Canadian Climate Institute

Climate Risks Associated With New Housing in Canada

Technical Report

September 2024

Prepared by SSG

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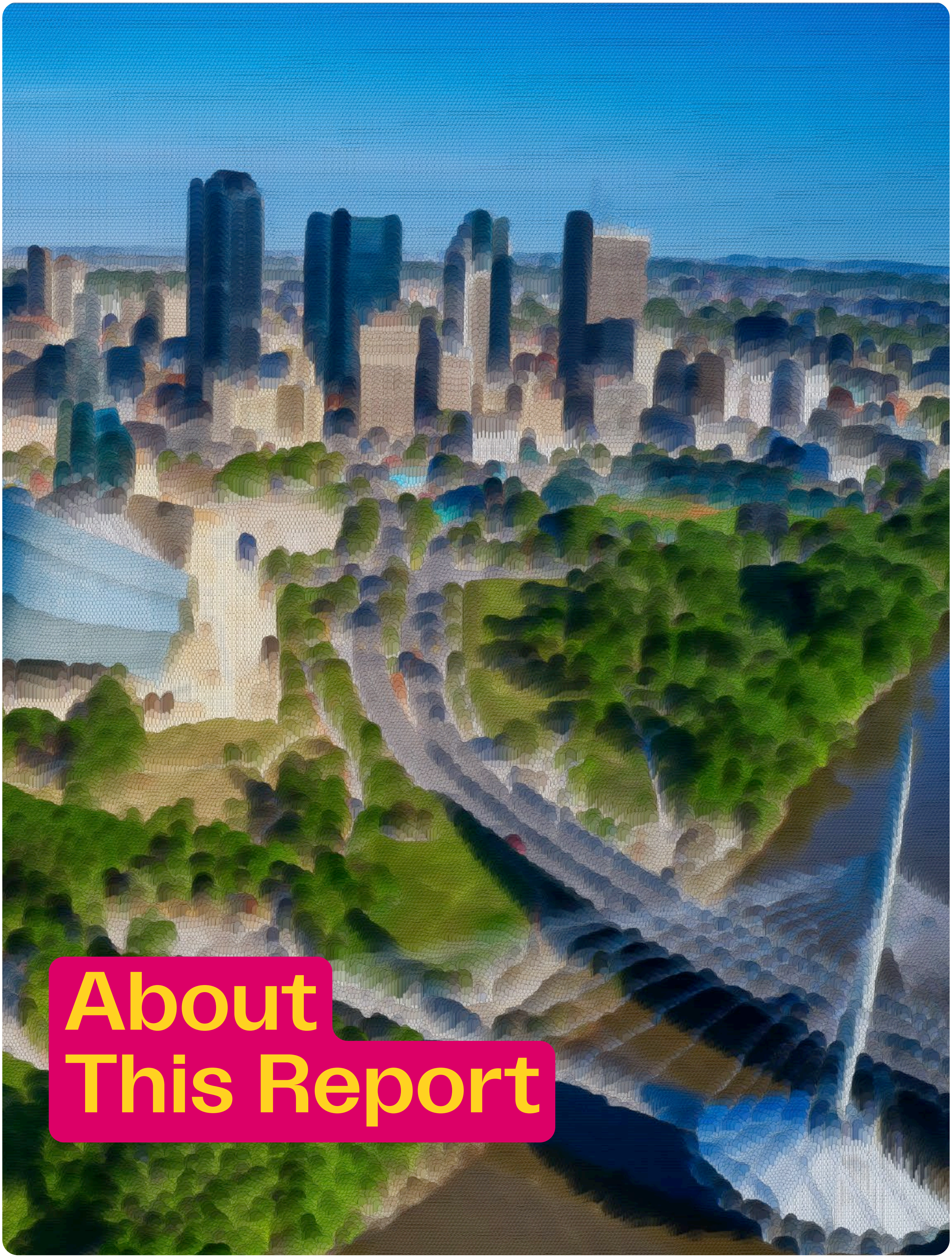
Acronyms and Abbreviations

AAFC	Agriculture and Agri-Food Canada
ADA	Aggregate dissemination data
AAL	Average annual loss
ALR	Agricultural Land Reserve
CCI	Canadian Climate Institute
CFS	Canadian Forest Service
CMHC	Canada Mortgage and Housing Corporation
CSD	Census subdivision
ECCC	Environment and Climate Change Canada
FSI	Flood Susceptibility Index
IPCC	Intergovernmental Panel on Climate Change
NRCan	Natural Resources Canada
OSM	OpenStreetMap
PSC	Public Safety Canada
RCP	Representative Concentration Pathway

About This Report



Project Context

Canada is in the midst of a housing affordability crisis. Canada Mortgage and Housing Corporation (CMHC) projects that 5.8 million new homes will need to be built between 2023 and 2030 to address population growth and housing affordability challenges. That represents an increase of 34 per cent in Canada's housing stock. In response to the housing crisis, all orders of government are taking action to increase the speed and scale of new housing construction.

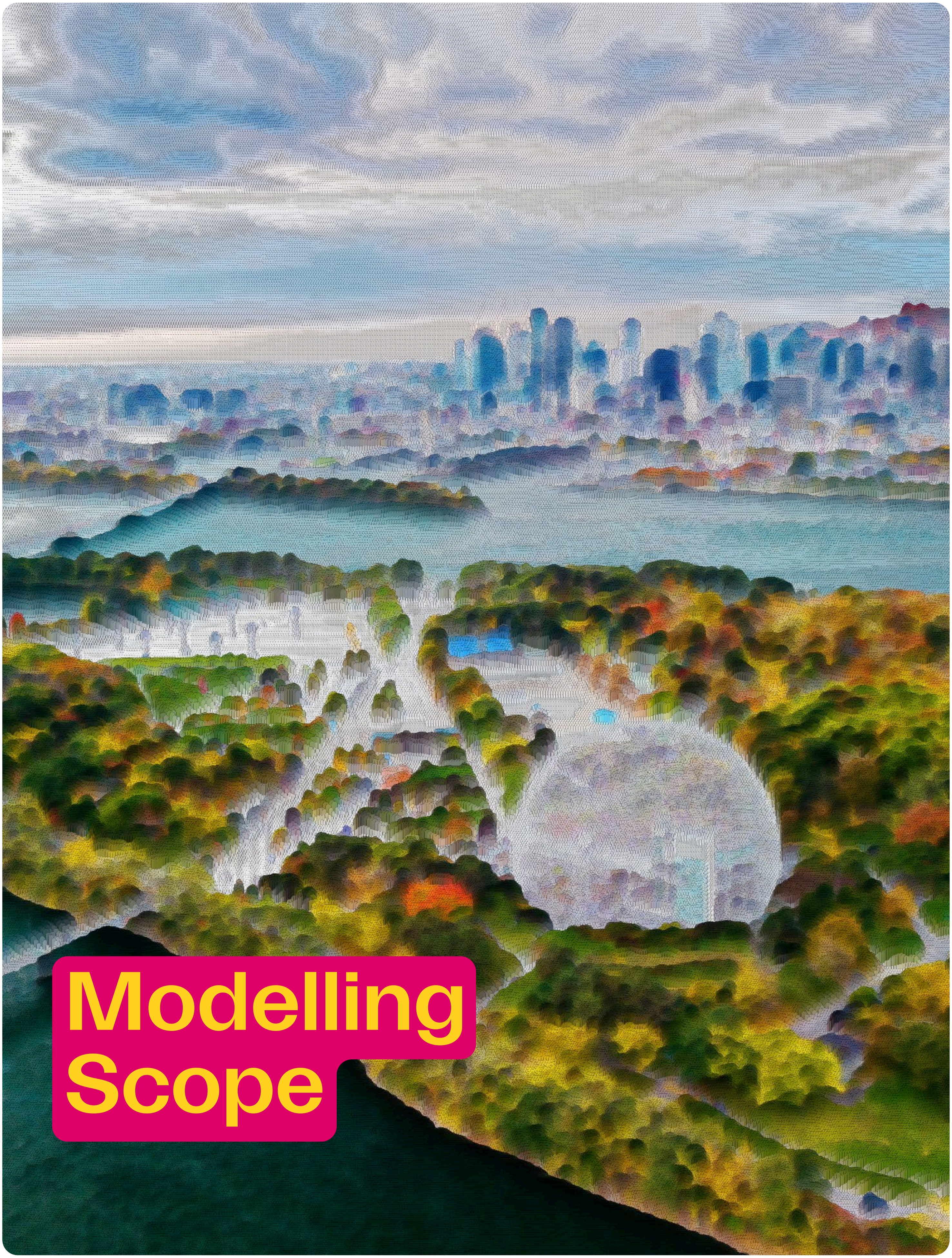
However, the expected pace of new housing development over the next decade could increase climate change risks to homes and residents across Canada. Despite widespread awareness that climate change is exacerbating climate-related hazards, such as floods and wildfires, homes in Canada continue to be built in hazard-prone areas. The pressure to dramatically accelerate the planning, approval, and construction of millions of additional homes increases the likelihood of decisions that put more homes in harm's way. It is important to examine how government policies can direct new homes across Canada to areas that will be safer in a changing climate.

SSG's Contribution

The Canadian Climate Institute (CCI) mandated Sustainability Solutions Group (SSG) to estimate climate risks associated with new housing in Canada. SSG estimated average annual coastal and inland flood damage, flood risk concentration, and average annual wildfire damage for new housing projected to be developed between 2023 and 2030. Risks were estimated under current climate conditions, as well as future climate conditions in 2030 under the IPCC RCP 4.5 climate change scenario.

To conduct this analysis, SSG performed the customized data modelling processes outlined in this document. First, SSG leveraged detailed spatial land-use and housing-stock data in conjunction with CMHC's new housing projections in order to spatially allocate new housing units across all municipalities in Canada. Next, SSG used spatial climate-hazard data on flood susceptibility, estimated flood damages, wildfire hazard, and wildfire damages to estimate implied flood and wildfire risk of building in these new locations. Damage estimates were modelled under current and future climate conditions. Additionally, SSG analyzed the potential concentration of new homes in highest-hazard areas to help assess the implications of stricter flood regulations for future development. This report outlines the methodology used for the analysis and provides an overview of future flood and wildfire risk estimated based on the projected spatial allocation of new housing.

Modelling Scope



Geographic Scope

The analysis estimates future flood and wildfire risk for each of the 5,161 census subdivisions (CSD) in Canada. Detailed spatial modelling was performed for the 943 CSDs with the highest projected housing growth; 99% of the new units projected by CMHC are expected to be built in these CSDs.

Spatial Resolution

New unit allocation, flood damage, and wildfire damage were estimated at a spatial resolution of 30 metres (30 m x 30 m) for each of the top 943 CSDs, while a simpler approach of adjusting flood and wildfire damages based on the number of new units was employed for other CSDs representing the remaining 1% of projected new units.

Temporal Scope

The base year for existing residential buildings and flood damages is 2023.
New housing units were projected to 2030 based on CMHC projections.

Climate Change Scenarios

Current climate conditions and future climate conditions representing an RCP 4.5 scenario for the year 2030 were used for flood damage estimates based on data provided by Fathom.

Hazard Scope

Two categories of hazards were included in the analysis:

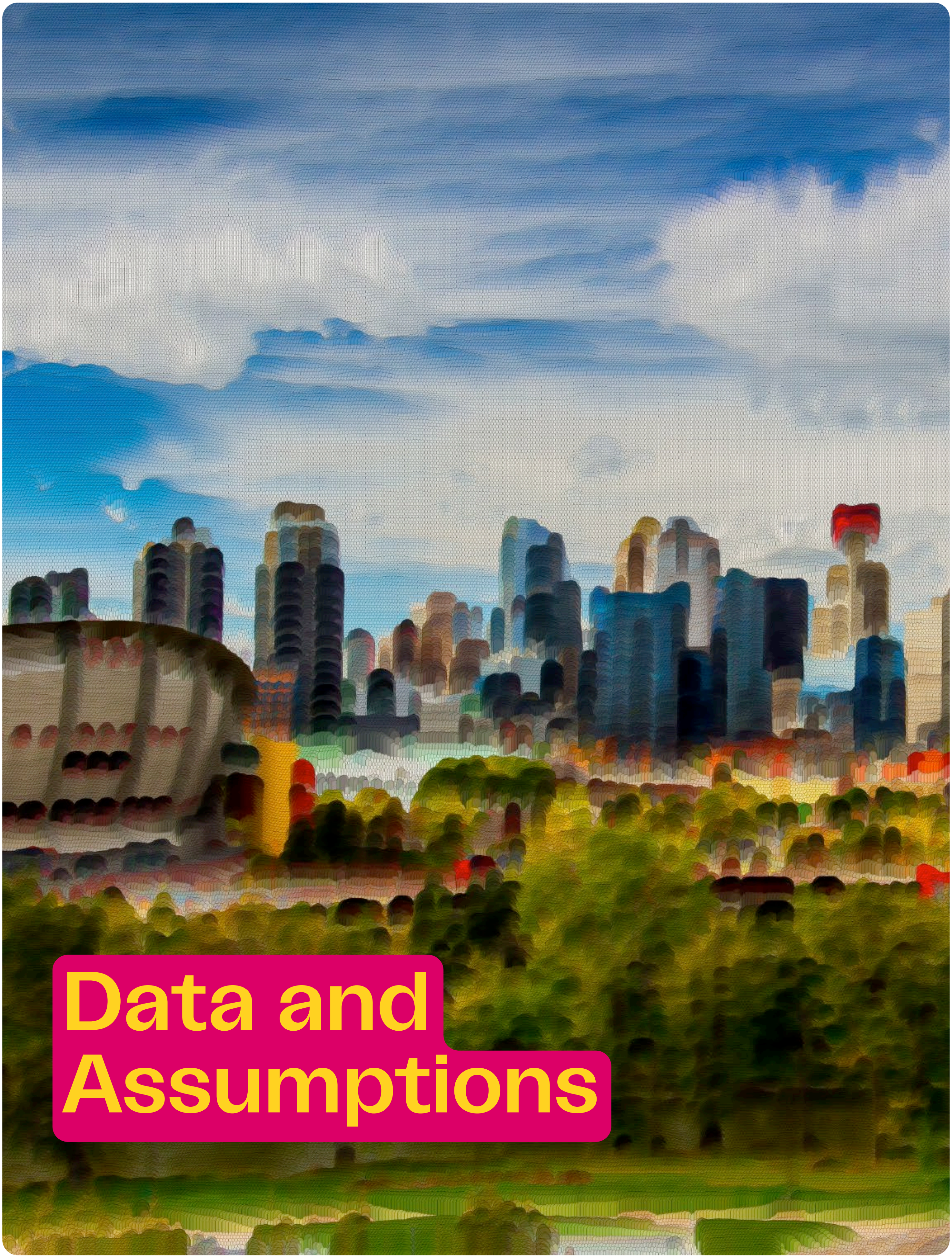
- Floods, including pluvial, fluvial, and coastal flooding; and
- Wildfire.

Impact Scope

Impacts analyzed included flood damage and wildfire damage. Both impacts were analyzed in the form of average annual loss (AAL).

Impacts of flooding were estimated using AAL results provided by Fathom.

Wildfire impacts were estimated by looking at estimated replacement values of buildings within different wildfire risk zones based on Canadian Forest Service (CFS) data in combination with AAL results per CSD provided by Co-operators.



Data and Assumptions

Table 1 details the data sets and related assumptions used for the analysis.

Table 1. Data and assumptions.

Category	**Existing buildings**
Sources and Assumptions	**References**
CCI provided SSG with a Public Safety Canada (PSC) dataset containing information on all existing buildings across Canada (up to 2023). Existing building location and characteristics were used in this analysis in order to spatially allocate and infer average annual loss (AAL) for new housing units.	**1.** PSC existing building stock data.

Category	**New housing projections by CSD**
Sources and Assumptions	**References**
New housing projections by province and territory by 2030 (# of units): AB 416,121 BC 993,162 ON 2,619,000 QC 1,128,265 MB 303,782 SK 136,943 NL 76,654 NS 81,622 NB 25,300 PE 5,034 YT 1,312 NT 1,340 NU 1,202	**2.** CMHC (2022). Canada's Housing Supply Shortages: Estimating what is needed to solve Canada's housing affordability crisis by 2030. **3.** Official community development plans for various cities for intra-provincial new unit distribution. **4.** Statistics Canada, Dwellings by CSD for 2016 and 2021.

Category	New housing projections by CSD *(continued)*
Sources and Assumptions	**References**
The intra-provincial distribution of new units to CSDs was determined by using projections of new units from official community plans for municipalities for which data was available (85% of new units were assigned to CSDs using this method). In municipalities where dwelling units projections were not available, dwelling growth was extrapolated using 2016–2021 data from Statistics Canada (the remaining 15% of new units were assigned to CSDs using this method).	

Category	Zonal projections of new units within CSDs
Sources and Assumptions	**References**
Projected locations of new dwellings are based on existing building locations, official community development plans, public land-use data, existing flood regulations for development, and historical growth by Aggregate Dissemination Area (ADA).	5. Official community development plans that include zonal demographic projections and GIS data for demographic projections for various cities. 6. Statistics Canada, Dwellings by ADA for 2016 and 2021.

Category	Land use
Sources and Assumptions	**References**
Land-use data was used to identify existing and potential future residential development. Several data sets were combined to identify potential areas for new development, including greenfield development, intensification, and re-development.	7. Agriculture and Agri-Food Canada (AAFC) Land Use 2020. Retrieved from https://open.canada.ca/data/en/dataset/fa84a70f-03ad-4946-b0f8-a3b481dd5248

Category	Land use *(continued)*

Sources and Assumptions	References
The data sets included Agriculture and Agri-Food Canada (AAFC) Land Use (30 m), National Resources Canada (NRCan) CanVec Topographic Data of Canada, NRCan National Railway Network, ECCC Canadian Protected and Conserved Areas Database, OpenStreetMap, BC Agricultural Land Reserve map data, and Ontario Greenbelt map data.	8. CanVec Topographic Data of Canada. Retrieved from https://open.canada.ca/data/en/dataset/8ba2aa2a-7bb9-4448-b4d7-f164409fe056 9. National Railway Network. Retrieved from https://ftp.maps.canada.ca/pub/nrcan_rncan/vector/geobase_nrwn_rfn/ 10. ECCC Canadian Protected and Conserved Areas Database. Retrieved from https://data-donnees.az.ec.gc.ca/data/species/protectrestore/canadian-protected-conserved-areas-database/?lang=en 11. OpenStreetMap map features retrieved using OSMnx 12. BC Agricultural Land Reserve. Retrieved from https://www.alc.gov.bc.ca/alr-maps/ 13. Ontario Greenbelt. Retrieved from https://data.ontario.ca/en/dataset/greenbelt-plan-mapping/resource/19e53abf-6642-4e59-af20-e279b2ffa250

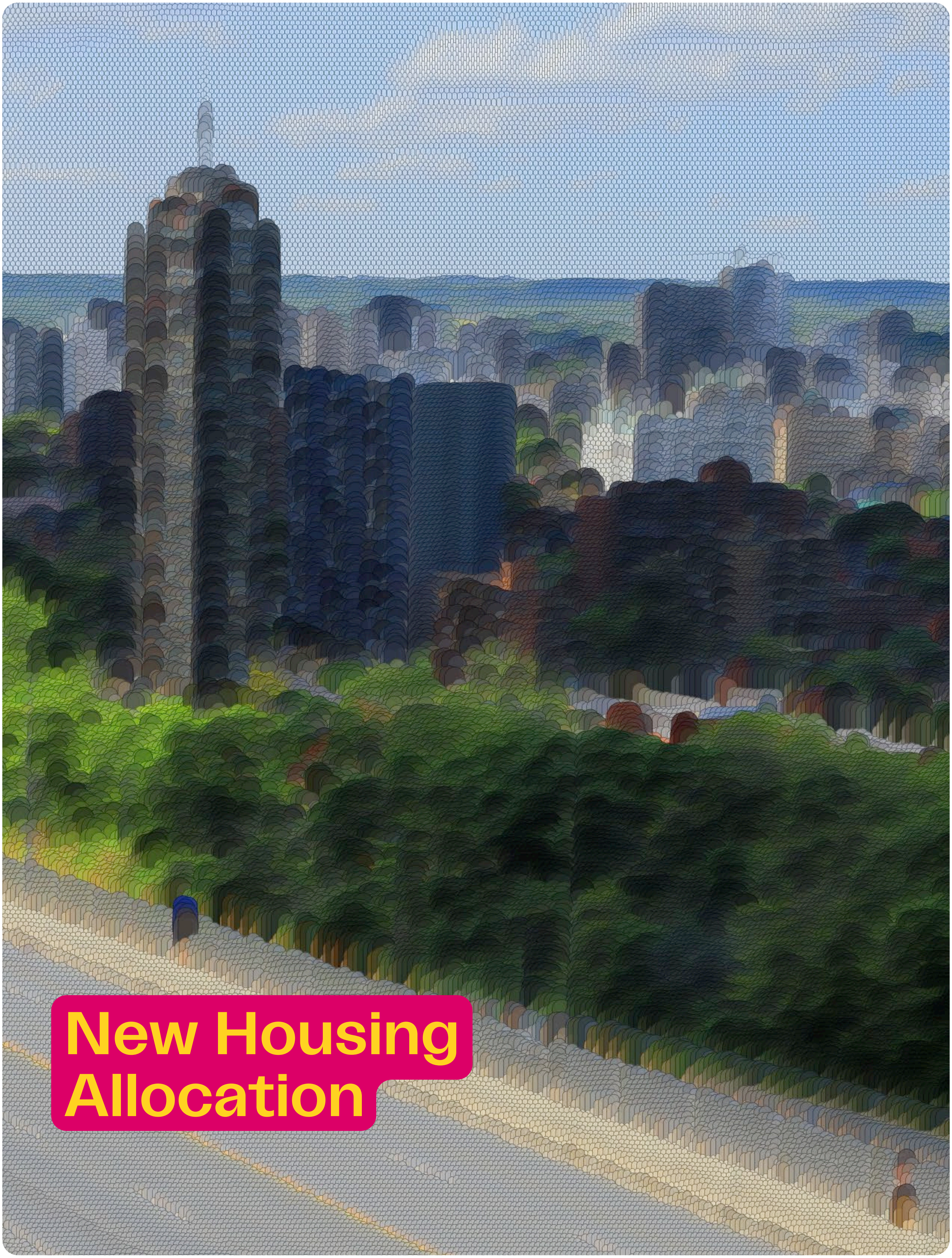
Category	Flood regulation
Sources and Assumptions	**References**
CCI provided flood standards and hazard maps for the following provinces: Manitoba, Newfoundland and Labrador, Nova Scotia, Ontario, Quebec, Prince Edward Island, and Saskatchewan. CCI also provided flood hazard maps for some of the largest Cities in Canada, including Toronto, Montreal, Calgary, Ottawa, Mississauga, Vancouver, Brampton, Hamilton, Surrey, Quebec City, Laval, London, Vaughan, and Gatineau.	**14.** Provided by CCI.

Category	Flood susceptibility
Sources and Assumptions	**References**
A publicly available Flood Susceptibility Index layer created by NRCAN was used to inform future flood-risk analysis by correlating AAL attributed to existing housing units from the Fathom dataset to Flood Susceptibility Index values in order to infer potential AAL of new housing units.	**15.** NRCAN. Flood Susceptibility Index. Retrieved from: https://app.geo.ca/result/en/flood-susceptibility-index-(fsi)?id=df106e11-4cee-425d-bd38-7e51ac674128&lang=en

Category	Flood AAL
Sources and Assumptions	**References**
CCI provided SSG with Fathom flood analysis results, including estimated AAL for all existing housing units contained in the PSC dataset described above under current and future climate conditions (2030 according to an RCP 4.5 emissions scenario).	**16.** Fathom AAL estimates for the PSC existing buildings dataset.

Category	Wildfire hazard map
Sources and Assumptions	**References**
CCI provided SSG with fire hazard spatial data produced by CFS. The data was in raster format with a pixel resolution of 250 m and indicated fire hazard value on a 1–100 scale. The fire hazard map was derived by combining the national burn probability and fire intensity maps.	**17.** Canadian Forest Service wildfire hazard map

Category	Wildfire AAL
Sources and Assumptions	**References**
Co-operators provided wildfire AAL estimates at the CSD level.	**18.** Co-operators AAL estimates for the PSC existing buildings dataset, aggregated by CSD


New Housing
Allocation

Reference Scenario

A reference scenario representing probable locations of the 5.8 million new units projected by CMHC was created as the basis of the future flood and wildfire risk assessment.

New dwelling units were modelled at a 30 m pixel resolution for 99% of the 5.8 million new homes projected by CMHC[1]. The projected locations of these new dwellings are based on existing building locations, official community development plans, public land-use data, existing flood regulations for development, and historical growth by aggregate dissemination area (ADA).

Zonal Projections

The first step in identifying probable locations for new units was to determine the distribution of new units across different neighbourhoods or zones within each CSD. These zonal projections of new units within CSDs were determined according to four different methodological tiers.

Tier 1

Housing projections in 61 of the highest-population CSDs drew on spatial demographic projections previously modelled by SSG. The projections were informed by official community development plans and were modelled at the traffic-zone level as shown in the example in Figure 1. Just over half—52%—of the 5.8 million new units projected by CMHC were distributed to these 61 CSDs.

1 In CSDs projected to have a marginal increase in housing stock by 2030 (less than 100 new units), housing stock was modelled at the CSD level instead of using 30 m pixel resolution. These CSDs account for less than 0.3% of new housing stock.

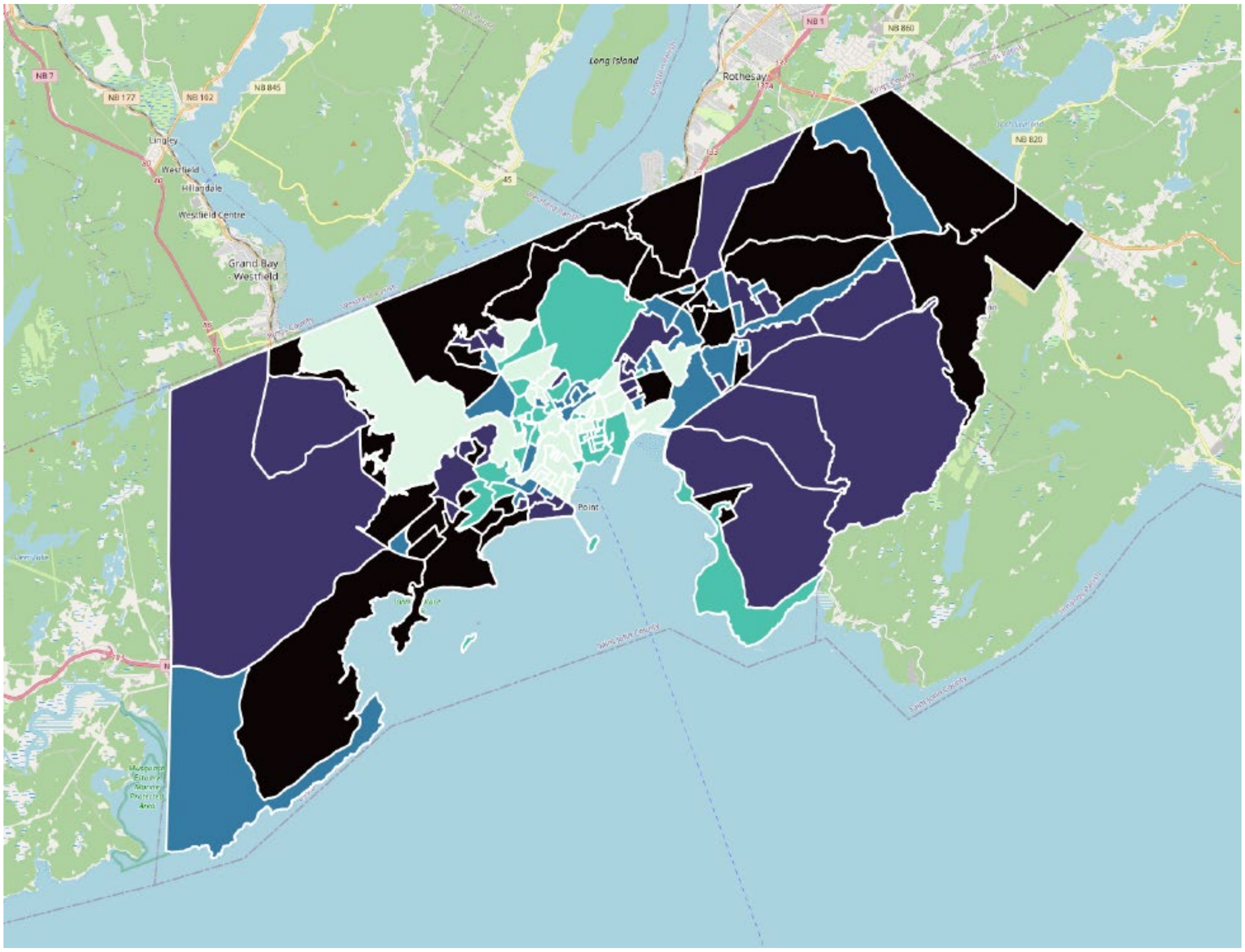


Figure 1. Projected new dwelling units using tier 1 methodology.

This example shows projected new dwelling units by traffic zone in Saint John, NB, 2023–2030. Light green areas represent fewer new units; dark blue areas represent more new units.

Tier 2

For an additional 9 CSDs, spatial projections were determined by finding publicly available spatial projections from community development plans or GIS layers. Thirteen percent of projected new units were distributed to these 9 CSDs.

Tier 3

For CSDs not covered in previous steps and with a projection of at least 100 new units by 2030, historical housing growth from 2016 to 2021 by ADA was used to determine future housing growth (areas with higher recent growth received a bigger share of new housing units projected for that particular CSD). Figure 2 shows an example of a CSD where new dwelling units were projected using ADA data Just over one-third, or 35%, of projected new units were distributed to these CSDs.

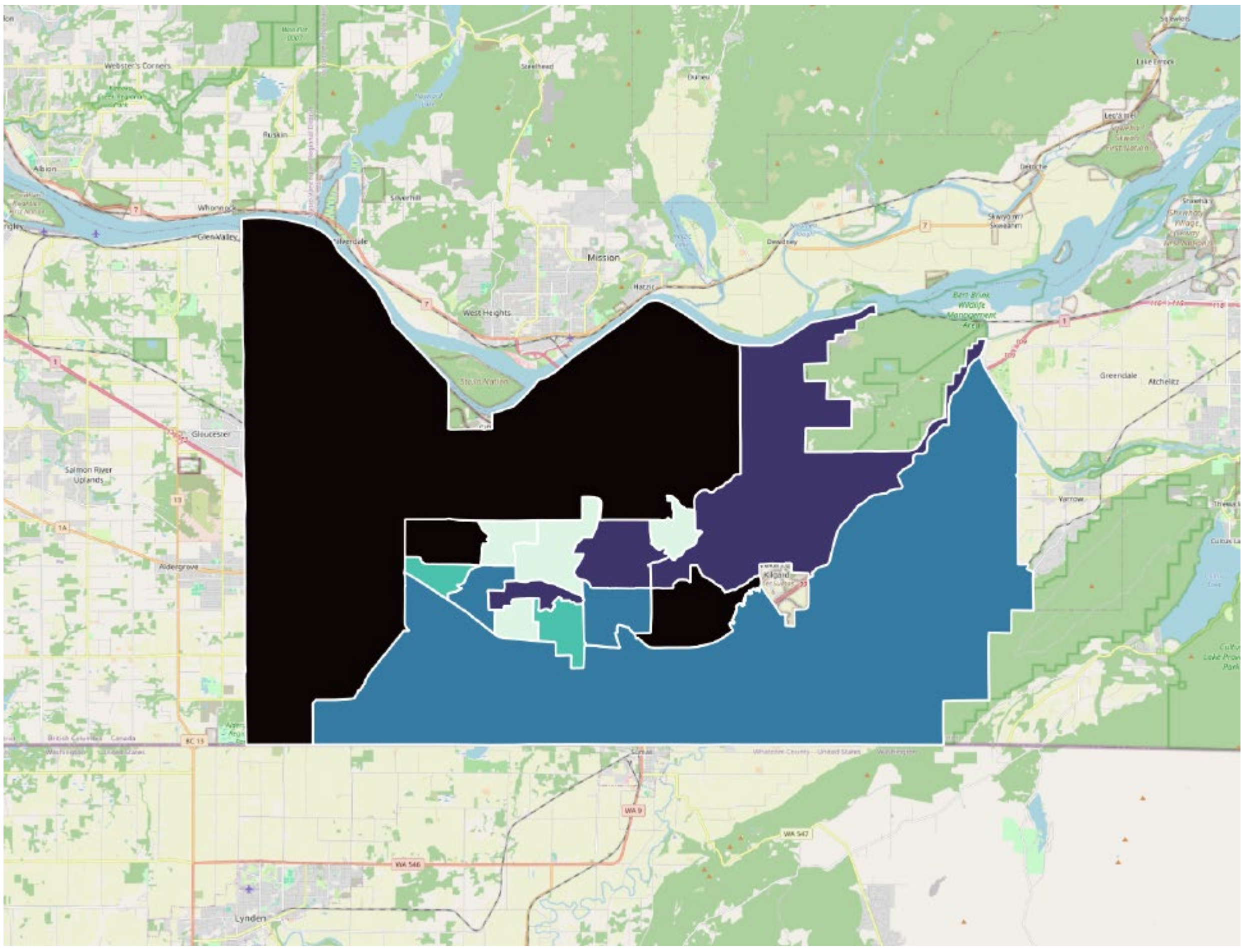


Figure 2. Projected new dwelling units using tier 3 methodology.

This example shows new dwelling units projected by ADA in Abbotsford, BC, 2023–2030. Light green areas represent fewer new units; dark blue areas represent more new units.

Tier 4

For the remaining CSDs with less than 100 new housing units projected by 2030, analysis was done at the whole-CSD level without spatially disaggregating housing projections. Of the total new dwelling units, less than 1% of new units were distributed to these CSDs.

Dwelling Types

The reference scenario and subsequent flood and wildfire damage estimates were modelled separately for apartments and other dwelling types. Other dwelling types include single detached, semi-detached, and row houses. For CSDs with Tier 1 zonal projections, the proportion of new apartments relative to other dwellings was informed by official community development plans. For all other zonal projection tiers, the proportion of new apartments relative to other dwellings was determined by the existing proportion of dwelling types in each zone.

Pixel Allocation

For each zone within each CSD as identified in the zonal projections, land-use data layers from Agriculture and Agri-Food Canada (AAFC) Land Use (30 m) data, CanVec Topographic Data of Canada, National Railway Network, ECCC Canadian Protected and Conserved Areas Database, OpenStreetMap, BC Agricultural Land Reserve (ALR), the Ontario Greenbelt, flood hazard maps, and local zoning layers were combined into a single merged map layer. Pixels with viable landscape and land-use types were identified as potential locations for new housing via redevelopment or greenfield development (Figure 3).

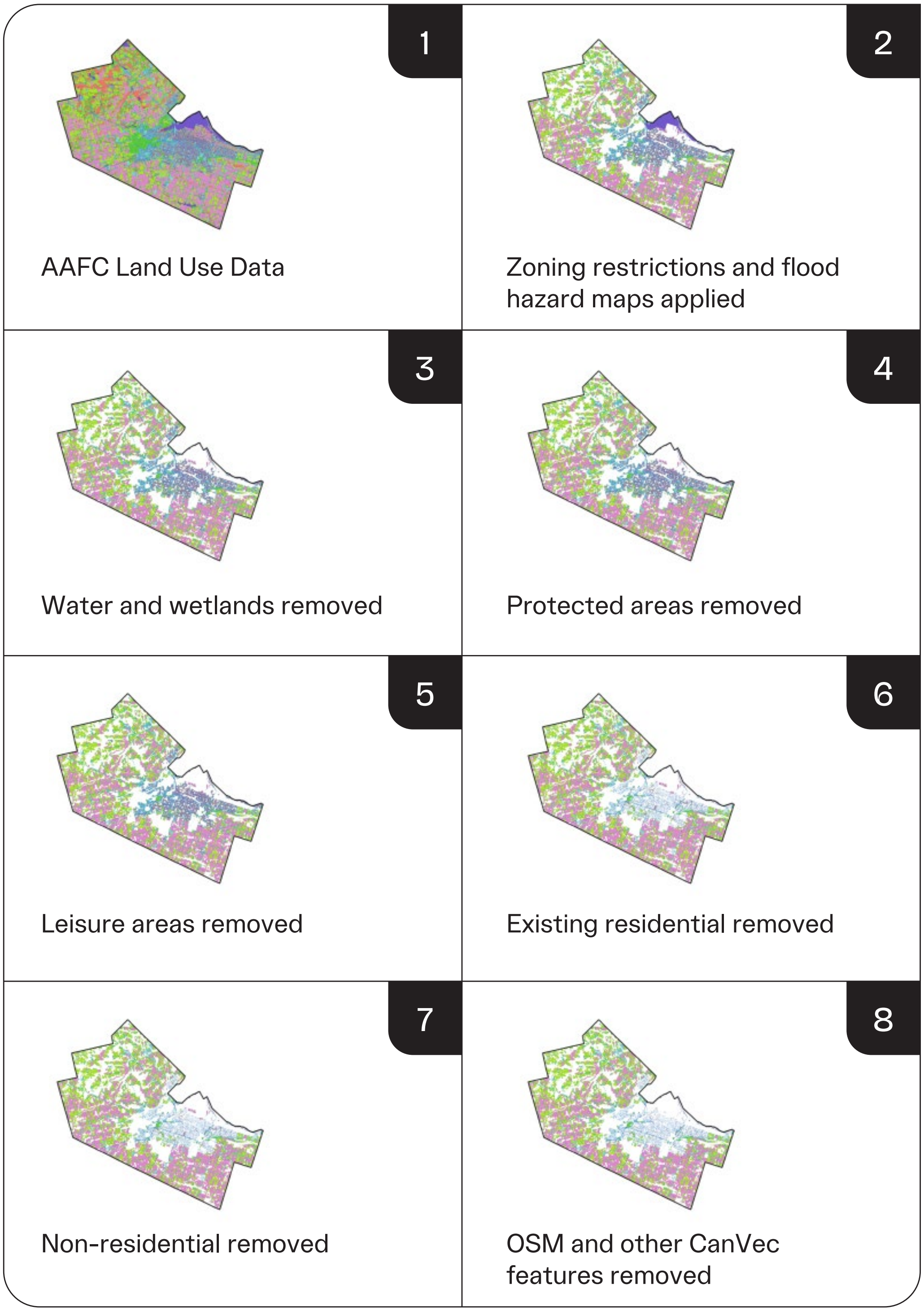


Figure 3. Identifying potential development locations.

Existing land-use and landscape-type data merged to determine potential locations for new developments in Hamilton, ON. Non-white pixels represent potential locations for new housing. White pixels represent locations that are unavailable for development. With each successive dataset, additional area is removed from the set of potential pixels.

Figure 4. Potential areas for new greenfield development.

Potential areas for greenfield development are illustrated with non-white pixels, in Hamilton, ON, based on land-use data from the previous figure merged with Ontario Greenbelt data.

Figure 5. Potential areas for redevelopment or densification.

Existing residential areas, illustrated with non-white pixels, in Hamilton, ON. Redevelopment or densification of dwelling

In some locations, particularly in coastal CSDs and CSDs bordering other water features, some discrepancy was identified between CanVec Topographic data layers, AAFC Land Use data, and visual analysis of satellite imagery. For example, marinas could appear as developed land rather than water. In other examples, wetlands might not be clearly identified. To prevent new developments from being allocated in these unlikely locations, a Flood Susceptibility Index (FSI) threshold was established for each zone. Available pixels were filtered so that new development would not occur in pixels that have a higher FSI value than the maximum FSI for existing dwellings in the zone.

Next, a maximum density of dwelling units per pixel was established by multiplying the maximum density of existing dwellings in the zone by 1.2, allowing for new development to be up to 20% more dense than existing development in the zone.

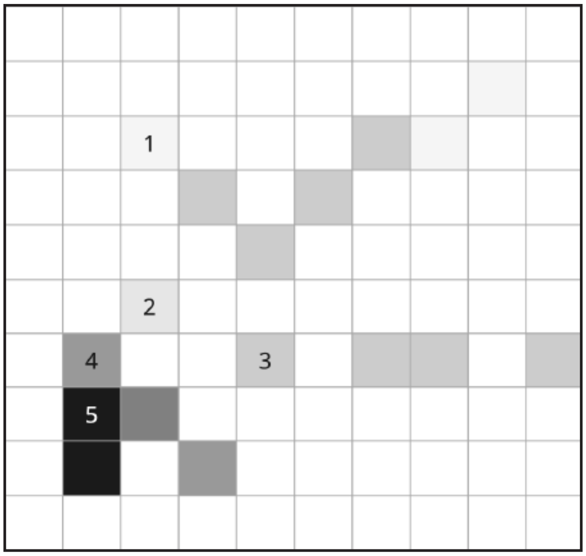


Figure 6. Example location showing existing dwelling units.

The grid shows a collection of 30 m x 30 m pixels. White pixels have no existing dwelling units. Greyscale pixels show existing units with 1 to 5 units per pixel; darker pixels have more units. If this collection of pixels comprised all the pixels within a single zone inside a CSD, the maximum allowable density for that zone would be 6 (5 units • 1.2 additional density = 6 maximum density).

New dwellings were then allocated to available viable pixels up to the maximum density. If further new dwellings were projected for a given zone, pixels with existing residential development were densified by allocating additional units up to the maximum density.

It is important to note that allocated pixels do not represent predictions of actual locations for new development. Rather, they represent probabilities of new dwelling units being built in those locations. Allocated pixels are generally represented as fractional amounts of new units. The sum of the values for all allocated pixels in a zone is equal to the number of projected new units for that zone.

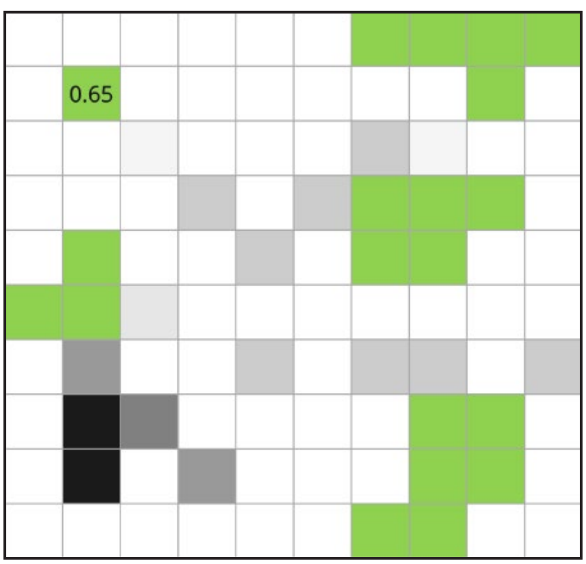


Figure 7. Example pixels with allocated units.

This example shows existing units (grey) and allocated units (green). The pixels with allocated units each have a value of 0.65 new units. There are 20 pixels and 13 total new units allocated in the zone in this example (20 pixels • 0.65 units per pixel = 13 new units).

In cases where all available viable pixels and existing residential pixels were allocated to the maximum density and further development was still projected, restrictions from the BC ALR and Ontario Greenbelt were relaxed by allowing development in restricted areas within 120 m of existing roads.

In cases where further development was still required after relaxing BC ALR and Ontario Greenbelt restrictions, as well as in provinces other than BC and ON, exclusion areas for existing features were relaxed by allowing new developments in previously excluded areas within 120 m of existing roads.

Figure 8. New development within close proximity to existing roads.

An example location where Ontario Greenbelt regulations (grey) are relaxed to allow new development (green) within 120 m of existing roads (white) provided that the existing land use or landscape type is suitable for development.

Finally, in rare cases where projected development was still not accommodated after the previous steps, the maximum density was increased to accommodate additional dwelling units.

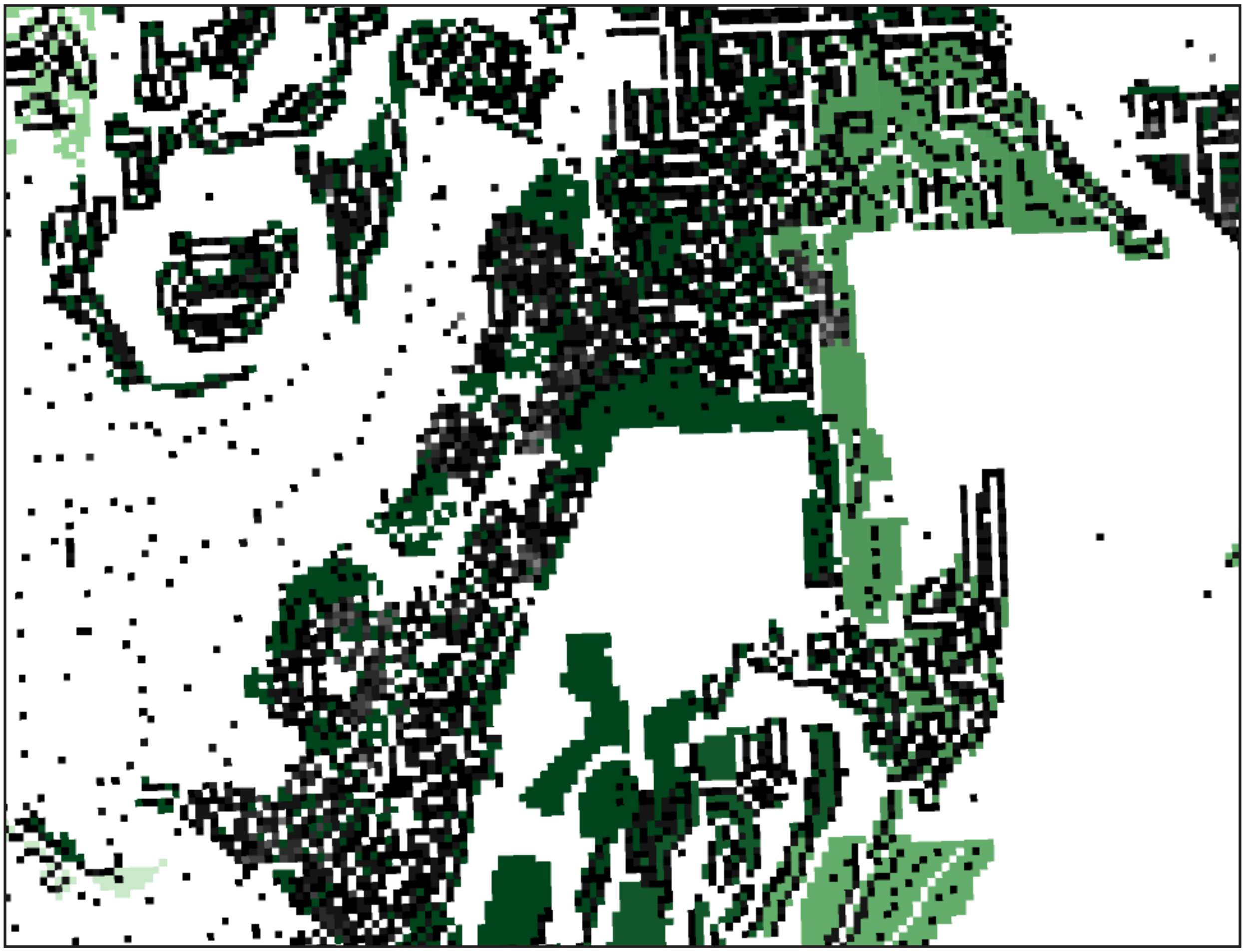
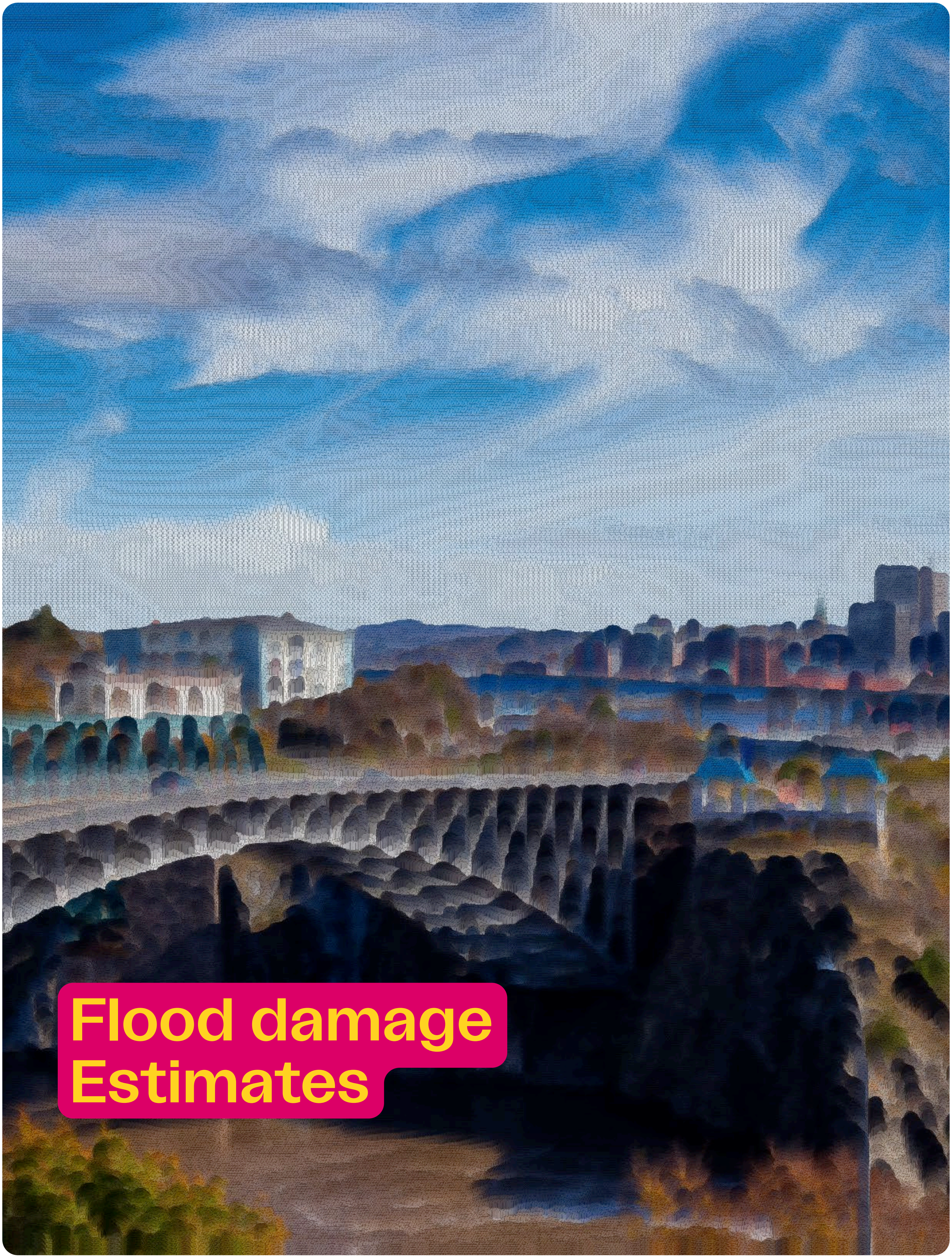


Figure 9. Spatial allocation of new dwellings.

An example of a location showing existing dwellings in greyscale (darker areas have more dwelling units than lighter ones) and spatial allocation of new dwellings in green (the darker the green, the higher the number of new dwelling units) across multiple zones.



Flood damage Estimates

Methodology for Estimating Flood Damages for New Locations

Fathom flood data[2] was limited to existing buildings. Calculating flood depth or AAL for all possible locations for new development was beyond the scope of Fathom's engagement with CCI. SSG developed a methodology to estimate flood AAL for new development locations based on four different estimation methods. The methods are presented in terms of modelling prioritization. The first method was the preferred approach to estimate AAL per unit; the second, third, and fourth methods were applied (in that order) if conditions for the previous method(s) in the list were not met. This methodology was applied to apartments separately from other dwelling types.

1. Nearest Neighbour

The first method for estimating AAL per unit was the "nearest neighbour" method. This method involves identifying if any pixels with existing building data (including flood AAL estimates) are within 1 pixel (30 m) of pixels with projected new dwelling units and then taking the average AAL per unit of all pixels with existing buildings within 30 m. This method is based on the assumption that new units built within 30 m of existing buildings will have similar flood risk (AAL per unit).

2. Contiguous Flood Susceptibility

The second method leverages the public Flood Susceptibility Index (FSI) dataset to infer a relationship between contiguous pixels with similar flood susceptibility scores and AAL per unit. If a pixel with new units is within 15 pixels (450 m) of a pixel with existing units and connected to it by pixels with an FSI score within a range of +/- 1 of the pixel with existing units, then the pixel with new units inherits the average AAL per unit of all pixels with existing buildings connected in this way.

2 Fathom flood data was provided for both defended and undefended flood scenarios. Projected AAL as well as flood-type determination was performed separately for each scenario.

3. Sub-regional Regression Analysis

For cases where new pixels did not meet the criteria for methods 1 or 2, a regression analysis approach was used at the sub-region level[3] if the sub-region had at least 100 pixels with existing dwellings with an AAL score (n≥100).[4] For CSDs from tiers 1, 2, and 3, a regression analysis was performed using the following regression equation:

$$probFloodDmg = \beta 1 \cdot FSI + \beta 2 \cdot Apartment$$

Where,

probFloodDmg = probability of an existing home having a positive AAL value;

FSI = Flood Susceptibility Index Score (Ranging from 0-100); and

Apartment = indicator variable (0 or 1) indicating whether the units on the pixel are apartments (1) or other (0).

ß1, *ß2* = regression coefficients

The premise of the equation is that there is a positive correlation between FSI values and existing dwelling flood damage provided by Fathom and that the probability of an apartment being flooded is different (typically smaller) than other dwellings.[5]

Once the probability of flooding is estimated using the estimated regression coefficients for a sub-region, it is multiplied by the average AAL per unit for the sub-region in order to determine AAL per unit for new development locations.

4. Regional Regression Analysis

In sub-regions where the number of pixels with existing dwelling AAL was less than 100 (n<100), a whole-CSD-level regression analysis was used to estimate AAL. This regression analysis used the same formula as the sub–regional regression analysis but incorporated data for the entire CSD.

3 Sub-region levels consist of traffic zones for tier 1 CSDs and ADAs for other tiers.

4 An estimate based on a regression analysis would be unreliable without sufficient observations.

5 The positive correlation between FSI and existing-dwelling AAL and the significant difference between probability of flooding for apartments and other types of dwellings was confirmed through regression test of different CSDs and sub-regions by looking at p-values of the regression coefficients and R2 value of the regression. Although the coefficients were consistently statistically significant and R2values were also consistent in their positive correlation, the R2value varied greatly from sub-region to sub-region; consequently, the two first methodologies were preferred whenever their conditions were met.

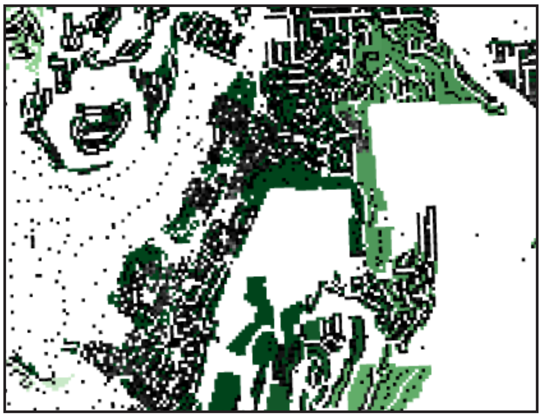


Figure 10. Example location with existing and new dwellings.

Existing dwellings (greyscale) and spatial allocation of new buildings (green) are shown across multiple zones.

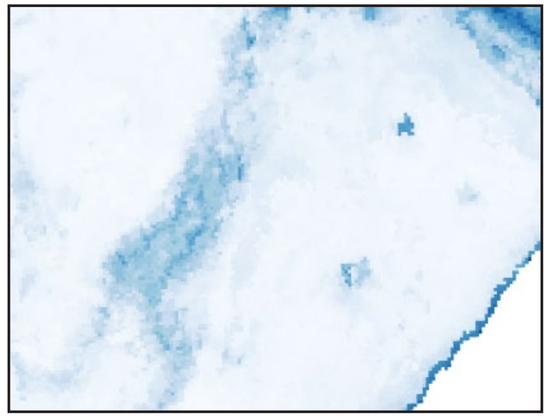


Figure 11. Flood Susceptibility Index (FSI).

FSI is shown in blue for the location in Figure 10. The darker the blue, the higher the pixel's flood susceptibility.

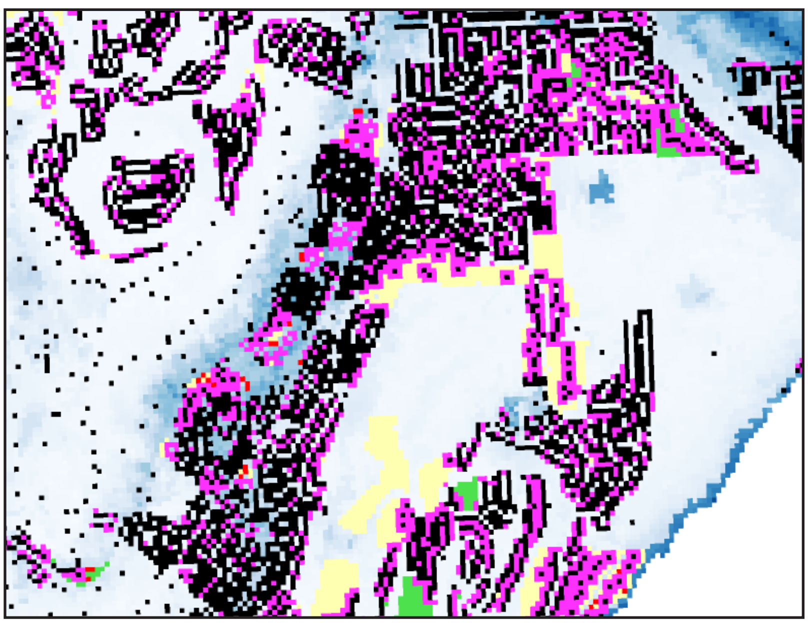


Figure 12. Application of flood-damage-estimation methods.

Using the same location as Figures 10 and 11, this example illustrates all four flood-damage-estimation methods being applied to locations with new dwelling allocations. Black pixels show existing dwellings. Pink pixels show locations where flood AAL was estimated using the neighborhood-analysis method. Red pixels show locations where AAL was estimated using the contiguous-flood-susceptibility method. Yellow pixels show locations where AAL was estimated using the sub-regional regression method. Green pixels show locations where AAL was estimated using the regional regression method. Blue gradient pixels show the FSI for reference.

Methodology for Projected AAL Results

Reference Scenario

Flood AAL results for the reference scenario were estimated by using the four-step methodology described in the previous section and multiplying the resulting AAL per unit estimated for new dwelling locations by the pixel-level dwelling-unit projections for each 30 m pixel for each CSD. Total AAL for each CSD and province was calculated bottom-up by aggregating the AAL values for individual pixels.

Analysis of Risk Concentration

In order to characterize the concentration of new residential flood risk in high-hazard zones, we identified the potential new-home locations responsible for highest levels of total new AAL. Risk concentration was analyzed separately for each province. We identified two categorization thresholds: a 90th percentile threshold and a 99th percentile threshold. These thresholds were based on normalized AAL values and were calculated as follows.

First, a mean replacement cost per unit was calculated based on existing dwellings. Mean replacement cost was calculated separately for each zone in every CSD in each province.

$$replacementCostPerUnit = \frac{1}{n}\sum_{i=1}^{n}\frac{replacementCost_{pixel,i}}{dwellingUnits_{pixel,i}}$$

Next, pixels were filtered to include only those pixels with new allocated dwelling units and with values for computed flood AAL per unit greater than 0. The mean replacement cost per unit was applied to these allocated units with non-zero AAL values in each pixel according to their zone.

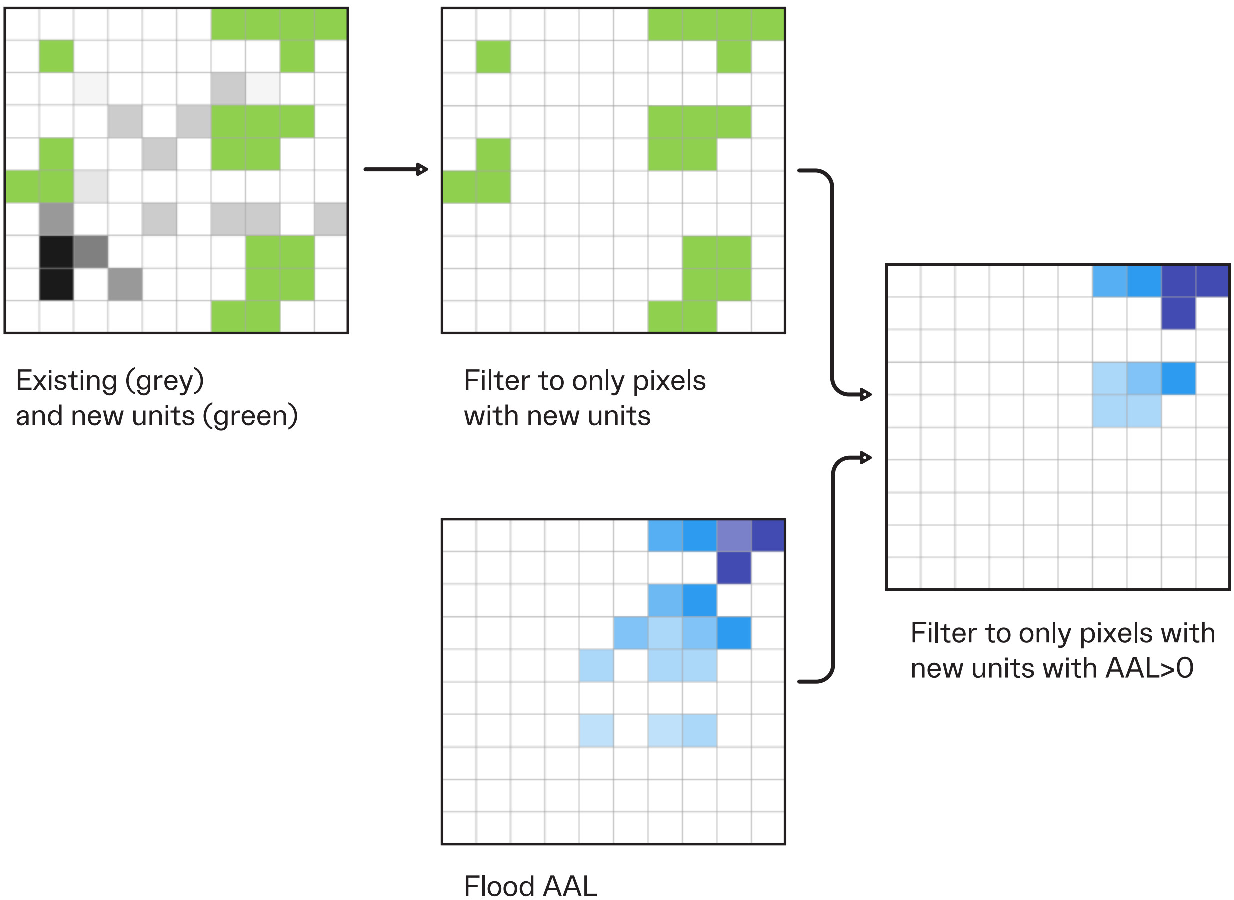


Figure 13. Identifying pixels with new units where AAL>0.

An illustration of how pixels were filtered for each zone to include only locations with new dwelling units where AAL>0.

Next, normalized AAL values were calculated in order to prevent undue weighting of damages based primarily on their local real estate values. AAL-per-dwelling-unit values were calculated for each pixel and each climate scenario.

$$floodAALPerUnitNormalized_{pixel} = \frac{floodAALPerUnit_{pixel}}{replacementCostPerUnit_{pixel}}$$

The normalized values for each climate scenario (current conditions and RCP 4.5 2030) were then summed into a single blended value for each pixel. This blended value was used as the basis for the identification of the 90th and 99th percentile quantiles. Thus, the flood risk concentration could be analyzed using a combination of all three climate scenarios, with each scenario being weighted equally.

Finally, the collection of pixels was filtered to include only those pixels in the 90th and 99th percentile quantiles, respectively, for each threshold for each province.

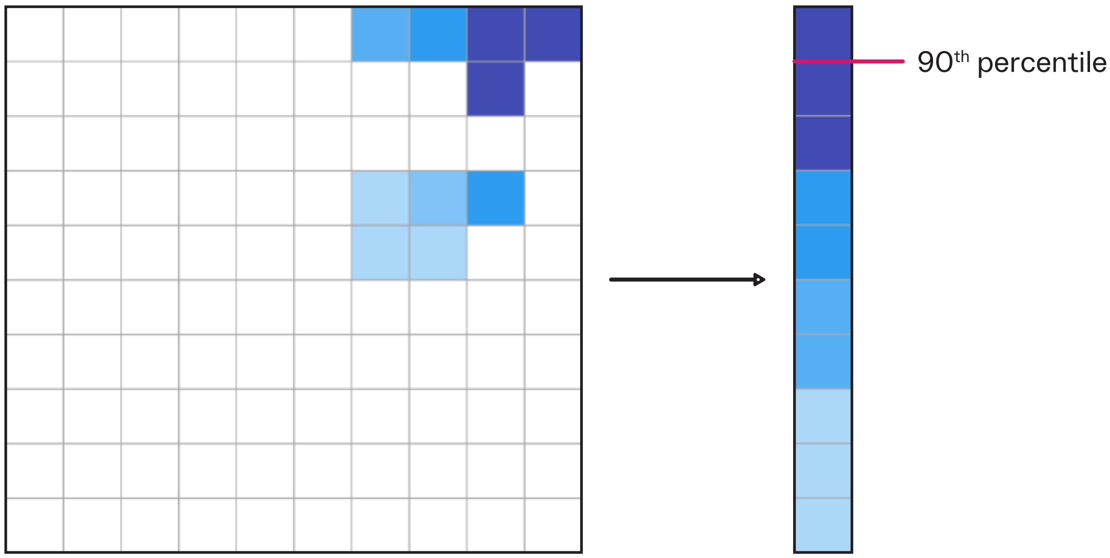


Figure 14. Identifying pixels in the 90th percentile.

This visual representation shows a partial sample of the quantile process for identifying pixels in the 90th percentile of normalized flood AAL per unit. The full calculation included all pixels with new units where AAL>0 from all zones in all CSDs within a given province.

The 90th percentile threshold was developed by identifying the collection of pixels that accounted for locations that had the highest 10% of per-unit normalized AAL values out of all pixels with non-zero AAL.

The 99th percentile threshold was developed by identifying the collection of pixels that accounted for locations that had the highest 1% of per-unit normalized AAL values out of all pixels with non-zero AAL.

The 90th and 99th percentile threshold results represent the quantities of dwellings and AAL values for the 10% and 1% of pixels with the highest risk. In other words, they represent the potential flood damage that could be avoided by implementing policies that prevent development in these pixels.

Methodology for Flood-Type Determination

Two approaches were used to estimate the split in AAL between inland and coastal flooding for projected units for the 90th and 99th percentile thresholds. The approach depended on whether the AAL was modelled or not.

Modelled CSDs

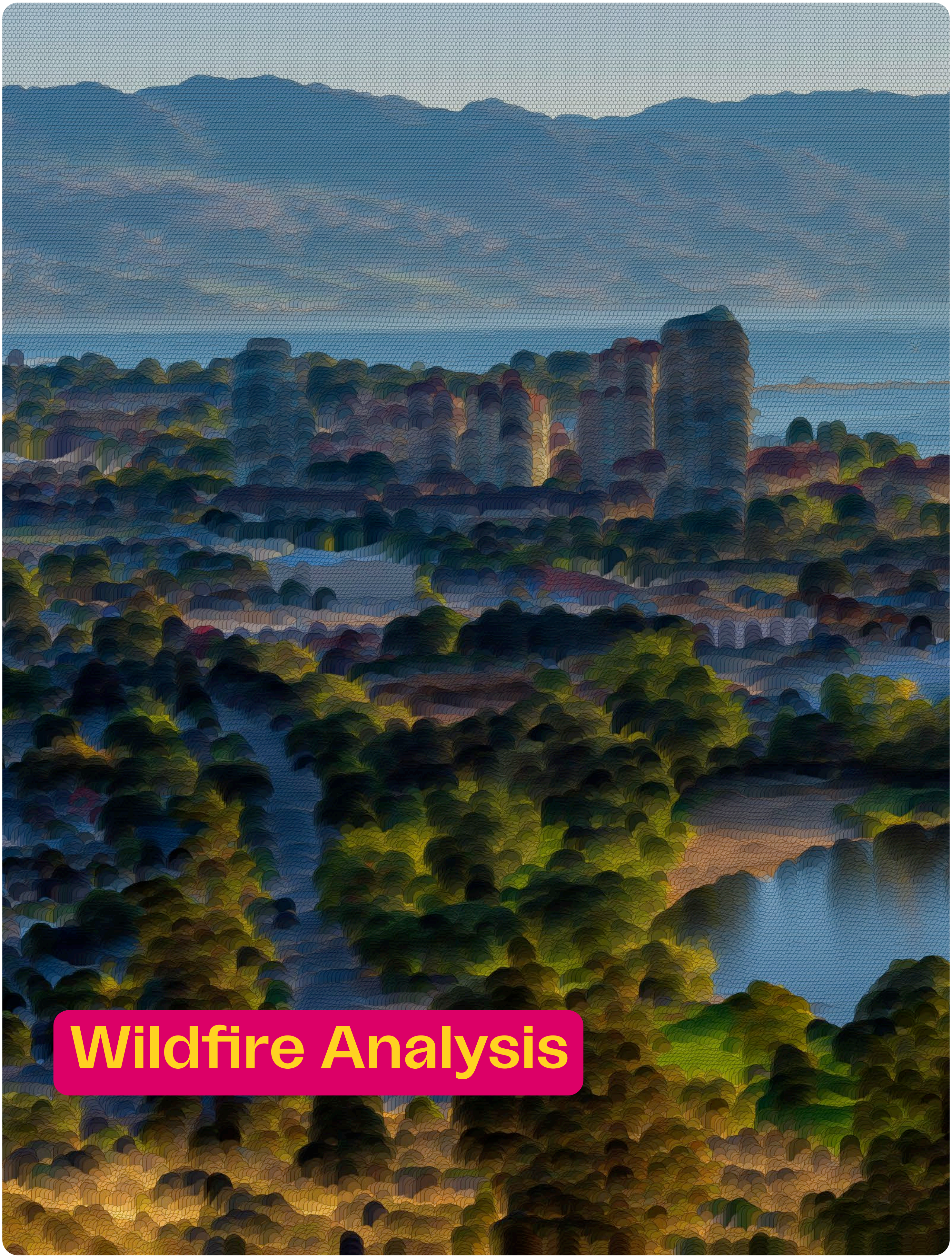
For all CSDs for which flood risk was modelled, flood-type splits were calculated by:

1. Calculating the proportion of AAL attributed to coastal versus inland flooding on a per-pixel basis for existing dwellings (often one dwelling per pixel, but some pixels contained multiple dwellings, especially in the case of apartments). The type of flooding was determined by using the Fathom flood depths as a proxy for how much existing AAL is attributed to each type of flood.
2. Aggregating coastal AAL and inland AAL, respectively, and determining the proportion of each flood type for each sub-region (traffic zones, ADAs, or other planning zones, depending on the bucket the CSD was processed in).
3. Estimating coastal AAL and inland AAL for projected new housing units by using the sub-regional proportions for new dwellings in each sub-region.
4. Summing sub-regional analysis results to calculate coastal and inland AAL for existing and new housing for the full CSD.

Non-modelled CSDs

For the remaining CSDs, the flood types were calculated by:

1. Calculating coastal and inland AAL for each existing dwelling using the Fathom flood depths.
2. Summing per-unit results to calculate coastal AAL and inland AAL, respectively, and determining the proportions of each flood type for the entire CSD.
3. Estimating coastal AAL and inland AAL for project new housing units using the existing ratio of coastal to inland AAL for the CSD.



Wildfire Analysis

Methodology for Estimating Wildfire Damage for New Development

Wildfire damages were estimated using the Canadian Forest Service Wildfire Hazard map (pixel values at 250 m resolution) and the Co-operators Wildfire AAL-by-CSD dataset. Wildfire damage for projected new dwellings were estimated using two approaches, depending on the available spatial data for each CSD (modelled versus non-modelled).

Modelled CSDs

Modelled CSDs included CSDs that:

1. Met the requirements for modelling new housing allocations at a pixel scale in the reference scenario; and
2. Had spatial data coverage in the Canadian Forest Service Wildfire Hazard map.

These CSDs accounted for 90.1% of the 5.8 million new units projected by CMHC.

For these CSDs, wildfire risk was calculated by:

1. Calculating a cost-weighted hazard index by multiplying the raw wildfire hazard value with the replacement cost of existing buildings on a per-pixel basis.

$$hazardIndex_{pixel} = wildfireHazard_{pixel} \cdot replacementCost_{pixel}$$

2. Calculating the sum of cost-weighted hazard index for each CSD.

$$hazardIndex_{CSD} = \sum_{i=1}^{n} hazardIndex_{pixel,i}$$

3. Determining a scaling factor for each CSD for aligning the wildfire hazard data with existing AAL from the Co-operators Wildfire AAL data by dividing the existing AAL for each CSD by the cost-weighted hazard index for each CSD.

$$scalingFactor_{CSD} = \frac{wildfireAAL_{existing,CSD}}{hazardIndex_{CSD}}$$

4. Calculating the calibrated AAL for existing dwellings per pixel by multiplying the cost-weighted hazard index with the scaling factor for each pixel in each CSD.

$$wildfireAAL_{existing,pixel} = hazardIndex_{pixel} \cdot scalingFactor_{CSD}$$

5. Calculating the mean replacement cost of dwelling units in each CSD.

6. Calculating adjusted wildfire hazard to apply to new developments for each CSD. To try to account for changes in landscape from development activities, we limited future wildfire AAL to the max AAL experienced by existing dwellings in a given CSD (Figure 15).

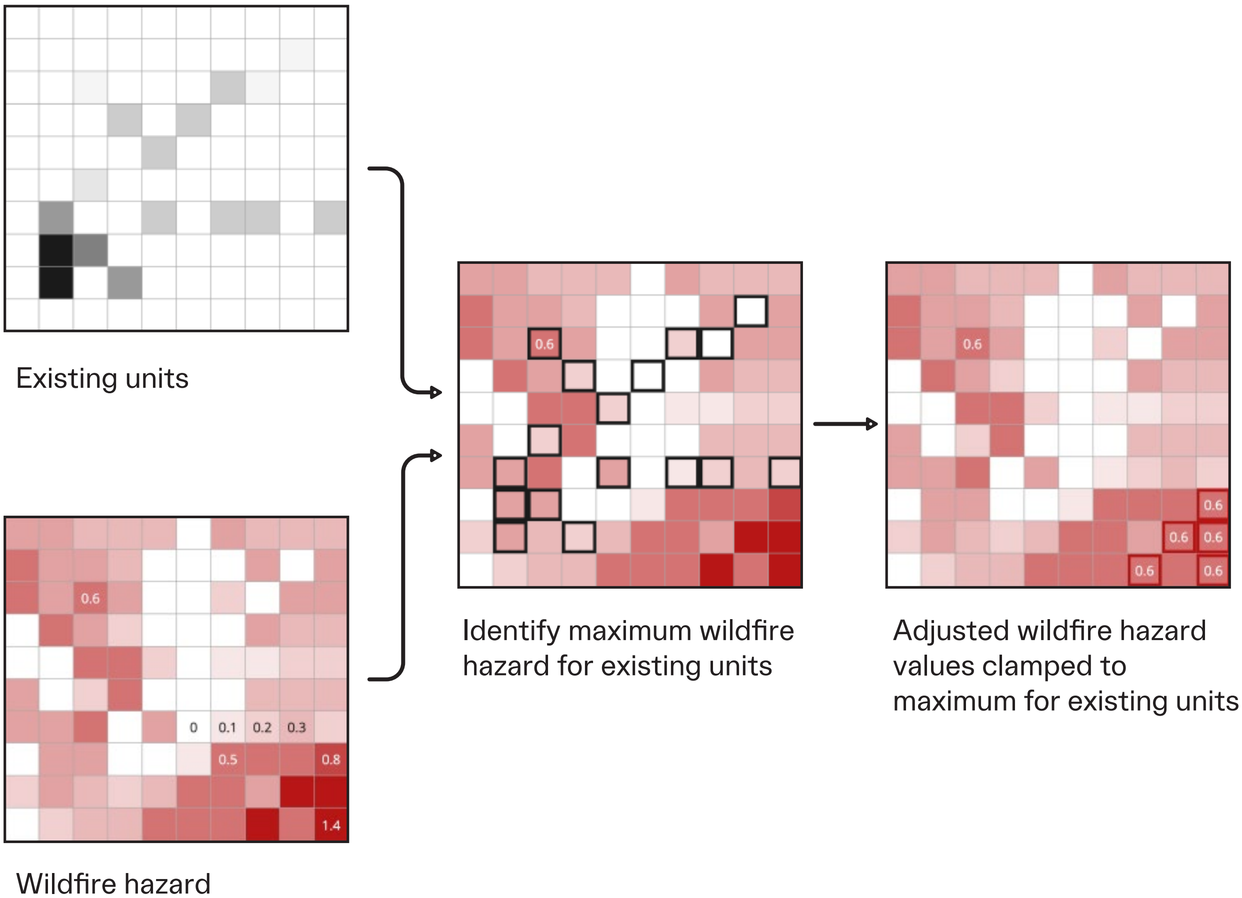


Figure 15. Calculating adjusted wildfire hazard.

An illustration of how adjusted wildfire hazard was calculated. The process involved combining data on existing dwellings and wildfire hazard to identify the maximum wildfire hazard for pixels with existing units. Wildfire hazard values for all pixels in the CSD were then clamped to the identified maximum. In this example, wildfire hazard values range from 0 to 1.4. The maximum wildfire hazard for a pixel with existing units is 0.6. In the final image showing the adjusted wildfire hazard, all pixels with values greater than 0.6 have been clamped to a value of 0.6.

7. Calculating the wildfire AAL per pixel for new dwellings in each CSD by multiplying adjusted wildfire hazard by mean replacement cost, new dwelling units, and scaling factor.

$$wildfireAAL_{new,pixel} = replacementCostPerUnit_{CSD} \cdot dwellingUnits_{new,pixel} \cdot scalingFactor_{CSD}$$

8. Calculating the total wildfire AAL for projected new dwellings in each CSD by summing the wildfire AAL for new dwellings for all pixels in the CSD.

$$wildfireAAL_{new,CSD} = \sum_{i=1}^{n} wildfireAAL_{pixel,i}$$

Figure 16. Example location with wildfire hazard.

The example shows wildfire hazard (red) and existing dwelling units (black). White pixels indicate spaces with no existing dwellings (AAL=0).

Figure 17. Estimated wildfire AAL of existing buildings.

Pink indicates locations with wildfire risk (AAL>0). Black indicates locations without wildfire risk (AAL=0). Red shows wildfire hazard for reference. White indicates areas without wildfire hazard (hazard=0). In these areas, AAL for existing buildings is also 0.

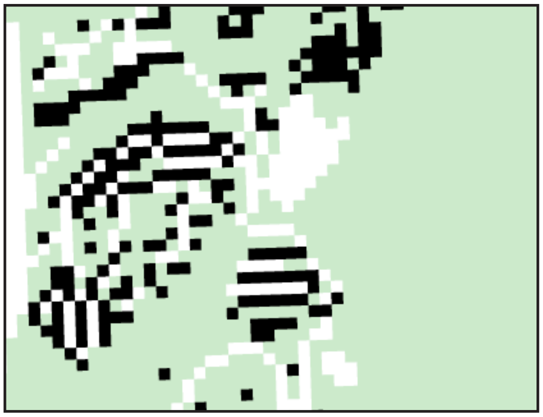


Figure 18. New dwelling units in an area with wildfire hazard.

The same location as the previous figures showing existing dwelling units (black), potential locations of new dwelling units (green), and locations with no new development (white).

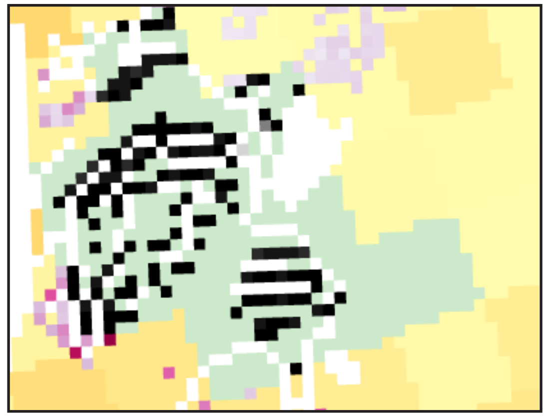


Figure 19. Estimated wildfire AAL for existing and projected new dwellings.

Pink indicates existing units with wildfire risk (AAL>0). Yellow/orange indicates projected new dwellings with wildfire risk (AAL>0). Black pixels indicate existing units without wildfire risk (AAL=0). Green indicates new dwelling locations without wildfire risk (AAL=0). White pixels indicate no existing or new development, (AAL=0).

Non-Modelled CSDs

Non-Modelled CSDs included all CSDs that did not meet the reference scenario modelling requirements or that did not have spatial data coverage in the Canadian Forest Service Wildfire Hazard map. Almost one-tenth (9.9%) of the new units projected by CMHC were included in these CSDs. For these CSDs, wildfire risk was calculated by:

1. Determining the total existing dwelling units and total existing wildfire AAL for each CSD, based on the Co-operators dataset.
2. Calculating the average AAL per unit for existing dwellings for each CSD.
3. Calculating the projected AAL for new dwellings in each CSD by multiplying Average AAL per unit with the number of projected new dwellings.