Supplementary Information

Recurrent flooding beyond the reach of flood risk management in New York City

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Supplementary Methods

The first part summarises the data and describes each dataset; the second gives the detail behind steps that the Methods of the main paper summarise.

Data summary and description

Every input is a public product. The summary below states what each dataset is used for, and the description that follows gives, for each dataset, the details that the Methods leave out; Supplementary Table 3 lists each dataset with its resolution, source identifier, access period and the check applied to it.

Summary. The table groups the inputs by role. The drainage design intensity (1.75 in h^{-1}) is a threshold rather than a dataset and is used to classify observed flood days.

Data	Used for
Coastal surge	
USACE NACCS joint-probability analysis	Still-water level against return period at The Battery, that is, how often each water level occurs; curves at three Jamaica Bay and Rockaway points check that one curve serves the city.
NOAA CUDEM elevation	Converts each water level into flooded area and depth (connected bathtub).
NOAA tide gauge at The Battery	Conversion of water levels to NAVD88; the highest water level since 2020, which shows that no surge flood occurred in the sensor record.
Rainfall and tide	
NYC DEP Stormwater Flood Maps	Rainfall flood footprints (moderate and extreme scenarios, two depth classes): basement lots, stations and building loss inside them, and their overlap with the flood map.
NOAA Atlas 14	Return periods of the two DEP scenarios and of the 1.75 in h^{-1} drainage design intensity.
NOAA Multi-Radar Multi-Sensor (MRMS) radar rainfall	Rainfall at each sensor and lot on each day: the probability of a flood by rain intensity, and street-ponding days per year at basement lots.
Automated Surface Observing System (ASOS) one-minute rainfall (LaGuardia, JFK, Newark)	Test of whether hourly rain understates the intensity on flood days (Supplementary Fig. 1e–g).
NOAA sea-level-rise inundation	Land flooded at high tide under +3 ft of sea-level rise (Fig. 1a).
Observed flooding	
FloodNet street sensors	Observed flood frequency at tidal and rain sensors, the share of flood days below the design intensity, and the flood rates applied to basement lots.
NYC 311 street-flooding complaints	Tests of the observation system only (sensor siting, flood duration); not used as a measure of hazard.

Data	Used for
Exposure	
USACE National Structure Inventory (NSI)	Value, storeys, foundation and first-floor height of each building; the asset base for loss.
USACE generic depth–damage functions	Damage fraction from depth relative to the first floor.
PLUTO tax lots	Small residential lots with a below-grade basement.
Estimates of unauthorised units (Pratt Center; City of New York)	Informal basement units allocated to basement lots, as upper and lower bounds.
HUD low-to-moderate-income share	Allocation weight for informal units; income groups for the insurance shortfall (Supplementary Fig. 3).
MTA stations and entrances	Underground stations and street entrances inside each footprint.
Census TIGER 2020 block groups and tracts	Spatial units at which policies, loss and exposure are joined.
Risk-management instruments	
FEMA National Flood Hazard Layer	Coverage of the rainfall exposure and of tidal sensors by the flood map in force.
FEMA 2015 Preliminary Flood Insurance Rate Map (FIRM)	Sensitivity test with the alternative map (Supplementary Table 2).
NFIP policies (OpenFEMA)	Take-up inside and outside the map; insurable share, shortfall decomposition and counterfactuals.
Validation	
Observed Sandy inundation zone	Footprint skill of the uncalibrated surge model.
City of New York Sandy damage estimate	Comparison with the modelled Sandy structure loss.
NFIP Sandy claims (OpenFEMA)	Contents share of insured loss; realised NFIP payment for Sandy.
Supplementary analyses only	
PLUTO floor-area valuation	Valuation check of the insurance shares (Supplementary Methods).

Description. The datasets are described in the order of the summary table.

Coastal surge hazard (NACCS). The hazard curve is the joint-probability still-water result of the USACE North Atlantic Coast Comprehensive Study for save point 7672 at The Battery [1,2] (TR-15-5, Fig. 8-19): 1,050 synthetic tropical cyclones and 100 historical extratropical cyclones simulated with the ADCIRC hydrodynamic model and combined with astronomical tide. The mean curve was digitised from the published figure, giving annual exceedance probability from 1 to 10^{-4} at ± 0.1 m; the resulting levels are 1.35 m (1 yr), 2.17 m (10 yr), 3.31 m (100 yr), 4.63 m (1,000 yr) and 6.22 m (10,000 yr) above mean sea level (Extended Data Fig. 2d).

Elevation, datum and tide gauge. The elevation model is NOAA CUDEM at 1/9 arc-second[3], averaged to 20 m (surge and rainfall grids) and 55 m (sea-level-rise grids and terrain covariates). Surge loss computations use a 20 m window covering the surge-exposed part of the city (74.12–73.72°W, 40.53–40.92°N), which contains 794,780 of the 881,621 structures in the inventory and 96% of their value, 81% of the five boroughs' area and 89% of the extreme rainfall footprint. The surge reach and every comparison with it are computed inside this window. The area of the rainfall footprint and its share outside the flood zone, the basement lots, subway stations and building loss inside it, and the sensor and complaint shares use the full city, on the same grid extended to the five boroughs; 2,210 of the 22,443 rain-exposed basement lots (1,883 in western Staten Island and 327 at the eastern edge of Queens) lie outside the window. The grid is geographic (0.00018°, about 15 by 20 m, called the 20 m grid in the text), and areas are computed from the true cell area at each latitude. Water levels published relative to mean sea level are converted to NAVD88 with the NOAA datum relationship at The Battery (NAVD88 = MSL + 0.063 m, tidal epoch 1983–2001)[4]. The largest annual maximum of verified water level at The Battery in 2020–2025, 1.80 m NAVD88 in 2022, corresponds to a return period of about 4 years on the NACCS curve.

Rainfall flood maps and rainfall statistics. The DEP Stormwater Flood Maps (NYC Open Data 9i7c-xyvv)[5] are hydraulic-model footprints for design intensities of 2.13 in h^{-1} (moderate, current sea level) and 3.66 in h^{-1} (extreme, 2080 sea level), each with two depth classes (nuisance, 4 in to 1 ft, and deep, ≥1 ft; representative depths of about 8 in and 1.5 ft). The city's stormwater plan describes the two scenarios as roughly 10- and 100-year storms[6]. We assign return periods from the NOAA Atlas 14[7] 60-minute precipitation-frequency curve at Central Park (1.07 in for 1 year to 4.11 in for 1,000 years) by log–log interpolation, which gives 18 years for the moderate scenario, 458 years for the extreme scenario and 7 years for the 1.75 in h^{-1} sewer design intensity (about 1 year at 30-min duration). The extreme footprint covers 65 km^2 (8.3% of the five boroughs' land, measured on the DEP polygons), 93% of it outside the effective flood zone; where surge is modelled, 87% lies outside the modelled 1-in-100-year and 72% outside the 1-in-1,000-year still-water reach; rainfall building loss, computed citywide, is USD 0.35 bn and 3.23 bn in the two scenarios. The maps also include a limited scenario (1.77 in h^{-1}), whose geodatabase uses a proprietary compression and could not be read. With a zero at the 1-year intensity, the trapezoidal integral of rainfall building loss over exceedance probability gives a partial annual figure of USD 242 million a year that omits flooding below the modelled intensities.

Radar rainfall (MRMS). Observed rainfall is the NOAA MRMS MultiSensor quantitative precipitation estimate (QPE) 1-hour Pass-2 product at 1 km[8,9], retrieved from the Iowa State archive for 1,172 UTC days (all days with rain at Central Park, a FloodNet event or ≥10 flooding complaints; 152 archive gaps), cropped to the city and aggregated to the local-day maximum hourly intensity and total.

FloodNet sensors. Street flooding is observed by the FloodNet network[10]: 479 ultrasonic depth sensors and 2,929 events from November 2020 to August 2026 (NYC Open Data aq7i-eu5q, events; kb2e-tjy3, sensors). An event is FloodNet's own definition: a continuous series of one-minute depth readings above 10 mm, checked by the FloodNet team; event times are

published in UTC, which radar timing confirms, and are converted here to New York local time. A flood is an event whose water takes at least 30 min to drain from maximum depth to dry (drain time from the same table; see the duration criterion below). Two kinds of record are removed: 1 event at a sensor missing from the sensor table, and 22 events at non-tidal sensors with no rain evidence (radar below 0.02 in h^{-1} at the sensor's and the eight surrounding 1 km cells from 2 h before to 2 h after the start, and no precipitation reported at Central Park, LaGuardia or JFK within 1 h); about half of these began at a high tide. Fog without rain, which could produce false echoes, accompanies only 5 of the 1,116 events at non-tidal sensors. Three sensors not flagged by FloodNet are treated as tidal by the following rule: each lies within 1 km of open water and has at least three floods on days with less than 0.1 in of radar rain, at least two-thirds of them within 2 h of a Battery level above mean higher high water. Of the 2,104 floods that remain, the 67 tidal sensors record 1,739 (83%), five of them 59% of the tidal floods. The released record lists every event with these flags and a code for each exclusion. Flood frequencies use sensors online for at least six months (49 tidal, 304 non-tidal); the network-wide rates are 11.9 (tidal) and 0.50 (non-tidal) flood days per sensor-year at any depth and 1.2 and 0.08 at 1 ft. The sensor-day table holds 40,379 rainy sensor-days at 407 non-tidal sensors, from seven days after installation to removal for the 31 sensors that were removed, 311 of them with a flood; 290 of the 311 flood days (93%) occur below the 1.75 in h^{-1} design intensity, as do 38 of the 54 (70%) whose deepest flood reached 1 ft. The response to rain differs strongly between sensors: 272 of the 407 never flooded on a rainy day, and at 1–1.75 in h^{-1} the flood probability of a sensor at the 10th and 90th percentiles is 1.8% and 43% against a network average of 11%. The published height of each sensor above its local low point explains little of the difference (Spearman correlation with the flood rate -0.14). For the 20,178 basement lots inside the 1-in-100-year surge reach, the surge frequency has a median of 0.025 floods per year at any depth (10th–90th percentile 0.011–0.11) and 0.016 (0.007–0.056) at 1 ft. Relative to the flood zone in force, 56 of the 67 tidal sensors lie inside and record 99% of tidal flood days; relative to the modelled 1-in-100-year and 1-in-1,000-year surge reach, 59 and 64 do.

Duration criterion for a flood. FloodNet records any run of one-minute readings above 10 mm as an event, and no public standard sets how long water must stay: the city's stormwater flood maps classify depth (4 in to 1 ft, and 1 ft or more) and area, and federal guidance on driving through water gives depths only. Of the 2,929 events, 27% drain from maximum depth to dry in less than 30 min and 55% in less than 60 min. Two tests on the 40,379 rainy sensor-days, with every event, set the threshold (Supplementary Fig. 1a–d). First, short events are not noise: the hourly rain maximum predicts flood days as well with no threshold (area under the receiver operating characteristic curve 0.88) as at 30 min (0.87), and less well at 60 min (0.83). Second, residents notice floods that last: a 311 street-flooding complaint within 250 m on the same or next day follows 1.8% of rainy days without an event, 12% of flood days whose water drains within 20 min, 19 to 23% at 20 to 45 min and 33 to 43% at 45 to 120 min. Splitting flood days at a drain time T, those draining for at least T draw more complaints than the rest, adjusted for rain, for every T from 15 to 60 min (at 30 min, 26% against 14%; odds ratio 2.1). Longer floods are also deeper, and with depth held fixed the contrast is significant only at 45 and 50 min, so the complaints mark floods that are both deep and lasting. We take 30 min, a round value within

the range the complaints support that keeps more floods in the record; the choice rests on these two tests alone. What the rule removes is mostly brief, shallow wetting in rain: removed events have a median depth of 1.6 in against 3.1 in for those kept, and on the night of 11–12 March 2026, when a thunderstorm and then a band of light rain crossed the city, the network recorded 112 events, of which 9 drained in 30 min or more. It also removes about half of the events in heavy rain, some of them deep, so it is conservative for heavy-rain flooding. The 1-ft frequency at rain-footprint basement lots depends on the threshold and is reported as a sensitivity: relative to 30 min it is 1.05 times as high with every event, 0.70 at 45 min, 0.50 at 60 min and 0.21 at 120 min, while the share of flood days below the design intensity stays between 93% and 96% at every threshold (Supplementary Fig. 1d). Frequencies at any depth depend more strongly on the threshold: with every event, the rainy sensor-days hold about twice as many flood days (610 against 311), 190 rather than 113 of the 304 non-tidal sensors online for at least six months record a flood, and the median tidal sensor floods on 6.2 rather than 3.9 days a year.

311 complaints. Street-flooding complaints[11,12] are NYC 311 service requests with the descriptor "Street Flooding (SJ)" (21,287 records, 2020–2026; NYC Open Data erm2-nwe9).

Sea-level-rise inundation. The grids are NOAA Office for Coastal Management inundation extents[13] for mean higher high water + 0, 1, 3 and 6 ft (hydrologically connected; 3 m), resampled to 55 m; newly inundated land within the five boroughs is 5, 16 and 69 km^2 at +1, +3 and +6 ft. Scenario years are indicated only loosely from the New York City Panel on Climate Change projections[14].

Buildings (NSI). The National Structure Inventory 2026 Base[15] was retrieved through its public API for the five county FIPS codes (36005, 36047, 36061, 36081, 36085). It gives, per structure, a modelled replacement value, the number of storeys, occupancy class, foundation type, first-floor height above grade and census block group. The inventory holds 881,621 structures with USD 1,200 bn of structure value; 70% have a basement foundation, and buildings above three storeys are 8% of structures but 52% of value. Only structure value enters the loss calculation, because the observed Sandy loss used for validation is dominated by structure damage and NSI contents ratios are occupancy defaults rather than observations. Two alternative exposures, PLUTO tax lots at a uniform USD 400 per square foot of floor area and LitPop, were used during model development (USD 2,208 bn and 1,835 bn, against 1,200 bn for NSI); PLUTO is used below as a valuation check. As a check against prior work, basement lots within 40 m of a flooded street number 152,825, consistent with the 180,000 small residential buildings that an independent analysis of the DEP rainfall maps places at risk[16].

Damage functions. The functions are the USACE generic depth-damage functions for residences (Economic Guidance Memoranda 01-03[17] for buildings without basements and 04-01[18] for buildings with basements), tabulated at 1 ft intervals relative to the first floor. Four functions are used, one storey or two-or-more storeys with or without a basement, assigned by NSI storey count and foundation type. They were derived from buildings of at most three storeys; applying them to the lowest three storeys (3/N for N storeys) excludes the 30% of all value that lies above the third storey. Under this rule buildings of one to three storeys carry 75% of structure loss at

the 1-in-100-year level (70% at 1-in-10 and 73% at 1-in-1,000 years; two-storey buildings alone 37%), although buildings of four or more storeys hold 52% of structure value. Alternative rules give USD 681 million a year (full value), 408 (2/N), 534 (4/N) and 339 (buildings of at most three storeys only; Extended Data Fig. 2i). An earlier storey-fraction curve, damage = k · min(1, d/2 m) · min(1, ⌈d/3 m⌉/N), recalibrated on NSI values (k = 1.06), is retained only as a sensitivity (USD 531 million a year).

Basements and informal dwellings. PLUTO's basement code[19] (full or partial below grade) identifies 456,346 lots among one-to-three-family houses and small walk-ups. The Pratt Center's estimate of 114,000 unauthorised units[20] is the 1990–2000 gap between census housing units and certificates of occupancy; it includes but is not limited to basement apartments, which the city puts at 50,000 or more[21]. The three allocation rules move the surge count by up to 15% and the rainfall count by 1%. By borough, the basement lots inside the 1-in-100-year surge reach and inside the extreme rainfall footprint number 8,850 and 11,810 in Queens, 8,090 and 5,591 in Brooklyn, 2,934 and 3,623 in Staten Island, 233 and 1,372 in the Bronx, and 71 and 47 in Manhattan (Extended Data Fig. 3b). Tract income is the HUD low- and moderate-income summary[22,23] (NYC Open Data qmcw-ur37), with quartile edges of 35, 51 and 70% LMI share.

Subway. Stations (496, of which 283 underground) and entrances (2,120) are data.ny.gov datasets 39hk-dx4f and i9wp-a4ja[24–26], and route alignments are from the MTA GTFS shapes file. A station is placed at its coordinate in the stations dataset; the entrance counts of Fig. 2b and Supplementary Table 1 use the entrance coordinates. Census block groups and tracts are the 2020 TIGER/Line geometry[27].

Sandy observations. The observed Sandy inundation zone is the field-verified extent[28,29] (NYC Open Data 5xsi-dfpx). The city's official Sandy damage estimate is USD 19 bn, of which over 13 bn is physical damage and almost 6 bn lost activity[30,31].

Flood map and NFIP data. The effective flood-hazard-zone polygons were retrieved from FEMA's public National Flood Hazard Layer map service in pages ordered by object identifier[32,33]; its 8,009 polygons for the five counties that are flagged as Special Flood Hazard Area (zones A, AE, AH, AO, V and VE) are rasterised onto the 20 m grid. Where surge is modelled, the SFHA covers 69 km^2 of land against 99 km^2 for the modelled 1-in-100-year still-water reach, and 83% of the SFHA lies inside that reach. The 2015 Preliminary FIRM (DFIRM 360497, issued 30 January 2015) was retrieved from FEMA's preliminary map service. In-force NFIP policies were retrieved from OpenFEMA[34,35] (NFIP Redacted Policies v3, effective on or before 21 September 2026 and terminating on or after 1 August 2026) and filtered to the five counties by census block-group GEOID: 36,961 contracts covering 70,179 insured units with USD 17.0 bn of building coverage. Policy coordinates are redacted to 0.1°; 51% of contracts carry an A or V rated flood zone and 8% are flagged as mandatory purchases. Of the contracts, 25,905 (70%) sit exactly at the USD 250,000 residential limit, and the 669 contracts above USD 1 million carry 7.5 of the 17.0 bn of building cover (Extended Data Fig. 4a). Take-up inside the flood zone uses 30,572 NSI structures inside the SFHA, and take-up outside it 851,049 structures. Sandy claims are from NFIP Redacted Claims v3 for losses dated 28 October to 5 November 2012 in the five

boroughs; all 16,498 carry FEMA's Hurricane Sandy event label and total USD 1.16 bn of building and 0.12 bn of contents payments, excluding USD 0.02 bn for increased cost of compliance. The retired Claims v2 dataset gives totals identical to v3.

Analyses

Spatial check of the single hazard curve. Per-save-point products were obtained from the USACE Coastal Hazards System: the tropical storm recurrence rates and storm relative probabilities (18,977 save points × 1,050 storms), the ADCIRC peak water levels of every storm at The Battery and at three Jamaica Bay and Rockaway save points (11982, 12049, 14200), the extratropical peaks, and the NACCS bias/uncertainty file mapped to the nearest ADCIRC node[1,2]. The NACCS simulations use the NACCS ADCIRC mesh, whose New York portion derives from the FEMA Region II mesh, and the report gives epistemic uncertainty separately from the mean curve, as confidence limits. A joint-probability curve was built with identical settings at all four points (tropical rate = relative probability × recurrence rate with a common scaling, extratropical rate from a 150-year record length, both convolved with the nodal uncertainty). Because the absolute level of such a reconstruction depends on the rate scaling, only the difference between points is used: the Jamaica Bay points sit 0.17–0.37 m below The Battery at 100–1,000 years and the Rockaway point within 0.11 m. Applying these offsets to the Jamaica Bay lots changes the annual loss by −2.3%, so the single Battery curve is retained (Extended Data Fig. 2e,f). Sandy's return period on the Battery curve is 139 years by log-linear interpolation between the 100- and 200-year levels.

Sandy validation. On the observed Sandy footprint 65,958 NSI structures with USD 78 bn of value are flooded. Within the five boroughs the connected bathtub at 3.44 m captures 93% of observed cells, 19% of modelled cells lie outside the observed zone, and the critical success index is 0.76 (Extended Data Fig. 2a). The observed zone does not extend into New Jersey or Nassau County, and the modelled-only cells are concentrated at JFK airport and in the wetlands of Staten Island, where the field survey ends at the built edge. The 60–70% direct share of the city's USD 19 bn estimate is an assumption that brackets the city's own figure of over USD 13 bn of physical damage. NFIP's Sandy claims put contents at 9% of building and contents payments, and contents shares of 9–30% imply an observed structure-only loss of 8.0–12.1 bn, which contains the uncalibrated estimate (0.85 of the central direct value of USD 11.4–13.3 bn; Extended Data Fig. 2b).

Valuation and the insurance shares. Building cover is fixed in dollars, so the insurable shares depend on the valuation of structures. Scaling all NSI values by 0.76 to 1.15, the range within which the modelled Sandy structure loss matches the observed 8.0 to 12.1 bn, moves every share in Fig. 4 by at most five percentage points: the upper bound becomes 67–71%, 52–60% and 26–33% at the 1-in-10, 1-in-100 and 1-in-1,000-year levels and 51–57% of annual loss, the expected share 17–19% of annual loss, and full participation at local and statutory cover 46–52% and 56–61%. PLUTO tax lots at USD 400 per square foot, assigned to the nearest NSI structures, double the modelled Sandy loss (USD 22.1 bn) and are therefore not used; even on that basis the upper bound falls with event size (40%, 36% and 17%) and participation remains the larger

lever.

What is not sampled. Three structural choices are stated rather than sampled in the Monte Carlo because no distribution can be defended for them: the absence of coastal defences in the bathtub, the single Battery water-level curve (checked at −2.3%) and present-day mean sea level. A second validation event does not exist for New York, a limitation shared by every surge model of the city. Per-structure depths at the 29 water levels are precomputed once, so each draw is a vector operation. The Monte Carlo has a median of USD 498 million a year, an interquartile range of 406–608 and a 5–95% range of 304–799, against a point estimate of 485.

Income groups. From the lowest to the highest LMI quartile, the expected payment is 13%, 23%, 17% and 26% of annual surge loss; take-up inside the 1-in-100-year footprint is 33%, 35%, 28% and 49%; the upper-bound insurable share is 47%, 57%, 51% and 73%; and the ceiling under full take-up at the statutory limit is 43%, 72%, 66% and 77% (Supplementary Fig. 3).

Sensor siting. The share of FloodNet sensors inside the DEP extreme footprint (68%, by point-in-polygon test on the DEP polygons) divided by the footprint's share of five-borough land (8.3%) gives the siting enrichment (8.1×). Street-flooding complaints to 311 are less concentrated: 41% fall inside the footprint (Extended Data Fig. 1a).

Supplementary Notes

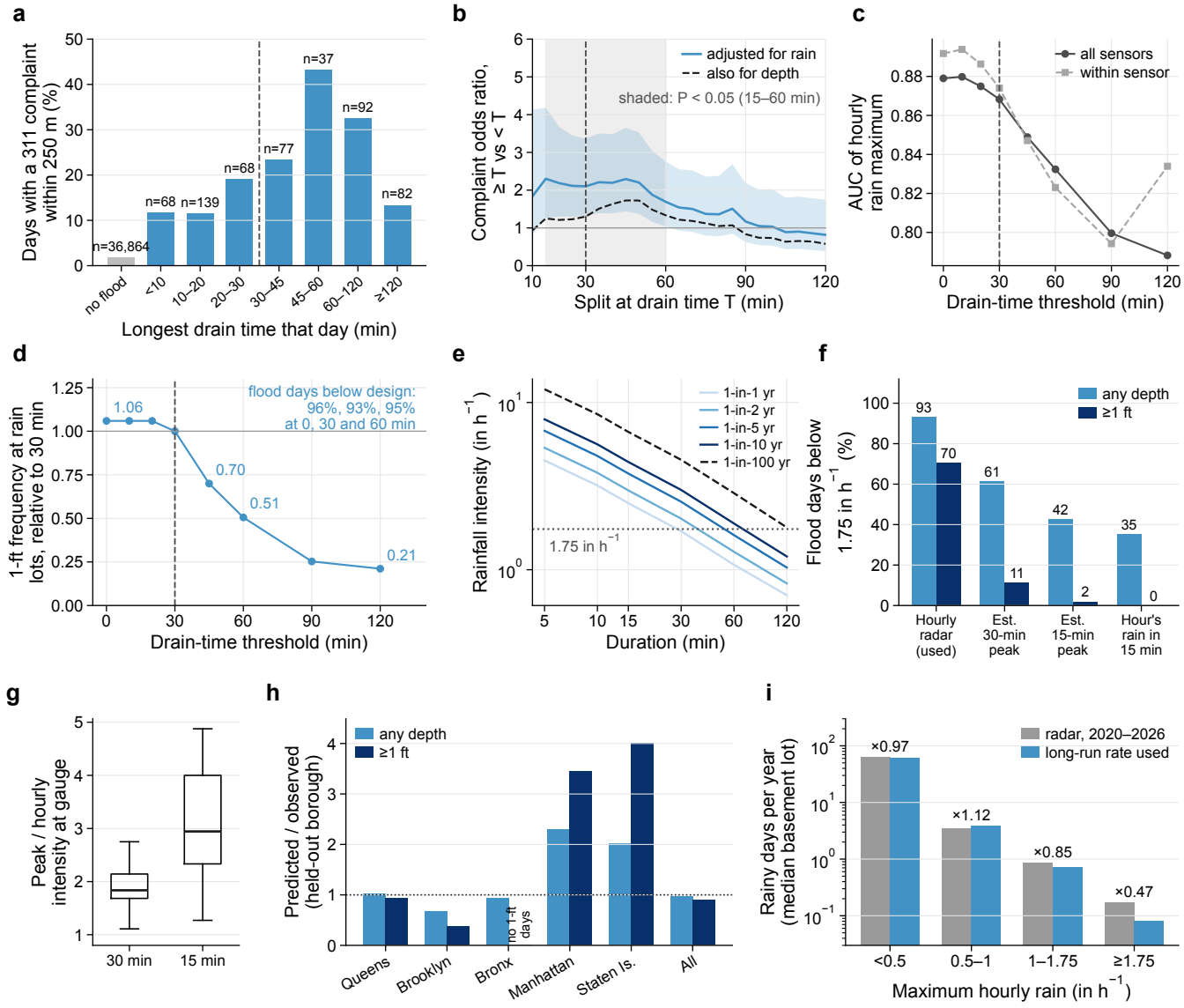
Supplementary Note 1 | Storms and places. The street-flood frequency at basement lots (Fig. 1b) rests on a model of each rainy day at each non-tidal sensor (Methods). The model is a logistic regression with a random intercept for the sensor, fitted by variational Bayes; FloodNet event times, published in UTC, are converted to New York local time before days are formed, as are the radar hours. Every interval for rain flooding resamples storm days, because a storm floods many sensors at once (100 model refits; 2,000 resamples for shares). Rain flooding is concentrated in a few storms: 72 storm days produced the 311 flood days, and on the 137 rainy days with at least 100 sensors reporting (November 2024 to August 2026), the five largest storm days hold 56% and the ten largest 68% of flooding, measured as the share of reporting sensors flooded (Extended Data Fig. 1b). Sensor-days of one storm are therefore not independent, and every interval for rain flooding resamples storm days. With random effects for the storm day and for the sensor, places differ at least as much as storms (standard deviations 1.7 and 1.4 on the log-odds scale at any depth, 1.2 and 1.2 at 1 ft). Storm effects are not independent of the rain bin, because the heavy-rain days come from the few long, wet storms, so frequencies are predicted from the model without the storm effect, whose bin probabilities average over the storms that produced each bin; this model reproduces the observed rates except in the heaviest bin, which holds 51 sensor-days (Extended Data Fig. 1c). Within 1 km of open water, a high tide raises the odds of flooding at the same rain 3.2-fold (95% interval 1.4–7.3) at any depth and 7.0-fold (2.4–20) at 4 in or more, with sensor fixed effects and the storm's citywide peak intensity held fixed; inland the effect is not detectable (1.3, 0.4–3.7) (Extended Data Fig. 1e). The rain model, whose sensor intercepts are drawn from a common distribution, gives consistent estimates at any depth: 2.6 (1.1–6.3) near open water and 1.6 (0.5–5.4) inland. Heavy hourly

rain was unusually frequent in 2020–2026: Central Park recorded five days above 1.75 in h^{-1}, against none in 2013–2019 and about one every 12 years expected from Atlas 14 for clock-hour totals (60-min depths divided by 1.13, which makes the 1-in-7-yr 60-min design intensity rarer), and the radar gives the median basement lot 0.17 such days a year against 0.08 from Atlas 14. Rainy days per year are therefore rescaled by bin to long-run rates (factors 0.97, 1.12, 0.85 and 0.47 from the lightest to the heaviest bin; Supplementary Fig. 1i); because a 1 km radar cell exceeds a threshold less often than a point, this correction is if anything too small. For the 22,443 basement lots in the extreme rainfall footprint, a typical lot (sensor effect zero) can expect street flooding 0.17 times a year (95% interval 0.03–0.22; 0.20 with the 2020–2026 rain record), the average over places is 0.39, and the 10th to 90th percentile of places spans 0.03–0.96; at 4 in or more the typical lot is at 0.09 (0.01–0.12), and at 1 ft at 0.040 (0.006–0.054), with the 90th percentile at 0.15 (0.05–0.28) and 20% of lots (2–29%) reaching 1 ft at least once a decade (Extended Data Fig. 1d). Against basement lots inside the 1-in-100-year surge reach (median 0.025 at any depth, 0.016 at 1 ft), the typical rain lot floods 6.8 times as often at any depth (1.3–8.9) and 2.5 times as often at 1 ft (0.4–3.4), so at 1 ft the two cannot be told apart. The rates must also transfer between boroughs, since sensors are not spread evenly. Holding out each borough in turn and predicting its sensors' flood days from the other four boroughs' rates gives a predicted-to-observed ratio of 0.96 citywide at any depth (0.68–2.3 by borough) and 0.90 at 1 ft (0.38–4.0; the Bronx recorded no 1-ft day) (Supplementary Fig. 1h). In the hydraulic models alone the rain side does not flood more often (Fig. 2c): where surge is modelled, the moderate (≈1-in-18-yr) rainfall scenario reaches 2,493 basement lots at 4 in or more and the surge at the same return period about 3,700 (log–log interpolation between the 10- and 20-year levels), and the extreme (≈1-in-458-yr) scenario 20,233 against about 32,900. The more frequent exposure of rain-side basements therefore rests on the street-level record, which measures flooding of the street at a lot rather than of the basement.

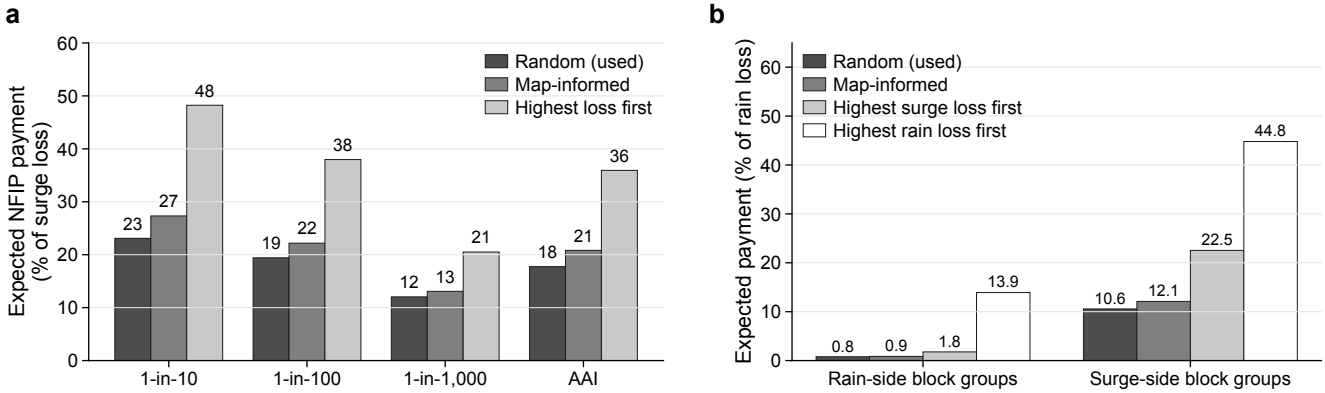
Supplementary Note 2 | Sub-hourly rainfall and the design intensity. The city's sewers were designed to the 5-year storm, stated as 1.75 in h^{-1}; on NOAA Atlas 14 at Central Park this lies between the 5- and 10-year 60-min intensities (1.61 and 1.89 in h^{-1}), whereas over 30 min it is reached about once a year and over 15 min more than once a year (Supplementary Fig. 1e), so the hourly maximum is the averaging time that matches the standard. The comparison with the 1.75 in h^{-1} design intensity uses the maximum clock-hour radar rainfall at each sensor, whereas street inlets respond to shorter bursts. One-minute precipitation at LaGuardia, JFK and Newark airports (ASOS, Iowa Environmental Mesonet archive, November 2020 to August 2026) was used to scale each flood day's hourly radar maximum at the sensor by the ratio of the maximum rolling 15- or 30-min intensity to the maximum clock-hour intensity at the nearest gauge on that day; 77 of the 311 flood days had a measurable gauge hour, and the others take the median ratios of 2.9 (15 min) and 1.8 (30 min) (Supplementary Fig. 1g). The estimated share of flood days below 1.75 in h^{-1} falls from 93% (hourly) to 61% (30 min) and 42% (15 min); even if each day's entire maximum hour had fallen within 15 min, 35% would remain below. For flood days reaching 1 ft the shares are 70%, 11%, 2% and 0% (Supplementary Fig. 1f). The one flood day at a sensor within 5 km of a gauge is below 1.75 in h^{-1} at every averaging time. Shallow, frequent flooding therefore occurs below the design intensity at every averaging time, whereas

deep flooding coincides with sub-hourly bursts above it, bursts that recur about once a year. In neither case does the standard specify how often a place floods; whether the deep floods reflect capacity below the nominal standard, blockage or tailwater cannot be separated with these data.

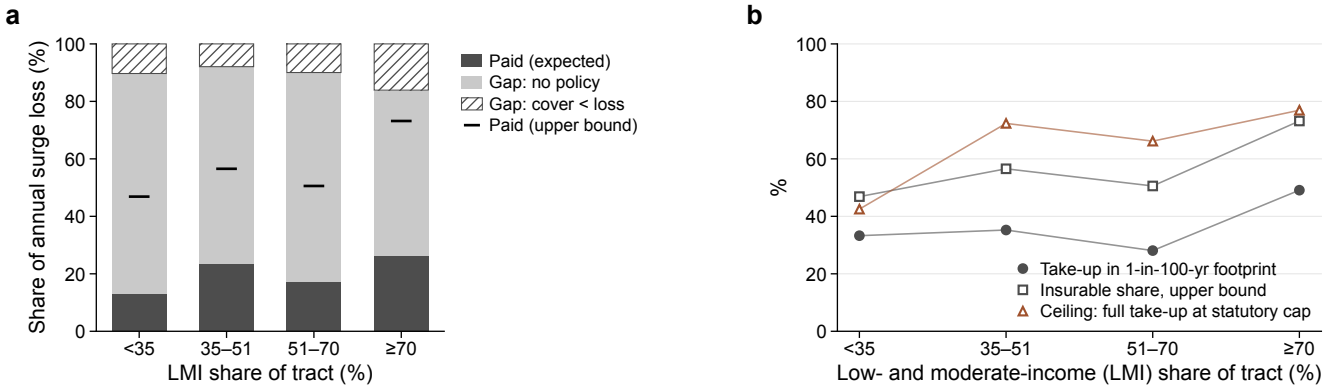
Supplementary Note 3 | Placement of policies within block groups. The expected estimate places a block group's contracts at random among its structures. Two alternatives conserve the number of contracts and the mean cover per contract in each block group: a map-informed placement, which assigns contracts rated in A or V zones to structures inside the effective flood zone and the rest to structures outside it, and an adverse-selection bound, which assigns contracts to the structures with the largest expected loss first. The expected share of annual surge loss is 18% (random), 21% (map-informed) and 36% (bound), and in every placement it falls with event size: from 27% at 1-in-10 to 13% at 1-in-1,000 with map-informed placement, and from 48% to 21% under the bound (Supplementary Fig. 2a). In the extreme rainfall scenario the expected share on the rain side is 0.8%, 0.9% and 1.8% under random, map-informed and surge-ranked placement, against 10.6%, 12.1% and 22.5% on the surge side; only if every contract sat on the buildings with the largest rainfall loss would the rain-side share reach 14% (45% on the surge side) (Supplementary Fig. 2b). The decline of coverage with event size is not a property of a capped instrument as such: with full participation at the statutory limit the insurable share stays at 59–64% from 1-in-10 to 1-in-1,000 (Fig. 4b).



Supplementary Fig. 1 Robustness of the street-flood frequency from rain. **a**, Share of rainy sensor-days at non-tidal sensors with a 311 street-flooding complaint within 250 m on the same or next day, for days without a FloodNet event and for flood days by the longest drain time (maximum depth to dry) of the day; dashed lines in **a**–**d**, 30 min, the threshold used. **b**, Odds ratio of a complaint for flood days draining for at least T against those draining for less, by T, adjusted for the hourly rain maximum (solid line; band, 95% interval) and also for the day's maximum depth (dashed line); grey, range of T with $P < 0.05$ for the rain-adjusted ratio. **c**, Area under the receiver operating characteristic curve (AUC) of the hourly rain maximum for flood days counted at each drain-time threshold, over all sensors and within sensors. **d**, Frequency of 1-ft street flooding at basement lots in the extreme rainfall footprint, relative to its value at 30 min, by threshold. **e**, National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall intensity against duration at Central Park for five return periods; dotted line, 1.75 in h^{-1}. **f**, Share of flood days below 1.75 in h^{-1} at any depth ($n = 311$) and at 1 ft or more ($n = 54$), using the hourly radar maximum at the sensor, its estimated 30- and 15-min peaks, and a worst case in which the hour's rain falls within 15 min. **g**, Ratio of the peak 30- and 15-min intensity to the maximum clock-hour intensity at the nearest of three airport gauges, on flood days with a measurable hour ($n = 77$); boxes, interquartile range; whiskers, 1.5 times the interquartile range. **h**, Flood days at each borough's non-tidal sensors predicted from the other four boroughs' rates, divided by the observed flood days, at any depth and at 1 ft or more; dotted line, perfect transfer. **i**, Rainy days per year by maximum hourly rain at the median basement lot: radar, 2020–2026, and the long-run rate used (Central Park gauge 2013–2019 for the two lower bins, NOAA Atlas 14 for the two upper), with the rescaling factor.



Supplementary Fig. 2 Sensitivity of the expected insurance payment to the placement of policies within block groups. **a**, Expected National Flood Insurance Program (NFIP) payment as a share of surge loss at three return periods and for the annual loss (AAI), with contracts placed at random among a block group's structures (used in the paper), A- and V-rated contracts placed on structures inside the effective flood zone (map-informed), or contracts placed on the structures with the largest expected loss first (bound). **b**, The same for building loss in the extreme rainfall scenario in rain-side and surge-side block groups, adding placement by the largest rainfall loss first.



Supplementary Fig. 3 Public insurance by income group. Census tracts grouped by low-to-moderate-income (LMI) population share, from the lowest to the highest quartile (n = 36,961 policies). **a**, Annual surge loss divided into expected payment (dark grey), a gap from buildings with no policy (light grey) and a gap where cover is smaller than loss (hatched); black ticks, upper-bound payment. **b**, Take-up (contracts per structure) inside the 1-in-100-yr footprint (filled circles), upper-bound insurable share (open squares) and the ceiling under full take-up at the statutory limit (open triangles).

Supplementary Tables

The tables are also provided as `Supplementary_Tables.xlsx` (one sheet per table) and as CSV files.

Supplementary Table 1 | Impact by surge return period on one still-water axis (Fig. 2). Water levels are the North Atlantic Coast Comprehensive Study (NACCS) Battery curve converted to the North American Vertical Datum of 1988 (NAVD88); footprints are the connected bathtub on the 20 m digital elevation model (DEM) at present-day sea level with no defences. Structure loss uses National Structure Inventory (NSI) exposure and US Army Corps of Engineers (USACE) generic depth-damage functions; basement lots are small-residential lots with a below-grade basement (Primary Land Use Tax Lot Output, PLUTO); informal units allocate the citywide estimate of unauthorised units (upper bound) or the city's figure for basement apartments (lower bound) uniformly to basement lots; stations and entrances are Metropolitan Transportation Authority (MTA) underground stations and their street entrances inside the footprint.

Return period (yr)	Still-water level (m NAVD88)	Structure loss (USD bn)	Basement lots	Informal units, 114,000 allocated (upper bound)	Informal units, 50,000 allocated (lower bound)	Underground stations	Station entrances
2	1.51	0.1	223	56	25	0	0
5	1.84	0.28	935	234	103	0	0
10	2.11	0.66	2,427	606	266	0	2
20	2.4	1.46	5,134	1,283	563	0	2
50	2.85	4.25	11,907	2,974	1,304	2	6
100	3.25	8.22	20,178	5,041	2,211	5	20
200	3.66	14.45	27,240	6,805	2,985	6	33
500	4.18	24.37	36,461	9,108	3,995	12	64
1,000	4.57	32.87	42,579	10,637	4,665	18	94
2,000	4.99	43.06	49,790	12,438	5,455	25	122
5,000	5.65	60.22	61,325	15,320	6,719	29	142
10,000	6.16	74.16	70,026	17,493	7,672	36	165

Supplementary Table 2 | Sensitivity of the headline numbers. Rainfall footprint outside the flood zone on the effective Flood Insurance Rate Map (FIRM), the 2015 preliminary FIRM, either map and the modelled 1-in-100-yr reach, for the extreme (2080 sea level) and moderate (current sea level) rainfall scenarios; storm-day bootstrap interval (2,000 resamples) for the share of flood days below 1.75 in h^{-1}; the rain-side and surge-side split at 25, 50 and 75% of structure value inside the 1-in-100 or 1-in-1,000-yr reach; National Flood Insurance Program (NFIP) take-up and tidal sensors on the preliminary map.

Quantity	Basis	Value
Rain footprint outside the 1-in-1,000-yr surge reach	rainfall extreme (2080 sea level, used); surge model domain	72%
Rain footprint outside the flood zone: area / basement lots / underground stations	Effective FIRM (used); rainfall extreme (2080 sea level, used)	93% / 97% (21,728 of 22,443) / 44 of 46
Rain footprint outside the flood zone: area / basement lots / underground stations	2015 preliminary FIRM; rainfall extreme (2080 sea level, used)	86% / 91% (20,415 of 22,443) / 44 of 46
Rain footprint outside the flood zone: area / basement lots / underground stations	Either map; rainfall extreme (2080 sea level, used)	85% / 91% (20,349 of 22,443) / 44 of 46
Rain footprint outside the flood zone: area / basement lots / underground stations	Modelled 1-in-100-yr reach; rainfall extreme (2080 sea level, used); surge model domain	87% / 90% (18,303 of 20,233) / 43 of 46
Rain footprint outside the 1-in-1,000-yr surge reach	rainfall moderate (current sea level); surge model domain	65%
Rain footprint outside the flood zone: area / basement lots / underground stations	Effective FIRM (used); rainfall moderate (current sea level)	84% / 91% (2,659 of 2,927) / 12 of 12
Rain footprint outside the flood zone: area / basement lots / underground stations	2015 preliminary FIRM; rainfall moderate (current sea level)	79% / 85% (2,487 of 2,927) / 12 of 12
Rain footprint outside the flood zone: area / basement lots / underground stations	Either map; rainfall moderate (current sea level)	78% / 85% (2,481 of 2,927) / 12 of 12
Rain footprint outside the flood zone: area / basement lots / underground stations	Modelled 1-in-100-yr reach; rainfall moderate (current sea level); surge model domain	80% / 85% (2,127 of 2,493) / 12 of 12
Flood days below 1.75 in h^{-1} (hourly)	storm-day bootstrap, 95% interval	93% (88–98%); at 1 ft 70% (44–86%)
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall extreme (2080 sea level, used); surge-side if ≥25% of value inside the 1-in-100-yr reach	88% / 18%; 1.4% vs 18.3%
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall extreme (2080 sea level, used); surge-side if ≥50% of value inside the 1-in-100-yr reach	90% / 24%; 1.7% vs 20.0%
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall extreme (2080 sea level, used); surge-side if ≥75% of value inside the 1-in-100-yr reach	92% / 34%; 2.0% vs 20.1%
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall extreme (2080 sea level, used); surge-side if ≥25% of value inside the 1-in-1,000-yr reach	73% / 10%; 0.6% vs 9.5%
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall extreme (2080 sea level, used); surge-side if ≥50% of value inside the 1-in-1,000-yr reach (used)	77% / 14%; 0.8% vs 10.6%

Quantity	Basis	Value
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall extreme (2080 sea level, used); surge-side if ≥75% of value inside the 1-in-1,000-yr reach	79% / 18%; 0.9% vs 11.5%
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall moderate (current sea level); surge-side if ≥25% of value inside the 1-in-100-yr reach	81% / 4%; 1.6% vs 22.3%
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall moderate (current sea level); surge-side if ≥50% of value inside the 1-in-100-yr reach	84% / 6%; 1.8% vs 26.7%
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall moderate (current sea level); surge-side if ≥75% of value inside the 1-in-100-yr reach	88% / 13%; 2.8% vs 48.9%
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall moderate (current sea level); surge-side if ≥25% of value inside the 1-in-1,000-yr reach	69% / 2%; 0.8% vs 12.9%
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall moderate (current sea level); surge-side if ≥50% of value inside the 1-in-1,000-yr reach	73% / 3%; 1.1% vs 13.8%
Rain-side share of rain loss / of NFIP contracts; expected insurable share rain side vs surge side	rainfall moderate (current sea level); surge-side if ≥75% of value inside the 1-in-1,000-yr reach	74% / 6%; 1.4% vs 14.0%
NFIP contracts per 100 structures, inside / outside the flood zone	2015 preliminary FIRM (A/V-rated contracts vs structures inside)	31 / 2.2 (61,009 structures inside)
Tidal sensors inside the flood zone	2015 preliminary FIRM	62 of 67 (effective FIRM: 56 of 67)

Supplementary Table 3 | Input data, sources and the check applied to each. Every input is a public product. The validation column reports the comparison or bias documented in Methods; "upper bound" and "comparison only" mark inputs whose limitation is stated in the text.

Dataset	What it gives	Resolution / period	Role	Validation or known bias	Source / identifier	Version / period accessed
USACE NACCS (TR-15-5; CHS save points)	Still-water-level return periods, storm rates, per-storm peaks, bias/uncertainty	18,977 points; 1–10,000 yr	Surge frequency	Sandy = 1-in-140; Jamaica Bay offset −0.17 to −0.37 m, AAI effect −2.3%	USACE Coastal Hazards System, chs.erdc.dren.mil (registration); ERDC/CHL TR-15-5 Fig. 8-19	NACCS 2015 products; CHS download 2026
NOAA CUDEM	Ground elevation, NAVD88	1/9 arc-sec → 20 m, 55 m	Inundation surface	Datum error found and fixed (33 m); connected bathtub vs Sandy footprint within the five boroughs POD 93%, FAR 19%, CSI 0.76	NOAA NCEI CUDEM 1/9 arc-second, Northeast Sandy tiles	2014 release, updated; accessed 2026
NYC DEP Stormwater Flood Maps	Hydraulic-model rainfall footprints, two depth classes	3 scenarios (1.77/2.13/3.66 in h^{-1})	Rainfall extent	Limited scenario unreadable; Extreme tied to 2080 sea level; 68% of FloodNet sensors inside 8.3% of land (siting bias 8.1×)	NYC Open Data 9i7c-xyvv (file geodatabases)	published 2024 (plan 2021); accessed 2026
NOAA Atlas 14 vol. 10	Rainfall frequency at Central Park, 5 min to 60 days	1–1,000 yr	Return periods of DEP scenarios and the design intensity	1.75 in h^{-1} is ≈1-in-7 yr over 60 min but ≈ annual over 30 min; DEP labels its scenarios 10 and 100 yr	NOAA HDSC Precipitation Frequency Data Server, Central Park (version 3)	2015, revised 2019; accessed 2026
FloodNet (events aq7i-eu5q; sensors kb2e-tjy3)	Street water-depth events	479 sensors, 1-min, 2020–	Observed flood frequency, tidal share	Sited at expected trouble spots (8.1×); the borough-average rate transfers (predicted/observed 0.96); 22 events without rain evidence and 1 at an unlisted sensor removed; 3 sensors reclassified as tidal	NYC Open Data: flood events aq7i-eu5q; sensors kb2e-tjy3	2020-11 to 2026-08
NOAA MRMS 1-h QPE Pass 2	Radar–gauge rainfall	1 km, hourly, 1,172 days	Rain at each sensor and lot	Heavy hours more frequent in 2020–2026 than long-run; rainy days rescaled by bin to Atlas 14 and gauge rates	Iowa State mtarchive, MultiSensor_QPE_01H_Pass2	1,172 UTC days 2020–2026; 152 archive gaps
NYC 311 street-flooding complaints	Complaint location and date	21,287 records, 2020–	Observation-bias tests	Used only to test the flood duration criterion and sensor siting	NYC Open Data erm2-nwe9, descriptor 'Street Flooding (SJ)'	2020-01 to 2026-09

Dataset	What it gives	Resolution / period	Role	Validation or known bias	Source / identifier	Version / period accessed
NOAA sea-level-rise inundation (NY metro)	Mean higher high water + 0–6 ft, hydrologically connected	3 m → 55 m	Tidal reach and sea-level-rise steps	Not coupled to surge; no groundwater	NOAA Office for Coastal Management Sea Level Rise Data (InPort 48106), NY_M block, MHHW +0–6 ft	accessed 2026
NOAA CO-OPS 8518750 (The Battery)	Datums, water-level record since 1920	6-min	Datum conversion, Sandy peak	Trend +2.9 mm yr^{-1}	NOAA Tides & Currents station 8518750, datums and verified water levels	tidal epoch 1983–2001; accessed 2026
USGS/NYC Sandy Inundation Zone (5xsi-dfpx)	Field-verified 2012 footprint	polygon	Validation	–	NYC Open Data 5xsi-dfpx (NYC SBS; from the FEMA MOTF field-verified surge extent)	FEMA MOTF 2013; portal 2015
FEMA NFHL, effective and 2015 preliminary	Special Flood Hazard Area polygons	8,009 effective polygons	Flood-map coverage	Rain area outside: 93% (effective) vs 86% (preliminary); 62 policies per 100 structures inside the effective flood zone, 2 outside	hazards.fema.gov NFHL (effective) and Prelim_NFHL, DFIRM 360497 (30 Jan 2015)	accessed 2026-09/10
ASOS 1-minute precipitation (LGA, JFK, EWR)	Sub-hourly rain at three airports	1 min; 1,099–1,258 complete days per gauge	Sub-hourly check of the design comparison	Gauges 5–20 km from most sensors; ratios applied to radar hourly maxima	Iowa Environmental Mesonet ASOS 1-minute archive	2020-11 to 2026-08
USACE NSI	Per-structure value, storeys, occupancy, foundation, first-floor height	881,621 structures	Exposure	Median USD 176 per sq ft vs PLUTO USD 400; valuation sampled $\sigma = 0.25$	USACE National Structure Inventory API, counties 36005/36047/36061/36081/36085	2026 Base; accessed 2026
NYC PLUTO (64uk-42ks)	Tax lots, basement code, building class	858,602 lots	Basement layer; working-model exposure	Basement code is structural, not occupancy	NYC Open Data 64uk-42ks (PLUTO)	2026 release
USACE EGM 01-03 / 04-01	Generic depth-damage functions	1 ft steps, ±SD	Vulnerability	Untuned Sandy loss within the observed range (0.85 of the central direct value)	USACE Economic Guidance Memoranda 01-03 (2000) and 04-01 (2003), tabulated functions	–
MTA stations, entrances, GTFS	Station structure type, entrances, alignments	496 / 2,120 / routes	Subway layer	Vents and depths not public	data.ny.gov 39hk-dx4f (stations), i9wp-a4ja (entrances); MTA GTFS static feed	accessed 2026

Dataset	What it gives	Resolution / period	Role	Validation or known bias	Source / identifier	Version / period accessed
OpenFEMA NFIP Policies, Claims	In-force policies, Sandy claims	block group; 36,961 contracts	Insurance	Coordinates redacted to 0.1° → upper bound; Sandy claims identical in v2 and v3; realised 9.4%	OpenFEMA NFIP Redacted Policies v3 (NfipPolicies) and NFIP Redacted Claims v3 (NfipClaims); filtered on censusGeoid	policies effective ≤2026-09-21 and terminating ≥2026-08-01; claims 2012-10/11
HUD/CDBG tract eligibility (qmcw-ur37)	Low/moderate-income share by tract	2,327 tracts	Income split; basement allocation	Proxy for income	NYC Open Data qmcw-ur37 (NYC DCP, from HUD LMISD 2016–2020)	accessed 2026
Pratt Center (2008); City of New York (2021)	Unauthorized units citywide (1990–2000 census vs certificate-of-occupancy gap); illegal basement apartments	114,000; ≥50,000	Informal-unit allocation (upper and lower bound)	114,000 is not basement-specific; allocation rule moves counts ≤15% (surge), 1% (rain)	Sheth & Neuwirth, New York's Housing Underground (Pratt Center, Chhaya CDC); The New Normal (p. 47)	2008; 2021
Census TIGER 2020	Block-group geometry	–	Joins	–	US Census TIGER/Line 2020 block groups, New York (tl_2020_36_bg)	2021 release

Supplementary Table 4 | Monte Carlo propagation of uncertainty in the surge annual loss. Per-structure depths at the 29 water levels are precomputed once; each draw is a vector operation over the 120-point exceedance grid. The three structural choices listed as "not sampled" are held fixed; the storey-share rule is varied separately in Extended Data Fig. 2i.

Item	Specification	Value	Unit
Hazard-curve digitisation	Uniform ±0.10 m shift of the NACCS still-water curve		
Structure valuation	Lognormal multiplier on all NSI values, $\sigma = 0.25$ (PLUTO/NSI ratio 1.84 $\approx 2.4\sigma$)		
Vulnerability family	USACE generic (EGM 01-03/04-01) or storey-fraction curve, equal weight		
USACE function scaling	Triangular 0.76–1.00–1.15 (observed structure-only Sandy loss USD 8.0–12.1 bn ÷ untuned USD 10.48 bn) × N(1, 0.03) tabulated-function noise		
Storey-curve scaling	Triangular 0.92–1.00–1.08 on k = 1.06 (recalibrated on NSI values)		
Not sampled (stated)	No coastal defences in the bathtub; single Battery curve (checked, −2.3%); present-day sea level		
Draws	4000		
Result: USACE point estimate		485	USD million a year
Result: median		498	USD million a year
Result: interquartile range		406–608	USD million a year
Result: 5–95% range		304–799	USD million a year

Supplementary Table 5 | Decomposition of the National Flood Insurance Program (NFIP) shortfall and counterfactuals (Fig. 4; Supplementary Fig. 3). Loss is based on National Structure Inventory (NSI) values, US Army Corps of Engineers (USACE) damage functions and North Atlantic Coast Comprehensive Study (NACCS) water levels; 36,961 contracts. Upper bound = min(block-group loss, block-group cover). Expected = take-up × min(structure loss, mean cover per contract). Gap: no policy = (1 − take-up) × loss; gap: cover < loss = take-up × max(loss − cover, 0). Counterfactuals: every structure covered at its block group's mean cover per contract, or at the statutory limit (USD 250,000 per residential unit, USD 500,000 non-residential). Income groups are tract quartiles of the low-to-moderate-income (LMI) population share published by the US Department of Housing and Urban Development (HUD) for the Community Development Block Grant (CDBG); take-up is contracts per NSI structure inside the 1-in-100-yr footprint.

Event	Loss (USD bn)	Paid, upper bound (%)	Paid, expected (%)	Gap: no policy (%)	Gap: cover < loss (%)	Full take-up, local cover (%)	Full take-up, statutory cap (%)	Take-up in 100-yr footprint (%)
1-in-10 yr	0.66	67.9	23.1	67.3	9.6	53.0	58.5	–
1-in-45 yr	3.84	67.8	23.7	64.2	12.0	57.0	64.2	–
1-in-100 yr	8.22	55.1	19.4	68.6	12.0	54.8	63.6	–
1-in-400 yr	21.75	36.2	14.0	74.6	11.4	48.5	61.4	–
1-in-1000 yr	32.87	28.4	12.0	76.7	11.3	45.2	60.1	–
Annual average (AAI)	0.485	53.0	17.7	71.9	10.4	48.4	57.7	–
AAI, tract LMI share <35%	0.231	46.9	13.1	76.6	10.3	38.9	42.5	33.3
AAI, tract LMI share 35–51%	0.115	56.5	23.3	68.7	7.9	60.3	72.3	35.2
AAI, tract LMI share 51–70%	0.08	50.6	17.0	73.0	10.0	51.5	66.2	28.1
AAI, tract LMI share ≥70%	0.058	73.2	26.2	57.7	16.1	58.4	76.9	49.1

Supplementary Table 6 | National Flood Insurance Program (NFIP) cover against rainfall building loss, surge-side versus rain-side block groups (data for Fig. 3b). Loss is computed on the Department of Environmental Protection (DEP) stormwater footprints (moderate ≈1-in-18-yr, extreme ≈1-in-458-yr) with National Structure Inventory (NSI) values and US Army Corps of Engineers (USACE) damage functions. A block group is surge-side if at least half of its structure value lies inside the 1-in-1,000-yr still-water reach and rain-side otherwise; block groups with less than half of their structure value where surge is modelled are reported separately. Upper bound = min(block-group loss, block-group building cover); expected = take-up × min(structure loss, mean cover per contract) with policies placed at random in the block group. The extreme scenario is tied to 2080 sea level in the DEP model.

Scenario	Group	Building loss (USD bn)	Share of scenario loss (%)	Block groups	Block groups with no policy	Contracts in block groups	Share of city contracts (%)	Upper-bound insurable share (%)	Expected insurable share (%)
Moderate, current SL	all	0.35	100	744	239	11,499	31.1	45.9	3.7
Moderate, current SL	surge-side block groups	0.06	17.5	111	8	8,736	23.6	68.2	13.8
Moderate, current SL	rain-side block groups	0.25	72.5	529	224	1,194	3.2	35.3	1.1
Moderate, current SL	block groups outside the surge model	0.03	9.9	104	7	1,569	4.2	83.6	4.4
Extreme, 2080 SL	all	3.23	100	3,000	1,193	24,323	65.8	31.4	2.7
Extreme, 2080 SL	surge-side block groups	0.59	18.4	408	30	17,195	46.5	64.3	10.6
Extreme, 2080 SL	rain-side block groups	2.48	76.7	2,403	1,144	5,088	13.8	21.2	0.8
Extreme, 2080 SL	block groups outside the surge model	0.16	5.0	189	19	2,040	5.5	67.0	2.9

Supplementary References

[1] Nadal-Caraballo, N. C., Melby, J. A., Gonzalez, V. M. & Cox, A. T. *North Atlantic Coast Comprehensive Study (NACCS): Coastal Storm Hazards from Virginia to Maine.* ERDC/CHL TR-15-5 (US Army Engineer Research and Development Center, 2015).

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