

Implementation of a Map-Based
Heat Vulnerability Assessment and
Decision Support System

**Data Documentation and
Protocol for Maintenance and Updating**

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Map-Based Heat Vulnerability Assessment

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For more information about Natural Resources Canada's Regional Adaptation Collaboratives Program, please visit http://adaptation.nrcan.gc.ca/collab/index_e.php

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1. Overview of GIS Project Organization and Data Files

The GIS project is organized hierarchically by type of data files. The file names listed in the following refer to the ESRI Shapefile format, in which each map layer consists of up to seven individual files ending in *.shp, *.shx, *.dbf, *.sbn, *.sbx, *.prj, and *.lyr. Within each of the following sections, the files are listed alphabetically by their filename.

- **Base layers** with information for general orientation and reference
 - Toronto_boundary.shp: City boundary
 - NonResAreas_region.shp: Non-residential areas to mask uninhabited parts of Census tracts, including industrial areas, ravines, and large parks
 - Hwy_main.shp: Highways such as 401, QEW, ...
 - mainstreets.shp: Major inner-City roads such as Yonge St, Bloor St, ...
- **Data layers - indicators and indices** represent Census tracts that contain (i) the complete set of indicators used to create the exposure and sensitivity maps, and to calculate the indices, and (ii) the five indices used to create the index maps and cluster maps
 - tor_2010_variables.shp: Boundaries, indicator (normalized), and index (composite) variables for Census tracts
 - tor_2010_var_lisa.shp: Cluster types (high-high, etc.) for Census tracts
 - tor_2010_nodata.shp: Boundaries of areas without population and dwelling data (Census tracts 0003.00, 0006.00, 0009.00, 0033.00, 0061.00, 0205.00, and 0376.06), for cross-hatch symbol on selected sensitivity and index maps
- **Data layers - coverage data** represent Census tracts with counts of selected vulnerable population groups
 - tor_2010_coverage.shp: Boundaries and coverage (raw-count) variables for Census tracts
- **Data layers - adaptation layers**, incl. parks, cooling centres, libraries
 1. UPARK_WGS84.shp: Public green areas (parks)
 2. icitw_wgs84.shp: Boundaries of City wards
 3. neighbourhoods.shp: Boundaries of social planning neighbourhoods
 4. priority_investment_nhods.shp: Boundaries of priority investment areas
 5. Toronto_IPSOS_FSA.shp: Boundaries of Ipsos-Reid postal code regions
 6. coolingctr.shp: Locations of cooling centres
 7. Recreation_halls.shp: Locations of community and recreation halls
 8. publicbuildings_library.shp: Locations of public libraries
 9. Toronto_rapidtransit_stops.shp: Locations of TTC subway stops

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10. Toronto_licensed_daycare.shp: Locations of licensed daycare centres
 11. Toronto_schools_03252011.shp: Locations of public schools
 12. Toronto_pools_geocoded_032011.shp: Locations of public pools and splashpads
 13. Toronto_hospitals_03312011.shp: Locations of hospitals
 14. Toronto_longtermcarehomes_03252011.shp: Locations of long-term care homes
 15. Toronto_shelters_032011.shp: Locations of shelters and hostels
 16. Toronto_roominghouses_03252011.shp: Locations of rooming houses
- **Map image files** contain JPEG images and PDF documents for the 71 decision support maps
 - JPEG_low-res: Subfolder with low-resolution (96 dpi) JPEG images
 - JPEG_mid-res: Subfolder with medium-resolution (300 dpi) JPEG images
 - PDF: Subfolder with medium-resolution (300 dpi) PDF documents
 - **Map project files**, the ArcGIS project files (MXD format) that store the data source and symbology for each map layer, the general settings for each map, and the code for the heat vulnerability mapping tool
 1. ExposureMaps: Subfolder for exposure maps
 2. (Sensitivity)
 - 2.1 SensitivityMaps_GenPop: Subfolder for sensitivity maps (general population sensitivity)
 - 2.2 SensitivityMaps_Seniors: Subfolder for sensitivity maps (seniors' sensitivity)
 3. AdaptationMaps: Subfolder for adaptation maps (transparent overlay maps)
 4. IndexMaps: Subfolder for index and cluster maps
 5. CoverageMaps: Subfolder for coverage maps (proportional circle maps)

The data sources for these files include Statistics Canada, the Community Social Data Strategy, IntelliHealth, Natural Resources Canada, the City of Toronto's Geospatial Competence Centre the City's open data catalogue (toronto.ca/open), and Toronto Public Health. These sources, any required processing of the data, and recommended update cycles are described in more detail in the following sections.

2. Base layers

2.1 Toronto_boundary.shp: City boundary

Data source: Toronto Public Health.

Data processing: Pre-processed shapefile.

Recommended update cycle: Every 5 years.

2.2 NonResAreas_region.shp: Non-residential areas

Data source: Toronto Public Health.

Data processing: Pre-processed shapefile.

Recommended update cycle: Every 5 years.

2.3 Hwy_main.shp: Highways

Data source: Toronto Public Health.

Data processing: Pre-processed shapefile.

Recommended update cycle: Every 5 years.

2.4 mainstreets.shp: Major inner-City roads

Data source: Toronto Public Health.

Data processing: Pre-processed shapefile.

Recommended update cycle: Every 5 years.

3. Indicator and Index Data

3.1 tor_2010_variables.shp: Boundaries, indicator (normalized), and index (composite) variables for Census tracts

The tables in this section list variable definitions and the field codes used in the GIS project files. The exposure variables shown in the following table have a variety of sources and processing.

3.1.1 Exposure Variables

Field Code	Exposure Variable
MEAN_TEMP	Surface temperature (thermal image)
GREEN_DIST	Proximity to green space
TREE_PCT	Tree canopy coverage
DwHR	Dwellings in high-rises (five or more storeys)
DwRHR86	Rented dwellings in older high-rises (built before 1986)
NETPDEN	Net population density

MEAN_TEMP – Surface temperature (thermal image)

Data source: Natural Resources Canada. Pre-processed thermal images were provided by Mr. Matt Maloley through ftp://ftp.ccrs.nrcan.gc.ca/ftp/ad/mmaloley/Thermal_mapping_GTA/. “This dataset is property of Her Majesty the Queen of Canada. It is not to be resold for commercial use. Notwithstanding the previous constraints, the dataset can be used without restriction in consideration for the user including the citation with any publication of results based on this dataset.”

Data processing: The surface temperature variable results from a zonal statistics operation in ArcGIS that calculates the mean of all cell values falling into a Census tract. The cell values were taken from the average of two thermal raster images taken on June 29, 2007 (file 20070629-1st.tif), and September 3, 2008 (file 20080903-1st.tif), which were clipped to the extent of the City of Toronto boundary. See final project report for details on data processing.

Recommended update cycle: Every 1 year. An annual review of the availability of new thermal images should be undertaken in order to capture changes in surface temperature due to ongoing urban development.

GREEN_DIST – Proximity to green space

Data source: City of Toronto (toronto.ca/open).

Data processing: The boundary file for green spaces (file TCL3_UPARK.shp) was used along with Census tract boundaries and non-residential area boundaries. Proximity to green space was calculated as the average distance to the closest park for the residential portions of each Census tract. See final project report for details on data processing.

Recommended update cycle: Every 3-5 years, or when a major new park is created.

TREE_PCT – Tree canopy coverage

Data source: City of Toronto (toronto.ca/open).

Data processing: The proportion of land cover pixels from the file toronto_2007_landcover.ige that are classified as tree canopy was calculated for each Census tract. See final project report for details on data processing.

Recommended update cycle: Every 3-5 years, or when there has been major disturbance of the tree canopy.

DwHR – Dwellings in high-rises (five or more storeys)

Data source: Community Social Data Strategy (accessed through Toronto Public Health).

Data processing: Count divided by corresponding total, i.e. number of apartments in buildings that have five or more storeys divided by total number of occupied private dwellings by structural type of dwelling.

Recommended update cycle: Every 5 years. Updating these data depends on the release of tabulations and cross-tabulations of demographic and socio-economic variables from the Census long form or National Household Survey by Statistics Canada.

DwRHR86 – Rented dwellings in older high-rises (built before 1986)

Data source: Community Social Data Strategy (accessed through Toronto Public Health).

Data processing: Count divided by corresponding total.

Recommended update cycle: Every 5 years. Updating these data depends on the release of tabulations and cross-tabulations of demographic and socio-economic variables from the Census long form or National Household Survey by Statistics Canada.

NETPDEN – Net population density

Data source: Community Social Data Strategy (accessed through Toronto Public Health).

Data processing: Calculated as number of persons divided by land area of Census tract excluding non-residential parts of tracts.

Recommended update cycle: Every 5 years. Updating these data depends on the release demographic and socio-economic variables from the Census short form by Statistics Canada.

3.1.2 Sensitivity Variables

Field Code	Sensitivity Variable
TotLicoAT	Low income persons (2005, after tax LICO)
KidsLicoAT	Low-income among children (age 0-5)
RENT50	Renter households spending \geq 50% income on housing
50LINonFa	Low-income renters spending \geq 50% of income on housing
No Eng	Persons not speaking English
RI	Recent immigrants (2001-2006)
LowEDUC25_	No high school certificate among adults (age 25+)
RG	Racialized groups
Disab25_64	Disability among persons age 25-64

Data source: Community Social Data Strategy (accessed through Toronto Public Health).

Data processing: Counts divided by corresponding totals.

Recommended update cycle: Every 5 years. Updating these data depends on the release of tabulations and cross-tabulations of demographic and socio-economic variables from the Census long form or National Household Survey by Statistics Canada.

3.1.3 Seniors' Sensitivity Variables

Field Code	Seniors' Sensitivity Variable
SR_FRAIL	Frail seniors (age 75+ with a disability) among total population
SR_LIAon1	Low income (2005, after tax LICO) and living alone among seniors (age 65+)
SR_LICOAT	Low income among seniors
SR_LIAon2	Low income among seniors living alone
SR_30EcFam	Senior families spending \geq 30% on housing
SR_30NonFa	Unattached seniors spending \geq 30% on housing
SR_NO_ENG	Seniors not speaking English
SR_RI	Recent immigrants (1996-2006) among seniors
SR_LowEDUC	No high school certificate among seniors
SR_RG	Seniors in racialized groups
SR_DisabNF	Unattached seniors with Disability
SR_Di65_74	Disability among persons age 65-74

Data source: Community Social Data Strategy (accessed through Toronto Public Health).

Data processing: Counts divided by corresponding totals.

Recommended update cycle: Every 5 years. Updating these data depends on the release of tabulations and cross-tabulations of demographic and socio-economic variables from the Census long form or National Household Survey by Statistics Canada.

3.1.4 Composite Indices

Field Code	Composite Index
EXP_INDEX	Exposure index
POP_INDEX	Population index
SR_INDEX	Seniors index
POP_V_INDEX	Vulnerability index
SR_V_INDEX	Seniors vulnerability index

Data source: N/A (based on other variables).

Data processing: Composed from exposure and sensitivity variables that were standardized for the influence of the size of Census tracts (transformed to proportions or other standardized values). Variables were further standardized to a common range of 0.0 to 1.0 by subtracting the minimum value from each value and dividing the result by the range (difference between maximum and minimum value). The tree canopy shading variable needed to be inverted, so that values near 1.0 would always represent high heat vulnerability. The resulting values were weighted according to the index definition in the final report and combined using their sum.

Recommended update cycle: Every 1 year or longer, depending on when any of the included indicator variables change.

3.2 tor_2010_var_lisa.shp: Cluster types for Census tracts

Data source: N/A (based on index variables).

Data processing: This file is based on tor_2010_variables.shp, but has added attribute fields. These were created from the output of the “Cluster and Outlier Analysis: Anselin Local Moran's I” tool under the Spatial Statistics toolbox in ArcGIS.

COType1 – Cluster output types for the exposure index

COType2 – Cluster output types for the general population sensitivity index

COType3 – Cluster output types for the seniors’ sensitivity index

COType4 – Cluster output types for the heat vulnerability index

COType5 – Cluster output types for the seniors’ heat vulnerability index

The values in these fields indicate a cluster of high (HH) or low (LL) values in the underlying index, or spatial outliers where high (HL) or low (LH) values are surrounded by opposite values. The local Moran's I statistics is calculated at a significance level of 0.05.

Recommended update cycle: Every 1 year or longer, depending on when any of the indices change.

3.3 tor_2010_nodata.shp: Boundaries of Census tracts without population and dwelling data

Data source: N/A (based on index variables).

Data processing: Census tracts 0003.00, 0006.00, 0009.00, 0033.00, 0061.00, 0205.00, and 0376.06 were selected from the complete Toronto Census tract boundary file (tor_2010_variables.shp) and saved as a separate file tor_2010_nodata.shp. This is used for the cross-hatch symbol for no-data CTs on exposure, sensitivity, index, and cluster maps. The only maps that do not use this layer are the surface temperature and green space indicator maps, because these exposure indicators exist everywhere, whether there is Census population or not.

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Recommended update cycle: Every 5 years. Updating these data depends on the release of population data from the Census data by Statistics Canada and identification of uninhabited Census tracts.

4. Coverage Data

4.1 tor_2010_coverage.shp: Boundaries and coverage (raw-count) variables for Census tracts

4.1.1 Coverage Variables

Field Code	Coverage Variable
X_DwHR	Dwellings in high-rises (five or more storeys)
X_DwRHR86	Rented dwellings in older high-rises (built before 1986)
X_TotLicoAT	Low income persons (2005, after tax LICO)
X_KidsLicoAT	Low-income children (age 0-5)
X_RENT50	Renter households spending \geq 50% income on housing
X_50LInonFa	Low-income renters spending \geq 50% of income on housing
X_NO_ENG	Persons not speaking English
X_RI	Recent immigrants (2001-2006)
X_LowEDUC25	No high school certificate among adults (age 25+)
X_RG	Racialized groups
X_Dis25_64	Disability among persons age 25-64

Data source: Community Social Data Strategy (accessed through Toronto Public Health).

Data processing: N/A.

Recommended update cycle: Every 5 years. Updating these data depends on the release of tabulations and cross-tabulations of demographic and socio-economic variables from the Census long form or National Household Survey by Statistics Canada.

4.1.2 Seniors' Coverage Variables

Field Code	Seniors' Coverage Variable
XSR_LIAlo1	Low income (2005, after tax LICO) and living alone among seniors (age 65+)
XSR_LICOAT	Low income among seniors
XSR_30EcFam	Senior families spending \geq 30% on housing
XSR_30NonFa	Unattached seniors spending \geq 30% on housing
XSR_NO_ENG	Seniors not speaking English
XSR_DisabNF	Unattached seniors with Disability
XSR_Di65_74	Disability among persons age 65-74

Data source: Community Social Data Strategy (accessed through Toronto Public Health).

Data processing: N/A.

Recommended update cycle: Every 5 years. Updating these data depends on the release of tabulations and cross-tabulations of demographic and socio-economic variables from the Census long form or National Household Survey by Statistics Canada.

5. Adaptation Data

5.1 UPARK_WGS84.shp: Public green areas (parks)

Data source: City of Toronto open data catalogue (toronto.ca/open)

Data processing: N/A.

Recommended update cycle: Every 3-5 years, or when a major new park is created.

5.2 icitw_wgs84.shp: Boundaries of City wards

Data source: City of Toronto open data catalogue (toronto.ca/open)

Data processing: N/A.

Recommended update cycle: Every 4 years, coincident with Council elections.

5.3 neighbourhoods.shp: Boundaries of social planning neighbourhoods

Data source: City of Toronto open data catalogue (toronto.ca/open)

Data processing: N/A.

Recommended update cycle: Unknown – when social planning neighbourhoods are revised

5.4 priority_investment_nhoods.shp: Boundaries of priority areas

Data source: City of Toronto open data catalogue (toronto.ca/open)

Data processing: N/A.

Recommended update cycle: Unknown – when priority investment areas are revised.

5.5 Toronto_IPSOS_FSA.shp: Boundaries of Ipsos-Reid postal code regions

Data source: Forward-sortation area (FSA) boundary file from City of Toronto (Geospatial Competence Centre).

Data processing: Boundaries of postcode regions were created as groupings of FSAs based on Ipsos-Reid's draft report on Access to Cooling survey (file "Ipsos_TPH Heat Vulnerability Draft Report v2 (Jan 4_10).ppt"), slide 5. Water areas were removed from FSA boundaries using ArcGIS' erase function. FSAs for each group were manually selected and merged using ArcGIS editor tools.

Recommended update cycle: Every 5 years, or when FSA boundaries are modified by Canada Post.

5.6 coolingctr.shp: Locations of cooling centres

Data source: City of Toronto (Geospatial Competence Centre).

Data processing: Shapefile updated with locations from recreation halls layer (see below) using ArcGIS editor tools to match list of cooling centres on Toronto Public Health Web site.

Recommended update cycle: Every 3 years, or when cooling centre locations change.

5.7 Recreation_halls.shp: Locations of community and recreation halls

Data source: City of Toronto (Geospatial Competence Centre).

Data processing: N/A. 153 locations.

Recommended update cycle: Every 3 years.

5.8 publicbuildings_library.shp: Locations of public libraries

Data source: City of Toronto (Geospatial Competence Centre).

Data processing: Locations of 84 libraries were selected from public buildings layer using a query for FCODE_DESC = 'Library'.

Recommended update cycle: Every 3 years.

5.9 Toronto_rapidtransit_stops.shp: Locations of TTC subway stops

Data source: City of Toronto open data catalogue (toronto.ca/open), in non-spatial format.

Data processing: Manually extracted from list of all transit stops.

Recommended update cycle: Every 5 years.

5.10 Toronto_licensed_daycare.shp: Locations of licensed daycare centres

Data source: City of Toronto open data catalogue (toronto.ca/open), in non-spatial format (address list)

Data processing: Imported from listing of licensed daycare centres with coordinates of buildings.

Recommended update cycle: Every 3 years.

5.11 Toronto_schools.shp: Locations of public schools

Data source: Ontario Ministry of Education Web site, lists of elementary and secondary schools retrieved from <http://www.edu.gov.on.ca/eng/sift/elementary.asp> and <http://www.edu.gov.on.ca/eng/sift/secondary.asp> (search by town/city).

Data processing: Geocoded by street address.

Recommended update cycle: Every 3 years.

5.12 Toronto_pools.shp: Locations of public pools and splashpads

Data source: City of Toronto Parks, Forestry & Recreation Web site (programs & activities, swimming & pools, outdoor/indoor pools; wading pools; splash pads).

Data processing: Geocoded by street addresses listed on the above Web pages.

Recommended update cycle: Every 3 years.

5.13 Toronto_hospitals.shp: Locations of hospitals

Data source: Ontario Ministry of Health and Long-Term Care (MOHLTC), Local Health Integration Networks (LHINs) of the Greater Toronto Area.

Data processing: Locations of 37 hospital sites geocoded by street address as reported by MOHLTC and LHINs.

Recommended update cycle: Every 5 years, or when a hospital is opened/closed.

5.14 Toronto_shelters.shp: Locations of shelters and hostels

Data source: City of Toronto (Geospatial Competence Centre).

Data processing: Locations of 648 hostels and social housing (HS_TYPE field), but only the 62 hostels are being mapped.

Recommended update cycle: Every 3 years.

5.15 Toronto_longtermcarehomes.shp: Locations of long-term care homes

Data source: Ontario Ministry of Health and Long-Term Care (MOHLTC), Local Health Integration Networks (LHINs) of the Greater Toronto Area.

Data processing: Locations of 86 long-term care homes geocoded by street address as reported by MOHLTC and LHINs.

Recommended update cycle: Every 3 years.

5.16 Toronto_roominghouses.shp: Locations of rooming houses

Data source: Toronto Public Health.

Data processing: 655 licensed boarding homes and rooming houses that are inspected for safety by Toronto Public Health were geocoded by street address from TPH-internal Excel list.

Recommended update cycle: Every 3 years.

6. How to Update the Geospatial Data

Geographically referenced datasets consist of geospatial (geometry), tabular (attribute), and temporal information. The time component is normally handled through one-time snapshots. For example, socio-demographic data are available from the Census for a given year, for which geospatial and tabular data are considered as fixed. As time progresses, there may be a need to update both geospatial and tabular data as described in this and the following section.

The geospatial data in this project include Census tract boundaries, other administrative boundaries (e.g. wards, neighbourhoods), and point locations (e.g. cooling centres, hospitals). These data are stored in individual ESRI Shapefiles for each data layer. To update boundaries or point locations, the corresponding Shapefile needs to be replaced. Updated boundaries will be readily available from the Geospatial Competency Centre, the Toronto Open Data catalogue, or from Statistics Canada. Updated point locations may result from updated address lists, which require geocoding in ArcMap.

To replace a geospatial dataset with an updated version, the administrator of the heat vulnerability assessment tool needs to find the corresponding file in the Data or BaseLayers subfolders. The updated shapefile should receive the same name as the corresponding file, in order to minimize other necessary changes to the existing maps. After a backup of the old file was made, replace it with the new file. This should then automatically load the next time that the tool is started.

If boundaries were updated that had linked attribute data (i.e. Census tract boundaries), the tabular data have to be linked to the new set of boundaries. This is explained in the following section.

7. How to Update the Tabular Data

Tabular data represent the attributes of geospatial entities, for example the population or dwellings of Census tracts. Tabular data (attribute tables) are organized by rows and columns, where each row represents a geospatial entity and each column represents an attribute (variable).

To link tabular data to geospatial data, the row identifiers need to match with the identifiers of geospatial entities. All identifiers must be unique, and it is recommended to use domain-specific identifiers such as the CT numbers/names provided by Statistics Canada.

A common challenge is the formatting of Census tract identifiers (CTName attribute). They should be formatted as text strings with four digits including leading zeros before the decimal point, and two digits including trailing zeros after the decimal point. For example, the computer cannot match the text-formatted “0001.00” to the numeric “1” or “1.0”. The tabular data source may need to be modified to match the required identifier format in the geospatial dataset.

Tabular data can be prepared in comma-separated value (CSV) files, DBase IV (DBF) files, or Microsoft Excel (XLS) files. These and a few other file types can be linked to geospatial data using ArcMap.

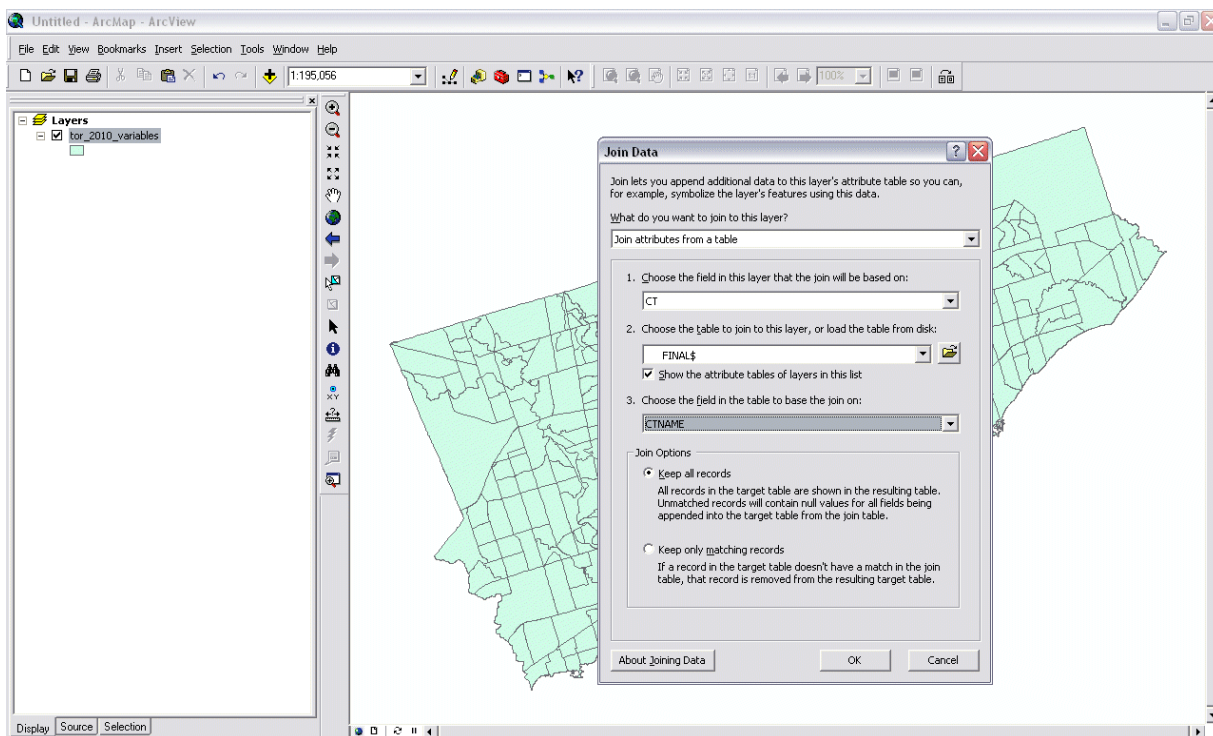
Warning: A complete backup of all files within the heat vulnerability assessment tool distribution should precede the following actions.

With a right-click on the geospatial layer name (e.g. tor_2010_variables), the “Joins and Relates” function can be accessed. First, “Remove Join(s)” – “Remove All Joins” should be performed. Next, the “Join...” function opens a new dialog window entitled “Join Data”. The goal of this operation is to “Join attributes from a table” (default setting of first dropdown box). The “field in this layer that the join will be based on” is the identifier of geospatial entities, such as “CTName” or “CT” for a Census tract boundary layer. If in doubt, the process should be cancelled and the attribute table for the geospatial layer loaded using right-click on the layer name and “Open Attribute Table”. The identifier column can be found and its format (text, numeric – see discussion above) be noted.

When the identifier is known, it is selected under step 1 in the “Join Data” dialog. In step 2, the updated data table is selected (if it was previously loaded into the map project) or the “Browse” icon is used to load the updated table from the file system. In step 3, ArcMap populates the dropdown box “Choose the field in the table to base the join on” with only those attributes in the table that match the format of the identifier field selected in step 1. If the dropdown box in step 3 remains empty or does not provide a valid choice, it is likely that there is an issue with the format of the identifier field as discussed above. In a final step before clicking “OK”, the default join option “Keep All Records” should be selected.

The following screenshot shows the “Join Data” dialog with sample input.

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This method can be used to link a new tabular dataset, or to re-link a modified attribute table.

Most importantly, the link between geospatial and tabular data created through ArcMap's join function should be made permanent by creating a new Shapefile. This is achieved by right-clicking the layer name and choosing "Data" – "Export Data...". In the "Export Data" dialog window, choose to export "All features" using the same coordinate system as "this layer's source data" and make sure that the output path is set to the folder within the heat vulnerability tool distribution where the corresponding Shapefile resided prior to updating.

Please note: By giving the resulting Shapefile the same name as the one that is being replaced, the heat vulnerability maps will load the updated data. However, with new value ranges that may be included in the updated data, the predefined decision support maps may become incorrect, because their choropleth classifications may not represent quintiles of the updated data. In addition, the legends of the predefined maps are fixed for page layout purposes and therefore will not automatically adapt to new data values. It is necessary to manually re-created those maps that may be affected by an updated of indicator data. The cartographic design guidelines described in section 4.2 of the user manual should be followed in this endeavour.