London Borough of Hounslow

WPI

Heatwave Vulnerability in Hounslow

Nicholas Benoit, Jerish Brown, Benjamin Mattiuzzi, Connor Murphy

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Heatwave Vulnerability in Hounslow

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by
Nicholas Benoit
Jerish Brown
Benjamin Mattiuzzi
Connor Murphy

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Report Submitted to:

Twm Palmer
London Borough of Hounslow, Contingency Planning Unit

Professors Dominic Golding and Jennifer deWinter
Worcester Polytechnic Institute

Abstract

The purpose of this project was to aid the London Borough of Hounslow in improving their heatwave emergency plans and to assist in an experimental project that aims to determine if heatwave models can be used for emergency planning. We accomplished these tasks by first reviewing previously developed models in order to build an operational definition of vulnerability. We then began a large-scale review of data available in the borough that could be used for heat wave modelling and emergency planning. Finally, we created a set of recommendations for the borough and highlighted areas we found to be most at risk to heatwaves based on the data we identified. We also pinpointed key areas of our project that future projects may want to expand upon.

Acknowledgements

Our project would not have been possible without the help and support of many amazing individuals and organizations during our time in the London Borough of Hounslow. We would like to thank the following individuals for their immense contributions to our project, without who we would not have been able to succeed.

First and foremost, we would like to thank our sponsor, Twm Palmer, Head of Contingency Planning and Resilience for the London Borough of Hounslow. It was our distinct pleasure to take the Piccadilly line to Hounslow every day; your guidance, steady hand, and impeccable British sensibilities made each and every day an amazing experience that we will not soon forget. Thank you for everything you have done to make our project a success.

To our colleagues at the London Borough of Hounslow, we would like to extend sincere thanks for making us feel welcome, and making time for us in your very busy schedules. We would like to thank Tim Arnold and Fiona Mair for all the help they gave us around the office. It was our pleasure to share the Emergency Control Center with you. We would like to thank Vinesh Govind for his GIS wizardry, our project would not have been possible without your help. We would like to thank Rory Prendergast and Martin Tomkins for answering our unending questions about housing data. Thank you to Laura Maclehose, John Morgan, Andrew Heap, and Sally Duhig for helping us investigate sensitivity data. Many thanks to Matthew Kay for your help in navigating the difficult PIA process. Thank you to Mark Blomfield, Sean Doran, and Martin Waddington for making themselves available to us.

To the Steering Group members at the University College of London, we would like to thank you for making yourself available to us, for your patience and constructive feedback on the direction of our project, and for your assistance with data modeling. We would like to thank Jonathon Taylor for his assistance in generating the indoor temperature model based on the EPC data, we could not have accomplished this without your help. Thank you to Anna Mavrogianni for leading us to multiple data sources, previous research projects that proved to be invaluable to our understanding of heatwave vulnerability, and providing us with contacts to heatwave vulnerability experts.

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Finally, we would like to thank our advisors, Dominic Golding and Jennifer deWinter, for all of their time and effort to help make sure we have the means to produce the best project possible. Your help editing reports and discussing methods, research, and deliverables was truly invaluable to our project. We could not have completed this without your help.

Executive Summary

Recent heatwave events, such as the European heatwave of 2003 that resulted in seventy thousand deaths across the European Union (Robine et. al., 2008), show that emergency planners need to be increasingly prepared for these situations in order to respond effectively. Understanding where vulnerable populations are located is important for emergency planners in mitigating the risk and damage of these events. To better understand which populations are vulnerable and where they reside, researchers have developed models that can determine the vulnerability of individual dwellings and the people who reside in them.

These models have been evaluated at the national and city-wide level, but not at smaller scales such as at the borough level. A group of researchers at the Greater London Authority, University College London, Meteorological Office, Public Health England, London Climate Change Partnership, and the University of Westminster are attempting to evaluate if heatwave models can be used to help emergency planning at the borough-level by piloting the study in the London Borough of Hounslow. Researchers need to know what data is available within the London Borough of Hounslow and what the use of that data is when compared to more widely available public data in order to complete the pilot study.

Our project's main objectives were to create an operational definition of vulnerability, work within the borough to identify data that can be used to further heatwave emergency planning efforts, and analyze the data found for its usefulness. We reviewed definitions of vulnerability within multiple heatwave models. This allowed us to understand what kinds of data may be useful. We then identified many sources of data within the borough by interviewing borough employees from various departments. Finally, we developed recommendations for the borough based on findings about the available data.

Developing an Operational Definition of Vulnerability

In order to develop an operational definition of vulnerability, our team researched four heatwave models. The LUCID project is the basis of many studies that have simulated urban heat islands and used localized weather data to analyze the indoor temperature of buildings within the Urban Heat Island (Kolokotroni, 2007). The Triple Heat Jeopardy Framework used age as a proxy for

vulnerability, combined with location within the Urban Heat Island and indoor heating modelled using building characteristics, to model mortality. AWESOME examined how air quality combined with indoor temperature affects health. Finally, the Development of a Heatwave Vulnerability Index for London is a study that assigned a vulnerability rating for each Lower Super Output Area based on 10 risk factors.

During our review of the literature, we found definitions of vulnerability are all characterized by a combination of internal and external factors, sensitivity and exposure. We defined vulnerability as a function of local exposure to heat and the sensitivity of individuals. By comparing similar vulnerability factors found within each project, our team identified a number of factors to be most prevalent to heatwave vulnerability: Regional climate, UHI location, indoor heat exposure, high population density, green space, proximity to industry, age, sex, medical condition, socioeconomic and demographic status, social isolation, minority status, and airborne pollutants.

Identification of Vulnerability Data

To identify available data sets on the discussed proxies, our team began by reaching out to interview staff in the London Borough of Hounslow that were recommended by our sponsor, and individuals outside the borough recommended by the Steering Group. The Steering Group is comprised of members of multiple organizations within the Greater London Area who have a stake in heatwave vulnerability planning. Members include our sponsor, the London Borough of Hounslow Contingency Planning Unit, researchers and heatwave vulnerability experts from University College London Institute for Environmental Design and Engineering, health and vulnerability experts from Public Health England, and policy makers from the Greater London Authority and the Mayor's Office.

We identified multiple sources of data within the London Borough of Hounslow and without; including the London Borough of Hounslow Social Housing databases, multiple layers of the London Borough of Hounslow GIS, a weekly Vulnerable Clients list sent to the Contingency Planning Unit, the public Energy Performance Certificates database, and the United Kingdom Census. From the EPC database, through collaboration with Jonathon Taylor at UCL, we were able to create a new data set that models indoor temperature for buildings in the London Borough of Hounslow at different outdoor temperatures.

Assessment of Datasets

In order to effectively evaluate the data sets identified, we created a set of standard criteria that could be used to assess the various different types of data we encountered. These suitability criteria would allow us to give a qualitative measure of their usefulness. The criteria we chose are accessibility, age, reliability, resolution, pertinence, and completeness of the data set. We chose these criteria based on the factors identified to us by our sponsor and the Steering Group as most important in the data we were discovering. We used these criteria to evaluate data from the United Kingdom Census, the Energy Performance Certificate database, the London Borough of Hounslow Social Housing database, the London Borough of Hounslow Geographic Information System database, and Indoor Temperature Model data provided by Jonathon Taylor at UCL.

Conclusions and Recommendations

Throughout our project, we were faced with challenges that made it difficult to collect and analyze important data, but despite these challenges we have been able to discover and analyze multiple data sets related to heatwave vulnerability.

Vulnerability Analysis

- An assessment of the effectiveness of complex vulnerability analysis and indices reliant on composite measures of vulnerability will need to be pursued by emergency planning officials within the London Borough of Hounslow and researchers from the Hounslow Heatwave Steering Group.
- We believe targeting vulnerable areas with additional information prior to and during heatwave events will help reduce the risk of increased morbidity and mortality during a heatwave. Using MOSAIC data available on the Hounslow GIS, targeted information can be broadcast to the residents of these areas using the most effective means of communication for the prevalent demographics.

Vulnerability Factors and the Indoor Overheating Model

When analyzing the layers from the GIS, there were areas that became clearly identifiable as vulnerable to a variety of proxies our team had identified. Though we were not qualified to identify the weights of comparative proxies within the layers, our team conducted a count of recorded areas and the prevalent proxies that were found for each.

- We recommend emergency planners use high indoor heat exposure trends to place cooling centers and allocate resources more effectively. Additionally, this can allow targeted warning and informing procedures for neighborhoods most likely to be adversely affected in the days leading up to a heatwave.
- We recommend targeting neighborhoods that show trends of overheating for improvement projects that mitigate the effects of heatwaves can target dwellings identified as most likely to overheat.

Housing Data

We found that the borough does not hold data on the privately owned housing within the borough. The indoor overheating model could be improved by having access to highly accurate data on all housing within the borough.

- We recommend that the borough carries out the CROHM assessment on privately owned housing stock in order to have a complete housing characteristics data set.
    - This data can be used by researchers to model indoor temperature exposure at the address level.
    - The data can be mapped in order to spatially analyze trends of high heat exposure. This has implications for emergency planning and long-term development and regeneration within the borough.

Future Projects

- We recommend that future projects look further into the data identified in this report by having thorough discussions with the teams and individuals identified as owners of the data. In particular, the borough's Health and Wellbeing and General Practitioners or Clinical Commissioning Groups that work with the borough. Collaboration may provide

Emergency Planners with more information about vulnerable people within the London Borough of Hounslow than they currently have access to.

- We recommend that future projects complete the Privacy Impact Assessment (PIA), a document that is required in order to access data that the borough holds, early on in their project timeline. The PIA was a major roadblock in our project and we anticipate that it will also be a challenge for future projects.

The London Borough of Hounslow has the opportunity to save lives, more effectively allocate resources, and improve the wellbeing of its most deprived citizens through improved heatwave response and emergency planning. Our recommendations can be implemented provisionally and assessed in by qualified researchers and emergency planners in order to test their effectiveness. If shown to be effective, these measures could be integrated into the London Borough of Hounslow's heatwave plan.

Authorship

Throughout the course of our project our team relied on the unique skills of each of our team members.

During our background research, all team members reviewed the same set of literature, however, we found the best use of our time was to designate one team member as the primary researcher for each piece of literature we reviewed. This allowed our whole to team to generally understand the concept, and have one group member with a depth of understanding. This procedure saved time for our group and allowed us to review more literature than if the entire group spent the same time on each document.

During our tenure in Hounslow, we assigned roles based on each team member's skills. This led to the work being distributed evenly and completed by the group member with the most relevant skill set. This procedure was continued during our writing process. Members contributed to the paper's body based on their areas of knowledge. Shown in the table below is a summary of our group's typical roles, which we believe to be equal in contribution to the success of this project.

Task	Roles
Background Research	NB, JB, BM, CM
Interview Secretary	NB, CM
GIS Map Creation & Analysis	CM
Indoor Temperature Map Creation & Analysis	JB, BM
Dataset Assessment	NB
Primary Drafting	NB
Secondary Drafting	JB, BM, CM
Major Editing	NB, JB, BM, CM
Line Editing	NB, BM, CM
Formatting	JB
Final Presentation	NB, JB, BM, CM

NB – Nicholas Benoit. JB – Jerish Brown. BM – Benjamin Mattiuzzi. CM – Connor Murphy.

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Introduction

Recent heatwave events, such as the European heatwave of 2003 that resulted in seventy thousand deaths across the European Union (Robine et. al., 2008), show that emergency planners need to be increasingly prepared for these situations in order to respond effectively. Understanding where vulnerable populations are located is important for emergency planners in mitigating the risk and damage of these events. To better understand which populations are vulnerable and where they reside, researchers have developed models that can determine the vulnerability of individual dwellings and the people who reside in them.

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Our project's main objectives were to create an operational definition of vulnerability, work within the borough to identify data that can be used to further heatwave emergency planning efforts, and analyze the data found for its usefulness. We reviewed definitions of vulnerability within multiple heatwave models. This allowed us to understand what kinds of data may be useful. We then identified many sources of data within the borough by interviewing borough employees from various departments. Finally, we developed recommendations for the borough based on findings about the available data.

Preliminary Research

Heatwaves are a growing problem for those living in the United Kingdom. Scientists and policymakers agree that the risk of harm from heatwaves in London has greatly increased as a result of climate change. (Murphy et. al., 2009) In the United Kingdom heatwaves are defined for emergency planners as an extended period of heat where the "average threshold temperature is 30 °C by day and 15 °C overnight for at least two consecutive days" (Met Office, 2017). In order to properly understand heatwave events in the United Kingdom and how emergency planners respond to these events, we reviewed heatwave vulnerability-related literature and the laws within the UK that define emergency planning. This section begins by discussing the nature of heatwave events in the United Kingdom and why they are becoming a more pressing issue for emergency planners. We then review the current heatwave emergency response practices for the UK, London, and the London Borough of Hounslow. Next we discuss the definitions of heatwave vulnerability and various models developed to predict characteristics and results of heatwave events. Finally, we examine each study's definition of vulnerability in order to provide a wide scope of definitions.

Recent History of Heatwaves in Europe and the United Kingdom

Heatwave events are becoming a more pressing issue for Europe due to climate change (Murphy et. al., 2009). Since 2003, The United Kingdom has experienced six major heatwaves. The most recent heatwave in 2013 lasted nearly the entire month of July (Meteorological Office, 2015a), and resulted in 540 to 760 excess deaths within only the first nine days of the heatwave (Silverman, 2013). The 2003 heatwave caused more than 70,000 deaths in the European Union, including around 2,000 deaths in the UK (Robine et. al., 2008). The 2003 heatwave had the most impact in France, however, where certain regions experienced up to a 10°C temperature anomaly (Figure 1).

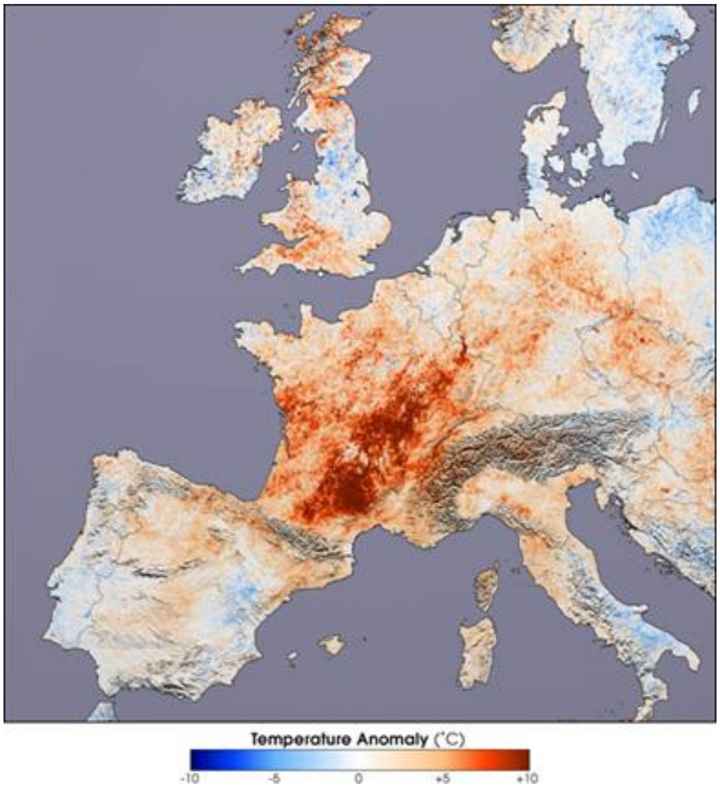

Figure 1. Temperature anomaly in Europe from July 1st to 31st 2003 (NASA, 2003)

Heatwave events are becoming more common as the climate changes and deviation from the typical temperature becomes greater (Figure 2). As such, emergency planners require more robust resources for predicting what areas, dwellings, and populations will be vulnerable to heatwave events.

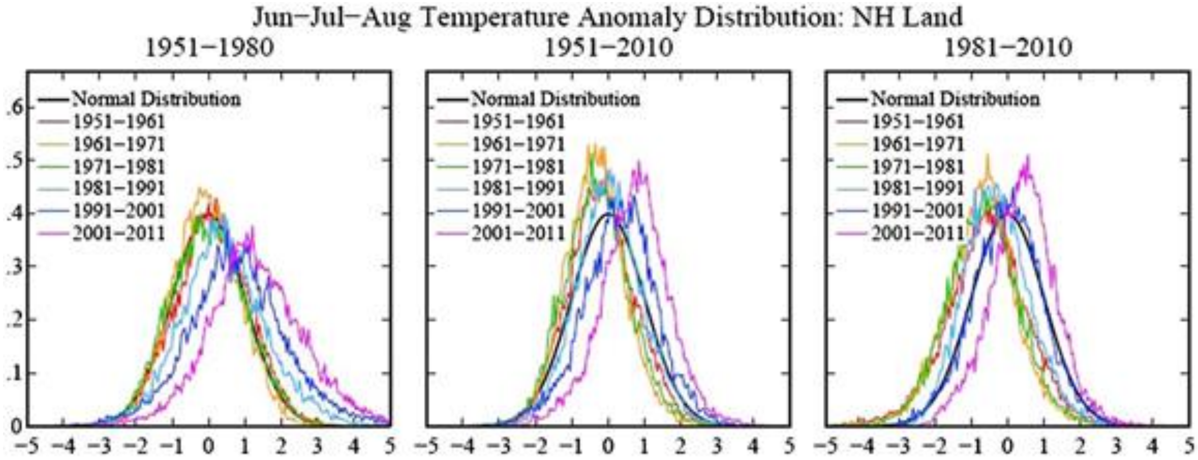

Figure 2. Frequency of summer temperature anomalies (deviation from historical normal) in the northern hemisphere (Hansen, Sato, & Ruedy, 2012)

Current Heatwave Emergency Response Procedures in the UK

National Emergency Response Procedures

According to the Civil Contingencies Act of 2004, an emergency is "a situation which threatens serious damage to human welfare … [or] the environment of a place in the United Kingdom" (The Civil Contingencies Act, pg. 2) and further defines an environmental emergency as any situation that threatens to "contaminate land, water, or air … [or the] disruption or destruction of plant life or animal life" (Civil Contingencies Act, pg. 1-2). The Act clearly defines what an emergency is, and who is to respond to these emergencies in what situations. In addition to giving emergency powers to certain individuals in specific cases, the Act generally sets up a framework for the government to delegate responsibilities to individuals and governing bodies. According to the Act, it is the responsibility of "a person or body to … from time to time assess the risk of an emergency occurring making it necessary or expedient for the person or body to perform his or their duties" (Civil Contingencies Act, pg. 2). Governments are responsible for protecting their citizens, and this includes protection from environmental disasters. In the United Kingdom government organizations like the National Meteorological Office work to raise awareness for emergency preparedness in the community, by releasing up to date weather data every day, sometimes multiple times a day. They make sure individuals can access information regarding different types of natural disaster including what defines different kinds of natural disasters like flooding and heatwaves. Many of the public offices such police services, fire and rescue services, the armed forces, non-departmental public bodies, and even Her Majesty's Coroner are responsible for responding to the needs of the citizens after an emergency. These responsibilities are detailed in the Civil Contingencies act of 2004. The Civil Contingencies Act of 2004 took major steps to define what an emergency is and to lay out plans of action in the event of different emergencies. In response to the Civil Contingencies Act, the London Borough of Hounslow put together the CPU to facilitate identifying and dealing with emergencies.

Regional Heatwave Planning and Response (London)

Heatwaves pose a serious threat to the general public, even though not all people are equally at affected by heatwaves. A joint effort between the National Health Service and Public Health England, the Heatwave Plan for England serves to inform citizens of the risks that heatwaves pose how they can stay safe in the event of a heatwave. The plan, released in 2004, is updated yearly in order to stay up to date with current emergency response practices. Beyond the requirements of the Civil Contingencies Act, the Heatwave Plan for England also lays out a specific framework for how the country as a whole is to prepare for, identify, and respond to heatwaves. The Heatwave Plan for England is composed of five main Alert Levels (Figure 3) and spans measure from year round "long term planning and joint work to reduce the impact of climate change and ensure maximum adaptation to reduce harm from heatwaves" (Heatwave Plan for England, pg. 13) all the way to actions that should be taken in the event of a severe nationwide heatwave.

Level 0	**Long-term planning -** All year
Level 1	**Heatwave and Summer preparedness programme -** 1 June – 15 September
Level 2	**Heatwave is forecast – Alert and readiness -** 60% risk of heatwave in the next 2 to 3 days
Level 3	**Heatwave Action -** temperature reached in one or more Met Office National Severe Weather Warning Service regions
Level 4	**Major incident – Emergency response -** central government will declare a Level 4 alert in the event of severe or prolonged heatwave affecting sectors other than health

Figure 3. Graphic representation of Heatwave Plan for London (Heatwave Plan for England, 2015)

The Heatwave plan consists of five Alert Levels. Alert Level 0 and Alert Level 1 are both preventative levels. London stays at Alert Level 0 year-round until the beginning of June. The period from June 1st to September 15th brings London to Alert Level 1. Then if the Meteorological Office predicts that there will be a heatwave in the next 2 to 3 days, the London moves to Alert Level 2 at which point government agencies begin to prepare to handle the consequences of the coming heatwave as well as reach out to the citizens and make them aware of the services that are available during the impending heatwave. Alert Level 3 is reached when the Meteorological Office officially declares a state of heatwave emergency. At this level a heatwave is expected to cause health risks, so hospitals and other healthcare institutions are on high alert. Finally, if a heatwave begins to threaten any kind of infrastructure, an Alert Level 4 emergency is declared

Local Heatwave Planning and Response (Hounslow)

The London Borough of Hounslow's heatwave plan operates in a similar fashion to London's heatwave plan. Emergency response to heatwave events operates under the five heatwave alert levels defined in London's heatwave plan. The borough receives notifications from the Met Office, including early warnings about potential heatwave events and warnings about severe or hazardous weather. The CPU alerts relevant internal and external organizations (Figure 4). Alert Level 2 is triggered once the Met Office determines that there is a "60 per cent chance of temperatures being high enough on at least two consecutive days to have significant effects on health" (London Borough of Hounslow, 2016).

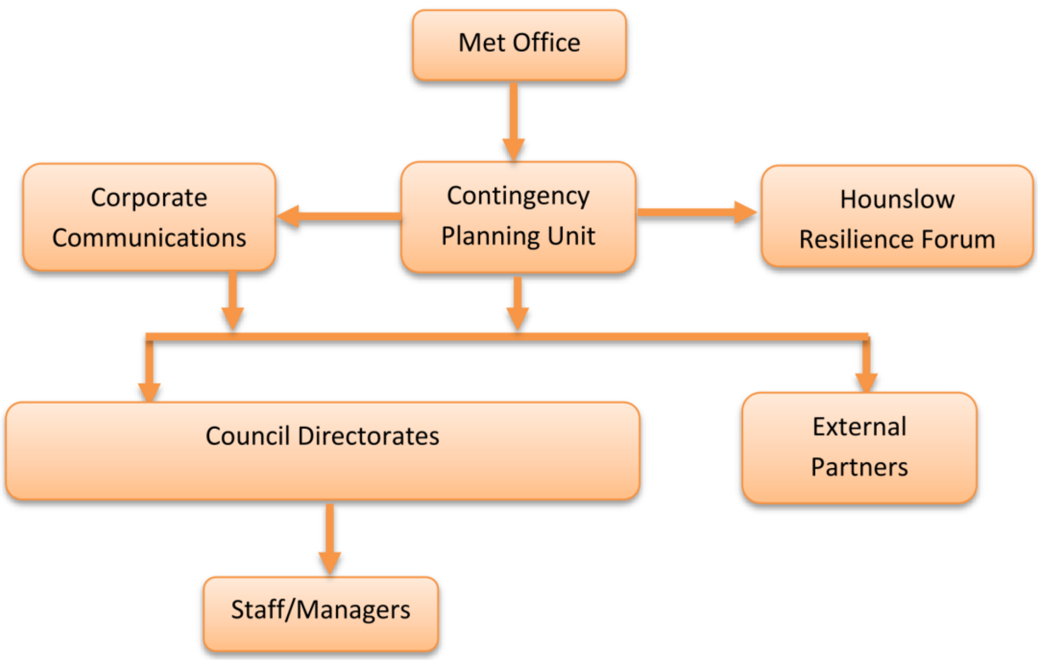

Figure 4. Communications Cascade (London Borough of Hounslow, 2016)

The heatwave plan defines the actions that organizations within the borough will take based on the declared alert level. These actions, laid out in "action cards," cover the entirety of high-level tasks that different organizations take in the event of a heatwave. Table 1 on the following page is an example of actions taken by chief executives within the borough. Alert Level 1, which deals with maintaining emergency awareness and readiness, is the lowest state for heatwave emergency planning. Alert Level 2 begins to give additional care and assistance to people who are deemed more at-risk to heatwave events (defined in section 1.1 of the heatwave plan). These people include the elderly, those with chronic or severe illnesses, those who are homeless, and those who take medications that affect the body's ability to manage its own temperature. Faith and voluntary groups check in once daily with these groups of people. Emergency planning efforts during Alert Level 2 include monitoring areas with thermostats are monitored to check if indoor temperatures exceed 30^{o}C, notifying schools and nursing homes that a heatwave is expected, and recalling staff who have a key role in managing heatwave emergencies. All care, residential, and nursing homes are required to keep cool rooms at 26^{o}C or under, and particularly vulnerable individuals are prioritized for time within the cool rooms. Finally, actions from Alert Level 3 that may need to be implemented are reviewed by the borough in order to maximize preparedness.

Table 1. Chief Executive Action Card

Phase	No.	Action	
Action Level 1	**1**	Maintain department business continuity planning	All
	2	Ensure awareness of response roles within a heatwave	All
Action Level 2	**1**	Distribute notification that Alert Level 2 has been reached to faith and voluntary groups with emphasis on checking at least once a day on those who are vulnerable during a heatwave. (those designated in Section 1.1)	Community Partnerships
	2	Community Partnerships 2 Distribute notification that Alert Level 2 has been reached to LBH funded and private care, residential and nursing care homes (including day centres).	Communications Team
	3	Develop Communications messages in partnership with the Contingency Planning Unit.	Communications Team
	4	In areas where thermometers are available, staff must inform the building manager (LA) if internal officer temperature exceeds 30oC.	Communications Team
	5	Collate a list of vulnerable employees and ensure they are alerted of a potential heatwave.	Human Resources
	6	Assess the need to cancel leave where staff have a role in managing key heatwave actions.	Human Resources
	7	Review actions from Alert Level 3 that may have to be implemented.	All
Action Level 3	**1**	Ensure that visits or phone calls are made to check on high risk individuals (those designated in Section 1.1)	Community Partnerships
	2	Ensure discharge planning takes into account the temperature of the accommodation and level of daily care during the heatwave period	Community Partnerships
	3	Ensure that visits or phone calls are made to check on high risk individuals (those designated in Section 1.1)	Community Partnerships
	4	Distribute messages to all staff that those undertaking site/home visits are to take appropriate personal protective equipment	HR Services

		including sunscreen and a bottle of water. All site and home visits must be rearranged to early or late in the day, where it is cooler. Staff should not work anywhere they are not comfortable in or indoor areas above 30ºC (or 26ºC if classed as vulnerable according to Section 1.1) and should take regular breaks in a shaded area. The manager of a service is responsible for deciding if site visits should be suspended due to health and safety reasons.	

Alert Level 3 is the most severe level handled at the borough-level. The heatwave plan dictates that high-risk individuals are all checked on daily and supplied with assistance and cold drinks. Temperatures are constantly monitored and controlled as feasible in all care, residential, and nursing homes. Educational facilities are advised to stop administering physical activities, and not use rooms that are above 30ºC. Alert Level 4 is declared and managed at a national level. At this point there is a risk of power and water shortages, and a threat to the integrity of health and social care systems. The borough continues actions from Alert Level 3, and responds to additional guidance from the lead government department.

Comparing Heatwave Vulnerability Modelling Techniques

In order to properly plan for and respond to emergency events, emergency planners must identify groups within the population that are considered vulnerable or more likely to suffer harm in a hazardous event. Vulnerability is unique to each individual, but also is reflective of a larger group of characteristics, such as age, medical conditions, economic status, or location. When analyzing the vulnerability of a population, considering both the sensitivity of the individual members and the levels of risk that are present across socioeconomic and spatial urban settings is important (Fernandez Milan & Creutzig, 2015). Exposure to heat, sometimes called 'extrinsic factors of vulnerability,' can be grouped into major categories of location susceptibility and social susceptibility. Individual sensitivity to heat, or the adaptive capacity of an individual to cope with extreme heat, is categorized by characteristics of an individual as well as socio-economic circumstances. We reviewed multiple studies concerning heatwave vulnerability, and identified the most common factors used to measure vulnerability, shown in Table 2.

Table 2. Exposure and Sensitivity

Study	Exposure			Sensitivity		
	UHI	Green Space	Indoor Exposure	Age	Medical Condition	Socioeconomic/ demographic status
HVI for London	X		X	X	X	X
Neighbourhood Microclimate	X	X	X	X	X	X
THJF	X		X	X		
LUCID	X	X				
AWESOME	X				X	X
Reducing Urban Heatwave Risk	X	X	X	X	X	X
Strategies for Urban Climate	X	X	X			

The factors identified in the table above represent only the most commonly identified factors contributing to heatwave vulnerability across the literature we reviewed. For more information about factors contributing to vulnerability, see the Appendix C.

Development of a Local Urban Climate Model and its Application to the Intelligent Design of Cities (LUCID)

The *Development of a Local Urban Climate Model and its Application to the Intelligent Design of Cities*, or LUCID, project was a research project funded by the Engineering and Physical Sciences Research Council to develop "world leading methods for calculating local temperature and air quality in the urban environment", and has become the basis of further studies that have simulated urban heat islands and used localized weather data to analyze the indoor temperature of buildings within the UHIs (Kolokotroni, 2007). For LUCID to accomplish its goal, the project set out three major objectives:

1. To develop a new integrated tool to model the local climate in urban areas based on the dynamic and thermodynamic processes associated with land use and building form;
2. To use the model to explore the complex relationships between the projected changes to regional climate and local urban climate and the impact on energy use;
3. To evaluate the impacts of local temperature and air quality on health as a result of a changing climate. (EPSRC, 2010)

These objectives were further deconstructed into five project modules designed to satisfy different parts of each objective. The first focused on model development using Cambridge Environmental Research Consultant's *ADMS-Urban Model* and the *Reading Urban Model* (RUM) to create a new tool for urban microclimates (Belcher, 2010). The ADMS-Urban models air quality in large urban areas, cities and towns is the only model that represents a full range of source types, taking emission sources such as "traffic, industrial, commercial, domestic, and less well-defined sources" into account to provide outputs from street-scale to urban-scale (Belcher, 2010). The Reading Urban Model calculates the fluctuation of thermodynamic energy throughout urban surfaces while also accounting for "shadowing and reflection by buildings on the radiative fluxes, storage of heat in the building fabric and transport of heat into the atmospheric boundary layer" over a unit of one square kilometer (Belcher, 2010). To "develop state-of-the-art methods for calculating local climate and air quality in the urban environment", the two models were linked; the RUM determined variables to be further used as boundary conditions for ADMS model, allowing "calculation of temperature variations at high spatial resolution (hundreds of metres)" (Belcher, 2010).

For the model to be used effectively, its validity was tested against measured temperature data obtained from an extensive monitoring program in the second module (Davies, 2010a). These data sets were collected from "an existing fixed measurement dataset of 80 locations within the Greater London area over an 18 month period, the London Air Quality Network (LAQN), mobile sensors installed in a group of taxis with associated GPS technology, remotely sensed satellite data, and supplementary fixed location temperature gathering experiments in selected locations", which together garnered a variety of complementary temperature data (Davies, 2010a). To use this data, the Project LUCID team implemented an existing virtual London model developed at the UCL's Centre for Advanced Spatial Analysis, in combination with aerial photos of London to validate existing characteristics of ground surfaces, to produce a three-dimensional representation of London's built form that was drawn and linked together (Davies, 2010a).

The third module explored the relationship between not only built form and temperature, but energy and land use to better devise design strategies for temperature control (Steadman, 2010). Existing data on traffic emissions, building activity, census records, and energy use were all used collectively to quantify general levels of energy production for different building types and activities. Furthermore, with the combination of gas and electricity supply data, the module built on "previous work which investigated the impacts of predicted climate change on buildings" (Steadman, 2010). Statistical analysis was then carried out to "relate the various descriptors of the urban built environment to the predictions of external temperatures, humidities, and air flows from the model developed in project module 1" (Steadman, 2010). The results of this module were used to develop guidelines for future design and planning in urban areas that would enhance airflow throughout the area while mitigating local temperature.

The application of the temperature and pollution model was to investigate the impacts on the health through studying the "variation in the risk of heat-related mortality within London and to estimate the potential future burdens of heat-related mortality over coming decades" (Wilkinson, 2010). The final result of LUCID emerged from the linking of four data sets: "modelled micro-variations in temperature and airborne pollutants, daily mortality data geo-referenced using full postcodes, socio-demographic characteristics, and data on the characteristics of domestic properties", through the use of a GIS database (Wilkinson, 2010). The analysis of these results compile the data in two forms: a simple graphical presentation (also expressed in table form), and a more sophisticated time-series regression (Wilkinson, 2010). These two deliverables were used in future urban planning with the help of predicted temperatures affected by the impacts future climate change, further explained in the fifth and final module, the final report (Davies, 2010b).

Mapping the effects of urban heat island, housing, and age on excess heat-related mortality in London (Triple Heat Jeopardy)

The "Mapping the effects of urban heat island, housing, and age on excess heat-related mortality in London" study by researchers at University College London, London School of Hygiene and Tropical Medicine, and University of Reading builds upon work from the LUCID project using modelled Urban Heat Island (UHI) for a period within the project where a hot spell occurred (May 26th to July 19th). The model combines age, sex, building characteristics, and the UHI into a single indicator of risk. These data sets were sourced from the 2011 Census, the Office of National Statistics, the English Housing Survey, and the Homes Energy Efficiency Database. The data sets were combined by summing the population, summertime mortality rate, and relative risk of mortality due to temperature for every age bracket in order to compute the relative risk of mortality for a specific ward. Inputting age and sex data from the Census allowed for the team to estimate mortality per million people (Figure 5) during the LUCID study period.

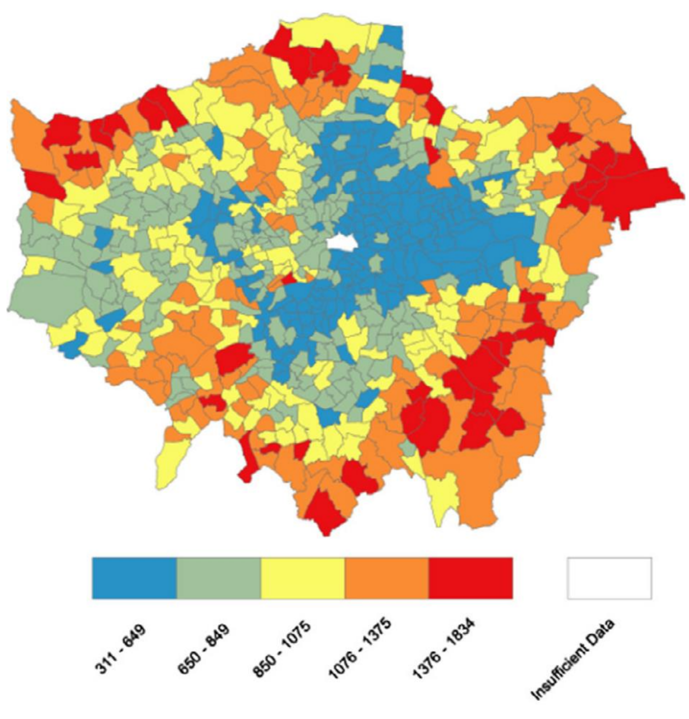

Figure 5. Estimated mortality per million people during the LUCID period (Taylor et. al., 2015)

Air pollution and WEather-related health impacts: methodological study based on Spatio-temporally disaggregated multi-pollutant models for present-day and future (AWESOME)

In order to examine how air quality combined with indoor temperature affects health, a group of researchers conducted studies from January of 2011 until December of 2014 in which the team tried to determine the best way to model the distribution of air pollutants and indoor temperatures within London. They detailed this project in their reports on Air pollution and weather-related health impacts: methodological study based on spatio-temporally disaggregated multi-pollutant models for present-day and future (AWESOME). The specific goals of the project were to produce were to examine how air quality combined with indoor temperature affects health. The specific goals of the project were to produce models of the air pollutants in London from 2000 to 2010 and perform epidemiological studies by comparing model results with data from sites in the Greater London area. Next the team successfully combined their air quality model with an indoor environment model (such as EnergyPlus) to create a composite exposure index. Finally, the team attempted to use the composite exposure model they created to analyze mortality and morbidity in the greater London area and determine how environmental policy changes in London affected the mortality and morbidity due to indoor and outdoor pollutant exposure. Vulnerability, as mentioned above, is a composite of a person's sensitivity to a stimuli and their exposure to it. AWESOME stands out from other similar projects because it aimed to explore different exposure metrics rather than sensitivity metrics. After the work on the project was completed the team was able to produce a systematic way to evaluate pollution data in context with the urban heat island effect.

AWESOME focused on two primary exposure factors, indoor temperature and air pollution. The indoor environment was modeled using EnergyPlus and the assumptions made by the team are detailed in Mavrogianni, Wilkinson, Davies, Biddulph, Oikonomou, 2012. The team used a set of 27 different build forms, two insulation levels for four construction elements (walls, windows, ground floor and roof), four directions of the front of the building (north, south, east and west), and lastly two external morphologies (whether the building is stand alone or part of a larger unit) (Mavrogianni, Wilkinson, Davies, Biddulph, Oikonomou, 2012). Note that of the 27 build forms, there are 15 build archetypes some of which have variations, and these variations are considered different build forms. These 15 archetypes include detached and semi-detached homes, bungalows, and blocks of flats with internal and external corridors (these two types of flats are considered different). This modeling of indoor temperature found many things, including that there tends to be an appreciable difference between mean and max indoor daytime living room temperature based on outside temperatures, that there were generally greater variances of temperature within different dwelling types than between them, and that the type of retrofitting that was done to the insulation mattered greatly in how the buildings temperature reacted (Mavrogianni et. al. 2012). These differences within each dwelling type likely stemmed from the imperfect nature of the model. The resulting data from the simulation can only be as accurate as the data put in, and since it would difficult to take accurate measurements on every building in London, the above assumptions had to be made to run the simulation. Since indoor temperatures rely so heavily on the qualities of the building, even small variations between buildings of a single type can have huge impacts on the final internal temperature. Furthermore, roof and window retrofittings were shown to decrease indoor temperatures while wall and floor retrofittings were shown to increase indoor temperatures (Mavrogianni et. al. 2012). Figure 6 below demonstrates that there were, in some cases, much larger changes in indoor temperature within a build form than between the build forms. This study of indoor environment laid the foundation for other studies to continue modeling indoor environment.

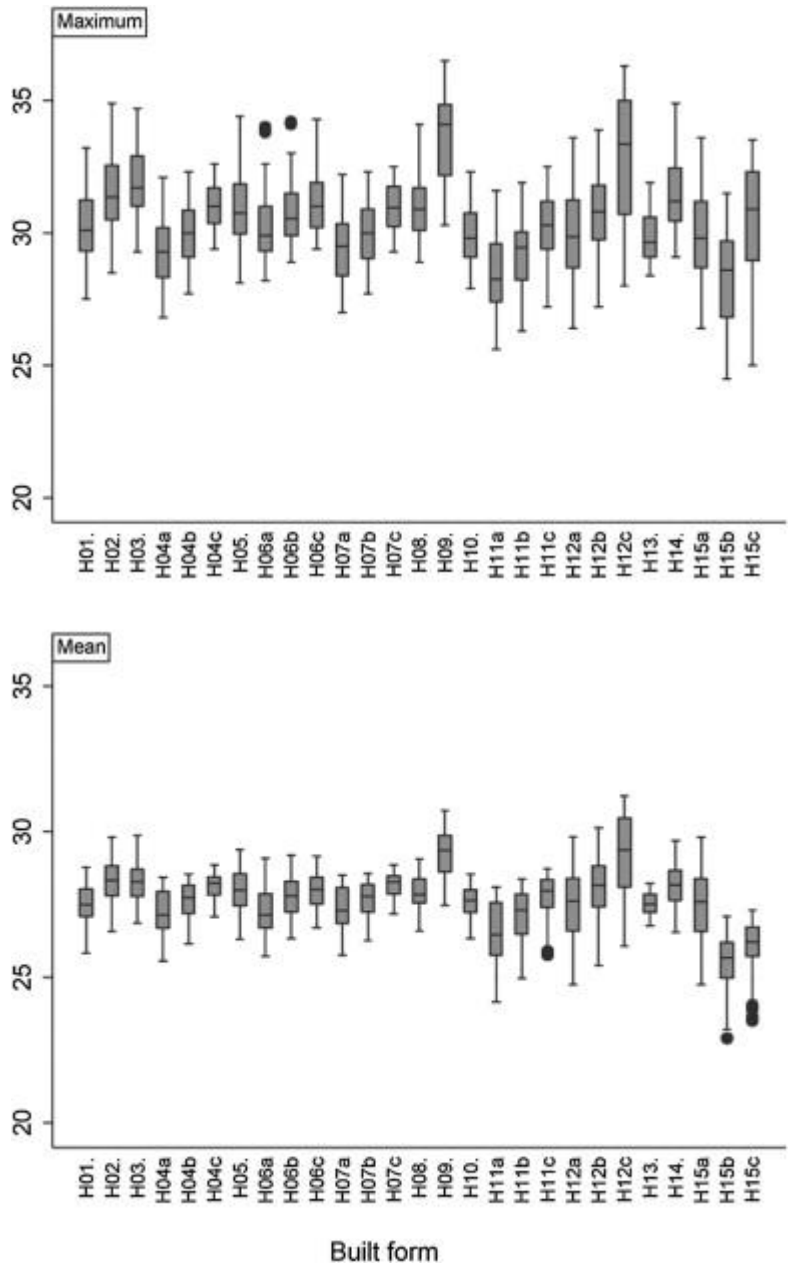

Figure 6. Mean and Maximum temperatures for different build forms tested in the EnergyPlus simulations (Mavrogianni et. al, 2012).

The second main focus of the AWESOME project was to model indoor pollutants, namely $PM_{2.5}$. $PM_{2.5}$ is any particulate matter that exists in the air that is less than 2.5 micrometers in diameter. These kinds of particles are generated by many everyday activities. Some common sources of $PM_{2.5}$ particles are a car's exhaust, burning natural gas or smoking a cigarette. $PM_{2.5}$ particles are small enough that they are easily inhaled and lodge in the lungs of exposed individuals leading to a variety of health problems. Three Percent of all mortality from cardiopulmonary disease and about 5% of cancer of the lungs, throat, and trachea are estimated to be caused by $PM_{2.5}$ (Taylor, Shrubsole, Davies, Biddulph, Das, Hamilton, Vardoulakis, Mavrogianni, Jones, and Oikonomou. 2014). Taylor et al (2014) tried to determine what affect the building type had on the indoor to outdoor ratio of $PM_{2.5}$ contaminants. The team used the same 27 build forms as detailed in Mavrogianni et al above to simulate the indoor to outdoor pollutant ratio. They ran their model for two different scenarios for the same buildings. In scenario one the only permeation of pollutants into the indoor environment was through the walls and around the windows and doors. The second scenario used data gathered from the CIBSE Guide A, a separate guide created by the Chartered Institution of Building Services Engineers, to simulate the indoor / outdoor pollutant ratio with human interaction to ventilation systems (i.e. people opening their windows when it gets hot inside their home). The two scenarios were run in the same model and the results are shown in Figure 7. The image shows both scenarios run for each of the different seasons (winter, spring, summer, and fall). Clearly, the opening of windows in the summer under scenario 2 greatly increases the indoor / outdoor ratio of air pollutants. The study showed that computer software could be used to simulate indoor pollutant concentration, however the accuracy of the model needs to be validated using real-world data.

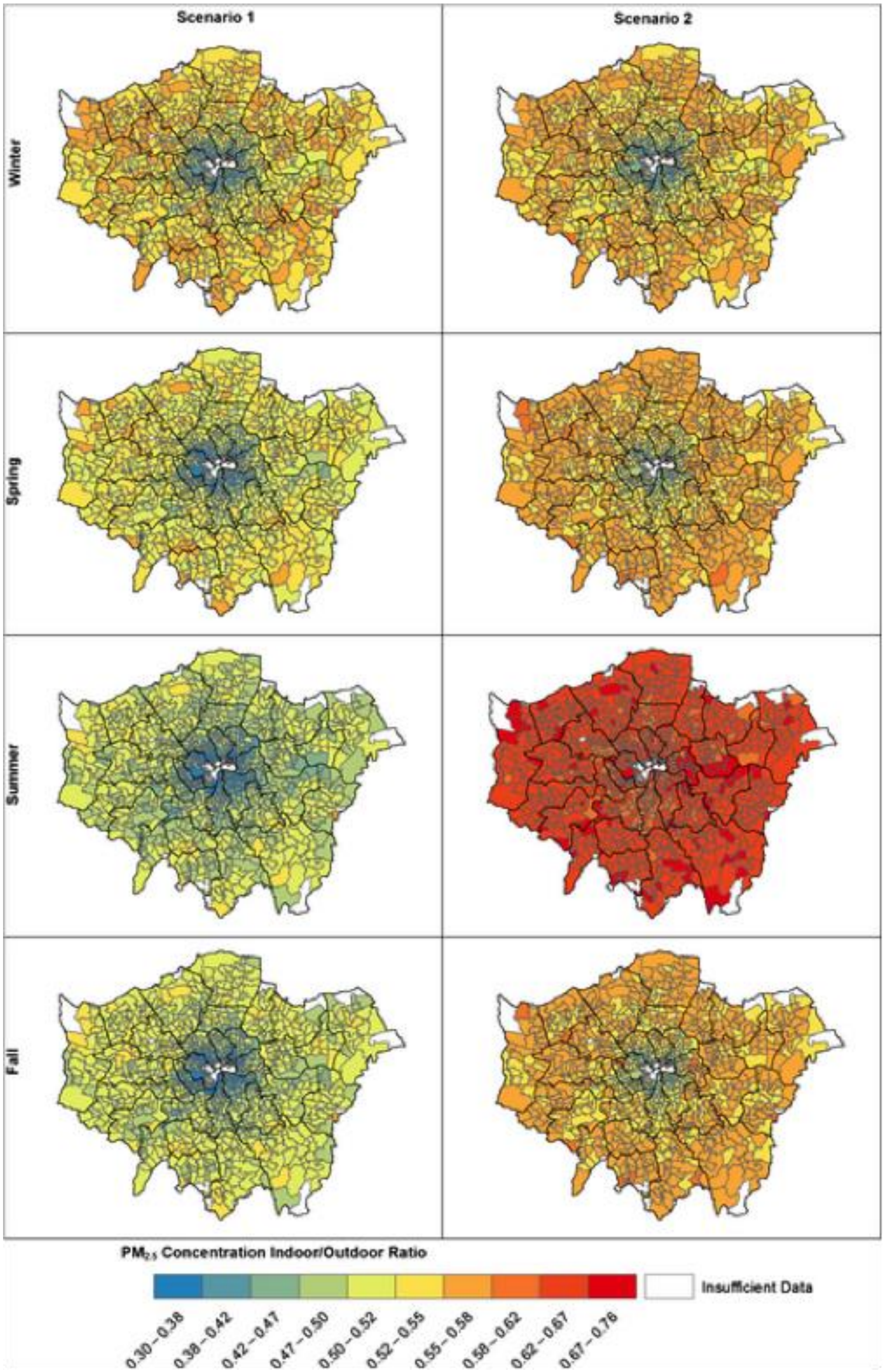

Figure 7. Average seasonal indoor / outdoor pollutant ratio for buildings across London for both scenarios. (Taylor, J. et. al., 2014).

Development of a Heat Vulnerability Index (HVI) for London

The heatwave vulnerability index for London, developed by Dr. Tanja Wolf of King's College London and Dr. Glenn McGregor of the University of Auckland, was created to analyze the location of communities vulnerable to heat within the Greater London Area. In this model, vulnerability is defined as the function of exposure to heat and the sensitivity of individuals, as shown in the figure below.

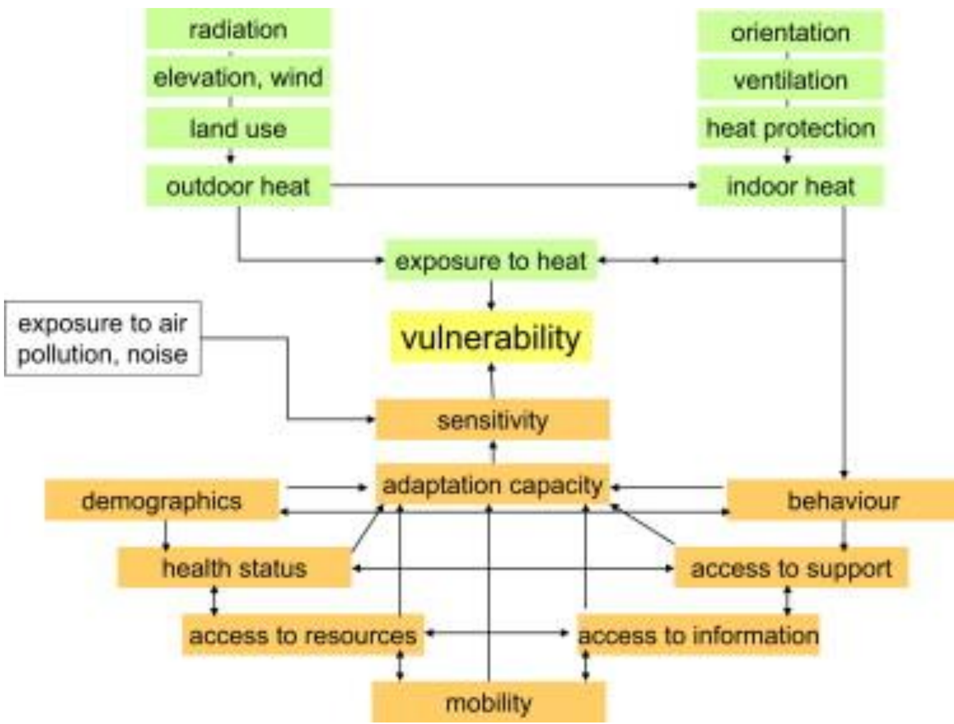

Figure 8. The components of vulnerability (Wolf & McGregor, 2015)

The heatwave vulnerability index uses Principal Components Analysis to analyze risk factors that contribute to sensitivity and exposure (Wolf et al., 2013). PCA was used because unless there are a small number of variables being analyzed or the relationships between the variables are very simple, looking at all of the variances and correlations between the variables are not useful. Instead, looking for a few derived variables, called Principal Components (PC), that preserve most of the information given by all of the variances and correlations in the whole data set is possible (Jolliffe, 1986). The large number and complex synergistic relationships of risk factors contributing to heatwave vulnerability suggests this approach. Five factors were identified as important to risk of exposure and sensitivity of individuals, grouped into four principal components, as shown in the table below.

Table 3. Heat risk factors, and associated census proxies, with associated principal component

Category	Risk Factor	Census Proxy	PC
Heat Exposure	Living in an inner city, and therefore being exposed to the UHI	Population density and MODIS image of the UHI effect	N/A
	Thermo-isolation of dwelling	Households in a rented tenure	1
	Living on a high/top story of a multi-story building	Households in a flat	1
	Living in an area with high population density	Population density (person/ha)	1
	No access to air conditioning	Households without central heating	4
Sensitivity	Being elderly	Population 65+ years of age	2
	Having a pre-existing illness, including mental illness	Population with long term limiting illness, self-reported health status of 'not good'	2
	Low economic or education status	Receiving social benefits	2
	Social isolation	Single pensioner households	3
	Minority status	Ethnic group not "White British"	3

The Principal Components Analysis also weighs the different principal component groups, because not all of the factors contribute equally to vulnerability. Not every factor was available from data collected by the census, so proxies were used based on the available data. Wolf et al. calculated 4765 Heat Vulnerability Index values, one for each Super Output Area in the Greater London Area. These values were grouped into deciles, with the resulting groups mapped to show the spatial variation of vulnerability throughout the city. Hot spot analysis was conducted to look for evidence of clusters of areas with high or low vulnerability, with a goal to find converging areas of high exposure and high sensitivity. Special attention was given to areas with evidence of clusters of high or low social vulnerability. To determine if there are areas within London where clusters of vulnerable people coincide with areas of increased temperature, the Heat Vulnerability Index values were overlaid with the MODIS image of ground temperature (Wolf et al., 2013).

The results of the Development of the Heatwave Vulnerability Index for London indicate a strong tendency for clustering of high vulnerability areas, as seen in the figure below, although there is no tendency for clustering of low vulnerability areas. Vulnerability is higher in central London, especially in the boroughs north of the Thames (Hammersmith and Fulham, Kensington and Chelsea, Westminster, Camden, Islington, Hackney, and Tower Hamlets), compared to the outskirts of the city. There are also small pockets of high sensitivity SOAs dispersed throughout London, often surrounded by SOAs of low sensitivity. 262 high vulnerability, high exposure SOAs exist within London, mostly clustered within the central boroughs of the city north of the Thames (Wolf et al., 2013).

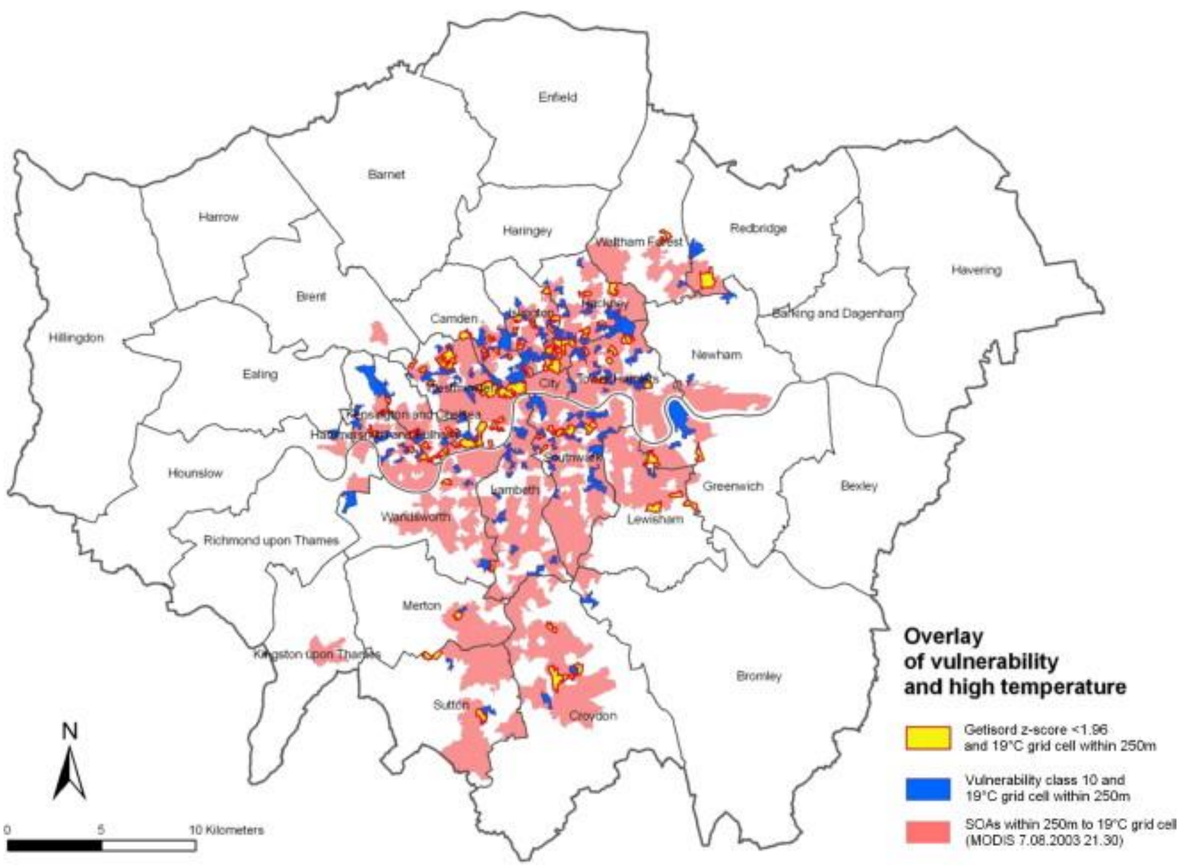

Figure 9. High Exposure and High Vulnerability Index areas (Wolf et al., 2015)

The Heatwave Vulnerability Index has been a major guide for our project in terms of identifying important factors that relate to vulnerability because this study was conducted recently and because it was developed specifically for London. The largest drawback of the HVI is its reliance on the census for data. Census data could be up to nine years old before it is recollected, and it is aggregated at the Output Area level. For emergency planning purposes, data that is more up-to-date and at a higher resolution is preferred. In a borough like the London Borough of Hounslow, where there is high population flux, this represents inaccuracy that emergency planners would like to avoid. Our goal is to identify data sources within the borough that can match with the census data used in the development of the HVI that are more current and at a higher resolution than the census.

Project Objectives

The purpose of our project was to determine what data sets would best be used to indicate heatwave vulnerability and where they were stored for future use in urban planning and emergency response. Our sponsor, Twm Palmer, Head of the Contingency Planning Unit of the London Borough of Hounslow whose responsibilities include managing the Council's responsibilities in Emergency Preparedness, Response and Recovery (EPRR) and the support of the Public Health teams in its delivery (The London Borough of Hounslow), will use the results found within our project to identify areas within the Borough that are the most at risk to adverse health outcomes as a result of extreme heat. Working with the project's steering group, composed of members from partner organizations on the project -- the Greater London Authority (GLA), University of College London (UCL), Meteorological Office, Public Health England (PHE), London Climate Change Partnership (LCCP), and the University of Westminster -- our team set three objectives for our project:

1. Develop an operational definition of vulnerability.
2. Identify and source vulnerability data & proxies in the London Borough of Hounslow.
3. Assess how data can be used for future emergency planning.

Developing an Operational Definition of Vulnerability

In order to develop an operational definition of vulnerability, our team researched past projects and reports on heatwave vulnerability discussed in the Comparing Heatwave Vulnerability Modelling Techniques section of this report, as well as reviewed the current Heatwave Plan for England and the London Borough of Hounslow. The Heatwave Plan for England, developed by the Department of Health to help reduce the harmful effects of heat, uses risk factors for individuals to identify vulnerable people within the population. In Reducing Urban Heatwave Risk in the Twenty-first Century, the primary focus is creating a common framework for reducing the urban heat health impact, combining public health, risk reduction, and urban planning. This approach identifies factors that contribute to the distribution of vulnerability to heat both intrinsically (person specific) and extrinsically (Fernandez Milan et al., 2015). The Heatwave Vulnerability Index, developed to identify the spatial trends of high risk areas in London, defined vulnerability as a function of exposure to heat and sensitivity of people (Wolf et al., 2013). The report Reducing Urban Heat Risk, which focuses on urban heat risk planning and visualization, investigates the effects of location within the Urban Heat Island, characteristics of buildings, and characteristics of people. These definitions of vulnerability are all characterized by a combination of internal and external factors, sensitivity and exposure.

We defined vulnerability as a function of local exposure to heat and the sensitivity of individuals. By comparing similar vulnerability factors found within each project (see Appendix C), our team identified these factors to be most prevalent to heatwave vulnerability: Regional climate, *UHI location*, *Indoor heat exposure*, high population density, *green space*, proximity to industry, *age*, sex, *medical condition*, *socioeconomic and demographic status*, social isolation, minority status, and airborne pollutants. Focusing on the italicized factors, as they were identified in a majority of the literature, we gathered information on the data held by the London Borough of Hounslow that related to the factors identified above.

Identification of Vulnerability Data

To identify available data sets on the discussed proxies, our team began by reaching out to interview staff in the London Borough of Hounslow that were recommended by our sponsor, and individuals outside the borough recommended by the Steering Group. From these initial conversations we were given additional people to reach out to. (Figure 10) Through this method, we established a growing list of contacts we could ask for information about data. For more information about our interview methods, see Appendix D.

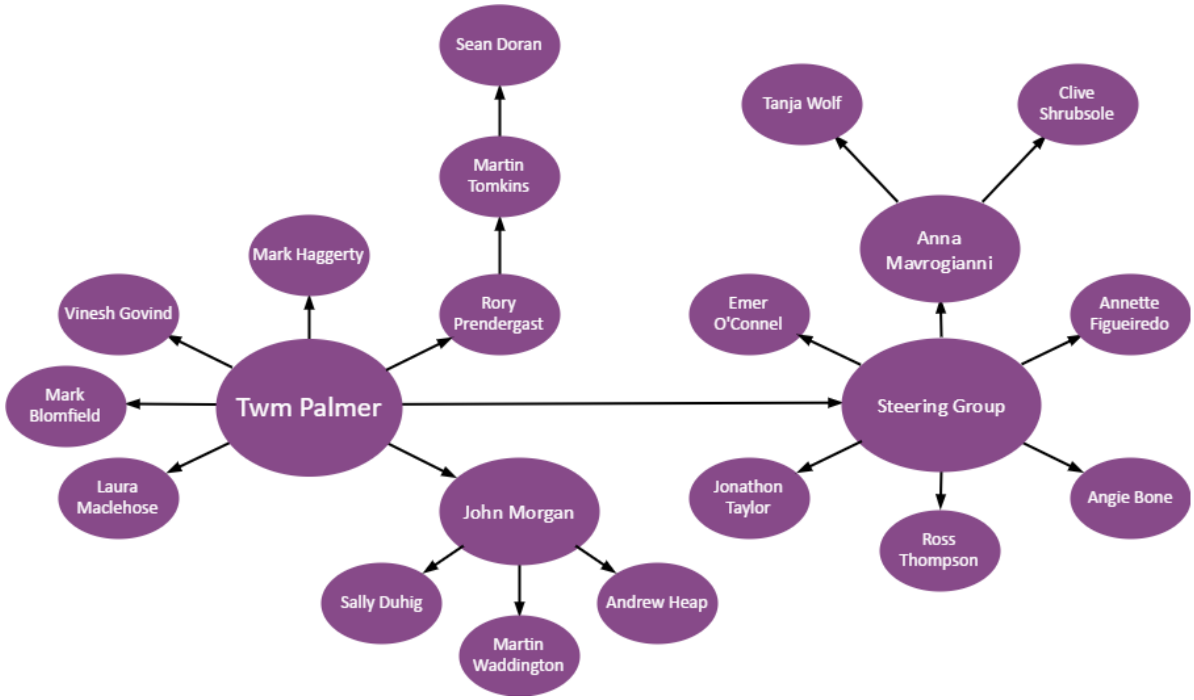

Figure 10. Contact Flowchart

The London Borough of Hounslow Heatwave Steering Group

The Steering Group is comprised of members of multiple organizations within the Greater London Area who have a stake in heatwave vulnerability planning. Members include our sponsor, the London Borough of Hounslow Contingency Planning Unit, researchers and heatwave vulnerability experts from University College London Institute for Environmental Design and Engineering, health and vulnerability experts from Public Health England, and policy makers from the Greater London Authority and the Mayor’s Office. During our first meeting with the Steering Group, we wanted to establish each organization’s stake in our project, as well as what relevant experience and previous projects each member has worked on.

The goal of our sponsor is to map where the most affected areas are during heatwave events to avoid increased mortality and morbidity. Twm Palmer, our sponsor and Head of Contingency Planning and Resilience for the London Borough of Hounslow, has identified the need for a tool to identify areas within the Borough that are areas of concern, based on vulnerability models, so that they can be warned and informed before and during a heatwave event.

The members of the Steering Group from the University College London are Dr. Anna Mavrogianni, Lecturer in Sustainable Building and Urban Design, Clive Shrubsole, Senior Research Associate, and Dr. Jonathon Taylor, Senior Research Associate. Dr. Mavrogianni was an author of the "Building characteristics as determinants of propensity to high indoor summer temperatures in London dwellings" paper and a member of the AWESOME project. AWESOME was a multiphase project, its main goal was to model indoor temperature and indoor pollution, and then using these models, the team attempt to see how different policies passed regarding air pollution in London changed the concentrations of pollutants. Dr. Taylor was instrumental to the success of our project, his model for estimating indoor temperatures of dwellings at specific outdoor temperatures allowed us to provide the Borough with a GIS map of at dwellings at risk for high heat exposure at specific temperatures. The UCL currently suffers from a lack of good data sets for vulnerability factors. Currently, researchers use census data and estimate ages for buildings, but would like to access more recent, higher resolution data available within boroughs to create more accurate models. Of major concern to the UCL is bad population data, they would like us to identify what data is available within the borough that can replace population data gained from the census.

Similar to the University College London, Ross Thompson and Angie Bone from Public Health England expressed the desire of PHE to know what data the London Borough of Hounslow has that can be used to identify vulnerable populations more effectively than is currently possible with census data. If these populations are more accurately identified, it will allow the Borough to focus its resources more effectively during heatwave events.

Emer O'Connell was the representative of the Mayor's Office and the Greater London Authority. The main concerns for the Mayor's office are to test the usefulness of Heatwave Vulnerability Indices for short and long term planning, assessing data sets and determining if they are useful, and determining what they can do ‘on the ground’ to protect people from harm during heatwave events.

Through our conversations with the Steering Group, a more holistic picture of the nature and scope of our project began to take shape. Discussing the goals of the different members of the Steering Group gave us a good idea of the direction our project should take, and we became aware of how little was known about the location and type of data available within the Borough. We began to set up interviews with Vinesh Govind, Spatial Information Services Manager in the London Borough of Hounslow Intelligence Hub; Rory Prendergast, Senior Design and Quality Officer of the London Borough of Hounslow Property Services team; and Laura Maclehose, a Public Health Improvement Consultant in the London Borough of Hounslow Public Health Improvement team.

Conversations with London Borough of Hounslow Staff

Vinesh Govind - Geographic Information Systems

Our first meeting was with Vinesh Govind, a GIS specialist. He gave us a crash course in the Borough’s GIS program, Earthlight, as well as an overview of some of the data bases the Borough maintains. Through our introduction to the GIS, it became clear that most of the data was available at the Local Super Output Area resolution. This was not ideal, because our sponsor had identified his desire for address specific resolution, but information at the address level was not available for most of the borough. We learned that the GIS had many hundreds of layers, ranging from infrastructure to census data, and a series of layers called MOSAIC from Experian. The primary focus for our research was on social, economic, and demographic vulnerability factors, so we investigated the layers that contained that type of information.

We quickly realized that most of the vulnerability data in the GIS was from the census, which was the data set we were trying to improve on. We found that the best alternative to the census data was to use the MOSAIC data from Experian. This data is collected from a variety of proprietary sources. MOSAIC creates classifications of socioeconomic and demographic groups based on the habits, shopping patterns, income, housing, and technology adaptation of different segments of the population. This data is updated yearly, ten times as frequently as the census, and the layers 'Vintage Value' and 'Municipal Challenge' align with the deprivation in the Borough identified by other sources. We think that these MOSAIC layers serve as good indicators for areas that are more susceptible to adverse health outcomes as a result of heatwaves. We didn't want to completely discount the census, however, and we plotted areas with large numbers of elderly persons, households without central heating, population density, rented tenure, and houses of multiple occupancy. Additionally, we mapped the Indices of Multiple Deprivation for 2010 and 2015 in deciles for comparisons of changing areas of deprivation. These maps allowed us to observe spatial trends in vulnerability that are discussed in the Geographic Information System Layers section of this report.

Laura Maclehose - Public Health Data

Our meeting with Laura represented our first attempt to access sensitivity data available within the Borough. This was especially significant, because the Steering Group had previously expressed their desire for as much information as possible on the population data held by the borough. Unfortunately, it emerged through the course of our conversation that the Public Health team does not retain information about residents of the borough, and further inquires into sensitivity data held by the Borough were unfruitful. We believe there may other sources of sensitivity data within the Borough that may be useful, we recommend further areas of study in the Conclusion and Recommendation section of this report.

John Morgan - Head of Prevention and Care Management

We were put in contact with John Morgan in further attempts to access or discover further sources of sensitivity data within the London Borough of Hounslow. As Head of Prevention and Care Management, he is in charge of multiple teams that handle discharge management, occupational therapy, and community recovery service in the London Borough of Hounslow. He identified to us a dataset of approximately 3,600 individuals containing information such as age, address, and needs, however he cautioned that some of these clients live outside the Borough and many vulnerable residents of the Borough would not be on the list due to ineligibility for benefits. To be eligible, an individual must require assistance with tasks essential to daily living, as established in the Care Act of 2014. We were unable to gain any more information about this database, however John Morgan was able to give us the contact information for Sally Duhig and

Andrew Heap, individuals he hoped would be able to provide us with further information about sensitivity data in the Borough. We were unable to get in contact with Sally Duhig, as she was not in the office.

Andrew Heap - Social Care Data

Andrew Heap was identified to us as 'having the data' about vulnerable persons in the London Borough of Hounslow. We reached out to ask what heatwave sensitivity data he had access to, specifically identifying age, deprivation, and pre-existing illness. He was able to forward us a copy of the Vulnerable Clients List, along with a list of the headers for the document. This document contains some of the sensitivity to heatwave vulnerability factors we had identified during our literature review, such as age (via date of birth), gender, and ethnicity. He also clarified to us that his records related to social care, not healthcare, so there would be minimal information about pre-existing illness, and that there was no specific field that was used to track deprivation. This was very useful for us to discover, but because this document contains very sensitive personally identifiable information, access to this information is very restricted.

Rory Prendergast and Martin Tomkins - Social Housing

During our discussion with Rory Prendergast and Martin Tompkins, members of the Borough's Housing Investment team, we discovered that the borough has extensive records for all the physical property attributes of the London Borough of Hounslow social housing stock. These records include information about the condition of the housing stock, works and improvements done to social housing properties, and an extensive Carbon Reduction Options for Housing Managers (CROHM) assessment of the properties. They also explained the priorities of the Housing Investment team. The London Borough of Hounslow had the worst cold weather death rate in England, and most of the Borough's resources go towards maintaining poorly constructed 1930s-40s era buildings so that they meet statutory requirements, with minimal consideration given for comfort. These requirements include providing up to date kitchen and bathroom facilities and minimizing health and safety risks and hazards. The Borough has to prioritize fixing issues that arise that pose health and safety risks, and due to the high mortality of cold weather, prioritize cold weather heating efficiency over summer heat exposure. The Borough doesn't have the resources to adapt the housing stock seasonally, resulting in buildings designed to maximize heating efficiency year round.

Rory explained most social housing properties use Mechanical Ventilation and Heat Recovery (MVHR) to passively maintain fresh air inside homes. There is very minimal air conditioning in England, due to the unstable electrical grid, cost to run, and adverse environmental impacts of air conditioning systems. These factors combine to create an environment within social housing that is at elevated risk for high heat exposure. To identify which buildings are most at risk for overheating, we wanted to provide Jonathon Taylor at the University College London with data from the Borough about the social housing properties, allowing him to model the indoor temperature for the social housing at different outdoor temperatures. From this model we would be able to provide the Housing Team and the Contingency Planning unit a map of the properties that are most likely to overheat.

Identifying High Heat Exposure Buildings

Identifying the high heat exposure dwellings would be useful to the Housing team for long term planning and retrofitting, allowing consideration to be given to properties that were likely to expose residents to high levels of heat so that future updates could reduce the impact of heat on residents. This information would be useful to the Contingency Planning Unit when a heatwave is forecasted to help determine the placement of cooling centers and identification of dwellings that contain individuals on the 'Vulnerable Clients List,' individuals identified within the borough as requiring additional support who have been deemed especially vulnerable due to their reliance on public services.

One obstacle to this endeavor was the lack of data available on private housing within the Borough. Although the London Borough of Hounslow maintains an accurate, up to date database of information on the social housing stock, there is very minimal information on any private properties. We were told by multiple members of the London Borough of Hounslow staff that a study had been commissioned in 2014 to assess the private housing stock in the Borough, but the staff member who had commissioned the study had since left the Borough, and no one could find the results of the study. The only data set we could discover that covered a majority of the

London Borough of Hounslow housing stock was the Energy Performance Certificate database, identified to us by Rory Prendergast and Vinesh Govind, as well as the Steering Group.

Energy Performance Certificates

Energy Performance Certificates are issued by a trained assessor for all buildings in England whenever they are built, sold, or rented. This document contains information about the general characteristics of the building, the property's energy usage and average energy costs, and recommendations about how to reduce energy use. The property information contained in an EPC includes the address of the building, the type of dwelling (flat, terrace, detached home, etc), the location of the property, and many different factors about its energy efficiency.

This data is useful because it can be used to model the exposure residents face while indoors, an important component in determining their vulnerability. Using a model developed at the University College London by Jonathon Taylor, a senior researcher, we were able to collaborate with the UCL to model the indoor temperature of a property based on the temperature outside. EPC data was used to create a model of the interior of a dwelling, which was used to estimate temperatures indoors for different outdoor temperatures. This was done for each building in the London Borough of Hounslow with a public EPC. These indoor temperature estimates were aggregated at the postcode level for accuracy, and then added to the London Borough of Hounslow GIS so that we could observe spatial trends of high exposure in the Borough.

The largest problem with the EPC data set is its gaps. EPCs are only required when a building is constructed, sold, or let, and if this hasn't occurred for an older property no EPC will have been created. There are also many exceptions for buildings that are not required to have an EPC, including for listed properties, religious buildings, and properties that are only occupied for less than four months of the year. Homeowners can also opt out of the public EPC database, further increasing gaps in the record. Despite the evaluations being conducted by trained assessors, housing experts in the London Borough of Hounslow have pointed out inconsistencies in the data across a single building with multiple flats. Despite these flaws, the EPC database remains the most complete picture of the Borough's housing stock.

Indoor Temperature Model

Attempting to export the social housing data to Jonathon Taylor was a major obstacle we encountered. Information governance laws did not allow us to send the social housing data outside the Borough, to do this, we needed to submit, and have approved, a Privacy Impact Assessment. A PIA provides justification for the need to access and, if requested, subsequently share data. The filer will need to identify the type of project or research that is being conducted, what 3rd party groups and other government organizations will be working on the project, the type and sensitivity of the information being accessed, how these data are stored, how they will be accessed including names of software and whether the borough has a contract with them for technical support, how they will be properly handled throughout the duration of the project, and how they will be responsibly destroyed at the end of the project. The PIA will be required if any data is to be accessed, this includes data that is not personal in nature. For more information about the PIA, see Appendix E.

Due to the difficulty exporting the social housing data from the Borough, we instead opted to use data from Energy Performance Certificates. We collaborated with Jonathon Taylor from UCL, he provided us with a GIS layers of indoor temperature estimates based on outdoor temperature using the publicly available EPCs for the London Borough of Hounslow. These temperature estimates are aggregated at the postcode level for accuracy, which is not the ideal resolution of individual addresses we were aiming for, but represents the most accurate model of indoor temperature currently achievable to us. Vinesh Govind was able to import these layers to the London Borough of Hounslow Earthlight GIS, which allowed us to analyze them for spatial trends of high heat exposure.

Indoor Heating Model Maps

We were able to collaborate with Jonathon Taylor to model the indoor temperature of individual buildings in the London Borough of Hounslow. The technique used to model indoor temperature is described in *Mapping the effects of urban heat island, housing, and age on excess heat-related mortality in London*. (Taylor et. al., 2015) The model uses Energy Performance Certificate data available for buildings in the borough, which we believe might be useful as an up-to-date reference of building characteristics. It is important to understand that Energy Performance

Certificate data has not been used for modelling indoor temperature in the past, so the information here should be taken as an experimental trial of the data. It is also important to understand that the spatial distribution of heat is often very different depending on the weather conditions. The resulting output was then entered into the London Borough of Hounslow Geographic Information System and displayed on a map. Figures 12 to 17 show the results of the indoor heating model run with the EPC data, aggregated at the post code level. The indoor temperature of a building is directly correlated with the outdoor temperature. The maps produced below show how indoor temperatures changes as the temperature rises outside. By examining the average Urban Heat Island of London during a heatwave (Figure 11), we can see that the London Borough of Hounslow is located in a moderately hot region during the simulation period for the UHI. Although it is important to note that the Urban Heat Island changes often, the average shown below can be taken as a rough approximation. Looking at the UHI map and the set of indoor temperature maps, we can form a rough understanding of what buildings will be most at risk during a heatwave event.

Collecting specific data on every dwelling in London would be near impossible. In order to compensate for this. the indoor overheating model uses average characteristics based on the building type. In the figures below, it is clear that as the outdoor temperature increases so does the simulated indoor temperature. As the outdoor temperature increases, many postcodes where there was no significant overheating become hotter and hotter. Many postcodes in the borough that started out with little overheating became severely overheated when the outdoor temperature reaches 28^{O}C.

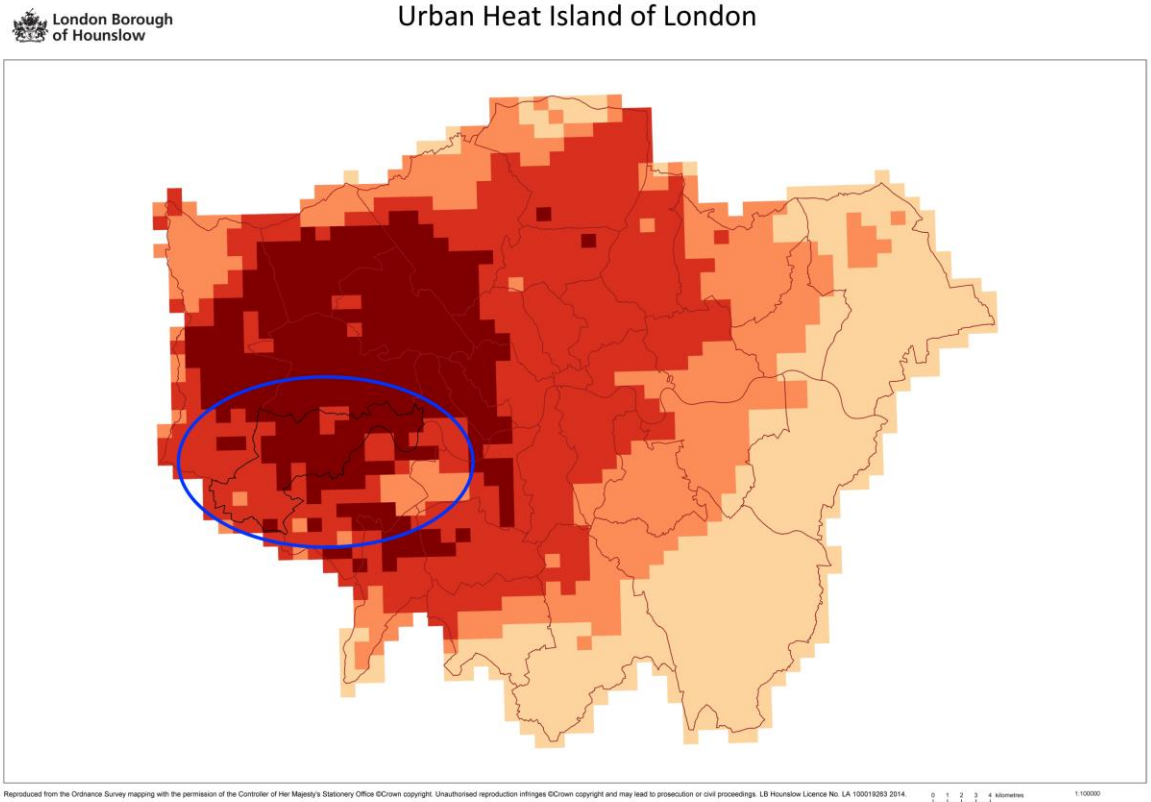

Figure 11. Average Urban Heat Island of London during a heatwave, with the London Borough of Hounslow located in the blue circle. (1 km by 1km block resolution)

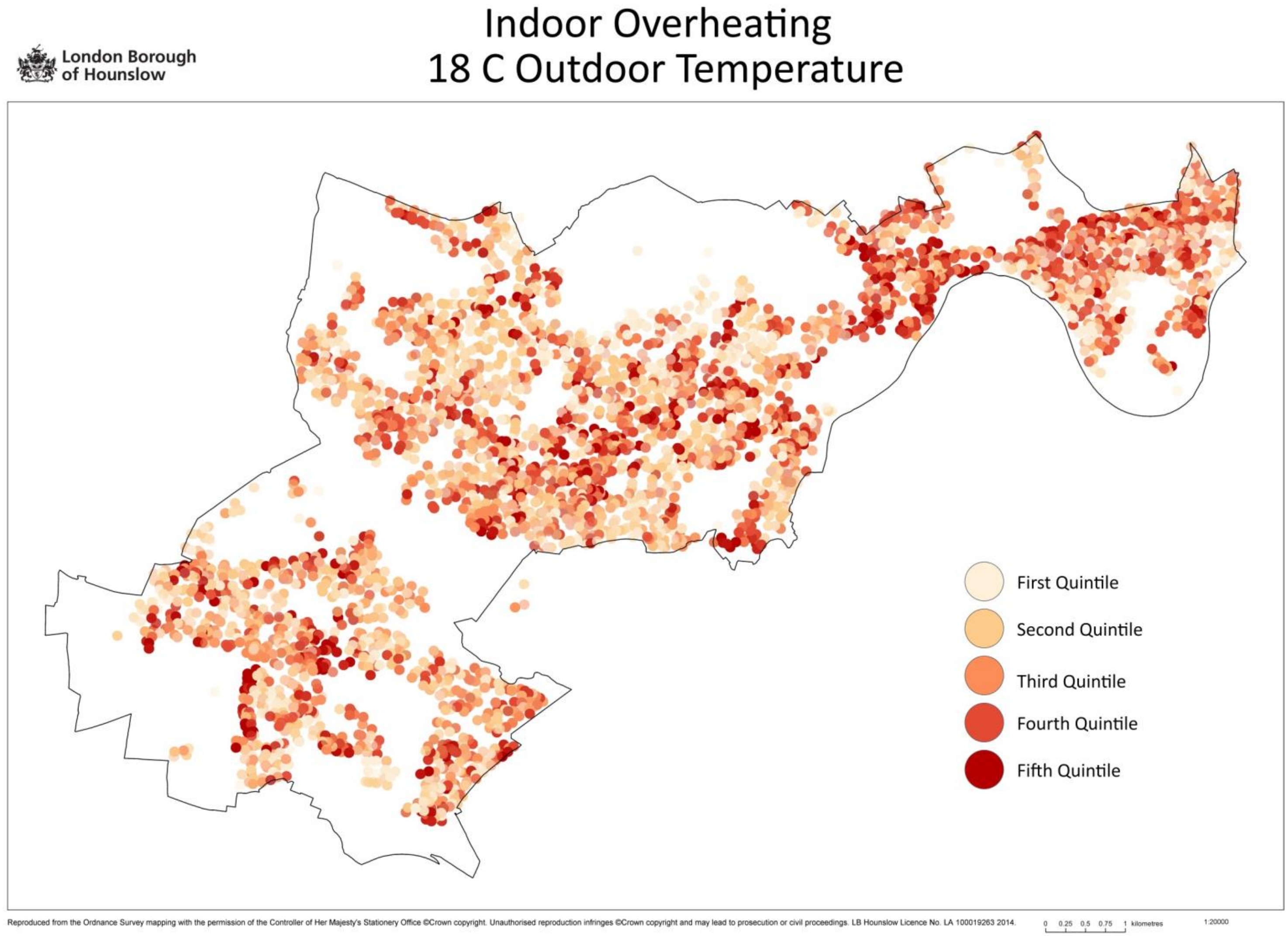

Figure 12. Average mean indoor temperature when rolling two-day average outdoor temperature is between 18-20°C.

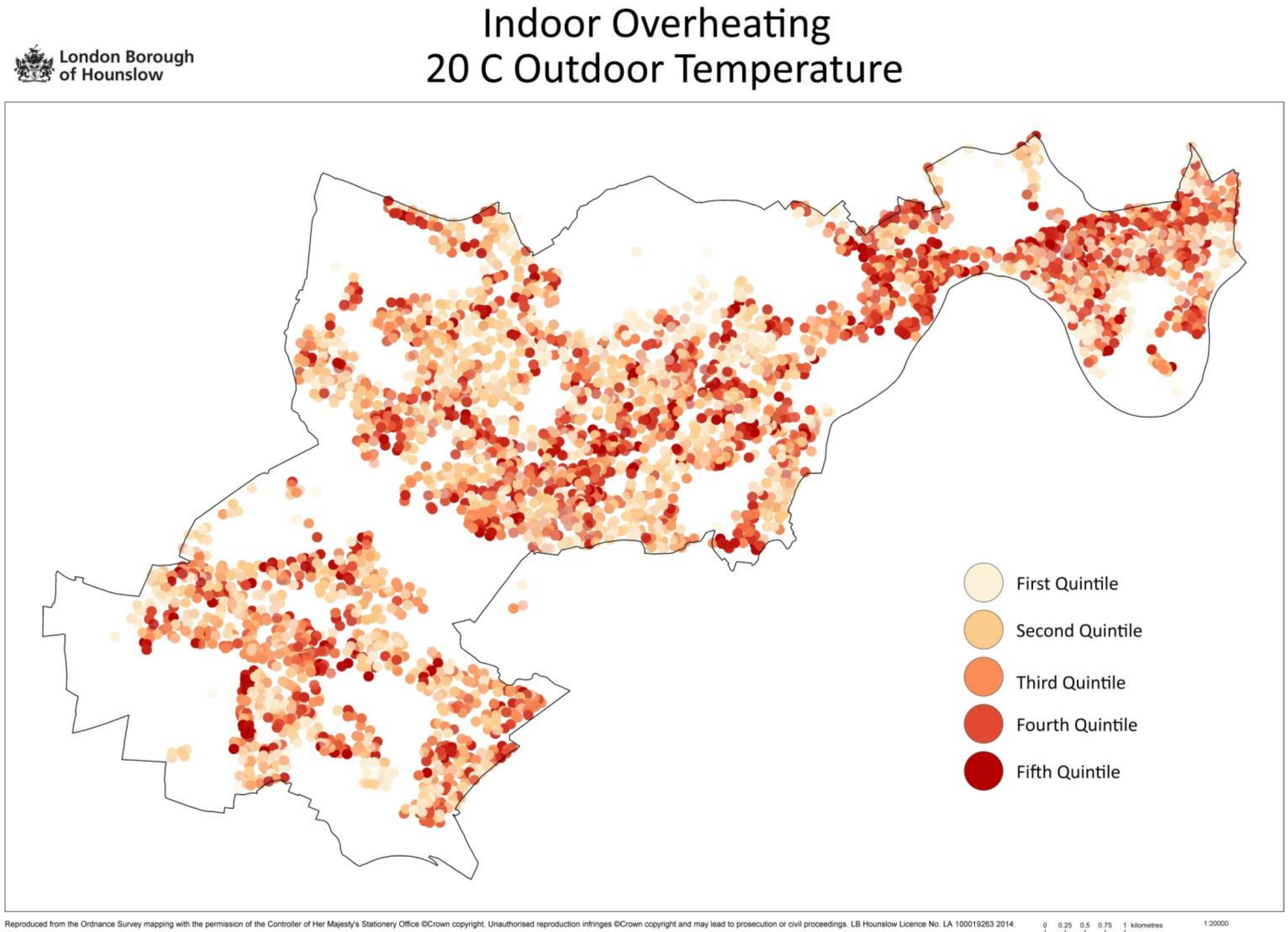

Figure 13. Average mean indoor temperature when rolling two-day average outdoor temperature is between 20-22°C.

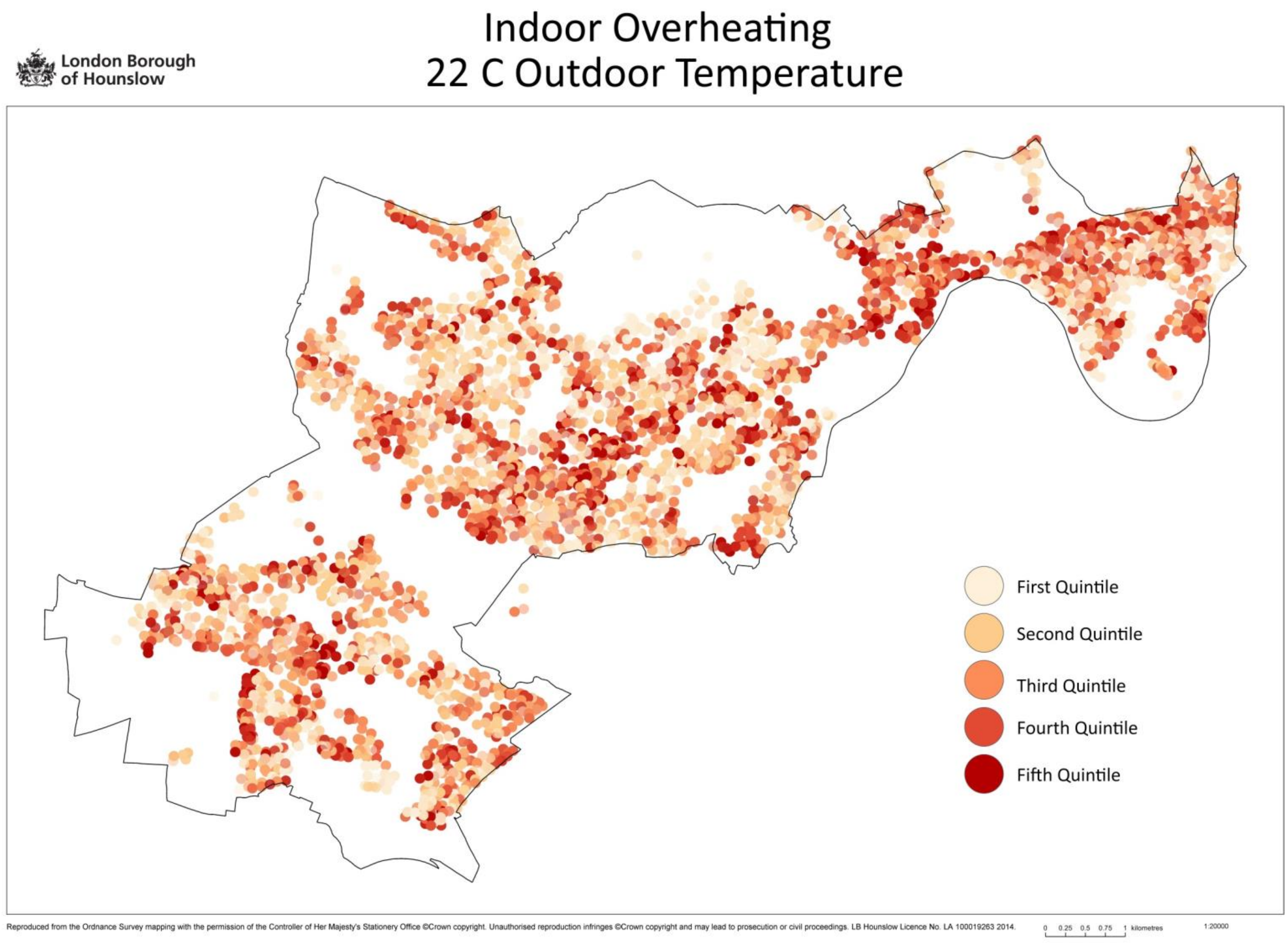

Figure 14. Average mean indoor temperature when rolling two-day average outdoor temperature is between 22-24℃.

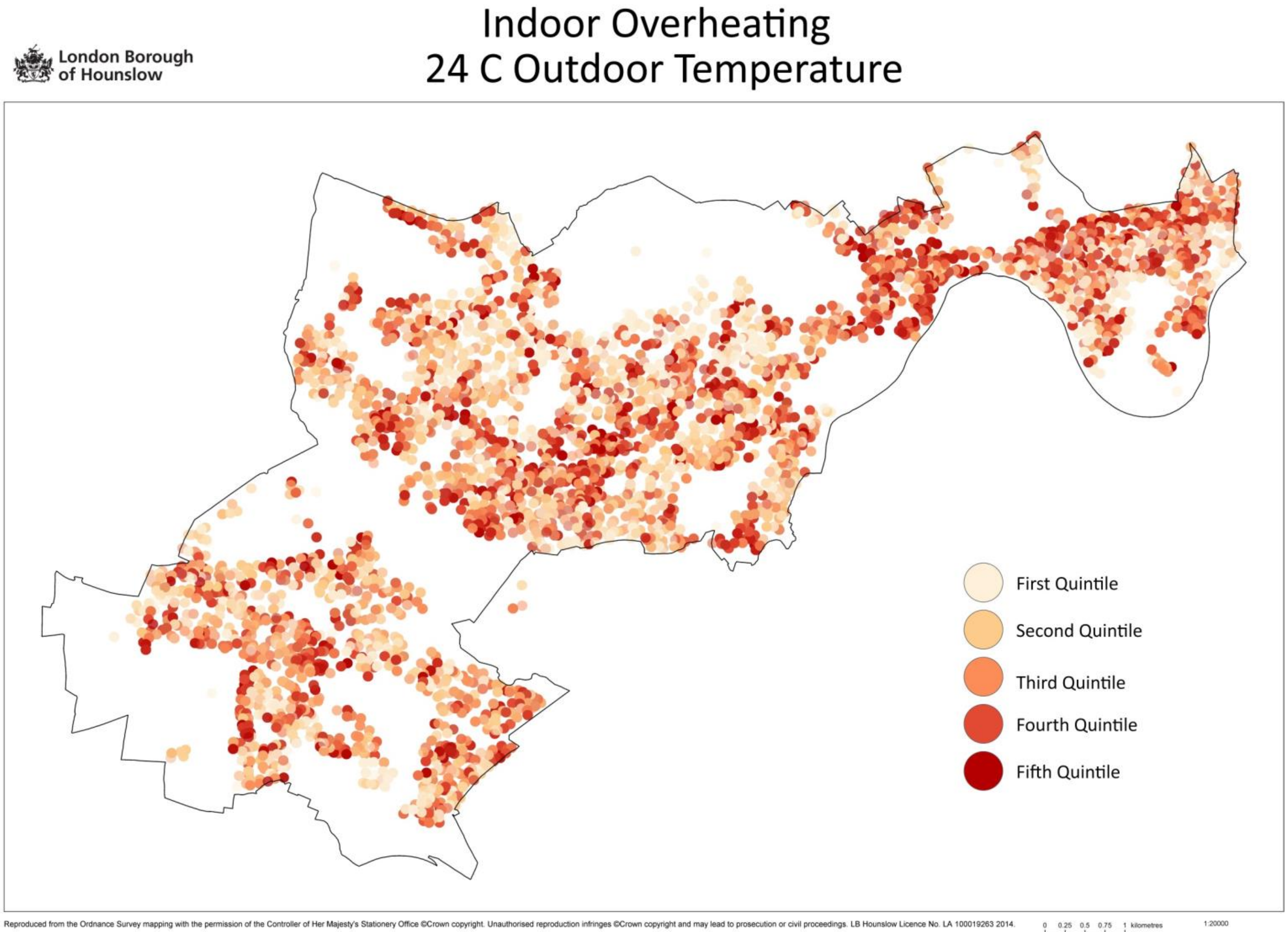

Figure 15. Average mean indoor temperature when rolling two-day average outdoor temperature is between 24-26°C.

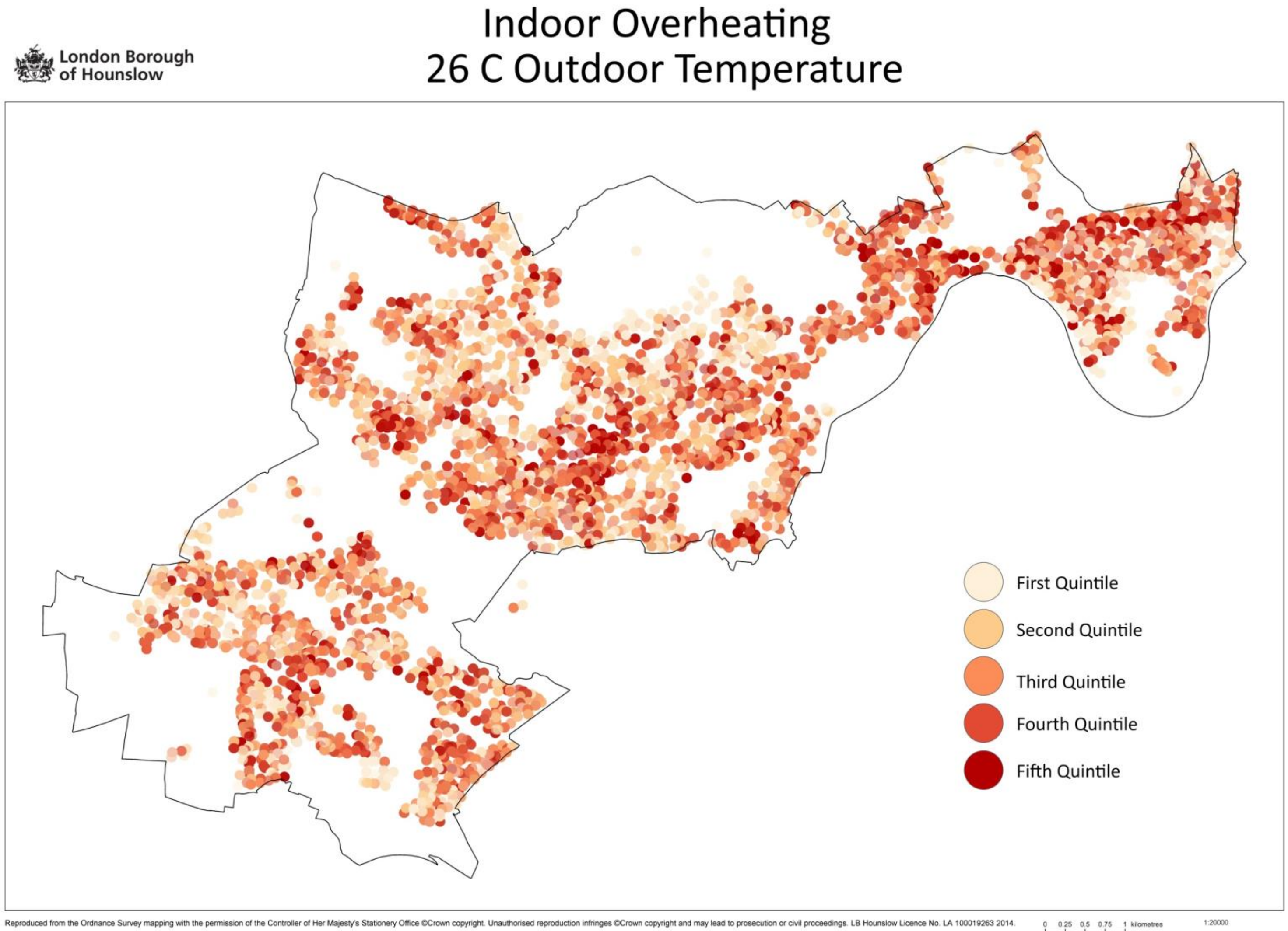

Figure 16. Average mean indoor temperature when rolling two-day average outdoor temperature is between 26-28℃.

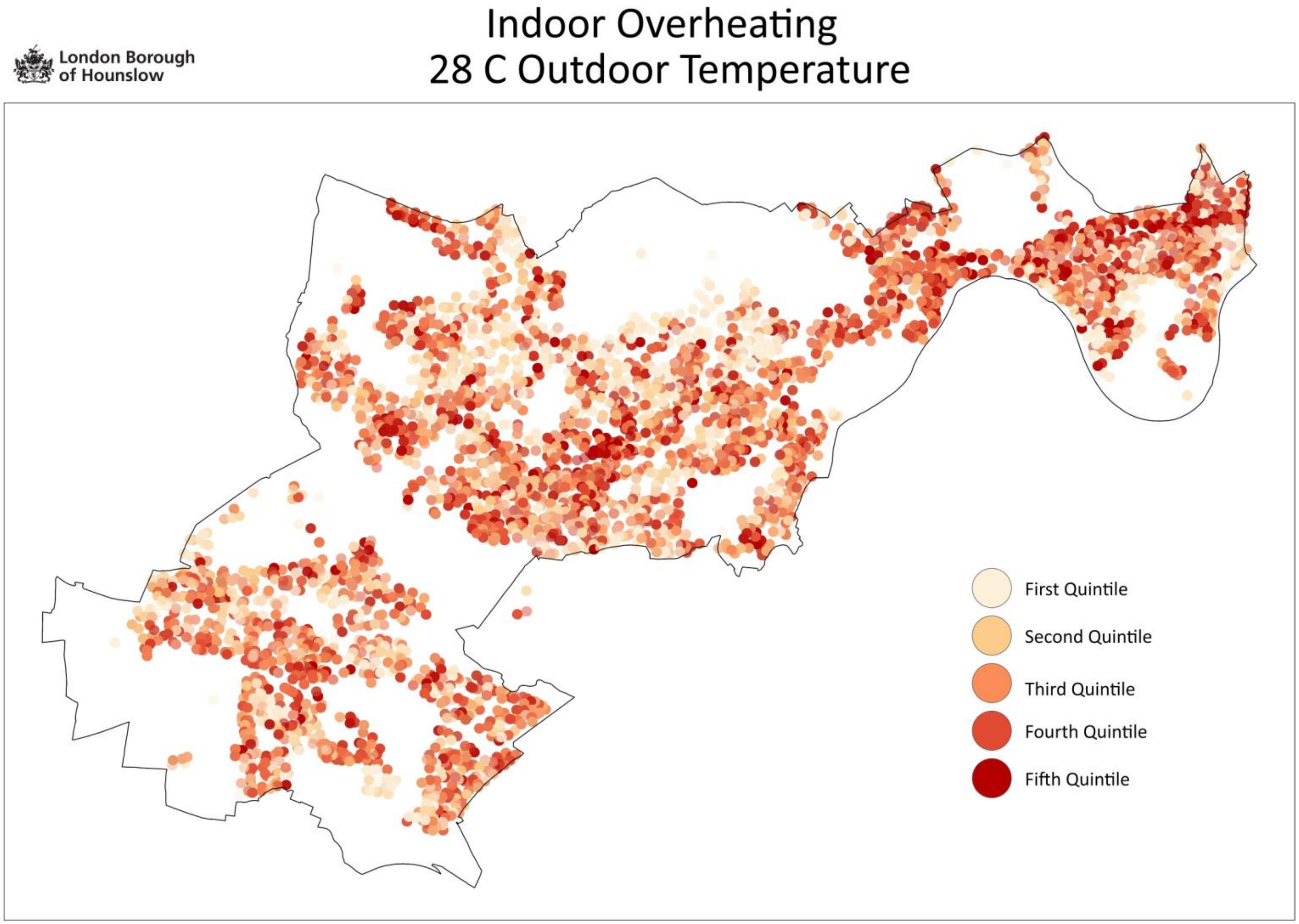

Figure 17. Average mean indoor temperature when rolling two-day average outdoor temperature is between 28-30°C.

Geographic Information System Layers

Due to the constraints placed on us by Information Governance laws, we were unable to view most of the data held by the London Borough of Hounslow. The data we were able to access, in addition to the public Energy Performance Certificate and Census data, was the Borough's GIS program. The London Borough of Hounslow GIS program is called Earthlight, and is accessed via the Borough's intranet service (The London Borough of Hounslow). It contains information from various databases, including the Census, and is organized spatially at resolutions from individual addresses to the entire borough. Through our experimentation and research with the system, we found multiple layers that are of particular interest to the London Borough of Hounslow as they relate to vulnerability.

The Indices of Multiple Deprivation

The Indices of Multiple Deprivation (IMD) are indices combining a variety of measures across distinct aspects that have been previously linked to deprivation. The IMD is used by a wide range of organizations; government departments, local authorities, as well as funding bodies to charities, businesses and community groups, and individuals. These organizations and individuals can use these indices to determine funding for projects, as well as determine what areas within their local area must be targeted first for public service, where their site facilities would work most effectively, or to simply grasp a better understanding of the area in general (Gill, 2015). There have been a total of four released indices that have been updated approximately every five years, with the most current being 2015 (followed by 2010). There are seven distinct dimensions or domains that encompass deprivation, with a total of 37 separate indicators within them. The domains are (Smith, 2015; Gill, 2015):

- Income deprivation
- Employment deprivation
- Health deprivation and disability
- Education, skills, and training deprivation
- Barriers to housing and services
- Living environment deprivation
- Crime

Each domain can be used to identify and measure various aspects of vulnerability in a population within an area, their purposes are as follows:

Table 4. IMD Domain Descriptions

Domain	Purpose
Income deprivation	Measures the proportion of the population that are experiencing deprivation due to low income, including both those unemployed and workers who have low income (calculated through means tests).
Employment deprivation	Measures the proportion of the *working age* population that are unwillingly excluded from the workforce. Individuals that suffer from employment deprivation would like to work but cannot due to unemployment, sickness, disability, or caring responsibilities that limit them.
Education, skills and training deprivation	Measures lack of educational success and skills in the local population within two subdomains; the first relating to children and young adults, and the other to adult.
Health deprivation and disability	Measures risk of premature death as well as the impairment of quality of life due to poor physical health and/or mental health, but lacks to acknowledge aspects of behavior or environment.
Crime	Measures risk of personal and material victimization.
Barriers to housing and services	Measures physical and financial accessibility of both housing and local services within two subdomains; the first, 'geographical barriers' (proximity of local services), and 'wider barriers' (affordability of housing as well as homelessness).
Living environment deprivation	Measures quality of the local environment within two subdomains; the first measures the quality of housing and indoor environment, and the second measures the quality of the outdoor living environment (such as air quality, road traffic accidents).

These domains are combined using a weighted scale to calculate "an overall measure of multiple deprivation experienced by people living in an area and is calculated for every Lower Layer Super Output Area (LSOA), or neighborhood, in England (Gill, 2015). The weights were determined by previous academic papers and consideration of the 'robustness' of each indicator. The domain weights are as follows:

Table 5. English Indices of Deprivation 2015 Briefing

Domain	Weight
Income deprivation	**22.50%**
Employment deprivation	**22.50%**
Education, skills and training deprivation *> Skills subdomain* *> Children and Young People subdomain*	**13.50%** 6.75% 6.75%
Health deprivation and disability	**13.50%**
Crime	**9.33%**
Barriers to housing and services *> Wider Barriers subdomain* *> Geographical Barriers subdomain*	**9.33%** 4.67% 4.67%
Living Environment deprivation *> Indoor subdomain* *> Outdoors subdomain*	**9.33%** 6.22% 3.11%

A majority of the indicators used for the 2015 release are based off of datasets coming from 2012 because these datasets were the latest available at the time of the index's creation. The sources of the data used varies; "most [came] directly from administrative sources, some [were] modelled or calculated using administrative and other data and some [come] from the 2011 Census" (Smith, 2015). It was found through these indices that the most deprived neighborhood in England is east of the Jaywick area of Clacton on Sea, and this was consistent in both 2010 and 2015 (Gill, 2015). The most deprived districts have also remained consistent, with the top five districts remaining within the top five: Liverpool (ranked 1st in 2010, and 4th in 2015), Middlesbrough (ranked 2nd in 2010, and 1st in 2015), Manchester (3rd in 2010, and 5th in 2015), Knowsley (4th in 2010, and 2nd in 2015), and Kingston upon Hull (5th in 2010, and 3rd in 2015). This trend is followed throughout all of England's boroughs, with 83% of those found to be deprived in 2015 were also found to be deprived in 2010 (Gill, 2015).

In the London Borough of Hounslow, the results of the 2010 and 2015 IMD have been represented in spatial layers in its GIS. The comparison of the borough's most vulnerable areas can be compared over the span of the five years for a better understanding of potential trends in vulnerability. Assuming these trends continue, vulnerable areas can be generally identified for further emergency response procedures (The London Borough of Hounslow). Shown in deciles, the more vulnerable areas are identifiable through darker shades of color, and likewise, the less vulnerable areas are identifiable through lighter shades of color.

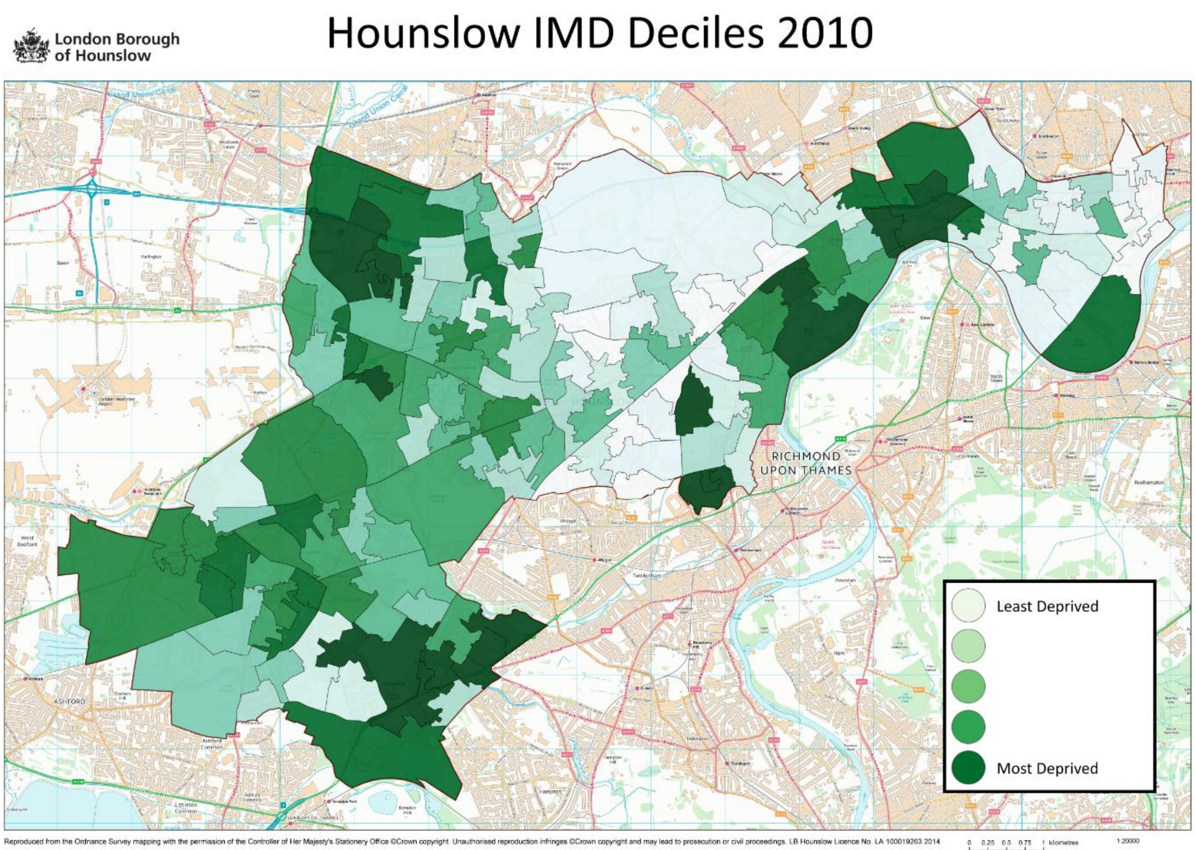

Figure 18. Hounslow Indices of Multiple Deprivation (2010)

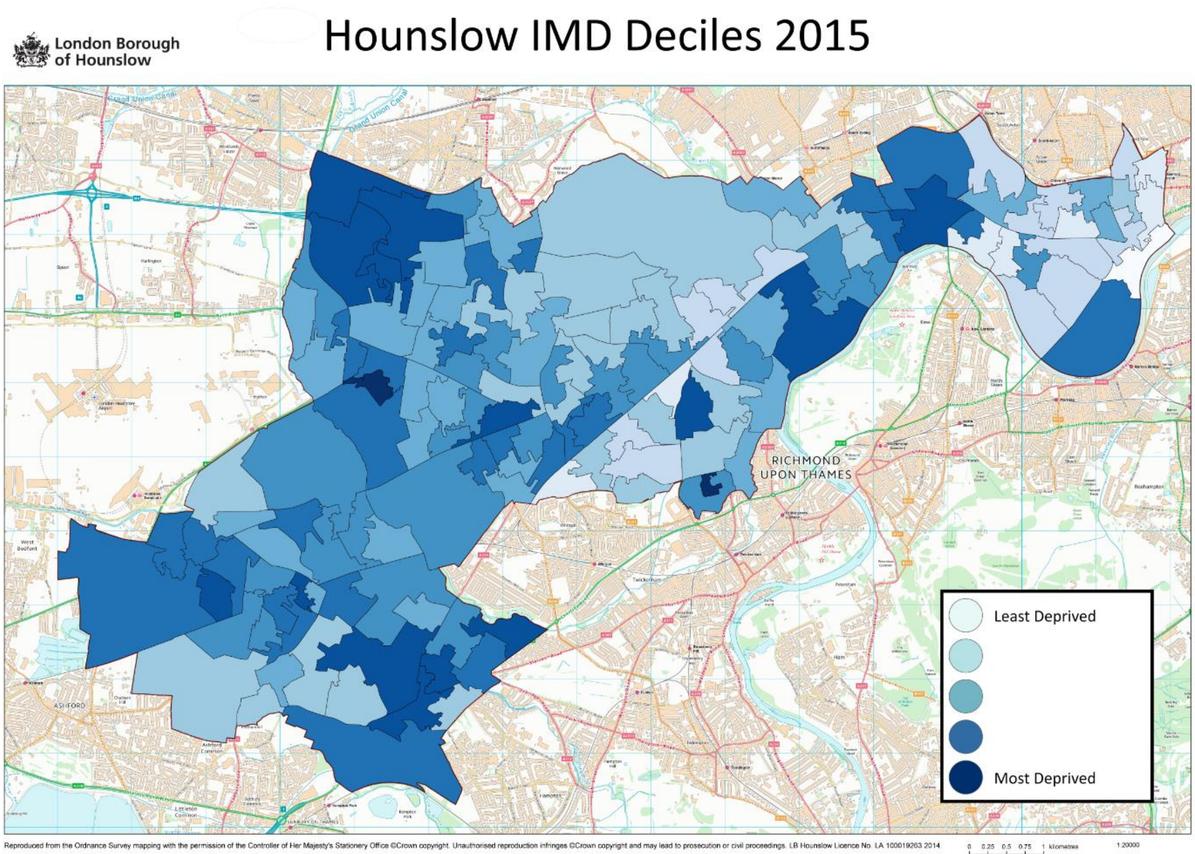

Figure 19. Hounslow Indices of Multiple Deprivation (2015)

In the first layer presented, the IMD 2010 layer over the London Borough of Hounslow is shown in shades of green. The western half of the London Borough of Hounslow appears to be much more generally vulnerable than the eastern half (especially vulnerable in the most northwestern and southwestern areas such as Hounslow West and Crawford), however there are a few neighborhoods in the east that are cause for concern; Brentford and Brentford End, as well as Chiswick are where some of the most vulnerable areas can be found. When compared to the IMD 2015 layer, which is shown over the London Borough of Hounslow in shades of blue, these areas have remained vulnerable. The most severely vulnerable neighborhoods have improved by a decile or two in some areas, however there also seems to be a general increase in vulnerability borough wide; This is most noticeable in central and eastern portions of the London Borough of Hounslow. Though these comparisons should not be the basis of emergency response procedure, they are helpful to note for a general knowledge of the London Borough of Hounslow's most vulnerable neighborhoods and the way vulnerability seems to be trending locally over time.

Rented Tenure and the IMD

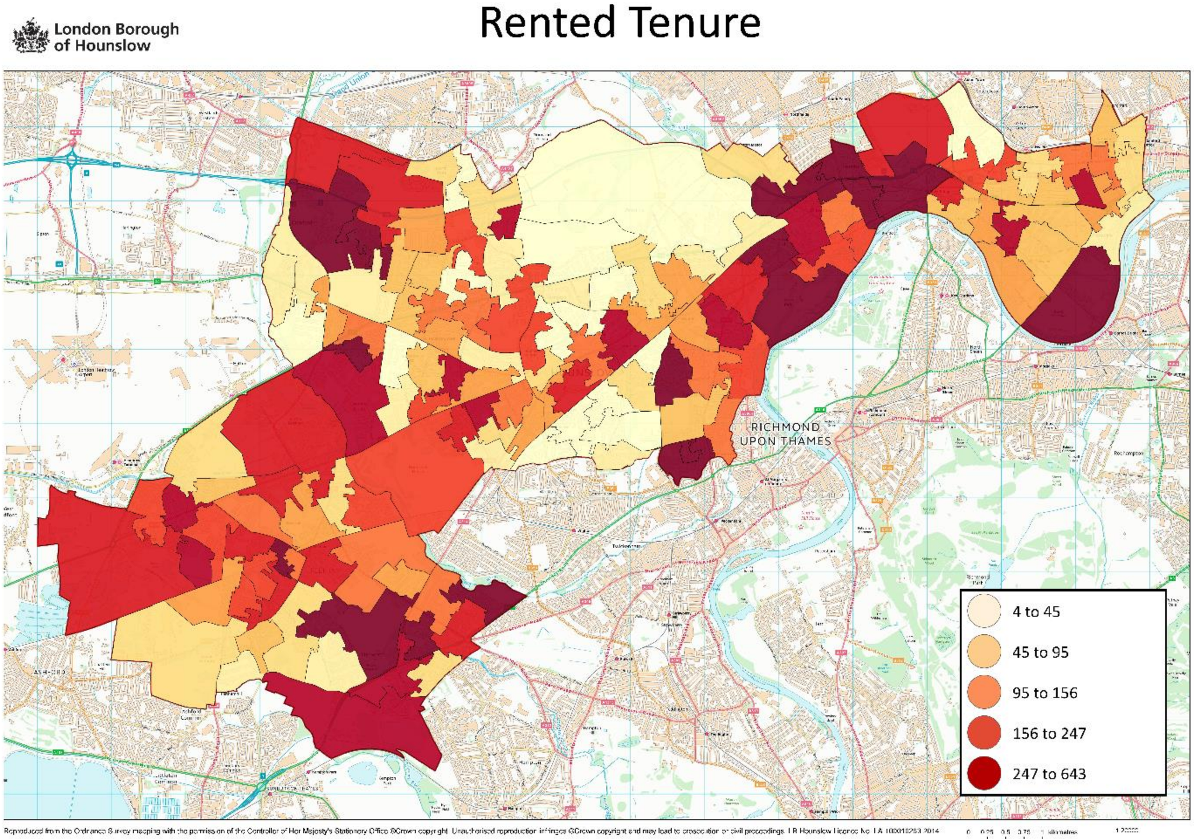

Figure 20. Rented Tenure Plotted in GIS

The density of rented tenure of the London Borough of Hounslow, which had come from the 2011 census, had also been mapped on a GIS layer, and when compared to the previously discussed IMD layers, there are some striking similarities (The London Borough of Hounslow). Generally, the most densely populated areas of rented tenure also seem to be the areas the IMD identified to be most vulnerable. This can be seen on the slight increase of rented tenure found in the western half of the London Borough of Hounslow, especially on the north and south-westernmost borders, Cranford, and Feltham and Hanworth, displayed with the darkest shades of red. Some of the densest areas of rented tenure can be found on the eastern half of London Road and Hanworth Road. Even the neighborhood along the Richmond upon Thames on the eastern border, Chiswick contains dense amounts of rented tenure; the IMD has identified all these areas as generally vulnerable. This link could be explained by the link of low income rented or social housing and vulnerability. Those living in rented homes are most susceptible to heatwaves due to the unfortunate fact that many landlords and title-owners are not particularly concerned about the wellbeing of the structure or its occupants and try to avoid paying as many upkeep costs as possible. This results in detrimental flaws in housing that can lead to an increase in morbidity and mortality during heatwave events.

MOSAIC

MOSAIC is a cross-channel consumer classification built by Experian, built to help its users understand the "demographics, lifestyles, preferences and behaviors of the UK adult population in extraordinary detail", allowing for communication with the population to become more effective (Experian, 2017a). The classification benefits its users by giving them the ability to accurately engage with customer and prospect groupings by reaching the right target audience through their preferred communication method(s), improving customer experience and driving retention (Experian, 2017a). MOSAIC is updated annually and synthesizes over 850 million source records built through a period of over 30 years to create an "easy to understand segmentation that allocates 49 million individuals and 26 million households into of 15 Groups and 66 detailed Types" (Experian, 2017a). Decided by more than 450 input variables, decided by a combination of "Experian proprietary, public [records and information], and trusted third party sources – including research findings and behavioral data – to build a pin-sharp picture of the latest UK consumer and social trends" (Experian, 2017a). Using MOSAIC, vulnerable groups can be identified through its statistical listings on social care and rented housing (property type), household income groups, access to technology, and age. The Groups that were decided to be most at risk during heatwaves were Group N: Vintage Value (Elderly people reliant on support to meet financial or practical needs), and Group O: Municipal Challenge (Urban renters of social housing facing an array of challenges).

Group N: Vintage Value

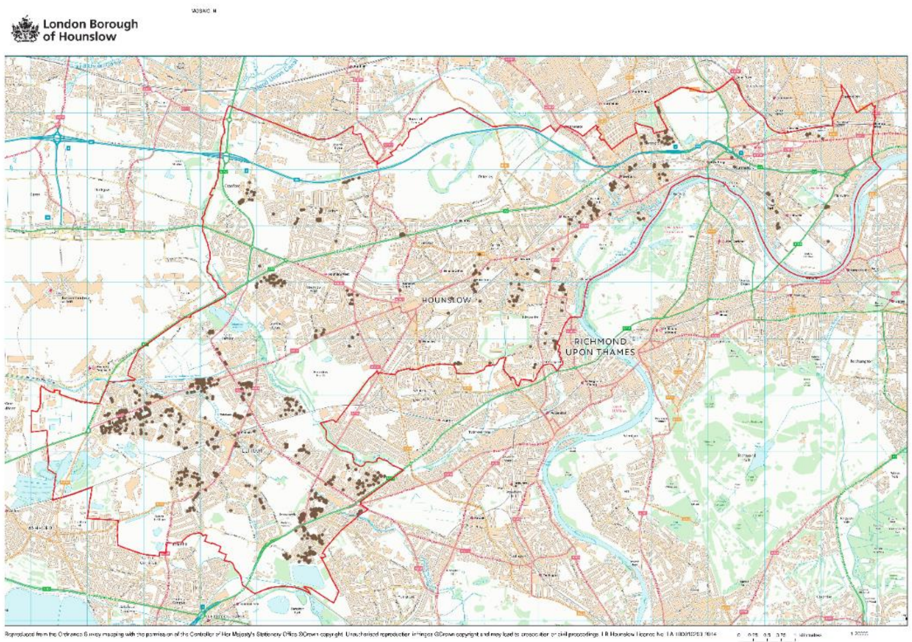

Figure 21. MOSAIC Group N

The Vintage Value grouping identifies the population that are both elderly and reliant on support, whether it be through social care, housing, or from bodies outside the London Borough of Hounslow Council in order to meet financial or practical needs (Experian, 2017b). The adult mean age is in the over 65 age bracket and a majority both are single and make under £15,000 annually (Experian, 2017b). In the London Borough of Hounslow, addresses that have been identified to fall within this grouping have been mapped spatially on the GIS represented with brown dots. The address locations most densely populated with the Vintage Value group are in the Southwest, especially in East Bedfont & Hanworth. There are also small areas in the Hounslow West neighborhood, as well as the Heston, and Cranford neighborhoods found slightly more north.

Group O: Municipal Challenge

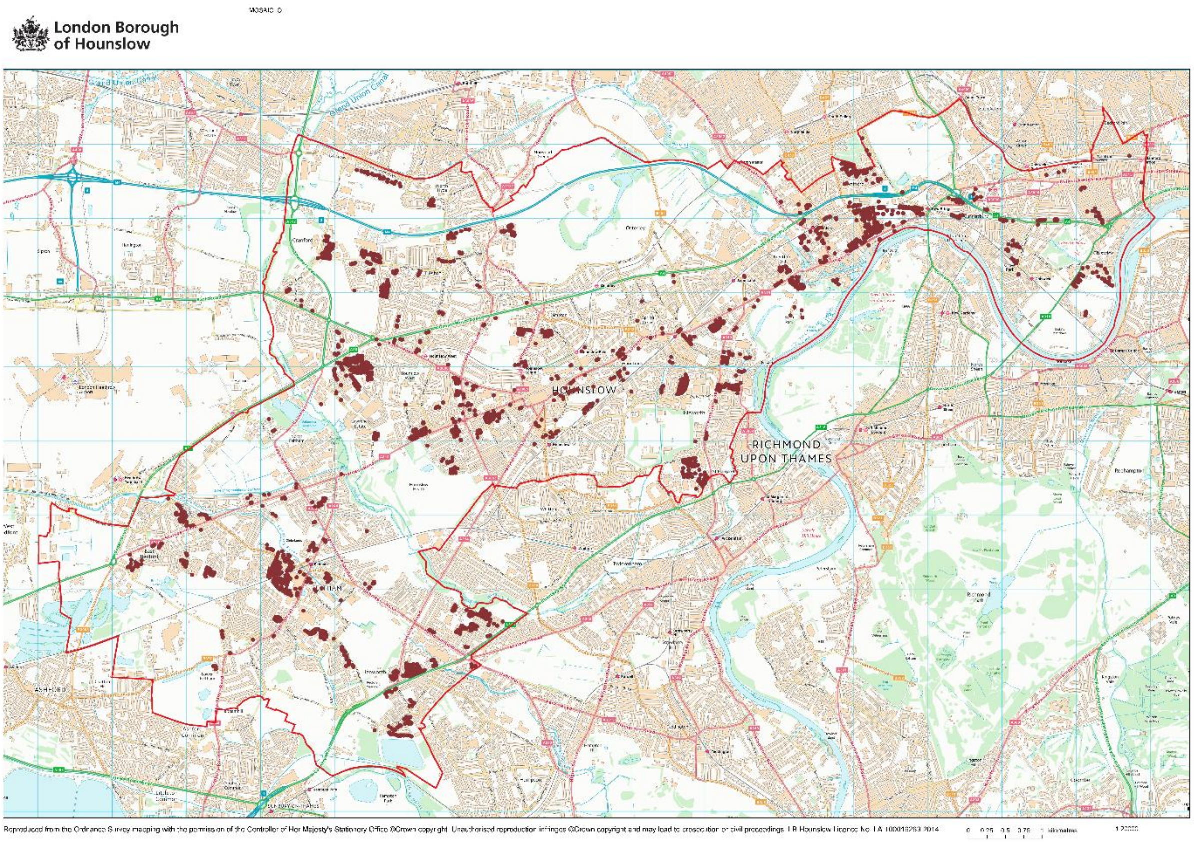

Figure 22. MOSAIC Group O

The Municipal Challenge grouping identifies individuals living in social, low cost housing in challenged neighborhoods that have low income and few employment options (Experian, 2017b). The adult mean age does not fit the age bracket of 65 years or older that has been identified as most vulnerable in the studies mentioned in Section 2, however, the average age still falls between 56-60 years old. The average income is under £15,000 annually with most living in Council provided housing, with no children (Experian, 2017b). Within the GIS, where similarly to Group N addresses within the group are mapped on a spatial layer, these addressed are marked with brown dots. This grouping is much more common within the borough, with major groupings found in Feltham, Brentford, Hanworth, and Hounslow West neighborhoods. In Isleworth, Chiswick, and Cranford, there are specific streets and/or buildings that are also hotspots of the Municipal Challenge group.

Population Density and Key, Secondary, and Tertiary Parks

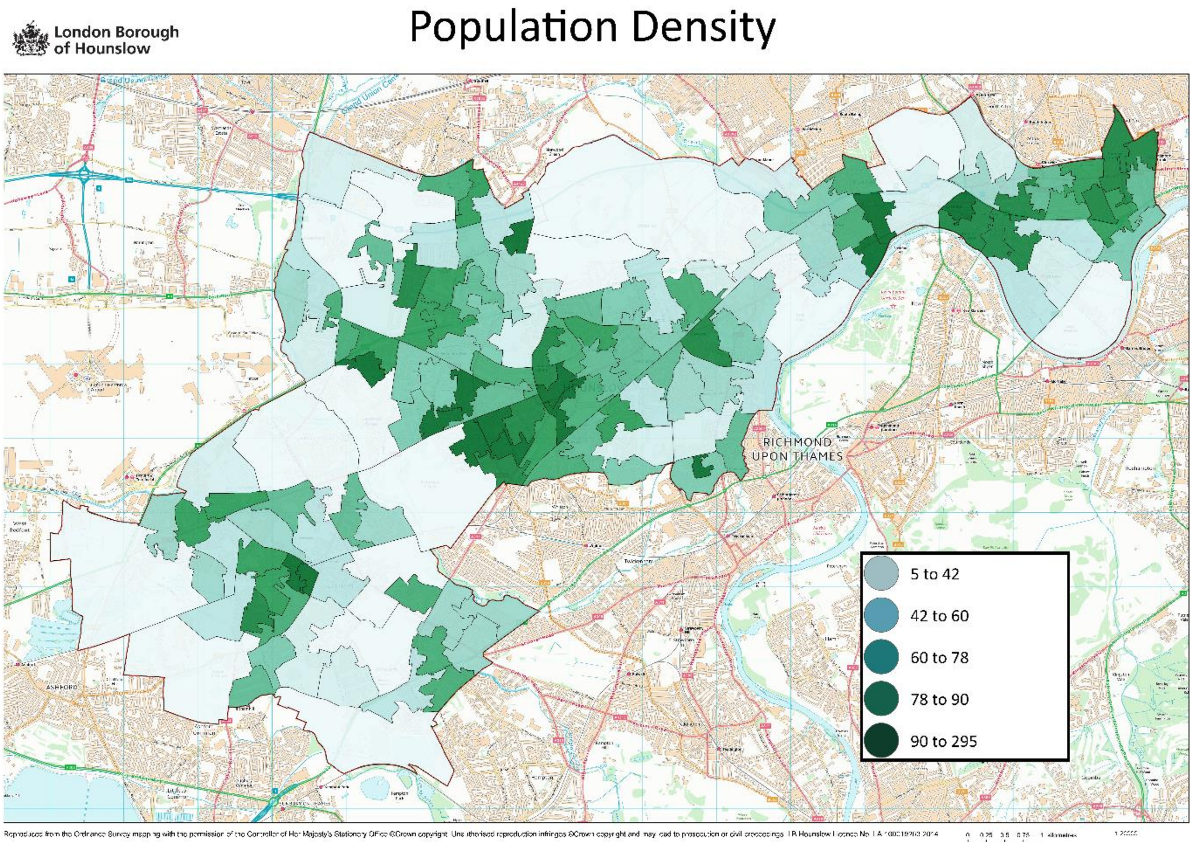

Figure 23. Population Density

The population of the London Borough of Hounslow is mostly concentrated in a few areas: Hounslow Central, Hounslow West, Heston, North Hyde, Feltham, Brentford, Gunnersbury, and Turnham Green. Less populated areas include Chiswick, Hounslow Heath, Osterley, Cranford, Lower Feltham, Hanworth, as well as areas in East Bedfont. This is due to the large amount of green space that occupies a majority of these areas. North Feltham and the Lawrence Estate also are less densely populated even though there is comparatively less green space with and a large number of buildings present. The data of population density derives from the 2011 Census, while the key, secondary, and tertiary park locations have come from local planners within the Borough (The London Borough of Hounslow). It is important to note that the population density is not the end-all-be-all of vulnerability to heatwaves, for example: Chiswick is not densely populated and has a lot of green space, but is one of the most deprived areas in the London

Borough of Hounslow due to other vulnerability factors such as income deprivation and barriers to housing and services.

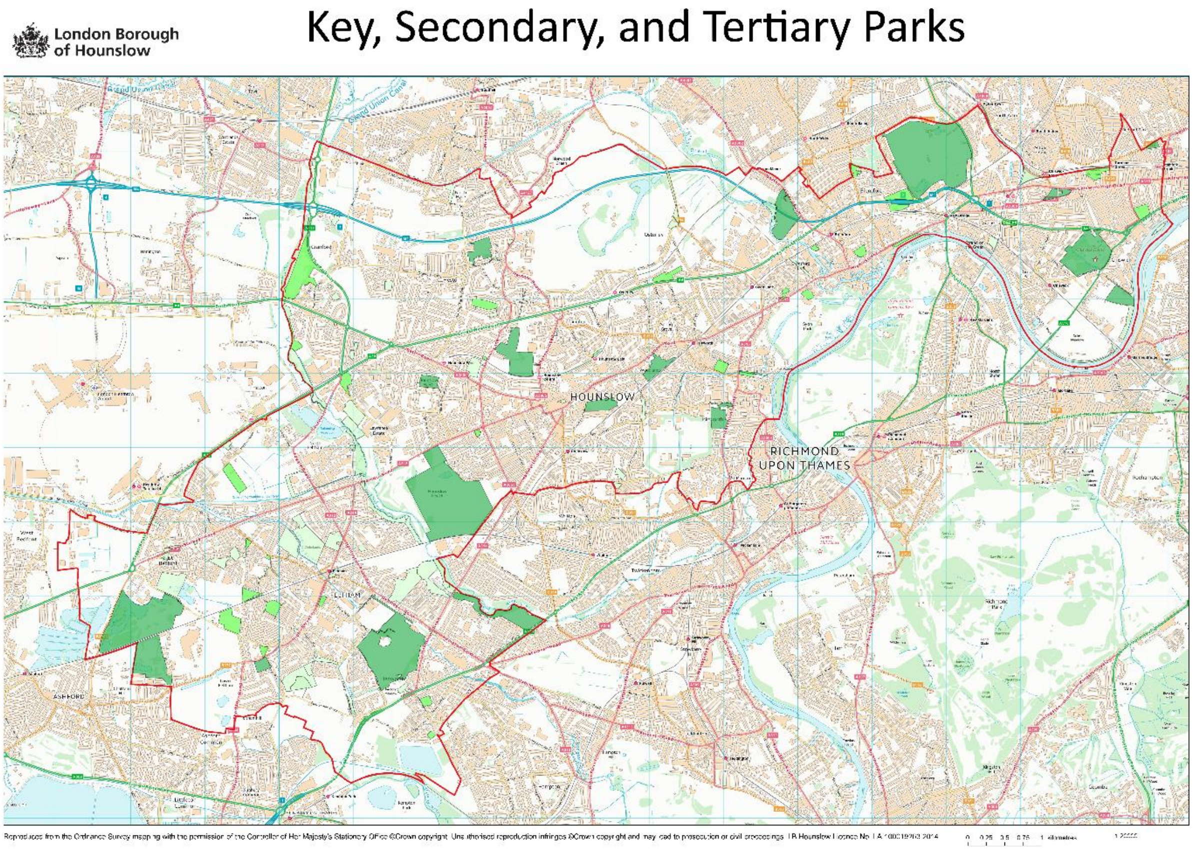

Figure 24. Key, Secondary, and Tertiary Parks

Houses of Multiple Occupancy

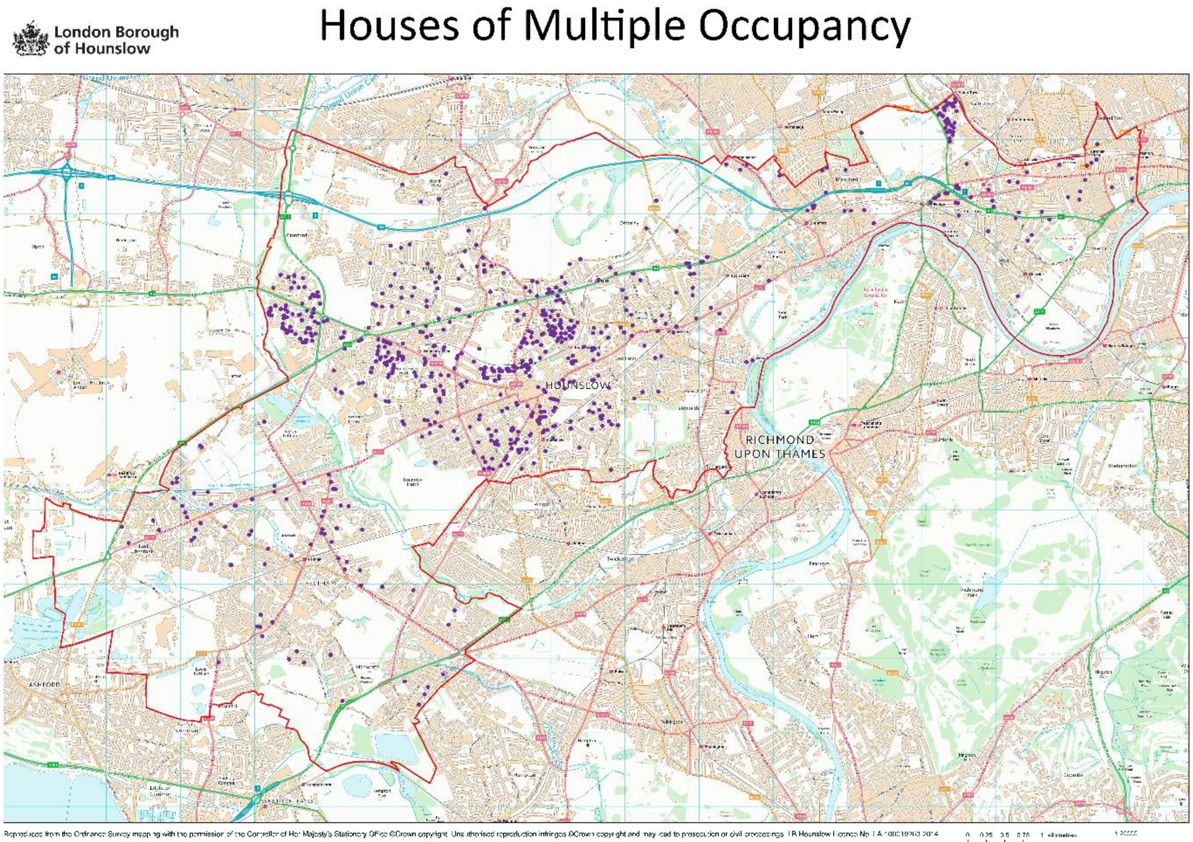

Figure 25. Houses of Multiple Occupancy

Buildings with multiple persons or families living together was identified through the HVI as a proxy factor for heatwave vulnerability. Coming from the 2011 Census, The London Borough of Hounslow has mapped these buildings on the address level within the GIS, represented in purple dots (The London Borough of Hounslow). The densest areas with houses of multiple occupancy are within Hounslow East, Central, and West, as well as in Cranford, Osterley, Spring Grove, Lampton, Heston, and heavily in Boston Manor. In the western part of the London Borough of Hounslow along High Street, Harlington Road East and Uxbridge Road in Feltham, as well as Staines Road in the neighboring East Bedfont, houses of multiple occupancy also appear. In northeastern parts of the London Borough of Hounslow, there is a noticeable number of these homes along High Street leading into Chiswick High Road, as well as along the A4, which is a major dual carriageway road.

Residents Age 65 and Over

London Borough of Hounslow

2011 Census Hounslow Residents Aged 65+

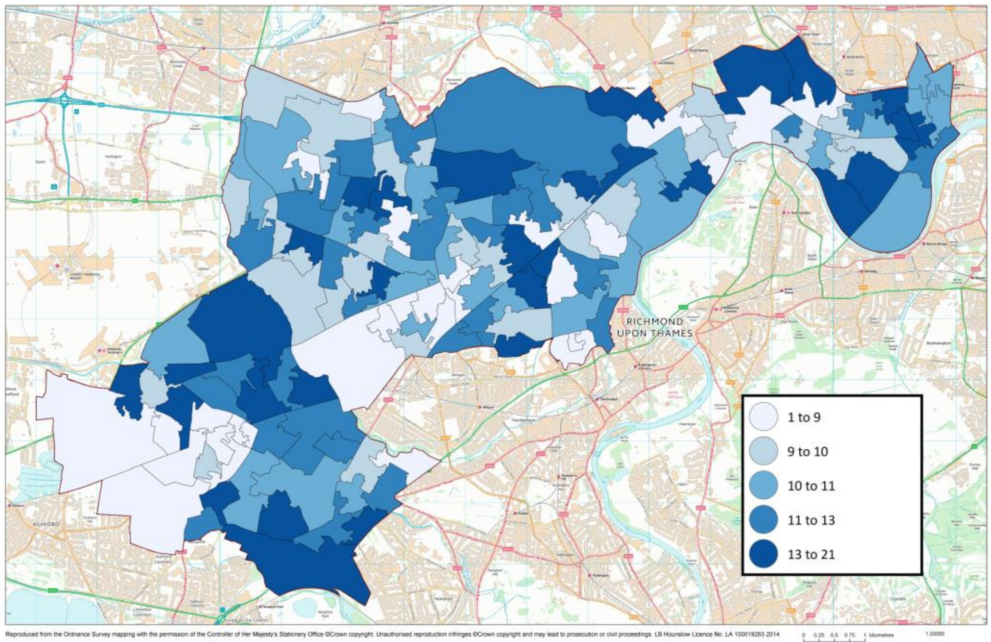

Figure 26. Hounslow Residents Aged 65+ (Census, 2011)

London Borough of Hounslow

2015 Midyear Estimates Citizens Aged 65+

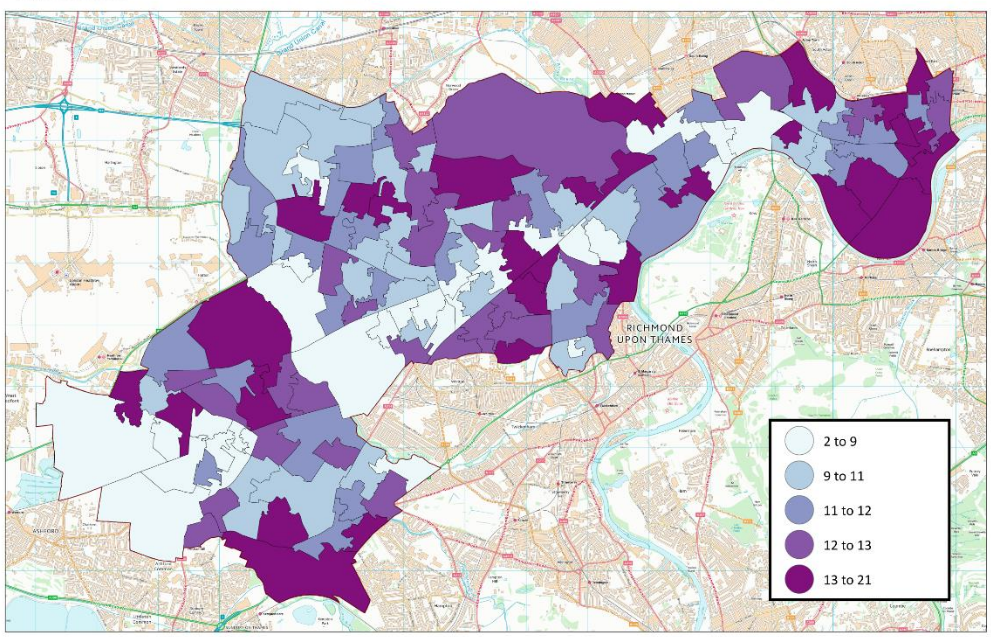

Figure 27. 2015 Midyear Estimates for Citizens Aged 65+

Age, specifically 65 and older, has been identified as the most important single indicator of vulnerability through our research. With the help of Vinesh Govind, the London Borough of Hounslow has created two new GIS layers using the 2011 census, as well as the mid-year 2015 population estimates. In the 2011 census layer as well as the mid-year 2015 population estimate, Hanworth (where many elderly homes are located), Feltham, North Feltham, Hounslow West, Heston, Lampton, Woodlands, Boston Manor, Grove Park, Turnham Green, and North Brentford were identified to be hotspots of this population. However, in the mid-year 2015 population estimate, Isleworth was also predicted to fall into this category, as well as Chiswick.

Risk of Loneliness in Older People

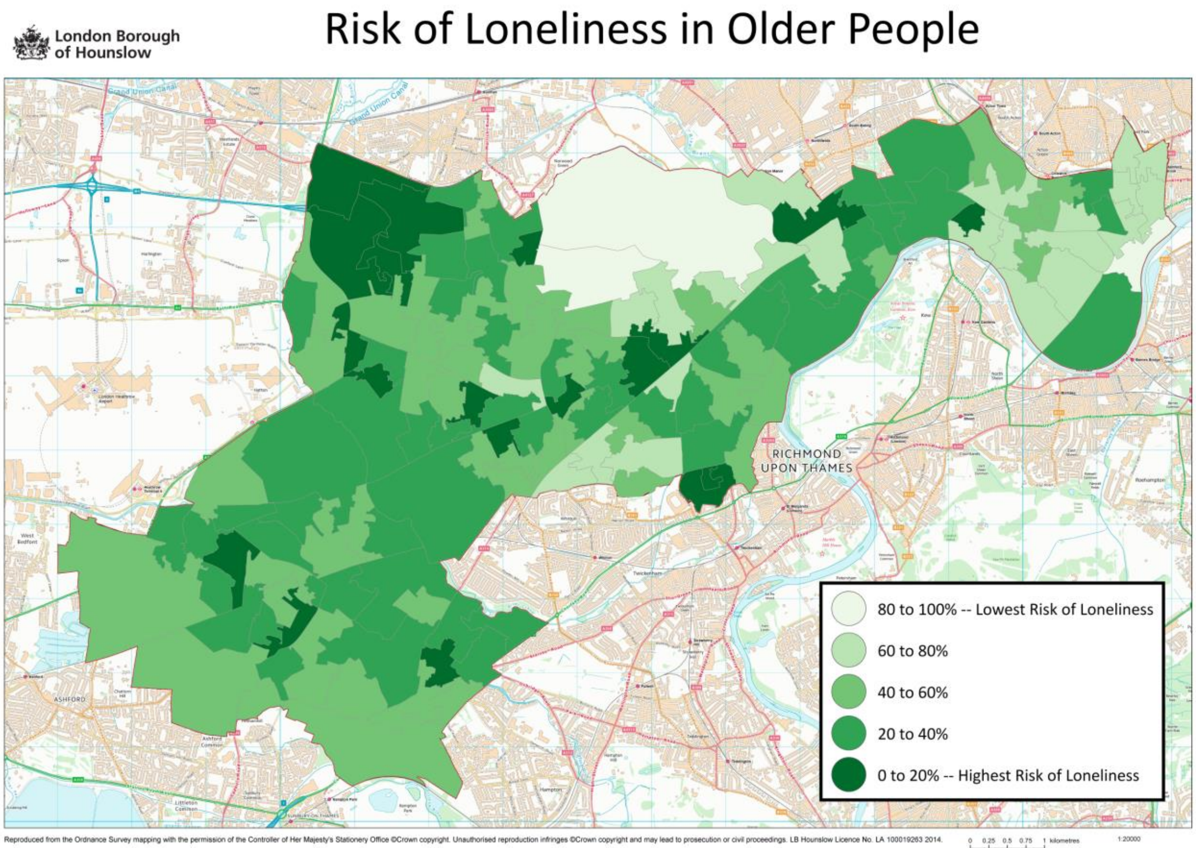

Figure 28. Risk of Loneliness in Older People

A major indicator of heatwave vulnerability recognized in the HVI and identified in the census is social isolation, especially in the elderly population. The London Borough of Hounslow's GIS system has graphed, using ONS Census table CT0467, the risk of loneliness in older people (The

London Borough of Hounslow). However, there is some discretion; with further investigation within the Census, table CT0467 could not be identified, which led us to believe this was an error. Alternatively, table CT0422, labeled "Living arrangements by age; Household composition (living alone) by age" is comparable to what the GIS layer had graphed, so it is possible that this is the data table used (census citation). The areas that social isolation affects the elderly the most can be seen in Hounslow West, Hounslow Central, Hounslow East, Cranford, southern Isleworth, Lampton, Brentford, Gunnersbury, Chiswick, Hanworth, East Bedfont, and along High Street in Feltham. Loneliness in the older population can be a serious risk during heatwaves because without any relatives or neighbors, those who are unable to care for themselves or are unaware of the incoming heatwaves and associated heat risks may not receive the attention they need.

Houses Without Central Heating

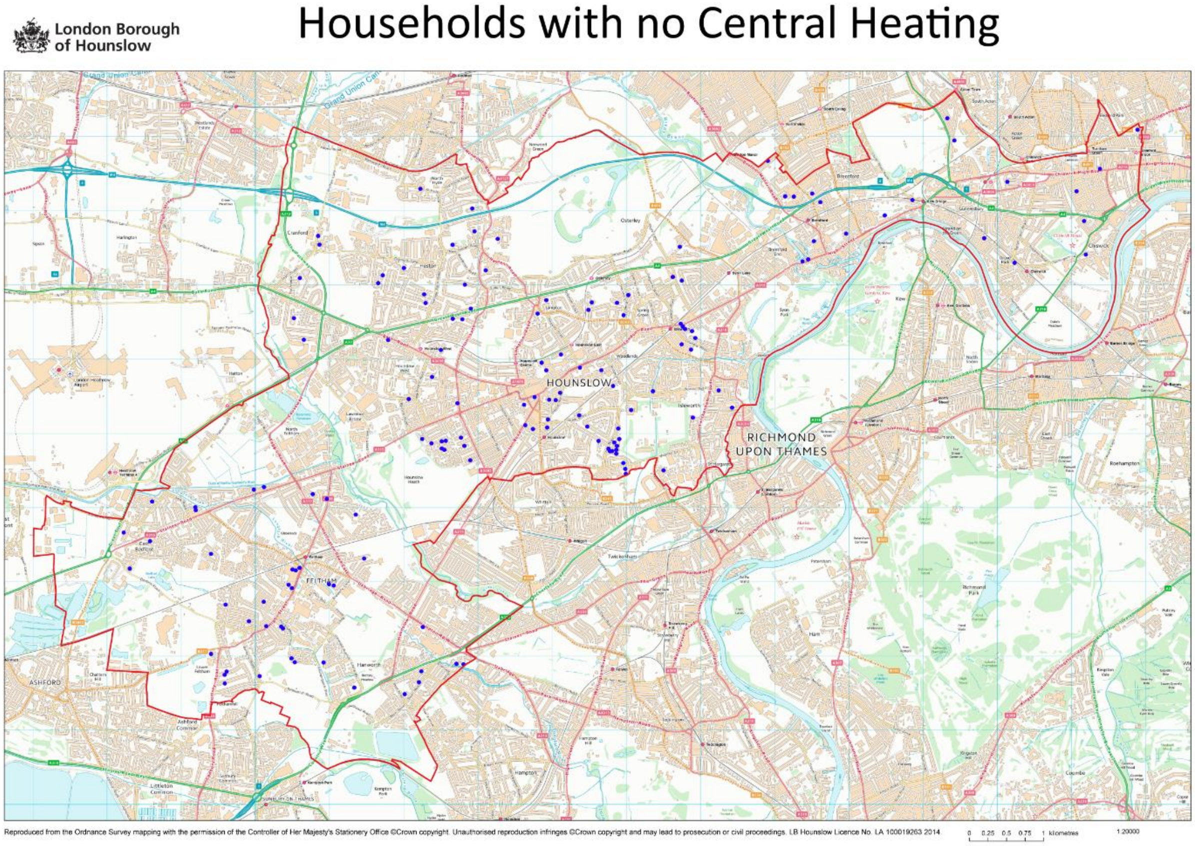

Figure 29. Households with no Central Heating

One risk factor identified by the Human Vulnerability Index is lack of access to air conditioning. In order to satisfy its requirement, households without central heating was used as the census proxy. This proxy has also been mapped in the London Borough of Hounslow's GIS on the postcode level, represented with blue dots (The London Borough of Hounslow). There does not appear to be any trends throughout the borough of lack of access to central heating, however on Hall Road near Central Hounslow there is a small cluster of buildings, as well as a few homes along Chertsey Road onto High Street in Feltham.

United Kingdom Census

One of the main goals of the Steering Group was to identify data within the London Borough of Hounslow that would be more accurate and up to date than the census. Our attempts to identify sensitivity data within the Borough were relatively ineffective, however, so we had to rely on the census for some socioeconomic and demographic information.

The United Kingdom Census is conducted every ten years by the Office of National Statistics, with a ‘mid-year estimate’ conducted approximately halfway between each census. The census collects social, economic, and demographic information that can be used to measure the sensitivity of individuals to heat stress. Studies like the Heatwave Vulnerability Index rely on the census for proxies to vulnerability factors that are otherwise not measured. Major components of vulnerability to heat measured by the census are age, social isolation, low education, and medical conditions. The London Borough of Hounslow GIS contains layers for census data aggregated to Output Areas, this allowed us to evaluate spatial trends, such as areas with large clusters of elderly residents or areas with high social isolation.

Another use of the census data is to assess the locations of minority groups within the London Borough of Hounslow. Minority communities face elevated sensitivity to heatwave events due to multiple factors, including a language barrier, unwillingness to approach police or emergency services, and community religious festivals that may impede or reduce individual’s adaptive capacity. Minority communities tend to group together, and we wanted to investigate if there are any areas where minority communities are coincident with areas of high exposure. This could be especially important during certain religious or cultural festivals where fasting is observed, such as Ramadan, which would make individuals in the community more sensitive to the adverse health effects of heatwaves.

Assessment of Datasets

The analysis of the data we identified was a crucial aspect of our project. We needed to assess whether the datasets we identified were useful for emergency planners, and whether this complex approach to describing vulnerability and planning for heatwaves was more helpful than traditional methods of response. Having identified multiple sources of data within the borough, we sought to learn as much as we could about them. This would allow us to analyze the data sets accurately. We directed questions about the data sets to the individual(s) who we had identified as working most closely with the data. The questions we wanted to answer are below:

- Who controls access to this data?
- Who works with this data within the borough?
- How often do you receive new data?
- Where does this data come from?
    - Does it come from other places inside the borough?
    - Does it come from outside the borough (GPs, NHS, etc)?
- Is this data electronic?
- What form does the data take (Spreadsheet, list, etc)?
- Does this data get entered into a database or retained in any way?
- Is the data anonymized?
    - Does the borough anonymize it?
    - Is there any individually identifying information retained by the borough?
- Is the data aggregated?
    - At what resolution is the data aggregated?
    - Does the borough do any further aggregation?
- Are there any spatial identifiers in the data (Postcode, address, UPRN, etc)?

We emailed individuals we had previously interviewed, giving them the list of questions above. We ran into difficulty getting responses from many individuals due to the tragedies that occurred in London during our project. Working with emergency planners runs the risk that emergencies will occur, and officials will be required to respond to these events instead of our emails.

Development of Usefulness Criteria

In order to effectively evaluate the data sets identified within the Borough, we created a set of standard criteria that could be used to assess the various different types of data sets we encountered. These suitability criteria would allow us to give a qualitative measure of their usefulness. The criteria we chose are accessibility, age, reliability, resolution, pertinence, and completeness of the data set. We chose these criteria based on the factors identified to us by our sponsor and the Steering Group as most important in the data we were discovering.

Accessibility

For data to be useful to the project, it needs to be easily accessible. The easiest data to access is public, which could be found on the internet or given without clearance to any member of the public by borough staff. Data that is accessible only to members of the council staff is still useful, but may represent an obstacle to the heatwave steering group or to the replicability of the project in other boroughs. Data that requires special clearance to access is not available to our team, and cannot be used for our project or by the steering group. Sometimes special considerations are given for academics, which should be taken into consideration when evaluating the accessibility of the data.

Up to Date

The data that is most useful to our project is often the most recently refereshed data available. Census data, while trustworthy, may be 9 years out of date before it is refreshed. We want to focus on data that has been updated recently to reflect the changing demographics and infrastructure in the borough.

Reliability

In order for this data to be an effective measure of vulnerability, it must come from a reliable source. We will rely on experts within the London Borough of Hounslow and the project steering group to determine the reliability of each data set that our team will use within the model.

Resolution

One aim of this project is to produce a model of heatwave vulnerability at a higher resolution than had previously been attempted. For this project, the best data is at the individual scale, as this can be used by contingency planners to provide the best assessment of vulnerability as an extreme weather event unfolds. As the scope of the data increases it becomes less useful to our project.

Pertinence

In each data set, there are attributes that may or may not be relevant to our project. We will rely on experts within the London Borough of Hounslow and the project steering group to determine the pertinence of these attributes and their ability to measure vulnerability.

Completeness

Not all data sets cover the entire borough. The completeness of a data set describes how fully it covers the borough, and describes any major gaps present in the data.

Data Set Usefulness

We used these criteria to evaluate data from the United Kingdom Census, the Energy Performance Certificate database, the London Borough of Hounslow Social Housing database, the London Borough of Hounslow Geographic Information System database, and Indoor Temperature Model data. We used this evaluation to produce a measure of how useful each dataset is. The usefulness of each data set is summarized in the table below.

Table 6. Data Source Evaluations Summary

Data Set	Usefulness
Census Data	The census is useful because it covers all of the United Kingdom and has a large variety of social, economic, and demographic data. This data is useful in determining the sensitivity of individuals based on factors such as age, isolation, medical conditions, and low economic or work status. The largest problem with the census is its age. Taken only once every ten years, the census can become inaccurate as it ages, especially in a borough with high population flux like the London Borough of Hounslow.
EPC database	The EPC database is useful because it provides specific information about

	dwelling properties that allow the indoor heat exposure to be modelled. The major downsides to the EPC dataset are its incompleteness and its inaccuracy. Despite this, the EPC database remains the best source of information on private residences.
Social Housing Data	The London Borough of Hounslow's social housing database is useful because it provides an in depth look at the Borough's housing stock, which is a good indicator of heat exposure. The social housing database is also useful because it is up to date and reliable. The major downside to the social housing database is that it only covers 23% of housing in the Borough, the rest is privately owned and there is minimal information about it retained by the Borough.
GIS database	The Earthlight GIS used by the Borough is useful because it shows the data spatially. The GIS database contains information from many different sources, including the census. The biggest downside to the GIS is that it can only be accessed through the London Borough of Hounslow intranet.
Indoor Temperature Model Data	The Indoor Temperature model data is useful to us because it allowed us to analyze spatial trends of indoor heat exposure, and therefore elevate vulnerability to adverse health outcomes from heatwaves, in a way that had never been done before in the London Borough of Hounslow. This data set gave us the opportunity to identify areas within the London Borough of Hounslow that are more vulnerable to heatwaves, which is information the Contingency Planning Unit can use to help place cooling centers and target specific areas to warn and inform before heatwaves occur. This can also help the Borough's Housing Investment team plan future improvements to social housing to improve the conditions for individuals living there.

In summary, we found that most of the data we assessed is not entirely up to date or complete. However, the resolution of all datasets other than the census and GIS database are at the address level. Additionally, all datasets are either public accessible or easily accessible if working with the London Borough of Hounslow. Finally, all the data sets that we reviewed are pertinent to heatwave emergency planning. These findings are shown in Table 7.

Table 7. Data Evaluation Visual Summary

	Accessibility	Up to Date	Reliability	Resolution	Pertinence	Completeness
Census Data	🟢	🔴	🟢	🟠	🟢	🟢
EPC Database	🟢	🟠	🟠	🟢	🟢	🔴
Social Housing Data	🟠	🟢	🟢	🟢	🟢	🔴
GIS Database	🟠	🟠	🟠	🟠	🟢	🟠
Indoor Temperature Model	🟠	🟠	🟠	🟢	🟢	🟠

When working with certain datasets, it is important to take into account the limitations of the data. For example, the Census Data and GIS database contain many smaller datasets that are important to our project, such as age, population density, etc., that may or may not be individually addressable. Each data set presented unique challenges and strengths, as seen in the table above. In the section below, we evaluate each data set individually and describe its usefulness to our project.

Census Data

The Census is conducted by the Office of National Statistics. All census data is available online.

Table 8. Census Data Evaluation

Criteria	Assessment	Comments
Easily accessible	This data is easily accessible.	The census data is all available online to the public.
Up to date	The data is not up to date.	A full census is only conducted every 10 years, the last one being in 2011. This data is six years old.
Reliability*	This data is reliable.	While there are errors within the census, it is overall a reliable source of information.
Resolution	This data is aggregated at the Output Area.	
Pertinence*	This data is very relevant.	The census covers all types of social, economic, and demographic information that is useful to our project.
Completeness	This data is complete.	The census covers the entire United Kingdom.

** Assessment will be conducted with assistance from expert opinion*

The census is useful because it covers all of the United Kingdom and has a large variety of social, economic, and demographic data. This data is useful in determining the sensitivity of individuals based on factors such as age, isolation, medical conditions, and low economic or work status. The largest problem with the census is its age. Taken only once every ten years, the census can become inaccurate as it ages, especially in a borough with high population flux like the London Borough of Hounslow.

EPC Database

This information is compiled by the Landmark Information Group on behalf of the Department for Communities and Local Government. All EPC data is available online.

Table 9. EPC Database Evaluation

Criteria	Assessment	Comments
Easily accessible	This data is easily accessible.	The EPC data is available to the public online.
Up to date	This data is semi-recent.	EPC's are only required whenever a property is built, sold, or rented, and last for ten years, so they may be several years out of date.
Reliability*	This data is semi-reliable.	Multiple members of the London Borough of Hounslow housing team have expressed hesitation about the reliability of EPCs, specifically concerns about the evaluator's ability to conduct an accurate performance review.
Resolution	This data is individually addressed.	EPCs are generated for specific properties, and have an address field.
Pertinence*	This data is relevant.	Exposure is a major factor contributing to vulnerability, and the type of building and its characteristics greatly influence the heat exposure residents face. The data provided in an EPC allows the approximate indoor temperature of a building to be modelled.
Completeness	The data is incomplete.	EPCs are only required when a property is built, sold, or rented, so there are many older buildings which do not have an EPC. Additionally, there are exceptions for listed buildings, religious properties, and properties that are occupied for less than four months of the year. Property owners can also opt out of the public EPC database, leading to further gaps in the record.

** Assessment will be conducted with assistance from expert opinion*

The EPC database is useful because it provides specific information about dwelling properties that allow the indoor heat exposure to be modelled. The major downsides to the EPC dataset are its incompleteness and its inaccuracy, despite this, the EPC database remains the best source of information on private residences.

Social Housing Data

This information is collected and maintained by staff in the London Borough of Hounslow. It is not available to the general public.

Table 10. Social Housing Data Evaluation

Criteria	Assessment	Comments
Easily accessible	This data is semi-accessible.	The housing data is stored in two Northgate databases in the Borough. It is accessible after the completion of a Privacy Impact Assessment. Supporting documentation is contained on spreadsheets in the Box system used by the Borough and is accessible to Borough employees.
Up to date	The data is up to date.	Staff and contractors for the Borough are constantly updating the database to account for improvement works and new assessments conducted on the social housing stock.
Reliability*	The data is reliable.	Renovations and improvement works are documented by the Borough, and surveys of the housing stock is conducted by trusted contractors.
Resolution	The data is individually addressed.	The data is recorded on a property by property basis, attached to individual addresses and UPRNs.
Pertinence*	The data is relevant.	Exposure is a major factor contributing to vulnerability, and the type of building and its characteristics greatly influence the heat exposure residents face.
Completeness	This data is incomplete.	The Borough has records for the social housing stock owned and maintained by the Borough, which only accounts for 23% of the buildings in the Borough.

** Assessment will be conducted with assistance from expert opinion*

The London Borough of Hounslow's social housing database is useful because it provides an in depth look at the Borough's housing stock, which is a good indicator of heat exposure. The social housing database is also useful because it is up to date and reliable. The major downside to the social housing database is that it only covers 23% of housing in the Borough, the rest is privately owned and there is minimal information about it retained by the Borough.

GIS Database

This information comes from a variety of sources, and is maintained by staff in the London Borough of Hounslow. It is available only on the Borough's Intranet, and not available to the general public.

Table 11. GIS Database Evaluation

Criteria	Assessment	Comments
Easily accessible	This data is semi-accessible.	The data is available on the Borough's intranet to all staff members, however, some layers are protected and only available to specific staff members.
Up to date	This data is semi-current.	The data in the database is updated every night by a script, so new changes are available within 24 hours. This does not mean all data is less than a day old. Census data, for example, is as old as the census.
Reliability*	This data is semi reliable.	The data in the GIS database is only as reliable as the data put into it.
Resolution	Variable.	Some data is individually addressed, some is aggregated at OA, SOA, MSOA, Wards, or for the whole borough.
Pertinence*	This data is relevant.	One of the aims of our project is to identify possible spatial trends in vulnerability throughout the Borough. This database allows us to visualize these spatial trends from data sets like the Census.
Completeness	Variable.	Most data sets cover the entire Borough, but not all.

** Assessment will be conducted with assistance from expert opinion*

The Earthlight GIS used by the Borough is useful because it shows the data spatially. The GIS database contains information from many different sources, including the census. The biggest downside to the GIS is that it can only be accessed through the London Borough of Hounslow intranet.

Indoor Temperature Model Data

This model uses a housing property data set to estimate indoor temperature at different outdoor temperatures. For this specific output, Jonathon Taylor used the publicly available EPC data for the London Borough of Hounslow. These outputs were added as a layer to the London Borough of Hounslow GIS, however they are only accessible to the Contingency Planning Unit staff.

Table 12. Indoor Temperature Model Data Evaluation

Criteria	Assessment	Comments
Easily accessible	This data is semi-accessible.	The indoor temperature model must be ran by Jonathon Taylor at the University College of London. For his research he is willing to run his model on any suitable data set. To analyze the outputs from this model, they must be input into Geographic Information System software.
Up to date	Variable.	The indoor heating model is reliant on an underlying building property data set. The resulting model outputs are as up to date as the underlying data set.
Reliability*	The data is semi-reliable.	Although the outputs from this model are only estimations, they can still be a powerful tool for heatwave mitigation planning. The model is most accurate when the results are aggregated to postcodes, although the accuracy of the model outputs is reliant on the underlying data set used to produce the outputs. If this underlying data set is prone to error, the results of this model will also be inaccurate.
Resolution	The data is individually addressed.	The model output is individually addressed, but as mentioned above, the output is more accurate when aggregated at the post code level. When aggregated at the postcode, or even higher at the LSOA level, the data will be a good representation of the mean indoor temperature at a given outdoor temperature.
Pertinence*	This data is relevant.	An important component of an individual's vulnerability is comprised of their exposure to heat. Indoor temperature is an important indicator of indoor exposure. The model outputs can accurately estimate the mean indoor temperature of buildings (when aggregated) which would allow emergency planners to pinpoint areas of the city where indoor overheating would be likely to occur at different outdoor temperatures.
Completeness	This data is semi-complete.	The model can be run for any building for which the requisite information is known. Any building

		that does not have appropriate data cannot be run through the simulation. The indoor temperature model that we used relied on the public EPC database, which is incomplete and sometimes has errors. Due to the problems with the underlying data set used to create the indoor temperature estimations and the inaccuracies of the model, we consider it semi-complete.

** Assessment will be conducted with assistance from expert opinion*

The Indoor Temperature model data is useful to us because it allowed us to analyze spatial trends of indoor heat exposure, and therefore elevate vulnerability to adverse health outcomes from heatwaves, in a way that had never been done before in the London Borough of Hounslow. This data set gave us the opportunity to identify areas within the London Borough of Hounslow that are more vulnerable to heatwaves, which is information the Contingency Planning Unit can use to help place cooling centers and target specific areas to warn and inform before heatwaves occur. This can also help the Borough's Housing Investment team plan future improvements to social housing to improve the conditions for individuals living there.

Conclusion and Recommendations

The main objectives of our project were to create an operational definition of vulnerability to Heatwaves, identify data within the London Borough of Hounslow related to heatwave vulnerability, and analyze the data available within the London Borough of Hounslow for its usefulness to emergency and civil planners. To create an operational definition of vulnerability, we reviewed a wide body of literature about heatwave vulnerability and planning. Through this review process, we created our definition of heatwave vulnerability. To identify data within the Borough, we interviewed members of staff from different departments about the data they had access to. To analyze the data, we spoke with vulnerability and emergency planning experts from within and outside the borough to decide what data was the most important, as well as evaluating the datasets for their usefulness using qualitative measures.

Throughout our project, we were faced with challenges that made it difficult to collect and analyze important data. Many of the staff we interviewed in the London Borough of Hounslow were extremely helpful and knowledgeable, but also very busy. During the course of our project, the United Kingdom was struck by three major emergencies, and many of the people we were dependent on for information became engaged in response efforts to these events. In the final ten days of our project, a massive fire destroyed a tower block in west London, again diverting people we were dependent on to tasks more pressing than our project. Despite these difficulties, we were able to collect and analyze data available within the London Borough of Hounslow to create a resource for emergency and civil planners to use.

GIS Layers

When analyzing the layers from the GIS, there were areas that became clearly identifiable as vulnerable to a variety of proxies our team had identified. Though we were not qualified to identify the weights of comparative proxies within the layers, our team conducted a count of recorded areas and the prevalent proxies that were found for each:

Table 13. GIS Layer Summary

Area	Count	Vulnerabilities
Hounslow West	8	Indices of Multiple Deprivation MOSAIC Group N MOSAIC Group O Rented Tenure Population Density/Parks – Dense Houses of Multiple Occupation Age - Census 2011 Risk of Loneliness
Cranford	7	Indices of Multiple Deprivation MOSAIC Group N MOSAIC Group O Rented Tenure Population Density/Parks – Not dense with Green Space Houses of Multiple Occupation Risk of Loneliness
Brentford	7	Indices of Multiple Deprivation MOSAIC Group N MOSAIC Group O Rented Tenure Population Density/Parks – Dense Age - Census 2011 Risk of Loneliness
Chiswick	7	Indices of Multiple Deprivation MOSAIC Group O Rented Tenure Population Density/Parks – Less Dense with Green Space Houses of Multiple Occupation Age - Mid-year 2015 estimate Risk of Loneliness
Feltham	7	MOSAIC Group O Rented Tenure Population Density/Parks – Dense Houses of Multiple Occupation Age - Census 2011 Risk of Loneliness Central Heating

Hanworth	6	MOSAIC Group N MOSAIC Group O Rented Tenure Population Density/Parks – Not dense with Green Space Age - Census 2011 Risk of Loneliness
Hounslow Central	4	Houses of Multiple Occupation Population Density/Parks – Dense Risk of Loneliness Central Heating
East Bedfont	4	MOSAIC Group N Houses of Multiple Occupation Population Density/Parks – Not dense with Green Space Risk of Loneliness
Brentford End	4	MOSAIC Group N Population Density/Parks – Not dense with Green Space Houses of Multiple Occupation Risk of Loneliness
Isleworth	4	MOSAIC Group O Rented Tenure Age - Mid-year 2015 estimate Risk of Loneliness
Hounslow East	4	MOSAIC Group N Population Density/Parks – Not dense with Green Space Houses of Multiple Occupation Risk of Loneliness
Heston	4	MOSAIC Group N Population Density/Parks – Dense Age - Census 2011 Houses of Multiple Occupation
Gunnersbury	3	Indices of Multiple Deprivation Population Density/Parks – Dense Risk of Loneliness
Lampton	3	Houses of Multiple Occupation Age - Census 2011 Loneliness

Osterley	2	Population Density/Parks – Not dense with Green Space Houses of Multiple Occupation
North Feltham	2	Population Density/Parks – Dense Age - Census 2011
Turnham Green	2	Population Density/Parks – Dense Age - Census 2011
Boston Manor	2	Houses of Multiple Occupation Age - Census 2011
Woodlands	1	Age - Census 2011
North Hyde	1	Population Density/Parks - Dense
Spring Grove	1	Houses of Multiple Occupation

From this table we found Hounslow West was the most prominent area with eight high heatwave risk vulnerabilities identified. Chiswick, Brentford, Feltham, and Cranford followed with counts of seven heat risk proxies. Hanworth is also noteworthy a with count of six. We have identified these areas on a map of the London Borough of Hounslow below: Hounslow West has been circled with a black circle, while areas with counts of seven have been circled with red circles, and Hanworth, the area with a count of six has been circled with a purple circle.

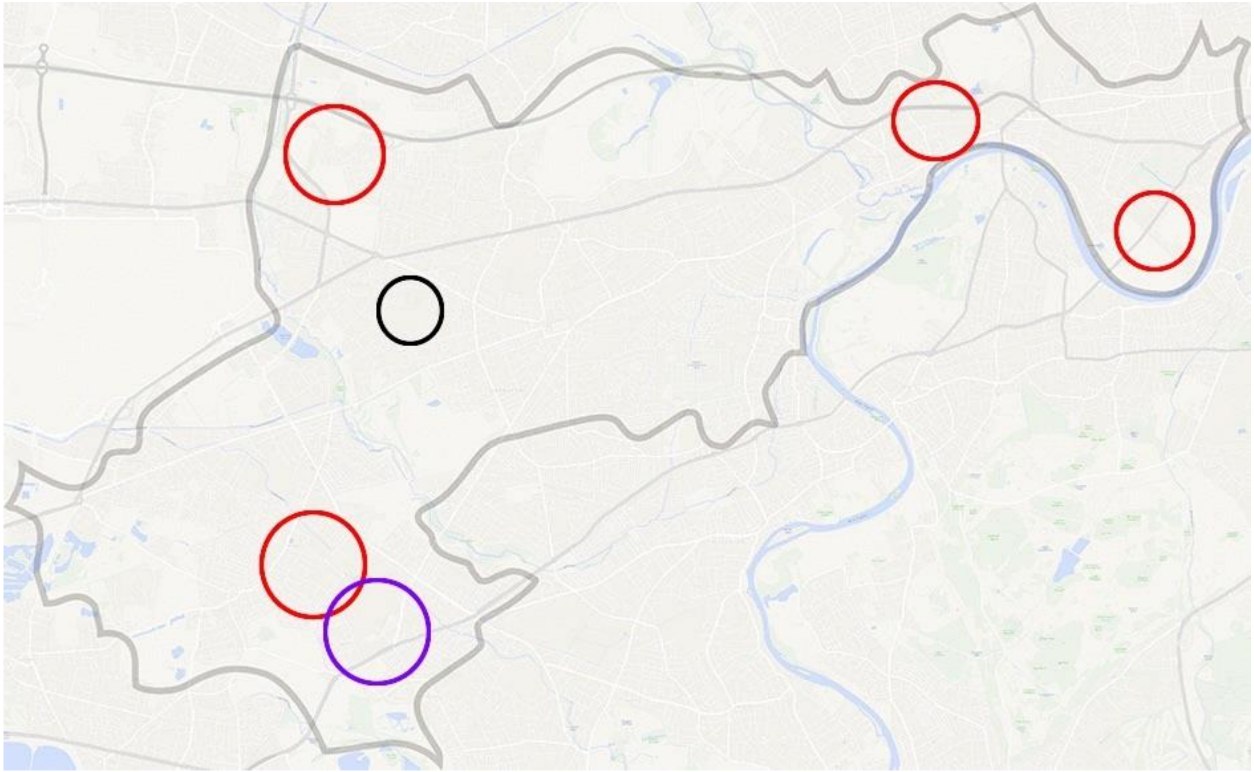

Figure 30. Identified Potential High-Risk Areas

Based off of the GIS maps, our team recommends that in heatwave emergency events, Hounslow West be the first area targeted for response, followed by the red zones (Chiswick, Brentford, Feltham, and Cranford). However, due to the close proximity of Hanworth and Feltham, the two areas should be dealt with simultaneously as to not waste time and energy that would be required with redeployment to the area. The next group of areas that response should be fixed on are: Hounslow Central, East Bedfont, Brentford End, Isleworth, Hounslow East, and Heston. These areas are still vulnerable to heatwaves with four proxies each, but are a slight drop off from the previously identified areas.

We found that there is no data located within the borough about private housing stock. The borough has accurate, up-to-date assessments of the borough-owned social care housing. The CROHM assessment provides a more accurate and in-depth profile of a building when compared to EPC data, which can be inaccurate or out of date. We believe this assessment can be used in the indoor temperature model or other building heating models to more accurately compute the risk of overheating for a particular building. Unfortunately, since the CROHM assessment only covers social care housing within the borough, it cannot be used to model the entirety of the borough. We recommend that the borough look into carrying out the CROHM assessment on privately owned housing in order to have a more complete housing characteristics data set.

Indoor Temperature Model Data

The indoor temperature model gives an estimate of temperature inside a building based on the outdoor temperature. While this is only an estimate, the Housing Investment team can consider this information when determining what social buildings need to be renovated first to best protect the health of vulnerable individuals in the event of a heat wave. The model accounts for many different characteristics of a building including things like build form, U Values, and height above ground. By renovating a building, it is possible to make it more resilient to overheating which helps lower the exposure faced by residents, helping to reduce their vulnerability to heatwaves. The Indoor Temperature model map can also be used to analyze spatial trends in high heat exposure. By combining exposure data like the Indoor Temperature model with sensitivity data like the Indices of Multiple Deprivation emergency planners can look at vulnerability in a more holistic fashion which may lead to better identification of vulnerable people.

Privacy Impact Assessments

Future projects that wish to view or work with any data within this borough, or any other in the United Kingdom, will be subject to Information Governance laws. To access data, completion of a Privacy Impact Assessment (PIA) will be necessary. A PIA is required any time a group wishes to access and subsequently share any kind of data held by the borough. The types of information required by the PIA include what data the team wants to access, where it's stored, and how they plan to safely handle it. After finding multiple roadblocks when trying to access personal information, we decided to focus on building data, but in order to access and share this data a PIA was still required. This process is lengthy and time consuming, so it should be started as early as possible to allow the maximum time for processing. If accepted, the PIA will allow the group to access the data sets they believe are important, as well as allow the group to share data sets with other partners identified in the PIA. We were unable to complete the PIA process during our time in the London Borough of Hounslow. For more information regarding the completion of a PIA, including a blank copy of the document, see the Appendix E.

Identified Data

We've compiled the data we found within the London Borough of Hounslow and other external sources into a table shown on the next page. For each dataset we have identified the source, our contact (if applicable), origin, format, resolution, if it contains protected anonymity, how often it is updated, the vulnerabilities factors pertinent to our project, coverage, and the accessibility. Future projects may use this as a starting point for further investigation of the datasets we analyzed as well as possible points of contact for new datasets.

Table 14. Identified Data Table

Dataset	Source	Contact	Origin of Data	Format	Resolution	Protected Anonymity	Refresh Rate	Specified Vulnerability(ies)	Completeness & Coverage	Data Access
Census Data	Office of National Statistics	N/A	Office of National Statistics	CSV / Excel	LSOA	✓	10 years	Age, Population, Ethnicity, Population Density, Housing Occupancy	Fully complete for country	Public
London Datastore	Greater London Authority	N/A	Greater London Authority	Varies: Excel, CSV, PDF, Website, ZIP, XML, Shapefile, Misc.	Borough level	✓	Rolling	Urban Heat Island	Complete but cannot see past borough level	Public
EPC Housing Data	Department for Communities and Local Government	Rory Prendergast	Individual Contractors	Excel	Address		Rolling	Indoor Heat Exposure	Only covers private homes being newly rented, sold, or renovated	Public
Indices of Multiple Deprivation	GIS / Earthlight	Vinesh Govind	Department for Communities and Local Government	GIS layer / Excel	Varied	✓	Rolling	Sensitivity (Deprivation)	Fully complete for country	Public / Borough staff for Earthlight
Social Care Housing Data	London Borough of Hounslow Housing Team	Rory Prendergast	LBH Housing	Excel	Address		Rolling	Sensitivity (Age, Gender, Ethnicity)	Only Social Care housing (23% of Borough)	Clearance Required
Mosaic	GIS / Earthlight	Vinesh Govind	Mosiac (Experian)	GIS layer / Excel	Postcode	✓	Yearly	Sensitivity (Age, Socioeconomic status, deprivation)	Full Borough	Borough staff
Age Mid-2015 Estimates	GIS / Earthlight	Vinesh Govind	Office of National Statistics	GIS layer / Excel	LSOA	✓	10 years	Age	Fully complete for country	Public

Places to Look for More Data

During the course of our project we do not think we were able to conduct an exhaustive search of the London Borough of Hounslow, nor do we think we identified all of the data sets available that could be useful to model heatwave vulnerability within the borough. Future projects may want to investigate the following areas:

Although individually identifiable information is nearly impossible to access, we recommend delving further into exactly what type of health and social care information the London Borough of Hounslow has access to. It may be useful to identify how the borough handles and stores sensitive, individually identifiable information, what sensitivity factors may be identified in this data, and how completely this data set may cover the population of the London Borough of Hounslow. In particular, we believe the borough's Health and Wellbeing team has data that could be used to further heatwave modelling and planning within the Borough. Identifying these key attributes of healthcare and social care should not require viewing the data, only asking individuals who manage the data set the right questions.

We were unable to interview any General Practitioners or Clinical Commissioning Groups, but we think it may be useful to reach out to GPs or CCGs that work with the borough to ask what data they may have access to and what sort of contingency plans they may have in place for heatwaves. This could be a potential source of collaboration for the borough, both during the warning and informing phase before a heatwave, and when dealing with the harmful effects of a heatwave as one unfolds.

Recommendations

During our time with the London Borough of Hounslow the major question we were unable to answer was if complex vulnerability analysis and indices reliant on composite measures of vulnerability are more effective at reducing excess heatwave mortality and morbidity than traditional procedures. This assessment will need to be pursued by emergency planning officials within the London Borough of Hounslow and researchers from the Hounslow Heatwave Steering Group once provisional changes have been made to Hounslow's heatwave response based on composite measures of vulnerability. The provisional changes we recommend to Hounslow's heatwave response plan are outlines below.

Having created and analyzed vulnerability factor maps we produced from the Hounslow GIS, our team has found areas that we believe are at heightened risk to heatwave events. The areas of Hounslow West, Chiswick, Brentford, Feltham, and Cranford are the areas within the borough at most risk to heatwave events due to the high occurrence of vulnerability factors within these areas. We believe targeting these areas with additional information prior to and during heatwave events will help reduce the risk of increased morbidity and mortality during a heatwave. Using MOSAIC data available on the Hounslow GIS, targeted information can be broadcast to the residents of these areas using the most effective means of communication for the prevalent demographics.

A major component of vulnerability is the exposure individuals face to heat regardless of their individual sensitivity. A leading factor in exposure to heat is the exposure individuals face in their own homes. The London Borough of Hounslow lacks complete, reliable, and up to date information for the privately owned housing stock within the borough. We recommend that the borough carries out the CROHM assessment on privately owned housing stock in order to have a complete housing characteristics data set. This information can be used in conjunction with the existing social care housing data held by the borough to form a complete housing characteristic data set for all housing in the borough. This data can be used by researchers to model indoor temperature exposure at the address level. The data can be mapped in order to spatially analyze trends of high heat exposure. This has implications for emergency planning and long-term development and regeneration within the borough.

Emergency planners can use indoor temperature exposure data to assess which buildings will reach dangerous temperatures first during a forecasted heatwave which can allow them to place cooling centers and allocate resources more effectively. Additionally, this can allow targeted warning and informing procedures for neighborhoods most likely to be adversely affected in the days leading up to a heatwave.

Housing investment teams within the borough need to prioritize limited resources and cannot accommodate seasonal changes within social housing. Improvement projects for social housing that mitigate the effects of heatwaves can target dwellings identified as most likely to overheat. Neighborhoods that show trends of overheating can be targeted for regeneration projects such as green space improvements to create spaces where residents can congregate to escape heat inside homes

We recommend that future projects look further into the data identified in this report by having thorough discussions with the teams and individuals identified as owners of the data. In particular, we believe the borough's Health and Wellbeing team has data that could be used to further heatwave modelling and planning within the Borough. Delving further into exactly what type of health and social care information the London Borough of Hounslow has access to may be useful to identify how the borough handles and stores sensitive, individually identifiable information, what sensitivity factors may be identified in this data, and how completely this data set may cover the population of the London Borough of Hounslow. We recommend interviewing any General Practitioners or Clinical Commissioning Groups that work with the borough to ask what data they may have access to and what sort of contingency plans they may have in place for heatwaves. Collaboration may provide Emergency Planners with more information about vulnerable people within the London Borough of Hounslow than they currently have access to.

The London Borough of Hounslow has the opportunity to save lives, more effectively allocate resources, and improve the wellbeing of its most deprived citizens through improved heatwave response and emergency planning. Our recommendations can be implemented provisionally and assessed in by qualified researchers and emergency planners in order to test their effectiveness. If shown to be effective, these measures could be integrated into the London Borough of Hounslow's heatwave plan.

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Appendices

Appendix A: Sponsor Description

This appendix describes our sponsor, the London Borough of Hounslow, and members of the Hounslow Heatwave Steering Group

The London Borough of Hounslow

The London Borough of Hounslow is located in western London, approximately 15 miles from the center of the city. It has a population of nearly 254,000 people (Office for National Statistics, 2011b) and covers an area of about 23 square miles. Heathrow International Airport is on the western border of the borough, providing 1 in 3 jobs available to Hounslow's West Area residents (London Borough of Hounslow, n.d.). Hounslow provides approximately 140,000 jobs, mostly in the service industry (London Borough of Hounslow, n.d.). Since 2001, the London Borough of Hounslow has grown by approximately 60,000 residents. Nearly 50% of the population is between the ages of 15 to 49, with 82.9% of households containing at least one english-speaking person (Office for National Statistics, 2011d).

Figure 31. Map showing Hounslow highlighted in red (Wikimedia, 2011)

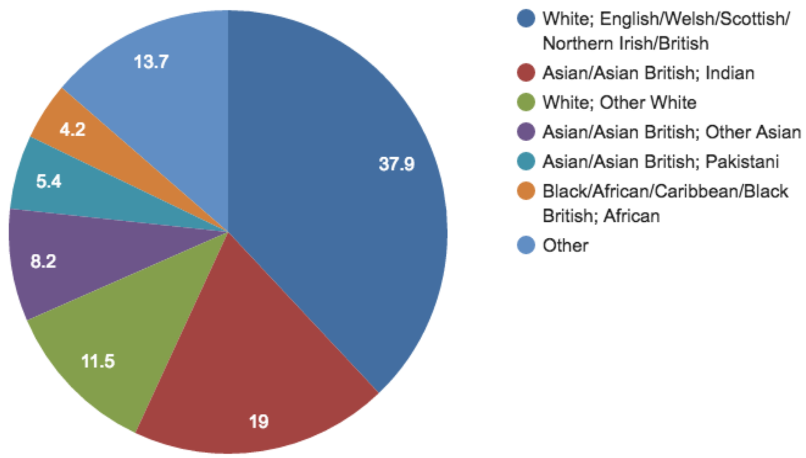

Figure 32. Hounslow population ethnicity (Office for National Statistics, 2011c)

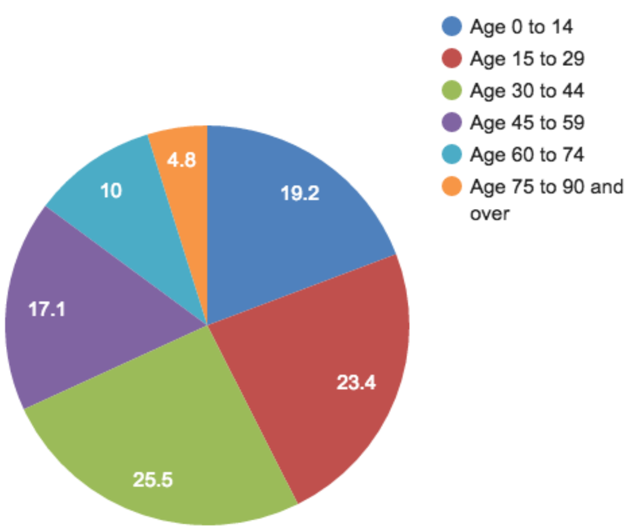

Figure 33. Hounslow population age (Office for National Statistics, 2011b)

The Hounslow Council provides many services to the residents of the borough, funded by the council tax. Residents of Hounslow pay on average a tax of £27 a week (London Borough of Hounslow, 2017, p. 1). The budget of the Hounslow Council funded by the council tax is £714,132. Of this seven-hundred-thousand-pound budget, the Borough spends 32 per cent on schools, 27 per cent on central services, 10 per cent on adult social care, and 10 per cent on community safety and environmental services. Services enabled by the council tax include free childcare and early education for children three to four years old (London Borough of Hounslow, 2016b), waste retrieval for rubbish and recycling, and support for elderly members of the community. The budget also provides funding to the 57 primary schools and 15 secondary schools in the borough.

The Civil Contingencies Act ("the Act") of 2004 established clear policies for emergency response and preparedness in the United Kingdom. Emergency planning aims to prevent emergencies and mitigate the damage caused by emergencies. The Act defines an emergency as "a situation which threatens serious damage to human welfare … [or] the environment of a place in the United Kingdom" (The Civil Contingencies Act, pg. 2) and defines an Environmental emergency as any scenario which threaten to "contaminate land, water, or air … [or the] disruption or destruction of plant life or animal life" (Civil Contingencies Act, pg. 2-3). Heatwaves are periods of time with abnormally high temperatures for an area. In 2006, England experienced one of the worst heat waves in its history, with record high temperatures reaching 38.5 degrees celsius lasting for 10 days in some areas. Heat waves can pose serious risks to public health, including dehydration, heat exhaustion, and heat stroke. Heat waves can also have negative environmental impacts, including heightened risks of forest fires and accelerated erosion of soil. In 2003, the heat wave that spread across most of England caused an estimated 2000 deaths and wildfires across the country (Meteorological Office, 2016). These kinds of weather patterns are becoming more and more common, 3 of the hottest temperatures on record at the Heathrow weather tracking station were in the past 10 years, and 7 out of the 10 hottest recorded temperatures were recorded in the past 30 years. In addition, there has been a general increasing trend in the temperatures recorded at the Heathrow weather station.

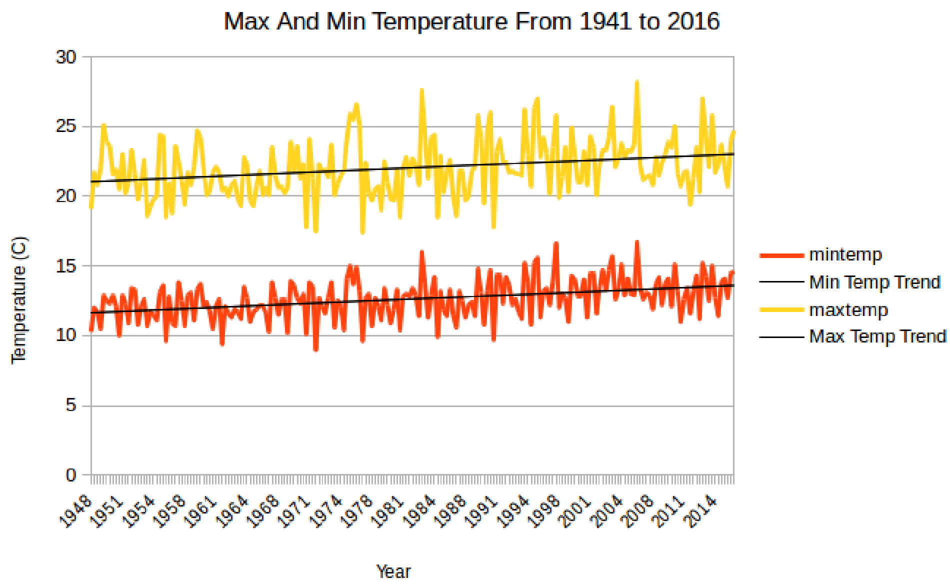

Figure 34. London min & max temperature from June to August (1984 to 2017)

The Act defines a framework for civil protection that handles pre-emergency management, assessment, prevention, and preparation (Cabinet Office, 2003). The Hounslow Contingency Planning Unit (CPU) is an organization founded under the Act in 2004, focusing on assessing local risks within Hounslow and developing response plans accordingly. The London Borough of Hounslow maintains a specific contingency reserve fund of £6 million to cover the cost of associated with emergencies (London Borough of Hounslow, 2016a). The CPU dedicates itself to minimizing vulnerability within the borough by interpreting hazards, creating risk maps, and implementing solutions to mitigate its negative effects.

Public Health England (PHE)

Public Health England (PHE) is an executive agency in the Department of Health (Public Health England). An Executive agency is a group that is considered separate from its parent organization, this includes management and budgeting. PHE was founded on April 1 2013 as a way to combined about 70 different health organizations across the United Kingdom into a single body (Public Health England). PHE employs about 5500 people, these employees include scientists, researchers, and health professionals as well as managerial staff at each of the 8 centers around England. Public Health England has many primary objectives including

- Make the public healthier and reduce gaps in health of different groups
- Promote healthier living
- Advise the government and support actions
- Protect the public from health hazards
- Prepare and respond to public health emergencies
- Improve public health by sharing experience and information
- Identify and prepare for future public health hazards
- Support local authorities and the National Health Service to plan for and provide health and social care services
- Conduct research on various public health topics and ways to better respond to different public health hazards (Public Health England)

Public Health England Particularly wanted to learn what information the London Borough of Hounslow had that would be able to better identify vulnerable people during a heat wave better than other national data sets, like the census, could.

University College of London (UCL)

The University College of London was founded in 1826 and currently employs 11000 staff and has a total student body of approximately 38000. Similar to Public Health England, UCL wants to identify what data the Borough has that can be used to better identify at risk and vulnerable populations during a heatwave. There are multiple individuals at the UCL working on the Heatwave Steering Group. The members of the steering group have worked on multiple different projects that relate to heatwave vulnerability, including AWESOME and LUCID. These were collaborative projects between the UCL and various other entities like the London School for Tropical Health and Medicine.

Greater London Authority (GLA)

The Greater London Authority was created after a referendum in 1998. The goal of the GLA is to create a safe healthy city to live in. The main concerns for the Mayor's office are to test the usefulness of Heatwave Vulnerability Indices for short and long term planning, assessing data sets and determining if they are useful, and determining what they can go ‘on the ground’ to protect people from harm during heatwave events.

Appendix B: Contact Sheet

This appendix contains a table of contact information for people inside and outside of the London Borough of Hounslow. Telephone numbers have been omitted.

This table contains the name, organization, role, and email address for all of the people we contacted for our project. We interviewed some of these people, some of them are on the steering group, while others still we only exchanged emails with. Each of these people helped us in some way reach our final product.

Table 15. Contact Sheet

Name	Organisation	Role	Email
Twm Palmer	The London Borough of Hounslow	Head of Contingency Planning & Resilience	Twm.Palmer@Hounslow.gov.uk
Ross Thompson	Public Health England	Environmental Public Health Scientist	Ross.thompson@phe.gov.uk
Jonathon Taylor	University College of London IEDE	Senior Research Associate	j.g.taylor@ucl.ac.uk
Emer OConnell	Greater London Authority	Public Health specialist	emer.oconnell@phe.org.uk
Annette Figueiredo	Greater London Authority	Principal Policy & Programme Officer	Annette.Figueiredo@london.gov.uk
Anna Mavrogianni	Institute for Environmental Design and Engineering, The Bartlett, UCL	Lecturer in Sustainable Building and Urban Design	a.mavrogianni@ucl.ac.uk
Rory Prendergast	London Borough of Hounslow	Investment Team [Housing]	rory.prendergast@hounslow.gov.uk
Vinesh Govind	London Borough of Hounslow	Policy, Scrutiny and Intelligence	Vinesh.Govind@hounslow.gov.uk
Matthew Kay	London Borough of Hounslow	Information Governance Manager	Matthew.Kay@hounslow.gov.uk
John Morgan	London Borough of Hounslow	Head of Prevention & Care Management	john.morgan@hounslow.gov.uk
Mark Blomfield	London Borough of Hounslow	Senior Joint Commissioning Manager -	mark.blomfield@hounslow.gov.uk

		Preventative Services and Supported Housing	
Mark Haggerty	National Health Service	North West Collaboration of Clinical Commissioning groups	mark.haggerty@nhs.net
Sean Doran	London Borough of Hounslow	Senior Housing Partnership and Solution officer	Sean.Doran@hounslow.gov.uk
Sally Duhig	London Borough of Hounslow	Head of Business development and performance	Sally.Duhig@hounslow.gov.uk
Martin Waddington	London Borough of Hounslow	Director - joint commissioning	Martin.Waddington@hounslow.gov.uk
Andrew Heap	London Borough of Hounslow	Data Analyst	Andrew.Heap@hounslow.gov.uk
Martin Tomkins	London Borough of Hounslow	Investment Officer	Martin.Tomkins@hounslow.gov.uk
Laura Maclehose	London Borough of Hounslow	Health and Wellbeing unit	laura.maclehose@hounslow.gov.uk
Angie Bone	Public Health England	Head of Extreme Events	Angie.Bone@phe.gov.uk

Appendix C: Heatwave Vulnerability Risk Factors

This appendix describes factors that are related to or contribute to heat wave vulnerability. Bolded risk factors are identified in a majority of the literature we reviewed.

Table 16. Heatwave Vulnerability Risk Factor

Risk Factor	Description
Regional Climate	The regional climate and geography where a city is located affects the frequency, intensity, and duration of heatwaves there. Cities in temperate climates, and those in regions where hot weather is infrequent, are more likely to lack sufficient response mechanisms to heatwaves. These cities are also less likely to have recovery plans in place for after a heatwave has occurred. Cities in tropical areas in low- and middle-income countries are also at increased risk for adverse effects of heatwaves due to water scarcity issues (Fernandez, Milan & Creutzig, 2015).
Urban Heat Island	Temperatures in the urban core of modern cities is significantly hotter than in suburban regions of the same city due to the Urban Heat Island (UHI) effect. Modern cities have dense concentrations of large buildings constructed from heat-absorbing, impervious materials that trap more heat during the day and release it more slowly at night than natural ground cover. This creates an effect whereby daytime temperatures are higher than in surrounding rural areas, and heat does not dissipate at night leading to a large temperature differential in urban areas (Harlan, Brazel, Prashad, Stefanov, & Larsen, 2006).
Indoor Heat Exposure	Indoor heat exposure is a composite factor. Poor quality housing is a leading contributor to indoor heat exposure. Roof type and construction is extremely important in determining the amount of heat that will be absorbed by a dwelling. A building with reflective roofing absorbs less solar energy and will result in a cooler dwelling than a building with less reflective roofing (Harlan et al., 2006). Homes with air conditioning will be cooler than those without air conditioning, although there are significant drawbacks to relying on air conditioning to keep dwellings cool. Electricity production can be disrupted by heatwave events, and large amounts of air conditioners in urban areas contribute to the UHI effect (Fernandez et al., 2015). The orientation of houses, along with the orientation of their windows, available ventilation, and heat protection measures affect the indoor temperature of a building. Individuals living in dwellings with high indoor heat exposure are at greater risk for adverse health outcomes (Wolf & McGregor, 2013).
High Population Density	Areas with high population density are warmer than areas with low population density, and often lack green space (Harlan et al., 2006).
Green Space	Neighbourhoods with less green space are exposed to higher temperature than those with more green space. Streets lined with shade giving trees and green open spaces such as parks help to significantly mitigate the UHI effect and create microclimates of much lower temperatures than surrounding areas with less green space (Harlan et al., 2006).
Proximity to	Neighbourhoods near industrial areas or transportation routes are subject to large

Industry	sources of anthropogenic heat. Asphalt pavement absorbs solar radiation and raises the temperature of the surrounding area. High vehicular traffic also produces heat and pollutants (Harlan et al., 2006).
Age	Elderly people (over the age of 65) and young people (under the age of 5) are particularly susceptible to adverse health outcomes arising from heatwaves. Elderly people have higher death and hospital admission rates during heatwaves than the rest of the population (Reid, O'Neill, Gronlund, Brines, Brown, Diez Roux, & Schwartz, 2009).
Sex	Physiological and thermoregulatory differences suggest that women are more sensitive to heat than men, although there are inconsistencies in these findings. Pregnant women may experience complications due to extreme heat (Fernandez et al., 2015).
Medical Condition	Many factors contribute to the increased heat risk faced by those with medical conditions. People with lower mobility, such as those confined to beds, and individuals with cardiovascular diseases, pulmonary illnesses, or renal problems all show higher susceptibility to heat related morbidity and mortality. Individuals with high risk perception or low behaviour adjustment are more susceptible to adverse health effects arising from periods of extreme heat (Fernandez et al., 2015). Respiratory and cardiovascular caused mortality, including heart attacks, increase during periods of extreme heat. Individuals with diabetes, nervous disorders, emphysema, epilepsy, cerebrovascular disease, pulmonary conditions and mental health conditions may also experience increased illness or death during periods of extreme heat (Reid et al., 2009).
Socioeconomic/demographic status	Low socioeconomic status often results in individuals living in more intense areas of the Urban Heat Island (ARUP, 2014), and in buildings that are not well adapted to handling extreme heat (Harlan et al., 2006). The poor disproportionately live in areas with high heat exposure and in buildings that are not equipped to handle heat (Harlan et al., 2006).
Socially Isolated	Individuals who live alone without regular contact with others are at heightened risk to adverse health outcomes related to extreme heat events. Isolated individuals are less likely to seek cooperation, trust, or help from their neighbours, leading to fewer resources to cope with extreme heat (Harlan et al., 2006).
Minority Status	Minority groups are more likely to live in warmer neighbourhoods and be exposed to greater heat stress. These neighbourhoods often feature high population density, little vegetation or green space, and fewer social resources to deal with extreme heat. Some communities may also struggle with a language barrier (Harlan et al., 2006). Mortality rates during heatwaves that vary by race can also be explained by a lack of heat coping resources, such as a lack of air conditioning (Reid et al., 2009).
Airborne Pollutants	Airborne Pollutants, specifically PM_{10} and $PM_{2.5}$ (particulate matter of diameter 2.5 - 10 microns and less than 2.5 microns respectively) can cause cardiovascular health issues and can lead to death. It is estimated that 3% of all mortality from cardiopulmonary disease and about 5% of cancer of the lungs, throat, and trachea are caused by $PM_{2.5}$. Heatwaves are known to exacerbate certain existing medical conditions, like cardiovascular disease and asthma. In addition, during heatwaves people are more likely to open windows thereby increasing the permeability of the building, which causes a greater proportion of airborne pollutants to enter (Taylor, J., Shrubsole, C., Davies, M., Biddulph, P., Das, P., Hamilton, I., Vardoulakis, S., Mavrogianni, A., Jones, B. and Oikonomou, E. 2014).

Appendix D: Interview Methods

This appendix describes the methods used during interviews to learn more about the various vulnerability data within the London Borough of Hounslow.

Throughout our time in the Borough, we strove to maintain a rigorous standard of information collection during interviews. Candidates were identified to us by our sponsor, Twm Palmer, and by members of the Hounslow Heat Wave Steering Group. Although the settings were informal, and most of the interviews were conducted as conversations, we prepared an outline of questions ahead of the interview. These questions were designed to focus the conversation on the topics most important to our project, while still allowing flexibility to deviate from our plan if new or interesting information was presented to us. Multiple group members took notes to ensure no important details were missed. After conducting each interview, our group would create one unified set of 'Minutes' to collect all the most important information in one document. During the course of some interviews, further candidates were suggested.

Arranging an Interview

When given a candidate to interview, the first step was to reach out to them by email. Below is a typical first email sent to an interview candidate.

> Hello *Candidate*,
>
> My name is *Group Member* and I am a member of a student team from Worcester Polytechnic Institute working with Twm Palmer in the Contingency Planning Unit in the London Borough of Hounslow. My team is working to identify heat wave vulnerability data within the borough that could be useful for emergency planning purposes. You were identified to us by *Reference*, and we hope that you will be able to meet with us to discuss data you are familiar with.
>
> Thank you very much,
>
> *Group Member*
> Contingency Project Planning Officer

After establishing contact with a prospective interviewee, we would arrange a time and place to meet. Most commonly our interviews were conducted at 11:00 in the Hounslow Civic Center Emergency Control Center.

Conducting an Interview

During our preparation for IQP, we created a list of possible questions we could ask during our interviews. The list is below.

- What method of combining scores of vulnerability with some weighting or statistical significance has the team found to be most successful?
  - What are the benefits of combining scores in this way?
  - What are the risks of combining scores in this way?
- What method of visualizing this data does the team think is the best?
  - If the model was to use the lists of vulnerable people instead of a mortality layer, how would the team choose to display the data?
- Is this tool helpful for making informed decisions for emergency planning?
  - What sort of evaluative criteria has the team considered to use when comparing the performance of the LBH before and after acquiring this tool?
  - Does the current level of precision give the map enough resolution, or is it necessary to upgrade it to make informed decisions?
  - What further work would be required to make the tool fully functional?
- What does the team expect in the near future for the project?
  - What is the cost to maintain the project?
  - Will there be enough funding to expand the project?
  - Would the integration of the web weather stations and the Met office weather data create higher resolution maps?
  - How does the team envision the model will be used in regeneration, housing, and environmental planning?

Once we arrived at the project site it became clear that we would need to revise our questions, and create a specific list for each interview candidate. We knew that each candidate may not be able to answer all the questions we had, or information they presented in the interview may interest us and lead us in a new direction. We remained flexible during the interviews, with each member of the group asking questions, and at least two members taking notes. A selection of the specialized lists of questions are below.

Vinesh Govind Interview Questions

- What is your current role within the LBH?
- What types of data does the LBH currently have?
  - How are they stored?
  - Who has access to them?
  - What is the resolution of the data?
  - Are they good proxies of vulnerability?
  - How do you envision the data currently held by the LBH will be used in emergency planning?
  - How do you envision the data currently held by the LBH will be used in regeneration, housing, and environmental planning?
- Can you explain the vulnerable persons spreadsheet?
  - What are the benefits/risks of identifying vulnerable people in this way?
- What method of visualizing this data have you used in the past?
  - What are the most important components of creating a vulnerability visualization?
  - What are the greatest challenges when constructing a vulnerability visualization?
- How does the borough deal with data security / anonymization of data?
  - How do we keep data useful while sufficiently anonymizing data.
- What tools does the LBH currently use for making informed decisions for emergency planning?
  - What sort of evaluative criteria are used to analyze the performance of the LBH before and after acquiring this tool?
  - Does the current level of precision give the CPU enough resolution to make informed decisions, or is it necessary to upgrade it?
  - What further work would be required to make the tool fully functional?
- What is the cost to maintain the databases?
  - Are there any third party services that the LBH uses?

  - Is there enough funding/resources to continue at the current functionality?
  - What resources is the LBH lacking that would allow it to perform better?
- Are tools like the THJF model helpful for officials making informed decisions for emergency planning?
  - What sort of evaluative criteria would you consider appropriate to use when comparing the performance of an official or organization before and after acquiring this sort of tool?
  - What sort of qualities (resolution, maintenance requirements, ease of use) are important to make a model like the THJF useful?

Rory Prendergast Interview Questions

- What is your current role within the LBH?|
- What types of building data does the LBH currently have?
  - How are they stored?
  - Who has access to them?
  - What is the resolution of the data?
  - Are they good proxies of vulnerability?
  - How do you envision the data currently held by the LBH will be used in emergency planning?
  - How do you envision the data currently held by the LBH will be used in regeneration, housing, and environmental planning?
- What (if any) method of visualizing this data have you used in the past?
  - What are the most important components of creating a vulnerability visualization?
  - What are the greatest challenges when constructing a vulnerability visualization?
- How does the borough deal with data security / anonymization of data?
  - How do we keep data useful while sufficiently anonymizing data.
- What tools does the LBH currently use for making informed decisions for emergency planning?
  - What sort of evaluative criteria are used to analyze the performance of the LBH before and after acquiring this tool?

    - Does the current level of precision give the CPU enough resolution to make informed decisions, or is it necessary to upgrade it?
    - What further work would be required to make the tool fully functional?
- What is the cost to maintain the databases?
    - Are there any third party services that the LBH uses?
    - Is there enough funding/resources to continue at the current functionality?
    - What resources is the LBH lacking that would allow it to perform better?
- Are tools like the THJF model helpful for officials making informed decisions for emergency planning?
    - What sort of evaluative criteria would you consider appropriate to use when comparing the performance of an official or organization before and after acquiring this sort of tool?
    - What sort of qualities (resolution, maintenance requirements, ease of use) are important to make a model like the THJF useful?

Laura Maclehose Interview Questions

- What is your current role within the LBH?
- What types of data does the LBH currently have?
    - How are they stored?
    - Who has access to them?
    - What is the resolution of the data?
    - Are they good proxies of vulnerability?
    - How do you envision the data currently held by the LBH will be used in emergency planning?
    - How do you envision the data currently held by the LBH will be used in regeneration, housing, and environmental planning?
- Can you explain the vulnerable persons spreadsheet?
    - What are the benefits/risks of identifying vulnerable people in this way?
- What method of visualizing this data have you used in the past?
    - What are the most important components of creating a vulnerability visualization?
    - What are the greatest challenges when constructing a vulnerability visualization?

- How does the borough deal with data security / anonymization of data?
    - How do we keep data useful while sufficiently anonymizing data.
- What tools does the LBH currently use for making informed decisions for emergency planning?
    - What sort of evaluative criteria are used to analyze the performance of the LBH before and after acquiring this tool?
    - Does the current level of precision give the CPU enough resolution to make informed decisions, or is it necessary to upgrade it?
    - What further work would be required to make the tool fully functional?
- What is the cost to maintain the databases?
    - Are there any third party services that the LBH uses?
    - Is there enough funding/resources to continue at the current functionality?
    - What resources is the LBH lacking that would allow it to perform better?
- Are tools like the THJF model helpful for officials making informed decisions for emergency planning?
    - What sort of evaluative criteria would you consider appropriate to use when comparing the performance of an official or organization before and after acquiring this sort of tool?
    - What sort of qualities (resolution, maintenance requirements, ease of use) are important to make a model like the THJF useful?

Post Interview

After conducting an interview, we would send the interviewee an email thanking them for their time, and asking any follow up questions we may have had. As a group, we would collect our notes into one document. This process allowed us to discuss the material while it was still fresh in our minds, and compile the most important information into one easily accessible document for the future. This organizational approach was crucial to our success, as it allowed us to easily retrieve information from past interviews quickly when it was needed in the future.

Major Findings

This table summarizes the key points from interview that we conducted.

Table 17. Interview Major Findings

Interviewee	Reason for Interview	Summary of Major Findings
Rory Prendergast, Investment Team, London Borough of Hounslow	Our project is concerned with exposure vulnerability data, including information about individual dwellings. Rory is part of the housing team in Hounslow, he is an expert on the borough's social housing.	● The London Borough of Hounslow owns 16500 properties; each property has an EPC (Energy Performance Certificate). ● The Borough stores housing data electronically, which can be printed in spreadsheet format. ● The Borough recently commissioned a CROHM assessment. This is similar to an EPC but is more in depth and trustworthy. ● Borough plans in 5 and 30 year increments, their three major foci are providing decent homes, meeting health hazard and safety risk standards, and asset retention. ● Data on privately owned buildings is minimal. EPC's are done for these buildings every time the owner performs a renovation. (Benoit, Brown, Mattiuzzi, Murphy, 2017)
Laura Maclehose, Health and Wellbeing Unit, London Borough Of Hounslow	A large component of vulnerability is an individual's sensitivity heat. Laura deals with health data within the Borough which can be used to determine people's sensitivity to heatwaves.	● The Health and Wellbeing unit does mostly statutory tasks. ● They receive about £17 million a year from the Department of Health, this money goes towards programs like sexual health services, drug and alcohol abuse services, wellbeing service, childhood obesity and oral health services. ● Other teams that deal with health in the borough, the Environmental Health Team and the Housing Team (part of the Better Homes Better Health program). ● The National Health Services performs about 11000 health checks every year. ● General Practitioners (GP's) collect data on patients during checkups, they can share that data with the health team. The health team can aggregate it and create borough wide statistics for every borough in London. ● This data is destroyed almost immediately after it has been processed because it is extremely sensitive. (Murphy, Mattiuzzi 2017)
Vinesh Govind Policy, Scrutiny and Intelligence, London Borough of Hounslow	Our project focused on identifying what data the London Borough of Hounslow has that could be used to better	● The London Borough of Hounslow stores its information in spatial SQL ● Borough employees can access the GIS through EARTHLIGHT, a software that runs on the Hounslow Intranet. EARTHLIGHT allows employees to view

	identify at risk populations. Vinesh is the resident Geographic Information System (GIS) expert in the Borough, he has access to the entire GIS and can	different data sets represented spatially across Hounslow. ● EARTHLIGHT allows certain layers to be password protected so that only certain employees can see it. ● The GIS describes building usage and information about properties. ● Each property in the United Kingdom has a 12 digit identifying number, called a UPRN. ● Maps can be created in EARTHLIGHT from existing data sets, parameters can be represented in many different ways. (Benoit, Brown, Mattiuzzi, Murphy. 2017)
Martin Tomkins, Investment Officer, London Borough of Hounslow	Our project required very specific building data to run simulations. While we were not ultimately able to run the simulation on the Hounslow building data, Martin controls many of the building databases that contain the specific information we would need.	● Sock building survey, recently completed CROHM assessment of approximately 80% of the social care housing in the Borough, about 5000 houses. ● The borough has U-Values for windows and doors but no U-values for floors. ● The system may have data on wall types and roof types. ● Floor level is available, and floor area and ceiling height should be estimable. ● The borough does not have any data on private housing, the best option to obtain information on privately owned buildings would be the publicly available EPC's, even though they are not the most accurate information source. (Benoit et. al. 2017)
Dr. Jonathon Taylor, Senior Research Associate, University College London	Jonathon Taylor, Phil Symonds, and Anna Mavorgianni developed the Indoor heating model that was used to simulate indoor temperatures in Hounslow using EPC's. Jonathon ran the simulation for us, as well as answering our questions about the simulation and other indoor environment factors.	● The building physics model was designed to simulate energy usage, indoor pollutants and indoor temperatures. It uses a series of tools built in the Python programming language. ● Some of the parameters required to run the model are window size, insulation type, and building type. ● The simulation given an estimate for the average building. It is not perfect, even with 100% accurate data the results may still not be truly representative of the indoor environment of the buildings simulated. It is a good estimate, not an accurate measurement. ● While the model would be unreliable at an address level, if it were aggregated at a post code level the estimates would be fairly representative of the actual temperatures. ● Due to differences in how the data is stored and how certain traits are expressed (i.e. Rd. versus rd. versus RD. in street names) when matching his data to the EPC's or Data held by the Borough there could be a miss rate as high as 50% meaning that

		half of the building would have to be entered by hand. (Benoit et. al. 2017)
Matthew Kay, Information Governance Manager, London Borough of Hounslow	Matthew is in charge of making sure that information is handled properly within the borough. We wanted to share data with other partners in the project, Matthew was one of the people in charge of making sure we did so responsibly.	● If we want to access and share any kind of data a Privacy Impact Assessment (PIA) must be filled out. For more information on the PIA see Appendix E. ● Any accessing and sharing of data we wished to do would have to conform to the Data Protection Act of 1998. (Benoit et. l. 2017)
John Morgan, Head of Prevention and Care Management, London Borough of Hounslow.	John Morgan is in charge of adult social care in the London Borough of Hounslow. As such he has access to information about social care housing that would make good proxies for vulnerability.	● The Borough has locality teams which work with adults (anyone over 18) who have disabilities. ● The borough has about 3200 cases, not all of which live in the London Borough of Hounslow. ● They provide services for tasks that are essential for daily living. ● Eligibility criteria are outlined in the Care Act of 2014. ● Children under 18 are protected by the Children Act of 2014 (Benoit et. al. 2017)
Dr. Tanja Wolf, World Health Organization European Center for Environment and Health, Research Associate	Tanja Wolf was the coauthor of the Heatwave Vulnerability Index that we discuss in this paper. She is considered an expert in the field.	● Factors should be broken up into two categories, internal and external. Internal factors are things like age, health status and social isolation. External are things like air pollution and green space. ● Combinations of these factors can be good indicators of vulnerability. Things like old people living alone and sick people living in a place with no green space. (Benoit et al. 2017)

Appendix E: The Privacy Impact Assessment

This appendix describes the process of filling out and submitting a Privacy Impact Assessment, of PIA.

Our time in the London Borough of Hounslow was primarily concerned with data identification and analysis. To view any data within the London Borough of Hounslow, we were required to complete a Privacy Impact Assessment. A Privacy Impact Assessment provides justification for the need to access and, if requested, subsequently share data from the borough. Information covered in the assessment include justification for the project, the specific data to be accessed, where the specific data is stored, how it is stored, and how it will be accessed. Additionally, plans must be made to properly handle the data while the project is happening and after the conclusion of the project. The filer must know how they will use the data, they must name the sources of the data (for example they must supply the name of the databases they will access), as well as what software they will use to access the data. Below is a blank copy of the PIA for the London Borough of Hounslow. Not included are some of the descriptive materials that come with the blank PIA. These include a brief introduction to why a PIA is required, some definitions of the terms used in the PIA, as well as some appendices describing different UK privacy and data protection act excerpts.

Business justification for the project/process change

1.1 Please provide a description of the project/programme /System /Technology being assessed	
1.2 Please state if this initiative is a new initiative/project or a process change to an existing initiative/system/Technology?	
1.3 Please state the Purpose/Objectives of the Initiative?	

Project Scope

2.1. Does this involve and/or require the processing of business sensitive or Personal data? (including Sensitive Personal data)	
2.2. Does the project or initiative involve multiple organisations? (i.e. joined up government initiatives, outsourcing to public sector)	
2.3. Does the project/process change involve a procurement exercise of a new ICT system or a service or both an ICT system and a service?	

Legal Justification

To be completed if the project or initiative involves the use of personal data.

3.1. Does any legislation (or regulation) explicitly require and/or govern the collection/use of specific personal information?	
***3.2.* Does any legislation (or regulation) govern the general/collection/use of personal information?**	
3.3. Does the project involve any activity which is exempt from legislative privacy protections?	*For example law enforcement and national security information system*
3.4. Is the justification for the new data-handling clear and/or published.	

Type of data to be collected and processed

4.1 Is the Personal data being obtained from existing data sets? If yes please state the existing data set.	
4.2 If the Personal data is being obtained from an existing data set, please state whether the purpose of processing has changed?	
4.3 Please state how you intend to notify data subjects if purpose of processing has changed?	*If purpose has changed then data subjects will need to be notified – Explicit consent will be required for sensitive personal data.*
4.4 For processing of sensitive personal data, please state how you would obtain explicit consent or where consent cannot be obtained meet a schedule 2 and schedule 3 criteria?	*Seek advice from the information Governance Team on schedule 2 and schedule 3 criteria*
4.5 If the personal data is being obtained from a new source then please state the source from where it is being obtained from?	
4.6 Which specific categories of personal information are necessary in order for the project/process change to succeed?	
4.7 Which specific categories of sensitive personal information are necessary in order for the project/process change to succeed?	
4.8 Which specific categories of business sensitive information are necessary in order for the project/process change to succeed?	
4.9 Can you demonstrate that the project/process change will not involve the collection/use of excessive information –i.e. it will only use adequate and relevant information?	

4.10 Risk assessment: rate the likely negative impact to the individuals concerned if the personal data to be shared were lost or stolen or misused in any way.	1. Rate the Impact if this occurred - 1 to 5 2. Rate the likelihood of this happening: 3. Type of harm that could be caused to an individual: (Exposure to ID Theft, Loss of Life, Harm or Distress, Financial, Reputational) 4. Potential number of people affected:
4.11 If the information is lost, What emergency actions are to be taken?	

Storage, Access, Retention and Disposal

5.1 How will the information be stored (electronically or manually) and where?	
5.2 Who will access to the personal data/sensitive personal data/sensitive business information?	
5.3 How will the access be managed/ determined?	
5.4 How long will the information be retained? Please state the legal justification where applicable	*Please refer to the Council's retention schedule*
5.5 What process do you intend to have in place to review retention date and in particular ensure personal data is not kept longer than necessary?	
5.6 What disposal arrangements do you have in/intend to have in place for the personal data/sensitive personal data/sensitive business information?	

Technical information

Complete this section for electronically held information.

6.1 Please state the location of where the information or the application will be held? I.e. on the, desktop, shared drives, application server, hosted on internet only, hosted on intranet, etc.	
6.2 Will the application be accessed by members of the public? Please state how (i.e via public web portal, via access Council network i.e. not web portal based).	
6.3 If the information is held on an application or a database, please state the name of the application/database?	
6.4 How will the application be supported by (internally by ICT or vendor)?	
6.5 Do you intend to have an SLA in place for support?	
6.6 Will the application or database have an interface with another system? Please state the system(s)	
6.7 Do you intend to have a backup regime in place for the application?	
6.8 Do you intend to have a system/hardware maintenance agreement with the vendor/ICT?	

Information Security

7.1 Please state the technical security controls you intend to have in place for electronically held information? (Legislative or Compliance requirements)	*i.e. username passwords, encryption, 2 factor authentication etc.*
7.2 Please state the physical security controls you intend to have in place for manually and electronically held information?	
7.3 Will the information be saved on a removable media, such as a CD, USB, or hand held device? If so what technical and physical security do you intend to apply to it?	
7.4 Please state the technical and physical security controls the 3rd party/vendor has in place, if the application is being hosted off off-site/by the vendor. (What accreditations they have)?	
7.5 Please state who (the departments) will be given access to the information?	
7.6 What auditing do you intend to have in place for transactions carried out on the information and access?	
7.7 Please detail all the security Arrangements' in place or you will have in place (Technical , Organisational and Physical) Includes:- · Technical · Systems · Office Security · People Management · Security when Transferring/Migrating · DR · Patching (Roadmap) **All Security arrangements must be appropriate for the classification of the Information.**	

3rd Party access

8.1 Will the information be disclosed/accessed by a 3rd Party including for vendor support?	
8.2 Please state the reason for disclosure/access and whether it is necessary in order for the project or process to succeed?	
8.3 Would any such disclosure / access be systematic or Ad-hoc?	
8.4 Can you guarantee that only adequate and relevant information will be disclosed/ accessed by the 3rd party and that the no excessive information will be disclosed/ accessed?	
8.5 Will any processing of the manual or electronic information be carried out off-site by a 3rd Party?	
8.6 Please state whether the 3rd party is registered with the Information Commissioner's Office and whether they have a Data Protection Policy, if the personal data/sensitive personal data is being processed by 3rd party?	
8.7 What processes will be used to ensure that Personal data/sensitive personal data/business sensitive information is not kept longer than necessary by 3rd Party/ Vendor and disposed of securely?	

Information Sharing: Multi-agency working

Includes information being processed by 3rd party on a joint initiative.

9.1 Will the information be used/ shared for Multi-agency/joint working? Please state the organisations.	
9.2 For multi- agency working please state whether an Information Sharing Agreement/Protocol has been signed by the agencies?	*Please consult Information Governance for Information Sharing Agreement*
9.3 Will the 3rd party/ multi- agency staff be working on-site and be needing access to the LBH network and applications? If yes, please ensure that a Legal Agreement (Non Disclosure Agreement) NDA is completed.	*Please consult Information Security or Legal for* **NDA**