expense of institutional investors, is a reasonable framework going forward.

[61] From Gallagher Re, referencing United States economic losses from natural catastrophes, shown in inflation-adjusted 2023 dollars.

Conclusions

We begin this simulation with a focus on three questions, concluding with two takeaways to each.

MODELING

Our question: what asset impacts are forecast by climate-sensitized modeling?

- **Base risk:** There is more current climate risk in the District than is generally supposed, and the risks are growing over time. This is particularly true outside of the obvious areas of concern, such as our focus neighborhoods of H Street NE and NoMA.

  Ultimately, we believe that our partners' modeled forecasts for these areas are credible, and reflect a combination of five critical factors: base climate, given the heat and humidity of the District microclimate; climate change, with emphasis on expected increases in temperature; topography, particularly in the areas immediately surrounding Union Station; development, which has reduced green space, impacting neighborhood drainage; and engineering, which has created channels that route water in high-impact ways.

- **Asset impact:** The modeling tools used enable a high degree of precision in estimating damage, particularly for insureds or direct insurers, whose detailed property knowledge enables a more refined analysis. Our projections, while merely indicative, given the limits of publicly available information, indicate both high levels of potential damage to our Focus Assets, and an increasing impact from climate change over time.

  Critically, this forecast is at odds with standard investor approaches, whether based on FEMA flood maps or other historically-oriented studies, as these approaches fail to account for the changing circumstances that drive much of the expected risk.

RECOVERY

Our question: How do we simulate the impacts of climate events, both economically and politically?

- **Economic costs:** Assets in exposed markets have the potential to bear economic costs in every component of net cash flow. Revenues are at risk as more sophisticated tenants elect to avoid areas with increased operational exposure; expenses are at risk due to expected increases in repairs, insurance, and property taxes; and capital expenditures may increase as owners invest in mitigation strategies.

  Ultimately, this should lead to lower relative values for exposed assets, no matter what valuation approach is taken.

- **Political risk:** We see a growing risk to well-capitalized investors with high-quality assets. This stems from two related concerns: first, an expectation that the growing frequency and severity of events, particularly in higher-risk areas, will lead to an increasingly zero-sum recovery process, and second, that political realities, especially in urban areas, will drive available resources to assets that are lightly capitalized and/or serve vulnerable populations.

  We acknowledge that this is a break from past events, such as Superstorm Sandy, in which efforts and financial resources were applied broadly, and in many cases led to net positive results over time. Unfortunately, the rapid growth in climate-driven losses suggest an increasingly adversarial process in allocating risk among owners, insurers, and government sources.

MITIGATION

Our question: what defensive strategies are available, and are there ways for the public and private sectors to work together to build community resilience?

- Constrained response: The types of scenarios that we studied lend themselves to underinvestment. This reflects two issues: first, the limited resources of municipal budgets, which suffer from high demand from every available dollar in the best of times,[62] and second, the nature of the risk studied, which focused on areas without demonstrated problems, focusing on lower probability cases.

  We must acknowledge that cities, particularly Washington, have invested in mitigation. However, we would argue that cities are appropriately attempting to solve currently known problems, and that this will likely absorb the financial capacity of the cities in question.

- Investment opportunities: New programs are needed to address these issues, but effecting meaningful results from private or public-private action is difficult.

  We see this as a source of investment opportunity. Near-term, this implies a particular focus on resilient materials, systems, and technologies, particularly in areas of public sector shortfall. Longer-term, we believe that the limitations of mitigation strategies will impact both asset economics and demographic demand, and should form a critical part of investment strategy going forward.

We advise all investors to actively investigate areas of potential climate exposure, and invest accordingly.

[62] This was not discussed in our simulation, but continued stress on commercial real estate assets, especially offices in the post-COVID / work from home environment, create further pressure from a combination of lower potentially property taxes, lower sales taxes, and a reduced multiplier effect from lower economics activity in urban areas.

Appendix A: External Actors

In bringing together insights from across the complex web of affected parties, we focused on the contributions of three primary groups:

- **District government agencies:** comprised of a broad range of municipally-focused governmental teams, such as the Department of Energy and Environment and Homeland Security and Emergency Management Agency;
- **Federal government agencies:** comprised of a key group of nationally-focused governmental teams, such as the Federal Emergency Management Agency and the General Services Administration; and
- **Private investors and capital providers:** comprised of investors in equity, debt, and alternative risk products, such as BXP, Chubb Insurance, Freddie Mac, and Goldman Sachs.

GOVERNMENT EFFORTS

In general, both District and Federal government teams maintain an active dialogue on climate issues. Key working groups with flood risk in their purview include the following:

- **Flood Task Force:** The **Flood Task Force for the District of Columbia** is led by the Department of Energy and Environment (DOEE) and the District of Columbia Water and Sewer Authority, reporting to the Deputy Mayor for Operations and Infrastructure.
- **Silver Jackets:** The **D.C. Silver Jackets** are the local chapter of the national Silver Jackets interagency flood risk initiative, sponsored by the US Army Corps of Engineers (USACE). Within the D.C. team, USACE jointly oversees all Federal-side agencies with the National Park Service, while DOEE serves as lead agency for all District-side agencies.
- **DC-CCCR:** The **District of Columbia Commission on Climate Change and Resiliency** came covers a broader scope of analysis than either of the two groups above. It is designed with a broader constituency of members; we would note in passing that of the 14 members (of which 13 were seated at the time of the simulation), 3, including the Chair, are full-time or part-time Georgetown faculty.

PRIVATE EFFORTS

There are a number of groups with an emphasis on understanding environmental risk within the built environment, many affiliated with either real estate investors or asset owners.

Examples include:

- **CREFC:** The CRE Finance Council, the industry group for commercial real estate lenders and debt investors, has launched a **Sustainability Initiative**, “focused largely on the intersection between climate risk and CRE finance.”
- **NAREIT:** The National Association of Real Estate Investment Trusts is an industry group dedicated to REITs and real estate companies; they have a number of relevant initiatives, including the **Real Estate Sustainability Council**.
- **ULI Americas:** The Urban Land Institute is a global organization of over 45,000 members. ULI Americas, a subset of the international entity, includes the ULI Randall Lewis Center for Sustainability in Real Estate, host of the **Urban Resilience Program**.

Appendix B: Georgetown Resources

Overall, our review found the government and private efforts to be frustratingly distinct from one another.

To help bridge the gap between these two approaches, we drew on the resources of Georgetown University to assemble an internal coalition with particular expertise in working across the public-private divide.

SPONSOR AND CO-SPONSORS

- **Steers Center:** The **Steers Center for Global Real Estate** leads the University's education, research, and applied solutions in real estate analytics and investment strategies. The Steers Centers integrates traditional academics, industry experts, and innovative tools to analyze issues, particularly those at the intersection of Georgetown's Jesuit mission and its Washington location.
- **Global Cities:** The **Georgetown University Global Cities Initiative** explores themes related to urbanization, with "research themes [that include] social equity, rapid urbanization, city diplomacy … and changing environmental resources."
- **Georgetown Climate Center:** The **Georgetown Climate Center** "was established in 2009 at the request of state leaders who recognized the need to strengthen connections between climate policies and policymakers at all levels of government and to help policymakers develop aligned strategies that work together to address climate change."
- **Georgetown Entrepreneurship:** A part of the McDonough School of Business, **Georgetown Entrepreneurship** leads the University's education and research efforts in support of the idea that "entrepreneurship is one of the world's most powerful forces for positive change."
- **Georgetown Sustainability:** The University's **Office of Sustainability** serves as a campus-wide resource, coordinating and advancing both the practice of sustainability in our own operations and through engagement with the broader communities of the district, the nation, and the world.

STUDENTS

We assembled a group of 20 students to aid in preliminary research, with students drawn from the following curricula:

- **Master of Business Administration**
- **Master of Data Science for Public Policy**
- **Master of Science in Environment and Sustainability Management**
- **Master of Urban and Regional Planning**
- Undergraduate, **Georgetown College of Arts and Sciences**
- Undergraduate, **McDonough School of Business**
- Undergraduate, **School of Foreign Service**

These students were then assigned to five functional teams:

- Commercial Real Estate – Industry Approaches, focused on investor sustainability practices, including business selection, underwriting procedures, and tools used.
- Commercial Real Estate – Office Assets, focused on the intensive diligence of the office properties among our Focus Assets.
- Commercial Real Estate – Residential Assets, focused on the intensive diligence of the multifamily properties among our Focus Assets.
- District infrastructure – Transit Systems, focused on key local participants including the District Department of Transportation, the Metropolitan Washington Airports Authority, and the Washington Metropolitan Area Transit Authority.
- District infrastructure – Utility Systems, focused on key local participants including DC Water and PEPCO.

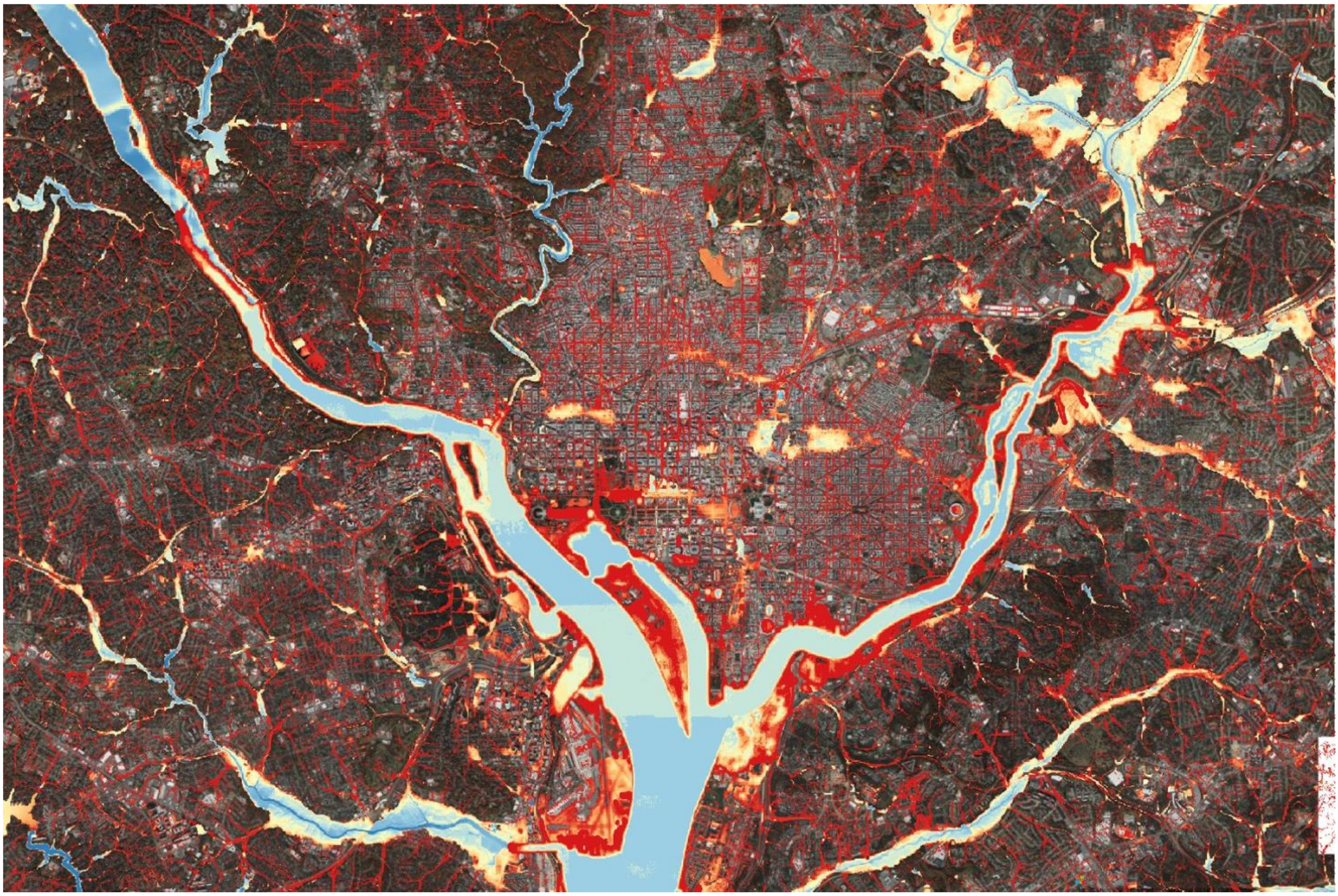
Each of these teams assisted in researching critical issues, speaking with key experts, including both simulation participants and outside groups, and helping to develop simulation scenarios and materials.

Appendix C: Simulation Participants

We are grateful to acknowledge the participation of the following organizations:

- Sponsor
  - Steers Center for Global Real Estate, Georgetown University
- Facilitators
  - Booz Allen Hamilton
  - Gallagher Re
  - Katrisk LLC
  - U.S. Naval War College
- Georgetown Contributors
  - Georgetown Climate Center
  - Office of Sustainability
- Capital / Investment Stakeholders
  - Acadia Realty Trust
  - BGO
  - BXP
  - Chubb
  - Freddie Mac
  - Goldman Sachs
  - Invesco Real Estate
  - JBG Smith Properties
  - JP Morgan Chase & Co.
  - Tishman Speyer
  - The World Bank Group
- Government / Infrastructure Stakeholders
  - Department of Energy and Environment
  - District Department of Transportation
  - District of Columbia Water and Sewer Authority
  - Federal Emergency Management Agency
  - Homeland Security and Emergency Management Agency
  - U.S. General Services Administration
  - Washington Metropolitan Area Transit Authority

Appendix D: Alternate Map Format



Appendix E: Loss Sensitivities By Focus Asset

Focus Asset Summary

Property	Neighborhood	Year Built	Appr. SF / Units	Key Tenants
MF-A	NoMa	2010	450	Market-Rate MF; Grocery Retail
MF-B	H Street NE	2020	425	Market-Rate MF; Mixed Retail
MF-C	H Street NE	1960	200	Seniors / Low-Income MF
OF-D	NoMa	1969/2012	315,000 SF	District Agency (Health-related)
OF-E	H Street NE	2005	360,000 SF	Federal Agency (Regulatory)
OF-F	H Street NE	1987/2015	85,000 SF	District Agency (Welfare-related)

Multifamily A (MF-A)

	Current	2025	2030	2040	2050	Multiple
Average Annual Loss	173,774	175,405	181,774	196,554	218,016	1.25x
1 in 100	3,913,735	4,002,444	4,666,351	6,026,721	7,838,159	2.00x
1 in 250	19,102,638	19,189,508	19,728,356	20,788,606	22,282,048	1.17x
1 in 500	28,651,584	28,735,274	29,188,082	30,351,362	31,441,602	1.10x
1 in 1000	36,597,024	36,777,596	37,146,476	38,060,536	38,945,668	1.06x

Multifamily B (MF-B)

	Current	2025	2030	2040	2050	Multiple
Average Annual Loss	148,558	149,278	153,815	165,888	185,246	1.25x
1 in 100	1,751,235	1,955,106	2,450,539	3,788,095	5,649,944	3.23x
1 in 250	16,891,324	16,880,466	17,313,742	18,400,236	19,854,478	1.18x
1 in 500	26,551,410	26,582,116	26,816,138	27,672,684	28,865,502	1.09x
1 in 1000	35,100,020	34,962,548	35,241,932	36,180,928	37,099,268	1.06x

Multifamily C (MF-C)

	Current	2025	2030	2040	2050	Multiple
Average Annual Loss	102,843	103,253	106,386	114,414	127,748	1.24x
1 in 100	-	-	-	578,800	1,844,690	N/A
1 in 250	11,390,309	11,407,232	11,728,264	12,625,372	14,073,001	1.24x
1 in 500	20,385,518	20,381,588	20,694,940	21,555,978	22,625,042	1.11x
1 in 1000	28,385,096	28,458,164	28,708,286	29,608,756	30,731,106	1.08x

Office D (OF-D)

	Current	2025	2030	2040	2050	Multiple
Average Annual Loss	159,973	161,362	167,035	179,704	198,671	1.24x
1 in 100	2,989,362	3,112,694	3,757,471	4,906,972	6,569,398	2.20x
1 in 250	17,824,278	17,851,516	18,333,606	19,305,700	20,766,362	1.17x
1 in 500	27,665,570	27,681,100	28,152,582	29,009,264	30,066,940	1.09x
1 in 1000	35,618,304	35,618,304	36,096,608	36,589,928	37,459,400	1.05x

Office E (OF-E)

	Current	2025	2030	2040	2050	Multiple
Average Annual Loss	134,678	136,640	140,881	151,444	168,703	1.25x
1 in 100	1,232,937	1,599,935	2,173,035	3,398,847	5,116,099	4.15x
1 in 250	15,080,935	15,243,445	15,666,448	16,569,728	17,930,162	1.19x
1 in 500	23,830,332	23,923,904	24,413,482	25,206,644	26,270,474	1.10x
1 in 1000	31,340,278	31,406,798	31,651,318	32,319,114	33,391,998	1.07x

Office F (OF-F)

	Current	2025	2030	2040	2050	Multiple
Average Annual Loss	159,980	160,692	165,489	178,396	198,908	1.24x
1 in 100	2,230,191	2,445,912	2,955,318	4,328,393	6,424,911	2.88x
1 in 250	18,518,566	18,585,262	18,986,150	20,029,822	21,374,456	1.15x
1 in 500	28,444,564	28,545,556	28,882,762	29,702,372	30,977,136	1.09x
1 in 1000	37,268,024	37,208,880	37,618,392	38,225,316	39,061,312	1.05x