

Developing a Geospatial Decision Support System to Address Extreme Heat and the Urban Heat Island Effect in the Greater Toronto Area

A User Needs Assessment

Prepared for GeoConnections
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About the Clean Air Partnership

The Clean Air Partnership (CAP) is a registered charity that works in partnership to promote and coordinate actions to improve local air quality and reduce greenhouse gases for healthy communities. Our applied research on municipal policies strives to broaden and improve access to public policy debate on air pollution and climate change issues. Our social marketing programs focus on energy conservation activities that motivate individuals, government, schools, utilities, businesses and communities to take action to clean the air.

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EXECUTIVE SUMMARY

Heat is a concern for municipal decision-makers in southern Ontario because it leads to premature death and disease, contributes to poor air quality and increases energy-demand. During the last decade heat waves have been responsible for tens of thousands of deaths in North American and Europe.

Heat does not affect people or places equally. Research over several decades has identified a number of variables that contribute to heat vulnerability including: geographical factors such as location, topography, climate and vegetation; and human factors such as age, socio-economic status and social isolation, which often vary by location. As a result, vulnerability to heat differs among cities and among neighbourhoods in the same city. Because of this spatial heterogeneity, a geospatial decision support system could be a powerful tool to support municipal decision-makers in both mitigating and responding to urban heat.

Broadly defined, a geospatial decision support system (GDSS) is a spatially-based computer application that assists a researcher or manager in making decisions. The possibilities for types of decision support systems are limited only by the needs of the end-users and the developer's imagination. The objective of this User Needs Assessment was to identify and describe the need for a decision support system to help local government decision-makers address questions relating to heat in the GTA. End-users were defined as municipal planning and public health staff in the Greater Toronto Area.

Although planning departments and public health units primarily approach urban heat questions from different perspectives (mitigation vs. response), both face similar challenges with respect to accessing data, allocating resources and garnering political support. Furthermore, they have common needs for a number of the data sets that could support heat-related decision-making (census, environmental, remote sensing data, etc.). Therefore the GDSS can and should support the needs of both planners and public health end-users – and possibly other potential end users such as urban foresters.

End-users identified three immediate needs for a decision support system: to assess vulnerability to heat of both populations and places in the GTA; to examine the relationship between 'hotspots' (locations where temperatures are consistently hotter) and other variables; and to develop heat-related communication materials for a variety of audiences.

Barriers identified by end-users to the creation and use of a geospatial decision support tool included lack of knowledge among some end-users about the application of GIS systems and lack of experience in addressing heat issues among others. Other barriers included lack of resources, organizational barriers and lack of political will to address urban heat. End-users also identified a number of useful data sets as well as barriers to data access and availability.

Based on the findings of this User Needs Assessment, it is recommended that a geospatial decision support system be developed to help meet the needs of municipal staff to improve their ability to address urban heat. To encourage knowledge-building among end-users in conjunction with the development of the decision support system, it is further recommended that end-users continue to review how other cities are using geo-spatial data in heat related work, through research and workshops.

The next step in the development of a decision support system should be an iterative exploration of the needs of end-users with respect to the functionality and operation of the decision support system. Questions of where a GDSS should be housed and who should be responsible for maintaining it remain unanswered and will need to be addressed early in the next phase of this project.

The Clean Air Partnership is developing a proposal for the next phase of this project, which will be submitted to GeoConnections in June, 2008. Potential end-users will be contacted in May to determine their interest in participating in this process. Based on the GeoConnections Funding Formula, up to \$150,000 may be available to support this initiative, with matching funds from participating organizations.

1. Addressing Urban Heat

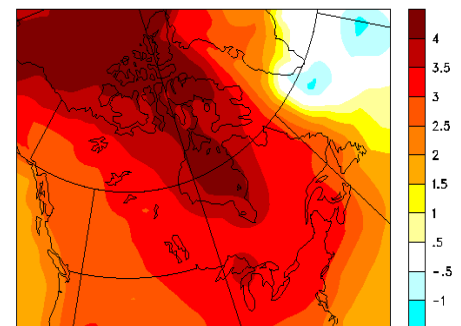
1.1 Introduction

Elevated temperatures impact municipalities in several ways. Extreme heat causes illness and death in vulnerable populations and accelerates the photo-chemical reactions that create smog. Hot weather also increases peak demand for energy in the summer, which leads to more air pollution in Ontario where peak energy demand is met by coal-fired power plants. In certain environments, extreme heat can also exacerbate drought, contribute to forest fires and destroy physical infrastructure, e.g. the strain of a heat wave in Greece during the summer of 2007 caused a number of transformers to explode (Health Canada, 2008).



SOURCE: HEALTH CANADA

During the last century, surface temperatures in southern Canada have warmed 0.5–1.5°C as a result of climate change (Meteorological Service of Canada, 2008a). In that same period of time, the City of Toronto has experienced an average temperature increase of 2.7°C (Environment Canada, 2006). This is higher than neighbouring rural areas due to the urban heat island effect, which occurs when natural landscapes are replaced by dark, heat-absorbing surfaces such as roofs, asphalt, and concrete. The displacement of trees and green spaces eliminates the natural cooling effect of vegetation, which through shading and evapotranspiration regulates ambient air temperature. Climate change, which is expected to raise temperatures in Canada 5–10°C (relative to 1975 temperatures) by 2090, will compound the urban heat island effect and exponentially increase heat stress on urban areas (Meteorological Service of Canada, 2008b). Toronto Public health estimates that heat-related mortality in the Toronto area will triple by 2080 from 120 to 360 deaths per year (Pengelly et al, 2005).



PROJECTED CHANGE IN MEAN SURFACE AIR TEMPERATURE (°C) IN CANADA IN 2041-2060 RELATIVE TO 1941-1960.

THE TEMPERATURE CHANGE OVER TORONTO IS PROJECTED TO BE 3-3.5°C, BUT THIS WILL LIKELY BE GREATER DUE TO THE URBAN HEAT ISLAND EFFECT.

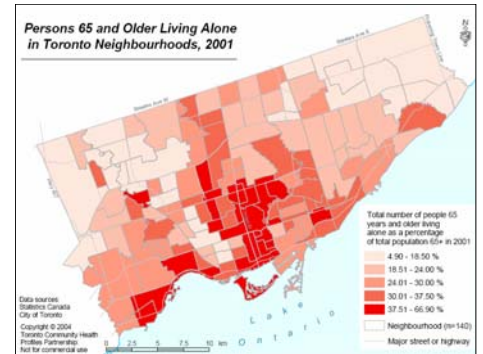
Source: Canadian Centre for Climate Modelling 2005

There is considerable spatial heterogeneity in the impacts of heat on cities and populations. Variables that are known to contribute to heat-vulnerability in populations include age, health, socio-economic status, social isolation, and limited access to air conditioning (Bernard and McGeehin, 2004). Other characteristics of the urban environment that contribute to increased impacts include multi-storey, older residential structures, high settlement density, and larger proportions of vulnerable populations like the marginally housed.

Decisions made by urban planners and public health experts determine how urban heat affects public health, air

quality and energy use. Through planning policy and the development approvals process municipal planners direct urban form and promote the use of “cool” building materials and practices (e.g. reflective roofing, permeable paving). Public health staff identify and alert the public to oppressive weather conditions, promote heat-safety education and develop heat mitigation strategies targeted to the most vulnerable members of society.

GIS, or Geographic Information Systems, are computer-based programs that are capable of collecting, storing, retrieving, and statistically manipulating geographic or location-based information. The overlaying function of GIS allows users to simultaneously view several separate data sets to better understand the spatial relationship between them. As such, GIS can be a valuable tool for studying urban heat islands and population vulnerability to heat. For example, a single map can capture risk factors such as socially isolated people over the age of 65, housing stock built before 1940, and areas of higher than average urban temperature. This could inform municipal decision-making and also aid in outreach and communications activities. However, there are a number of barriers and challenges to using GIS to address urban heat. Issues around data access, quality and timeliness pose particular challenges. Other important considerations are limited resources in terms of both personnel and technology necessary to perform mapping and analysis.



PERSONS 65 AND OLDER LIVING ALONE IN TORONTO NEIGHBOURHOODS BASED ON 2001 CENSUS DATA

SOURCE: TORONTO COMMUNITY HEALTH PROFILES

1.2 User Needs Assessment

With support from Geo-Connections, the Clean Air Partnership conducted a User Needs Assessment (UNA) during the winter of 2007-2008. Potential end-users were identified as municipal planners and public health staff throughout the Greater Toronto Area.

The goals of the UNA were to:

- Identify current municipal approaches to addressing extreme heat;
- Assess current GIS capacity of potential end-users;
- Identify the need for a GIS-based decision support system to support heat-related decision-making;
- Identify the geomatic infrastructure (data, services, policies and technologies) needed by end-users to address extreme heat; and,
- Assess the potential of the Canadian Geospatial Data Inventory (CGDI), managed by GeoConnections, to assist in municipal decision-making with respect to heat and to identify where data enhancements to the CGDI are needed.

This User Needs Assessment corresponds to two GeoConnections priority areas, Public Health (health emergency response and inter-emergency planning) and Environment and Sustainable Development (land use planning).

1.3 Background

The Clean Air Partnership

The Clean Air Partnership (CAP) is a registered charity whose mission is to work with municipal and other partners to facilitate the implementation of actions that improve local air quality, reduce greenhouse gas emissions and reduce the impacts of climate change.

CAP acts as the secretariat for the Greater Toronto Area Clean Air Council (GTA-CAC), an inter-governmental working group with representatives from federal, provincial and municipal governments. The GTA-CAC facilitates ongoing municipal dialogue and action on regional air quality and related issues. It is a forum for municipalities to share best practices and provides a framework under which local strategies for cleaner air are developed.

Twenty-two municipalities in the GTA, the Region of Waterloo and the City of Hamilton are members of the GTA-CAC, as are seven public health units.

CAP is responsible for facilitating the planning and implementation of the GTA-Clean Air Council's work program through monthly meetings, workshops, organization of communities of practice, and research and policy analysis.

Project Advisory Group:

To provide guidance and support for this User Needs Assessment an advisory group was formed with representatives from Toronto City Planning, Toronto Public Health and the GTA Clean Air Council. Participants in this group included:

- **City of Toronto, Planning Division**
The City Planning Division manages the growth and physical form of the City. The division is responsible for reviewing and processing development approval applications taking into account community, urban design, and transportation planning perspectives. It is also responsible for developing and updating planning policies that are expected to reduce urban heat, including the Green Development Standard and the



FROM A SCAN OF CLIMATE CHANGE IMPACTS ON TORONTO, CLEAN AIR PARTNERSHIP, 2006

Green Roof Incentive. The Green Development Standard is a set of performance targets that are applied through the development approvals process and encourage sustainable site and building development.

- **City of Toronto Public Health**

Toronto Public Health has responsibility for operating the City's Heat-Health Watch/ Warning System and coordinating emergency response during heat and extreme heat alerts. The Environmental Protection Office of Toronto Public Health is responsible for conducting research and developing policies to support the City's heat response team. They have also been active in researching the health impacts of climate change in the City and climate change adaptation options.

- **Greater Toronto Area Clean Air Council UHI Advisory Group**

The GTA Clean Air Council is an inter-governmental working group that promotes the reduction of air pollution emissions and increased awareness of regional air quality issues in the Greater Toronto Area. Members are municipal staff from a number of sectors, including planning and public health. In April 2007, an Urban Heat Island (UHI) Advisory Group was established as a sub-committee of the GTA-CAC. The UHI Advisory group is composed of representatives from Peel, Halton and York regions, the City of Toronto (City Planning, Public Health and the Toronto Environment Office), the City of Vaughan in York Region and the Town of Ajax in Durham Region.

- **Natural Resources Canada, Earth Science Sector**

The Earth Sciences Sector (ESS) of Natural Resources Canada (NRCan) supports federal environmental, social and economic objectives by focusing its programs and services on innovative projects that improve the quality of life of Canadians. Key priorities for ESS include support for environmental health decision-making and enhancing climate change resilience in Canadian communities. ESS is also a member of the GTA-CAC Urban Heat Island Advisory Group.

CAP Heat Mitigation and Adaptation Research:

The mandate of the Clean Air Partnership is to address local air quality and climate change issues. Increased heat, particularly in urban areas, accelerates the photochemical reactions that create smog. It also leads to

increased energy use during peak load periods in the summer. Consequently, preventing and adapting to increased heat is of significant concern for CAP. Over the last few years CAP has been involved in a number of urban heat-related research projects. These projects include hosting the North American Urban Heat Island Summit in 2002, the development of a menu of climate change adaptation options for addressing increased urban heat in the City of Toronto¹, and a scan of heat alert systems and hot weather response plans across the GTA².

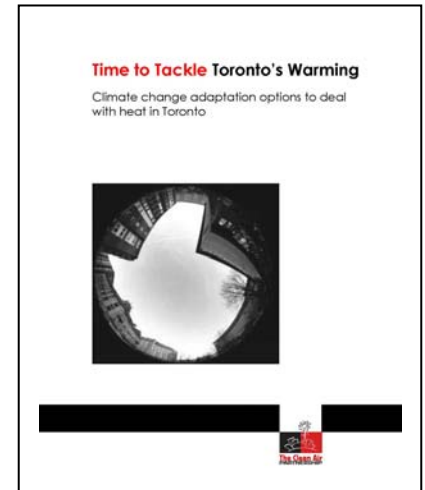
CAP and the GTA-CAC are currently partnering on an urban heat island initiative with researchers from Natural Resources Canada's 'Enhancing Resilience in a Changing Climate' (ERCC) program. ERCC aims to reduce Canadian vulnerability to climate change through effective adaptation strategies informed by geo-science and geomatics. The project, "Identifying Urban Heat Island (UHI) Vulnerabilities and Adaptation Options in the Greater Toronto Area (GTA)", will enhance the identification and characterization of the urban heat island in the GTA.

As part of this project, researchers from NRCan are using remotely sensed thermal satellite imagery, in combination with land use and vegetation cover data, to assess the relationship between urban heat and urban form in the GTA. To validate satellite thermal imagery, and to collect a data of higher spatial and temporal resolution, NRCan deployed over 84 air and surface temperature sensors at 31 sites across the GTA over the summer of 2007. This data will allow scientists to improve their understanding of how the urban environment influences micro-climates in the GTA and will provide key information that will assist in the development of policies to mitigate and respond to urban heat. Temperature measurements will continue until March 2009.

1.4 Literature Review

Using Remote Sensing and GIS to Characterize Urban Heat Islands and Evaluate Mitigation Strategies

GIS and remote sensing data have been used in many studies of urban heat islands and their relation to surface characteristics (Voogt and Oke, 2003). As in NRCan's research in the GTA, these studies typically combine the use of satellite thermal imagery with land use and/or land cover maps to assess spatial patterns of surface



TIME TO TACKLE TORONTO'S WARMING
SOURCE: CAP, 2007



ROOF TOP AIR TEMPERATURE MONITOR,
MOUNTAIN EQUIPMENT CO-OP ROOF
TORONTO, JULY, 2007

SOURCE: NATURAL RESOURCES
CANADA

¹ Available on-line at: www.cleanairpartnership.org/pdf/time_to_tackle_toronto_warming.pdf

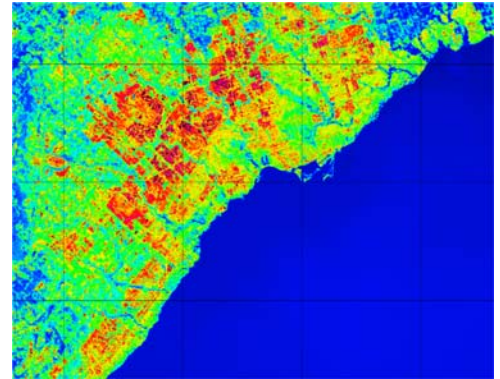
² Available on-line at: www.cleanairpartnership.org/pdf/heat_report.pdf

temperature. Satellite thermal images are most often derived from the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (Balling and Brazel, 1988; Gallo et al, 1995); or US Geological Survey Landsat satellites (Carnahan and Larson, 1990; Ahmand and Hashim, 2006; Garcia-Cueto et al., 2006; Morgan et al, 2001). Of the two, Landsat images are of higher resolution (60 or 120 m compared to 1.1 km) and thus are considered more adequate for studies in the urban area (Garcia-Cueto et al., 2006).

Landsat thermal imagery can be very informative for an analysis of the relationship between urban form and urban heat islands. However, it is not of high enough resolution for a detailed analysis of the thermal behaviour of urban surfaces in relation to surface materials (Gorsevski, 1998). For a study of this detail, high resolution thermal imagery (<15m), usually obtained from airborne remote sensors, has been found to be more adequate (Estes Jr. et al, 1999; Lo et al, 1997; Gorsevski, 1998).

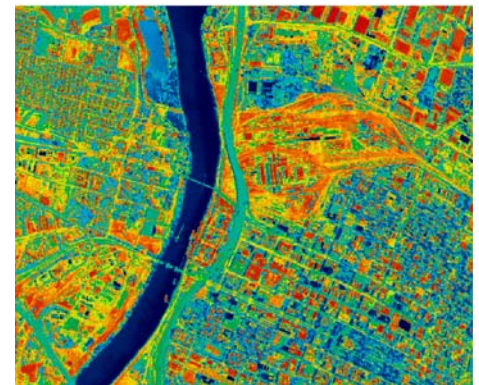
The Urban Heat Island Pilot Project (UHIPP), a joint partnership between the US Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA) and five American cities³, was undertaken to estimate the benefits of implementing urban heat island mitigation strategies in those cities (Estes Jr. et al, 1999; Gorsevski, et al., 1998). For this initiative NASA obtained high resolution (<10m) thermal imagery of each city from airborne remote sensors. This high-resolution data allowed researchers to conduct an 'urban fabric analysis' or an analysis of the contribution of specific urban surfaces and materials to the urban heat island effect (Gorsevski, et al, 1998). This analysis (in conjunction with meteorological and air quality modelling conducted by the Lawrence Berkeley National Laboratory) was used to quantify the potential benefits of UHI mitigation measures for each city in terms of reductions in ambient air temperatures, energy savings and air pollution reductions (Konopacki and Akbari, 2002). Fine-scale thermal data also proved useful for demonstrating to decision-makers and the public the benefits of heat mitigation strategies (Gorsevski, 1998).

Modelling of UHIPP data showed that a reduction in ambient air temperature was possible in each pilot city through heat island mitigation measures, specifically: strategically placed shade trees, high-albedo roofing and paving materials, increased urban vegetation or a combination of all four (Konopacki and Akbari, 2002).



THERMAL SATELLITE IMAGE OF THE GTA
TAKEN WITH THE LANDSAT 7 SATELLIE –
AUGUST 10, 2002 AT 10:00 AM

SOURCE: NATURAL RESOURCES CANADA



HIGH RESOLUTION THERMAL IMAGE OF THE
CITY OF SACRAMENTO CALIFONIA TAKEN
WITH AN AIRBORNE SENSOR

SOURCE: EPA URBAN HEAT ISLAND PILOT
PROJECT ON-LINE

³ Salt Lake City, Baton Rouge, Chicago, Houston and Sacramento

Furthermore, modelling indicated that these temperature reductions would lead to improvements in air quality as well as energy savings in each city (Taha et al, 2000).

The New York State Energy Research Development Authority (NYSERDA) recently published a study that used a regional climate model (MM5) in combination with observed meteorological, satellite, and GIS data to determine the impact of urban forestry, green roofs, and light-colored surfaces on near-surface air temperature and the urban heat island in New York City. Various scenarios were evaluated based on their cost-effectiveness at reducing air temperature and resulting energy demand. Results showed that all of the mitigation strategies examined have a significant temperature impact. However, a combined strategy that maximizes the amount of vegetation by planting trees along streets and in open spaces, as well as installing green roofs, offers more potential cooling than any individual strategy. Researchers concluded that the choice of a strategy should take into account the specific characteristics and priorities of the neighborhood, including the available area for implementation of each strategy and benefit/cost factors (Slosberg et al, 2006).



GREEN ROOFS ARE ONE URBAN HEAT ISLAND MITIGATION STRATEGY - GREEN ROOF ON CHICAGO CITY HALL.

SOURCE: EPA WEBSITE

This research supports previous findings that strategically planting trees and increasing the reflectivity of surfaces can decrease urban ambient air temperatures and improve air quality. What is less obvious is the effect that these strategies have on individual cities given the numerous variables that are particular to different regions such as climate, topography, population density and land use patterns (Gorsevski et al., 1998).

Using GIS for Environmental Health Assessments

Excess mortality during heat waves rests disproportionately on the elderly, newborn babies, young children, the infirm, the poor, the socially isolated and people with mental disabilities (McGeehin and Mirabelli, 2001). The amount which temperatures deviate from the norm, the timing (beginning or end of the summer), intensity and duration of a heat wave also impact heat-related mortality and illness (Basu and Samet, 2002). In response to increasing numbers of heat waves and elevated urban temperatures, and as a result of devastating heat-wave events in Philadelphia (1993), Chicago (1995) and Europe (2003), several cities around the world have developed heat alert systems and hot weather response plans.

EUROPEAN HEATWAVE KILLS 30,000 IN 2003

The heat wave that hit Europe in 2003 began in June and lasted until mid-August. Temperatures were 20 to 30% higher than normal, reaching extreme maximums of 35 to 45°C.

The fatalities were reported as follows:

France	14,802
Germany	7,000
Spain	4,200
Italy	4,000
UK	2,045
Netherlands	1,400
Portugal	1,300
Belgium	150

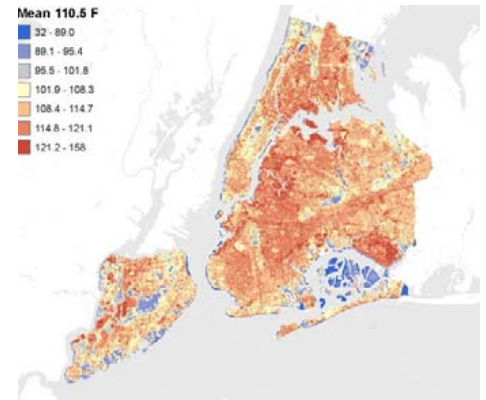
Source: De Bono *et al.* 2004

Public health practitioners are increasingly in need of new assessment and analytic tools that can be used at the local and community-level (Choi et al., 2006). GIS is a powerful tool that allows health professionals to explore and examine distributions of at-risk people by looking at combinations of risk factors and health outcomes in terms of their geographic relationship (Cromley & McLafferty, 2002). Despite advancements in the use of GIS for tackling other public health concerns, no comprehensive methods have been developed for utilizing GIS in the mitigation of the impacts of extreme heat on an urban population (Wilhelmi et al, 2004). Nevertheless, preliminary research has shown that population vulnerability assessments and community-based hazard mitigation plans could benefit from applications of GIS (*ibid*; J. Samenow, 2008).

In a study of the July 1966 heat wave in New York City, Schuman (1972) discovered that areas of the City with more concrete and less vegetation exhibited higher heat-related mortality. More recently, analyses of heat vulnerability at a local scale have been conducted in Philadelphia, Phoenix, Montreal and London using GIS. There is no broadly accepted formulation for local indicators of risk to heat. Variables with respect to heat-vulnerability differ from study to study and often depend on data availability (Stephanie Gower, personal communication). In many cases the selected variables are weighted equally, although more rigorous studies are based on a statistical analysis of the relationship between individual variables and heat-related mortality and illness.

In a study published in 2005, Vescovi et al integrated climate variables and socio-economic parameters using GIS to produce maps of estimated present and future public health risks due to heat in Quebec. To characterize current climate hazards, data from 310 Environment Canada stations in southern Quebec were used along with mean number of days with temperatures greater than 30C and mean number of extreme heat episodes per year. Social vulnerability was calculated using four sub-indices: age, poverty, social isolation, and education. This study will inform other Quebec researchers who are currently developing a spatially explicit on-line analytical processing tool using web-GIS technology to identify areas potentially vulnerable to climate change (Vescovi et al, 2006).

In a 2007 EPA-funded pilot project researchers used GIS to determine Philadelphia's vulnerability to heat on a neighbourhood scale by overlaying U.S. census data with satellite imagery, mortality rates, and emergency dispatch call data. Areas of the city identified as 'vulnerable' (likely



REMOTELY SENSED THERMAL SATELLITE DATA. LANDSAT ETM, AUGUST 14, 2002 AT 10:30 AM, RESOLUTION IS 60 METERS.

SOURCE: SLOSBERG, 2006 (NYSERDA)

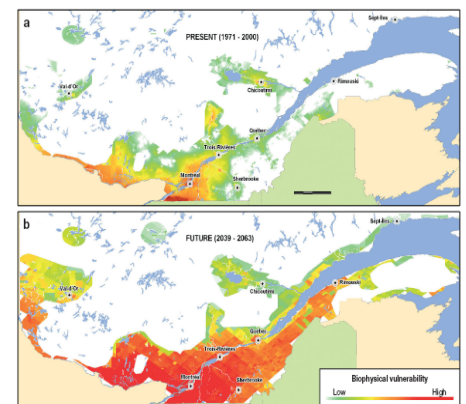
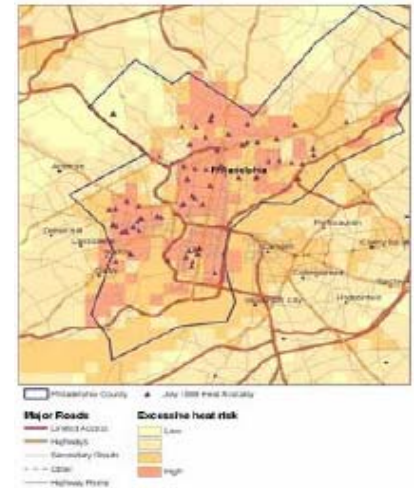


Fig. 5. (a) Present and (b) future public health risk

SOCIAL VULNERABILITY OVERLAID ONTO CLIMATE HAZARD MAPPING

SOURCE: VESCOVI ET AL, 2006

to be at higher risk from excessive heat) were found to overlap significantly with historic mortality data from Philadelphia's 1999 heat wave (J. Samenow, 2008). A similar EPA initiative was also conducted in Phoenix Arizona to characterize heat stress in eight urban neighbourhoods based on demographics, neighbourhood thermal characteristics, resources for coping with heat, and outdoor temperature. In Phoenix, researchers found that higher income, predominantly white neighbourhoods were at lower risk from heat than lower-income neighbourhoods (Harlan et al, 2006). While initial research assumed that all variables had equal weight, researchers in both cities are following up with a statistical analysis to model which indicators are important in each city to predict heat-vulnerability. Preliminary results indicate that the important predictors of heat vulnerability could be different for different cities (*ibid*).



SUPERIMPOSING 1999 HEAT WAVE MORTALITY CASES SUGGESTS ANALYSIS CAN PREDICT WHERE HEAT RELATED HEALTH IMPACTS ARE MOST LIKELY.

SOURCE: J. SAMENOW

These studies and others (Smoyer, 1998; Klinenberg, 1999) indicate that there is spatial variability in the impact of heat and that GIS can be a powerful tool for analyzing this variability at a neighbourhood-level. Further research is needed in the GTA to: 1) identify the variables which contribute the most to population heat-sensitivity in this region; and 2) to identify local variation in vulnerable populations (and locations) is needed.

Though there are some limitations to the health applications of remote sensing, including difficulties accessing high spatial and temporal resolution data and continuous data sets (Vicente and Maynard, 2002), remote sensing can be an important resource for public health practitioners. To encourage the use of GIS and remote sensing in local decision-making with respect to heat, Wilhelmi (2004) calls for improved communications between data providers and the users, as well as a need for user-friendly and low-cost decision-support systems.

2. Data Collection and User Profile

2.1 Methodology

Based on a review of existing resources and with input from City of Toronto partners, a draft set of interview questions was created and circulated to the GTA-CAC Urban Heat Island Advisory Group in December 2007. Shortly afterwards, a meeting of the Advisory Group was held to receive comments and solicit feedback on the project workplan and draft interview questions.



A WOMAN IS EVACUATED FROM A HIGH-RISE APARTMENT BUILDING IN SOUTH CHICAGO DURING A 2006 HEAT WAVE.

SOURCE: ASSOCIATED PRESS

During the first meeting of collaborators it became apparent that knowledge levels with respect to both GIS and heat mitigation, vary considerably among end-users. Those that are familiar with GIS – usually planners – are not typically involved in heat mitigation. Likewise, those that are responsible for responding to extreme heat – public health practitioners – are not generally familiar with GIS. This made it very hard for individual end users to answer questions about their geomatic needs and the development of a decision support system. To build knowledge among end-users and to encourage information sharing, CAP decided to hold a series of ‘group interviews’ or workshops across the GTA.

In total, thirty end-users participated in workshops, which were held in Toronto, Peel and Halton.⁴ (See Appendix I for a complete list of interviewees.) Public health staff (15) and planners (9) predominated, but staff from emergency measures (1), geomatics (1), information technology (1), environmental policy (1), transportation (1) and urban forestry departments (1) also attended. Where there were information gaps or points in need of clarification, individual follow-up interviews were held with a smaller number of key informants.

Each workshop began with a presentation (Appendix II) that outlined the need to address urban heat, identified current urban heat island initiatives in the GTA, and described similar projects in other jurisdictions. The presentation concluded with a description of the User Needs Assessment process and the next phase of the project, the development of a Geospatial Decision Support System (GDSS). Following the presentation, CAP staff led participants through a series of questions (Appendix III), which were provided in advance. During a break in the session (except in Toronto where they were asked to do this in advance) participants completed an ‘Information Sheet’ (Appendix IV) to gather background information about each workshop participant.

Overwhelmingly, both CAP and the participants considered the workshops to be very successful. In particular, workshops provided an opportunity to:

- 1) Present detailed information about the use of GIS to address urban heat;
- 2) Share information across departments and jurisdictions and to brainstorm about common objectives;

⁴ Attempts were made to conduct a workshop in York Region; however, timing and staff availability made this impossible within the period of this project.

- 3) Solicit information about the needs and experiences of different end-users.

Workshops also generated a great deal of interest in the project among end-users and support for Phase II, the development of a geospatial decision support system.

2.2 End- User Profile

In the GTA, public health units are operated at the upper and single-tier levels of government.⁵ Health units are responsible for responding to the threat to public safety posed by extreme heat. While activities vary across the region, typical response activities include: operating heat alert systems; coordinating hot weather response plans; developing and implementing heat intervention strategies; and conducting public education and outreach activities related to heat safety. For this User Needs Assessment, public health staff from the City of Toronto, the Region of Peel and Halton Region were interviewed. These end-users included policy developers, researchers, epidemiologists, environmental health and chronic disease and injury prevention staff.

Planning departments are housed at both regional and municipal levels of local government in the GTA. Regional planners are responsible for developing and reviewing official plans and land-use policies and for conducting and implementing planning research. Municipal planners are responsible for community development including reviewing and commenting on development applications, urban design and, along with regional planners, community consultation. Actions taken by both regional and municipal planners affect urban form and thus can have a significant impact on urban heat. Staff consulted for the user needs assessment included policy developers, urban designers and community planners from Toronto, Peel, Halton, Mississauga and Oakville.

Public health and planning staff were identified as the primary end-users for this User Needs Assessment, but it should be noted that Urban Forestry department policies and programs can significantly impact urban heat. Moreover, in some lower-tier municipalities Emergency Response Services are charged with implementing hot weather response plans in partnership with Parks and Recreation departments.

⁵ Municipalities in Ontario are designated as single, upper or lower-tier levels of government depending on their individual responsibilities. The City of Toronto is a single-tier government, while regional governments in the GTA (York, Halton, Peel and Durham) are upper-tier.



FOREST FIRES IN PORTUGAL ON AUGUST 3, 2003 CAUSED BY A CATASTROPHIC HEAT WAVE THAT KILLED 35,000 IN EUROPE

IMAGE COURTESY JACQUES DESCLOITRES, MODIS RAPID RESPONSE TEAM AT NASA GSFC.

SOURCE: UNEP ENVIRONMENTAL ALERT BULLETIN, MARCH 2004

A total of 37 people participated in three workshops held in Toronto, Peel and Halton. Of these participants 30 completed Key Informant Information Sheets (the results of which are summarized in Table 1). While this may not be a statistically representative sample, data collected from these participants provides an indication of the level of knowledge and comfort of municipal staff with GIS and urban heat-related decision-making in Toronto, Peel and Halton.

Table 1: End-User Profile

	Total Number	Currently working specifically on heat issues	Experience with GIS	Using GIS in current position	Familiar with the CGDI
Planners	9	0	<ul style="list-style-type: none"> - Considerable knowledge (4) - Working knowledge (3) - Some knowledge (0) - No knowledge (2) 	<ul style="list-style-type: none"> - Often (4) - Sometimes (2) - Never (3) 	<ul style="list-style-type: none"> - YES (3) - NO (6)
Public Health	15	4	<ul style="list-style-type: none"> - Considerable knowledge (0) - Working knowledge (1) - Some knowledge (6) - No knowledge (8) 	<ul style="list-style-type: none"> - Often (1) - Sometimes (2) - Never (12) 	<ul style="list-style-type: none"> - YES (3) - NO (12)
Other	6	1	<ul style="list-style-type: none"> - Considerable knowledge (2) - Working knowledge (1) - Some knowledge (3) - No knowledge (0) 	<ul style="list-style-type: none"> - Often (1) - Sometimes (3) - Never (2) 	<ul style="list-style-type: none"> - YES (2) - NO (4)

Experience working on Heat Issues

Five end-users (16%) mentioned heat mitigation or response activities in a description of their primary job responsibilities. With one exception, these end-users are public health staff involved in managing heat alert systems or hot weather response plans. The exception was an environmental coordinator at a lower-tier municipality involved in developing that jurisdiction’s hot weather response plan.

Experience working with GIS

While 20% (6/30) of respondents reported having considerable experience with GIS, over 30% (10/30) reported having no experience, 33% (10/30) some knowledge, and 16.6% (5/30) a working knowledge. Of the respondents with considerable GIS experience, all were from planning or IT/ Geomatics departments. No public health employees reported considerable experience with GIS and only one possessed a working knowledge.

Not surprisingly, of the respondents with no GIS experience, 83% (10 of 12) were public health staff.

Over 43% (13/30) of respondents reported using GIS 'often' or 'sometimes' in their current position while 56.6% (17/30) 'never' use GIS.

Respondents were asked to identify which spatial data sets they routinely use. End-users mentioned the following data layers: land use, orthophotography, street networks, rivers and water courses, parcel fabric, building footprints, utility corridors, parks and recreation facilities, census data, topography, mortality, hospitalization and emergency room visits.

Of the respondents who reported using GIS software the most common applications were the ESRI suite (ArcInfo, ArcGIS, ArcMap, ArcView). Other applications such as Map Info, GeoMedia and GIS Dashboard are also used.

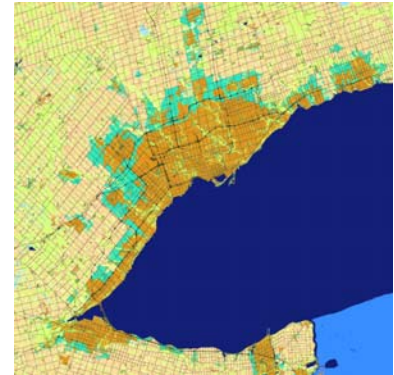
Knowledge of the CGDI

To assess knowledge of the CGDI and use or experience with distributed data, respondents were asked if they were familiar with the CDGI and if they had ever accessed any of the resources available through the Public Health Information Network of Canada or GeoConnections. Overwhelmingly, 73.3% (22/30) of end-users were not familiar with the CGDI. Of those that were, 37% (3/8) were public health unit staff and 63% (5/8) planners and geomatics staff. Finally, only one end-user reported accessing data from the CGDI (through the Public Health Agency of Canada).

2.3 Municipal Heat Mitigation and Response Efforts

While only five end-users indicated that they were directly responsible for heat-related policies and programs (all public health staff), a number are involved in developing green development or sustainable land use policies, urban forestry programs and/or energy conservation plans. Programs and policies of this nature have the potential to significantly impact urban heat, despite the fact that it is not always an explicit priority.

Current heat mitigation and response activities in the GTA fall into two broad categories: heat alert systems and intervention activities; and, green development policies and/or sustainable land-use plans.



GIS CREATED MAP SHOWING URBAN GROWTH IN THE GTA, 1985-2005

SOURCE: CANADA CENTRE FOR REMOTE SENSING, 2007

Heat/Health Watch-Warning Systems

Both the City of Toronto and the Region of Peel issue heat alerts when an oppressive air mass is forecast and the likelihood of excessive mortality is calculated to exceed 65% (Heat Alert) or 90% (Extreme Heat Alert)⁶. Alert systems were custom-designed for both Toronto and Peel, based on the spatial synoptic classification method, using location-specific data (Sheridan and Kalkstein, 2004). Despite the fact that Peel and Toronto are adjacent municipalities, local populations show different levels of vulnerability to hot weather events. Furthermore, due to the diversity in urban form, geography and population within Peel Region, a 17-20% difference in mortality rates exists between Mississauga and Brampton/Caledon. Synoptic heat alert systems are capable of responding to variation in heat-vulnerability at a city level (populations >500,000) but are not currently refined enough to determine differences in vulnerability at the neighbourhood level.

Halton Region's heat alert system is triggered by Environment Canada's Humidex advisories. The Humidex combines temperature and humidity into one number to reflect perceived temperatures. Advisories are issued when the maximum daily Humidex value is expected to exceed 40, or when Humidex values are expected to exceed 36 for an extended period of time (3 days). Humidex advisories do not reflect variability in human response to extreme heat.

Heat Health Intervention Strategies

Typically, heat/health watch-warning systems are operated in parallel with intervention strategies. Most intervention strategies, such as opening cooling centres, providing water, operating heat information lines, or extending the operating hours of municipal facilities, are geared towards the general public, rather than specific at-risk populations. Intervention strategies targeted specifically at vulnerable people, e.g. home visits by public health inspectors, are costly and difficult to implement.

Toronto public health operates the GTA's most comprehensive hot weather response plan, which involves up to 800 community partners. The majority of intervention activities are directed at the general public, but some targeted interventions take place, e.g. public health inspectors are sent to boarding homes and rooming houses to monitor indoor temperatures and encourage



TORONTO'S HEAT-HEALTH WATCH WARNING SYSTEM WAS IMPLEMENTED IN 2001

Source: Toronto Public Health

⁶ For a description of Synoptic heat alert systems, see: www.cleanairpartnership.org/pdf/heat_report.pdf

property managers to provide cool communal areas. After seven years of opening cooling centres in the City's large civic buildings, Toronto Public Health is moving towards ward-based community cooling centres in the hope of better serving at-risk populations. The health unit is also considering the use of two mobile drinking water vehicles to target at-risk areas of the City during heat and extreme heat alerts.

Peel and Halton Regions also coordinate public health intervention strategies during extreme heat events, including issuing heat notifications, providing support to lower-tier municipalities and conducting community outreach with respect to heat-safety. Peel Region also coordinates water distribution (through the Red Cross) and other intervention activities with various community partners. Several lower-tier municipalities in both regions implement a variety of heat intervention strategies directed at the general public including extending the operating hours of swimming pools, opening cooling centres⁷.

Green Development/ Building Policies

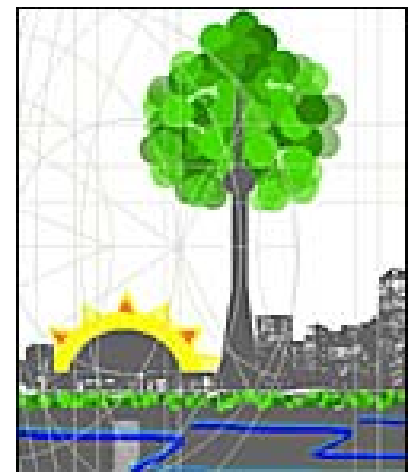
Many upper and lower-tier municipalities in the GTA have implemented, or are in the process of implementing, green development, green building⁸, energy conservation and/ or climate change plans. Where these plans exist they represent a political commitment to address environmental and public health issues, including urban heat. At the implementation level, a number of plans call for urban heat island reduction initiatives, such as tree planting, green roofs, or the use of "cool" building and paving materials.

In February 2006, Toronto City Council adopted a green roof strategy that provides incentives to property owners for green roof installation. City planners are currently in the process of developing a green roof by-law and will be using GIS to assess when and where to require green roofs. In May of 2006 Council adopted the Toronto Green Development Standard⁹, a set of performance targets that encourage sustainable site and building development. The Standard contains targets and strategies for reduction of urban heat. It also contains many targets that indirectly support urban heat island mitigation such as urban forest enhancement, increasing permeable surfaces, natural heritage enhancement and energy efficiency. City officials are also in the process of developing guidelines for



EXTENDING THE OPERATING HOURS OF SWIMMING POOLS IS A POTENTIAL HEAT INTERVENTION STRATEGY FOR MUNICIPALITIES

SOURCE: CAP, 2007



THE CITY OF TORONTO'S GREEN DEVELOPMENT STRATEGY WAS IMPLEMENTED IN 2006

SOURCE: CITY OF TORONTO

⁷ For information about heat response activities in the GTA see: www.cleanairpartnership.org

⁸ For information about green development in the GTA see: www.cleanairpartnership.org

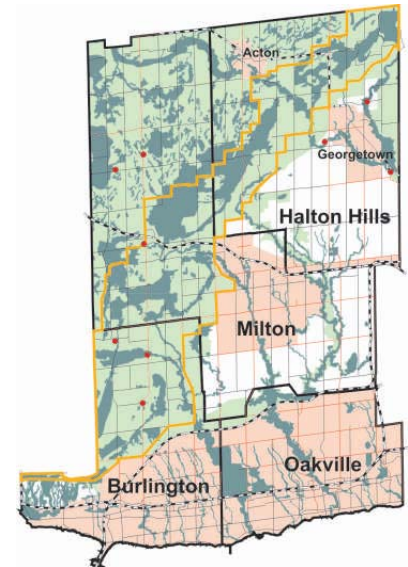
⁹ <http://www.toronto.ca/planning/greendevlopment.htm>

greening surface parking lots and a sustainable sidewalk pilot project.

The Region of Peel is currently developing a corporate LEED (Leadership in Energy Efficient Design) Building Policy and an Energy Efficiency Standard for the Region. A regional woodlands study is ongoing and will address the impact of significant woodlands on urban microclimates. Halton Region is developing a plan to manage expected growth and development in the Region over the next twenty-five years known as Sustainable Halton. It is also developing a Sun Safety and Shade Policy, which will require the provision of shade and tree planting around the region.

The Town of Oakville has developed a sustainability checklist for development in north Oakville, which is currently in the midst of one of the largest secondary planning initiatives in North America. The checklist includes consideration of heat mitigation strategies such as permeable paving, green roofs and reflective roofing, among other things.

Most municipal “green” plans and policies are developed and implemented on a citywide basis rather than at the neighbourhood, scale. Spatial explicit data about the magnitude and location of urban heat islands and ‘hot spots’ will allow municipal decision-makers to strategically address heat on neighbourhood by neighbourhood.



HALTON REGIONAL PLAN,
PRODUCED BY THE REGIONAL
MUNICIPALITY OF HALTON

SOURCE: SUSTAINABLE HALTON
UPDATE JUNE 2006

2.4 Heat, Health and GIS-related Research

In addition to municipal programs and policies relating to heat mitigation and response, end-users are currently working with researchers and universities to learn more about the nature of urban heat, how it affects public health and how its impacts can be reduced.

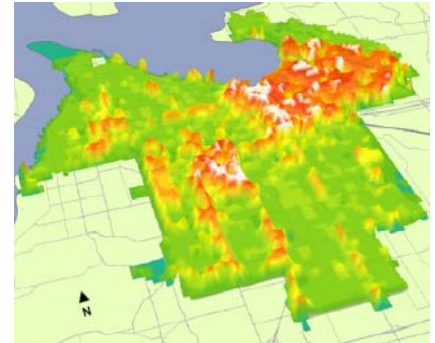
Workshop participants identified the following heat and/ or GIS related research initiatives in the GTA:

- Kate Bassil, a PhD candidate at the University of Toronto, is investigating the use of 911 medical dispatch data for the syndromic¹⁰ surveillance of heat-related illness in the City of Toronto. The study is exploring the association between temperature and 911 data and the development of a surveillance system to monitor heat-related illness in Toronto. This study has the potential to help Toronto Public Health make

¹⁰ Surveillance using health-related data

decisions about where to target public health interventions during periods of extreme heat.

- Ricky Hernden, a Masters student at the University of Toronto recently completed a study of the application of cool paving technologies to Toronto's road network, specifically porous and light-coloured paving. The study calculated the potential for air temperature reduction through the implementation of these technologies throughout the City as roads are resurfaced.
- In collaboration with the GTA Clean Air Council Urban Heat Island Advisory Group, Natural Resources Canada is studying the magnitude and structure of the urban heat island effect in the GTA (see section 1.3). During the summer of 2007 thermal monitors were deployed across the GTA to measure air and surface temperatures at ground level and on rooftops. This data will be used to validate and calibrate satellite thermal imagery of the region. A spatial analysis of land use/ land cover and heat will provide important information about the relationship between urban form, vegetation and urban heat. This data will allow scientists to improve their understanding of how the urban environment influences micro-climates in the GTA and will provide key information that will assist in the development of policies to mitigate and response to urban heat.
- Derek Yee, a student in Ryerson University's Masters of Spatial Analysis program, is currently undertaking a project with Peel Public Health to use spatial analysis for pandemic planning. While not related to heat, this project is the first at Peel Public Health to use spatial analysis and is building awareness about the potential for GIS to inform public health planning and decision-making.
- Researchers at Toronto Public Health are participating in an initiative to map air quality in the City of Toronto, in relation to the Air Quality Health Index, using satellite imagery. (This project is contingent on funding.)
- Toronto Public Health is planning to fund a scan of vulnerability assessments for heat that have been carried out in other jurisdictions.
- The City of Toronto is currently developing a Climate Change Adaptation Strategy, which will develop policies and programs for adapting to local climate changes including extreme heat.



THREE DIMENSIONAL REPRESENTATION OF THE TACOMA URBAN HEAT ISLAND SHOWING CONCENTRATIONS IN COMMERCIAL AND INDUSTRIAL REGIONS

SOURCE: SEHMEL & THOMPSON, 2006



EXAMPLE OF PERMEABLE PAVING IN A PARKING LOT

SOURCE: USDA, 2008

- The Clean Air Partnership and the City of Toronto are participating in a pilot project led by the University of British Columbia to develop visioning tools for local decision-makers with respect to climate change. The pilot in Toronto will focus on developing 3D visualizations of the Urban Heat Island effect and will compile information on available models, scenarios and spatial data. This pilot will inform Toronto's developing climate change adaptation strategy.

3. User Needs

3.1 End-user Needs

Public Health Units

Staff at two focus group sessions described a need to pinpoint populations and places that are vulnerable to extreme heat. Understanding where vulnerable locations are, who is most vulnerable to heat, and where vulnerable people live will help Public Health units more effectively deliver scarce resources. In the words of one participant, "Right now (our heat intervention strategies) are not reaching those who need it the most." For example, Toronto Public Health is struggling with the question of where to locate community-based cooling centres. Staff feel pressure to distribute cooling centres equally throughout the City. However, there is no evidence to suggest that this is an appropriate strategy or an effective use of resources. A spatial analysis of at-risk populations and neighbourhoods would assist Public Health in identifying appropriate locations for these new cooling centres. Moreover, identifying neighbourhoods at high risk for heat mortality and illness could also be useful for targeting the efforts of public health inspectors or locating mobile drinking water vehicles.

In one region, workshop participants expressed doubt about the possibility of locating pockets of vulnerable people. It was felt that at-risk people are not clustered in specific areas, but distributed throughout the region, thus making a spatial analysis of vulnerability of limited value. Mapping would be a useful tool to either confirm or refute this perception.

Staff from each workshop expressed a need for more information about the correlations among mortality, heat-related illness and risk factors such high temperatures, old age, lifestyle and socioeconomic status in the GTA. Mortality is currently the most common measure used to



OLDER PEOPLE WERE THE MAIN VICTIMS OF FRANCE'S 2003 HEAT WAVE

SOURCE: BBC NEWS, 2003

assess population vulnerability to heat. Given the ultimate nature of this measure (death is the only consideration) and the limitations of this data set (See section 3.2.), there is a need for other approaches of analyzing heat vulnerability. A spatial assessment of vulnerability, considering both intrinsic (person-related) and extrinsic (place-relates) vulnerability could provide a useful supplement or alternative to scarce mortality data.

Finally, mapping of urban heat islands and hot spots could be powerful education and communication tools for heat safety campaigns and other public outreach activities.

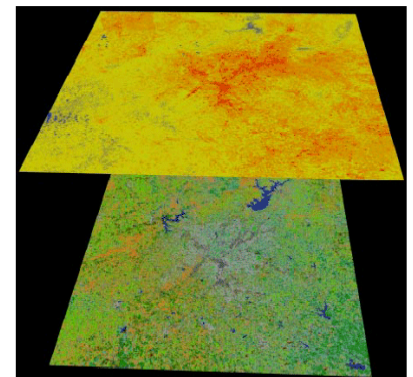
Planning Departments

Planning staff expressed the need for additional support to:

- 1) Identify the factors that contribute to the urban heat island;
- 2) make policy and development recommendations and monitor their impacts; and,
- 3) communicate the importance of heat mitigation efforts to a variety of audiences.

In order to make informed decisions about policies, by-laws or incentive programs specifically directed towards heat, planning staff indicated a need for more information about the relationship between urban form (land use, land cover, vegetation, etc.), development and heat. There are a number of prevailing assumptions about the impact of the built environment and vegetation on heat, but very little primary research has been done in the GTA. NRCan's initiative to measure the extent and magnitude of the urban heat island using remote sensing and thermal monitors, will provide some of this information (in particular the location of "hot spots") but the need for more research was expressed by several end-users. In particular, comparative information about the mitigation benefits of different strategies is needed. End-users also mentioned the need to be able to measure and quantify the impact of heat mitigation strategies in order to justify their broader implementation.

End-users also expressed a need to visually show how heat and the urban form are related. Audiences for this type of communication include developers, property owners, community groups and the Ontario Municipal Board. Depending on the audience, the resolution, precision and accuracy of data become more important. Planners are often asked to make comments on development applications or policy decisions and their analyses must hold up to scrutiny.



AN IMAGE FROM THE LANDSAT 5 SATELLITE (TOP) SHOWS HOT AREAS (RED) CORRESPONDING WITH URBAN AREAS (GRAY) IN THE FALSE-COLOR IMAGE OF THE CITY OF ATLANTA (BELOW).

SOURCE: NASA EARTH SCIENCE OFFICE

At least one end-user expressed a need for a spatial analysis of urban ‘hotspots’ to enable a neighbourhood by neighbourhood approach to decision-making that incorporates consideration of urban heat. A neighbourhood assessment of hot spots would also assist in identify priority locations for heat-related pilot projects and other mitigation activities.

Finally, one or two planners spoke of a need for a decision support tool, not limited to heat-related questions, but for all environmental decision-making. The tool envisioned would provide access to a broad range of environmental data including energy-use, air quality, storm-water management, natural heritage and biodiversity. According to end-users such a tool would be used to support policy research and the development of integrated approaches to address local environmental issues, including heat mitigation strategies.

Urban Forestry Departments

Although urban foresters were not a user group that was targeted for this User Needs Assessment, increasing urban forest cover has been shown to be one of the most effective ways to mitigate urban heat (Slosberg et al, 2006). A heat-related GDSS could be used by urban forestry to prioritize areas for planting and to help with species selection (e.g. choosing heat-resistant species for hotter areas of the city).

3.2 Data identified as useful for heat-related decision-making

A spatial analysis of multiple layers of data using GIS can provide information about the location of vulnerable populations or vulnerable areas and assist in decision-making and resource prioritization. Layers of data can include environmental factors (tree cover, impermeable surfaces, etc.), health information (mortality rates, heat-related EMS calls, etc.), census data (income, age, etc.), and remotely sensed information (satellite thermal imagery or aerial photography). An analysis of this kind has not yet been done in the GTA; however there are a few examples of similar initiatives in other North American cities (see Section 1.4).

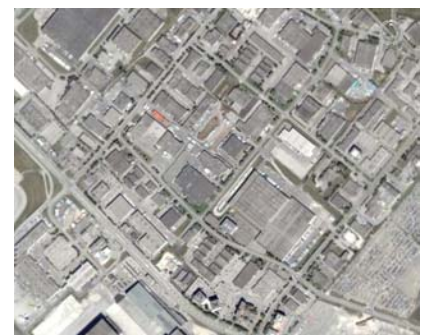
Health Outcome Data

The data sets described below were identified by end-users as being potentially informative for a spatial analysis of heat



AERIAL PHOTOGRAPH OF A TREED RESIDENTIAL URBAN NEIGHBOURHOOD

SOURCE: CANADA CENTRE FOR REMOTE SENSING



AERIAL PHOTOGRAPH OF A LIGHT INDUSTRIAL NEIGHBOURHOOD

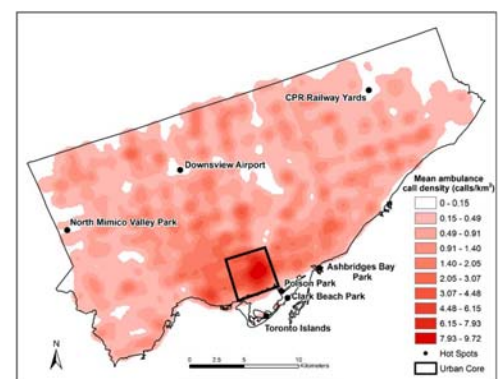
SOURCE: CANADA CENTRE FOR REMOTE SENSING

vulnerability. Information with respect to each data-set was provided by end-users.

Mortality Data – While an important measure of heat vulnerability, mortality data is problematic. Heat is more often a contributing factor than the sole cause of death in a vulnerable person, and consequently the cause of death is usually attributed to an underlying illness such as cardiovascular disease. As a result, heat-related mortality in Canada is under-reported. Under-reported mortality data presents a problem for mapping because the figures are so low. In 2006, only four deaths were attributed to extreme heat by the City of Toronto Coroner’s Office (E. Pacheco, 2008), though Toronto Public Health estimates that the average number of heat-related deaths is approximately 120 per year (Pengelly et al, 2005). Another difficulty with mortality data is that there is a significant time lag between the deaths and the availability of mortality data to public health units. For example, official figures for the very hot summer of 2005 are still not available (Campbell, 2008).

Hospitalization Data – Several key informants felt that information with respect to hospitalizations (morbidity) could be very useful for identifying heat vulnerability, particularly given the relative timeliness of the data as compared with mortality information (less than one year). However, as with mortality data there is likely significant underreporting in this data set. Complicating matters, hospitalization data is coded differently than EMS data and approximately 2% of the entries are missing postal codes (Toronto Community Health Profiles, 2008).

EMS Data – A number of key informants spoke of the possibility of using EMS call data for a spatial analysis of urban heat impacts. This data has been used before to assess heat impacts in the City of Toronto. Using a GIS Dolney and Sheridan (2005) analyzed four years of ambulance call data in Toronto to understand the spatial variability of calls on oppressively hot days. Kate Bassil, a PhD Candidate at the University of Toronto, is completing research aimed at investigating the use of EMS call data for the syndromic surveillance of heat-related illness in Toronto. While Dolney and Sheridan examined total numbers of EMS calls during oppressively hot days, Bassil examined only those calls relating specifically to heat. It is possible for researchers to look at spatial variability of 911 calls relating to heat providing a case definition is created (Bassil, 2008). Currently there is a project underway to bring Canadian EMS data coding in line with World Health Organization standards. Standardized codes will make it



MEAN DENSITY OF AMBULANCE CALLS IN TORONTO DURING WEEKDAYS 1999-2002

SOURCE: DOLNEY AND SHERIDAN, 2005

possible to create one standard case definition for heat-related calls that can be used by all jurisdictions.

OHIP Data – According to end-users, physician visit data (collected by OHIP) could provide some indication of the burden of illness caused by extreme heat and the location of vulnerable populations. However, most end-users consider this data to be unreliable due to the fact that there is no standardized coding system in place for heat-related illness, approximately 25% of the data entries are missing postal codes, and many of the health insurance addresses are out of date (Toronto Community Health Profiles, 2008).

Barriers and Data Gaps:

There was consensus among end-users that health outcome data presents numerous barriers and challenges for spatial analysis. Problems with coding, timeliness and privacy issues were the most frequently mentioned. With respect to privacy, most data providers (Ministry of Health, Canadian Institute of Health Information, OHIP, etc.) require that health data be aggregated to protect the identity of patients. This level of aggregation may be Forward Sorting Area (FSA - the first three digits of a postal code) or even census tract, depending on the data. From the perspective of the end-users, this scale was not considered refined enough to make determinations about spatial vulnerability to extreme heat.

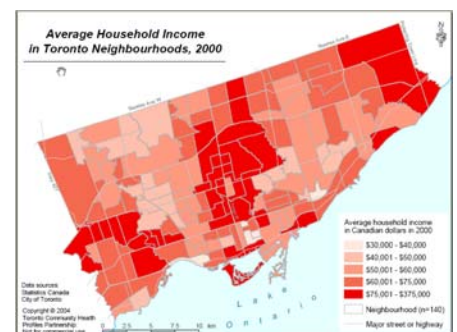
Census Data

A number of demographic variables contribute to the vulnerability of a population to extreme heat. These factors include age, gender, socioeconomic status and social isolation. As such, demographic data collected through the national census every five years is extremely valuable for its potential to locate vulnerable populations or places. Census data is the best and only source of social and demographic information for the entire population.

The totality of the latest census data (2006) will be available by the end of this year. All municipalities surveyed for this report indicated that census data is routinely purchased. Because the latest census was conducted relatively recently, this data should fairly accurate (not withstanding issues of under counting which are described below).

Barriers and Data Gaps:

Three or four interviewees mentioned a potential fault with the 2006 census. According to one end-user, several Canadian cities are currently studying what seems to be a significant under count in the data. Another potential



AVERAGE INCOME TORONTO
BASED ON 2001 CENSUS

SOURCE: TORONTO COMMUNITY
HEALTH PROFILES, 2005

weakness in the 2006 census data appears to be in the reclassification some structure types, which may make it difficult to compare data from multiple censuses. Finally, as data is collected in census tracts only it can not be disaggregated to a finer level for the purpose of analysis.

Environmental Data

End-users identified a number of environmental data sets that are important for heat-related research and decision-making. These include:

- Land use / Land cover
- Building footprint
- Data from weather monitoring stations
- 24-hour air and surface temperature data
- Urban canyon information (to examine the impact of tall buildings on urban heat)
- Remotely sensed thermal data
- Urban forest cover
- Permeable and impermeable surfaces
- Surface materials of roofs
- Surface reflectivity
- Vegetative cover

While most municipalities have access to land use, land cover and building footprint information, the remainder of this data is less readily available. (For a discussion with respect to municipal data holdings, see the attached Technical Addendum - *A Summary of Municipal and CGDI Geospatial Data Holdings to Support Heat-related Decision-making.*)

Surface temperatures, impermeable surfaces and vegetative cover can be determined from remote sensing. Satellite imagery is available from Natural Resources Canada at a processing cost of approximately \$500 per image (Maloley, 2008). The Landsat 5 and 7 satellites operated by the US Geological Service pass over the GTA every 16 days and capture images of the region at 120m and 60m scale resolution respectively. NRCan has made one satellite thermal image available to decision-makers in the GTA (taken on August 10th, 2002 at 10:00 am). Many end-users expressed a desire for more images to be made available, possibly through the CGDI. In particular, end-users requested historical images that reflect how the urban heat island has changed over time, images from the summer of 2005 (the hottest on record in the GTA) and winter images.

As a communication tool, satellite thermal imagery, even at 120m resolution, was considered very powerful by many



HIGH RESOLUTION URBAN
LANDCOVER: OTTAWA-GATINEAU.
QUICKBIRD SATELLITE.

SOURCE: CANADA CENTRE FOR
REMOTE SENSING, 2007

end-users. Many of the heat intervention activities conducted by health units focus on education and outreach. The ability to visually communicate to the public, not only the location of hotspots, but also the correlation between increased heat and vegetation loss and development, was considered very useful. Likewise, community planners who conduct outreach to the public on a regular basis appreciated the satellite data as a valuable communications tool.

Barriers and Data Gaps

Some planning staff indicated that 120m or even 60m resolution thermal imagery may be too low for an analysis of the factors that contribute to urban heat and temperature variability across the region. It must be noted however that most end-users did not feel they had enough knowledge or experience with remote sensing to determine what an appropriate scale of data should be. Research in other jurisdictions (see Section 1.4) indicates that 120m or 60m resolution thermal imagery is appropriate for an analysis of the relationship between the urban heat island and urban form.

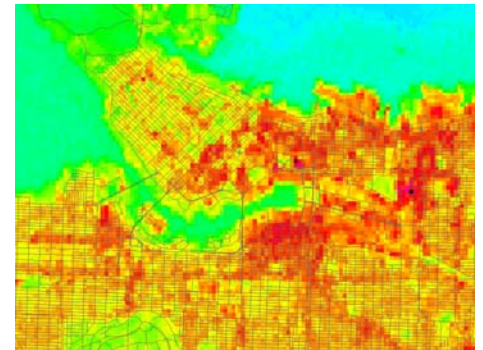
Some of the needs expressed by end-users, especially for assessing the contribution of specific surfaces to the urban heat island and for monitoring and evaluating mitigation strategies, cannot be met without high-resolution (both spatial and temporal) thermal data. Several GTA municipalities are in the practice of collecting annual or bi-annual aerial photographs of their regions. These flyovers may present an opportunity in the future to collect high-resolution airborne thermal imagery. However, without financial support from other sources, collection of high-resolution thermal imagery is well beyond the means of most municipalities.

Other data gaps include information about building and paving materials, surface reflectivity or albedo and urban canyon data. Future research goals should address these data needs.

3.3 Barriers and challenges identified to increased use of GIS in heat-related decision-making

Knowledge

As previously mentioned, some of the end-users interviewed for this report have experience working on heat-related issues and some have experience with GIS



SATELLITE THERMAL IMAGE: OTTAWA
GATINEAU

SOURCE: CANADA CENTRE FOR
REMOTE SENSING

and spatial analysis. However, relatively few end-users have a background in both. As a result, it was difficult for most interview subjects to respond to questions about how GIS could support heat response and mitigation. Likewise, most end-users did not have enough knowledge to comment extensively on specific data needs ('as much as possible' was a common response) or an appropriate scale of data needed for decision-making. To overcome this challenge, CAP conducted a literature review to identify the data that other jurisdictions have used for a spatial assessment of heat. This information was conveyed to end-users by means of a Powerpoint presentation at the beginning of each workshop. In this way, workshops were an opportunity for end-users to increase their knowledge and understanding of urban heat island issues. One end-user in particular commented that as a result of the workshop, planning staff are much more comfortable talking about the urban heat island effect and introducing it in their discussions with developers.

Overall, end-users had difficulty visualizing how a decision support system would work and what it would do. Several end-users expressed concern that the construction of a Geospatial Decision Support System would be prohibitively complicated and require data that was either not available or difficult to access. For the next phase of this project, CAP is proposing an iterative design process wherein a portion of the decision support system is quickly constructed, then tested, improved, and enlarged in systematic steps with the participation of end-users throughout. This will result in the development of a support tool that is as useful as possible for end-users.

Resources

Limited resources impact a municipality's ability to build GIS capacity, to collect and purchase data, to support the development of a decision support system, and to implement heat mitigation or intervention activities.

Common struggles mentioned by end-users include a lack of funding for new projects, hiring freezes, inadequate provision for employee training or software, and competing priorities. Nevertheless, heat has been recognized as a key priority in some jurisdictions and budgets reflect this. The City of Toronto's budget for heat response activities has increased from \$40,000 to \$380,000 since 2001 (corresponding to an increase in the average number of heat-alert days from 5 to 13-15). Peel Region's health unit has applied for GeoConnections funding to conduct strategic planning with respect to building the department's GIS capacity.

Internal or Organizational

One complication that may arise from the construction of a decision support system for both planners and public health staff is a lack of information sharing within municipalities. Through the workshops it became apparent that municipal departments do not have a standardized approach for sharing information among themselves, even when addressing common problems such as heat. One of the major benefits of conducting workshops was that they provided, in some cases for the first time, an opportunity for cross-departmental information sharing on the subject of heat.

End-users in Toronto described difficulties in accessing data internally as a result of cost-recovery. In Halton Region there is no centralized data management division and this responsibility falls to the Planning and Public Works department with a GIS staff of three people for the whole region. One end-user reported that this department is beginning to be over burdened as demand for GIS service increases. Conversely, data management in the City of Mississauga and Peel Region is centralized. One department, with considerable resources, handles all requests for data and analysis and cost-recovery is not an issue (see the attached *Technical Appendix* for a discussion of Municipal GIS Capacity).

Data sharing between municipalities is complicated by the need to negotiate Memoranda of Understanding (MOU) and data-sharing agreements, which can take from 8 months to over a year. Furthermore, municipal data is considered a corporate asset and not routinely shared without a fee.

Political Buy-in

The feeling among some end-users was that political support for heat mitigation and intervention strategies must come *before* the development of the decision support tool. It was argued that without political will to address heat, there would be no funding available to build GIS capacity or a support tool. Despite the number of heat-related programs and policies in effect or planned for the GTA, one end-user felt that without an official policy to address heat, or explicit mention of heat in official plans, it would be very hard to make heat a political priority. Nevertheless, other end-users pointed to climate change strategies and green development plans as proof of political will to address heat. For example, Toronto's Official Plan directly mentions heat in several places and was the basis for the

development of the green roof incentive program and the Green Development Standard.

Another barrier discussed by end-users is the lack of provincial policy support for addressing urban heat in the form of provincial policy statements or explicit mention in the Planning Act. This makes it difficult for planners to defend planning opinions before the Ontario Municipal Board.

4. Conclusion and Recommendations

4.1 Conclusion

Addressing extreme heat is a difficult urban challenge. Unlike other extreme weather events, heat waves do not have visible impacts on infrastructure and the risk to public safety from heat waves is frequently underestimated. Responding to extreme heat through heat alerts and health interventions is costly and the success of these programs is difficult to evaluate. The benefits of heat mitigation strategies are complicated by the fact that they are incremental and difficult to isolate and quantify. Often it requires devastating heat waves, such as that experienced in Europe in 2003, to motivate politicians and decision-makers to act. Based on the findings of this User Needs Assessment, municipal decision-makers are in need of a tool that assists them in understanding the relationship between urban form and heat, assessing and evaluating mitigation strategies and communicating heat risk to the public and decision-makers.

The municipalities included in this user needs assessment can be considered early-adapters with respect to heat. Toronto, Peel and Halton public health units have made heat a priority and have allocated resources accordingly. Likewise, planning departments are undertaking policies and programs that will impact heat positively, though this is not always an explicit goal.

In addition to the municipalities profiled in this report, many other jurisdictions in the GTA are beginning to address extreme heat. Public health staff in York Region are actively considering options for responding to extreme heat and recently drafted a council report detailing the risks of urban heat (Helen Doyle, 2008). A 2007 scan of hot weather response activities across the GTA revealed that several municipalities are involved in heat intervention strategies (Mersereau, 2007).

Municipalities across the GTA are developing sustainable building and land use policies and prioritizing tree planting and natural corridor protection. The public too is becoming more concerned about the health effects of extreme heat. The Town of Oakville recently drafted its first hot weather response plan as a result of pressure originating from within the community. A decision support tool for heat would benefit not only the early-adapters interviewed for this report, but many other municipalities in the GTA as well, particularly if the products can be used to build political and staff support for heat-related actions.

The Need for a GDSS

Broadly defined, a decision support system is a spatially-based computer application that assists a researcher or manager in making decisions (USGS, 2008). The possibilities for types of decision support systems are limited only by the user group and the developer's imagination. Geospatial decision support systems can be powerful modelling tools, or easy-to-use tools for relatively straightforward applications.

Despite the activities being undertaken across the GTA to respond to and mitigate urban heat, current approaches could be characterized as unfocussed and in some cases limited in their impact (particularly given the difficulties evaluating both response and mitigation activities). End-users need a tool that will support coordinated and strategic decision-making as well as long-term planning and policy development. A geospatial decision support system will help to support this need.

End-users identified three main needs for a GDSS:

1. To assess the heat vulnerability of both populations and places in the GTA. An assessment of this kind would support end-users to:
 - Identify and locate clusters of at-risk populations;
 - Make decisions about where to direct heat intervention efforts and dollars; and,
 - Study the correlation between morbidity, mortality and environmental and demographic factors.
2. To identify the relationship between 'hotspots', or locations where temperatures are consistently hotter, and other variables. This information would support end-users to:
 - Prioritize and direct intervention and mitigation activities on a neighbourhood-by-neighbourhood basis;

- Assess the contribution of urban form and building and paving materials on air temperatures;
 - Track and evaluate the effectiveness of heat mitigation activities; and,
 - Inform negotiations during the development approvals process and when making recommendations to council.
3. To develop heat-related communication materials. These materials would support end-users to:
- Build political support for allocating resources to heat mitigation and response activities;
 - Build staff understanding and support for addressing urban heat and the urban heat island effect; and,
 - Communicate information to the public with respect to heat-safety and activities that mitigate urban heat islands, including: maintaining vegetation cover, using permeable pavement, installing green or reflective roofing, etc.

4.2 Recommendations

Next Steps:

1. Based on the findings of this User Needs Assessment, it is recommended that a geospatial decision support system (GDSS) be developed to support end-users in addressing urban heat. In phase II, CAP will be responsible for coordinating the development of the GDSS in collaboration with participating end-users and a software developer (to be determined);
2. It is further recommended that the GDSS be developed to support the needs of both planning and public health end-users (and potentially urban forestry as well). Although public health units and planning departments primarily approach urban heat questions from different perspectives (mitigation vs. response), both face similar challenges with respect to accessing data, allocating resources and garnering political support. Furthermore, a number of the same data sets are required by both end-user groups.
3. It is recommended that end-users participate in an iterative design process wherein a portion of the decision support system is quickly constructed, then tested, improved, and enlarged in systematic steps. This will enable end-users to provide informed input on the operation and functionality of the GDSS throughout the design process. Preliminary recommendations for the GDSS infrastructure, include:

- 3.1 The GDSS should be flexible enough to utilize data that is currently available as well as to easily incorporate new data as it becomes available;
- 3.2 End-users should have common ability to input data of their choosing and to determine who has access to that data;
- 3.3 Access to the GDSS should be restricted to protect the security of municipal data assets and the privacy of health care data; and,
- 3.4 GDSS end-users should have access to all of the data resources available through the CGDI.

To improve the quality and availability of regional heat-related data in the GTA, it is further recommended that:

4. Remote sensing data, in particular thermal imagery, be made available by the Canada Centre for Remote Sensing and other federal agencies through the Canadian Geospatial Data Inventory;
5. Public health units and other health agencies continue to advocate for more timely access to mortality data from Statistics Canada;
6. Municipalities collect data with respect to public uptake of heat intervention strategies (e.g. the location where heat hot-line calls originate; demographic information about visitors to cooling centres, etc.);
7. Municipalities in the GTA investigate the cost of collecting high-resolution thermal imagery from airborne sensors in conjunction with the collection of aerial photography, and;
8. Coroner's offices in the GTA strive to diagnose when heat is a contributing factor to death.

To encourage knowledge-building at the municipal level in conjunction with the development of the GDSS, it is recommended that:

9. In collaboration with CAP, end-users across the GTA continue to meet and share information through the GTA Clean Air Council Urban Heat Island Advisory Group;
10. An expanded literature review be conducted by CAP of examples where GIS and remote sensing has been used to support the development of municipal policy with respect to heat;
11. CAP and the GTA-CAC Urban Heat Island Advisory Group host a one-day conference on the subject of using GIS to address heat. The conference will build knowledge and capacity among end-users by

- bringing together decision-makers and researchers to network and share best-practices. Health Canada has recently announced its intention to support heat-related research initiatives across Canada and would be an ideal agency to approach for funding;
12. Municipalities apply for GeoConnections funding to support strategic geomatics planning and capacity building (Peel Region Public Health has already applied for this funding); and,
 13. Planning departments, health units and policy developers should explicitly identify heat as a departmental priority through official plans, statements from the Medical Officer of Health, Council directives, etc.

4.3 Phase II - The Development of a Geospatial Decision Support System

Going forward with phase II of this project, the development of a geospatial decision support system, CAP must initially address some critical questions, specifically: 1) which end-users will participate in the second phase; 2) who will develop the GDSS; and 3) where the GDSS will be housed.

Several end-users expressed interest in participating in Phase II. Providing GeoConnections agrees with the recommendations put forward in this report, \$150,000 will be available for Phase II. However, this funding must be matched by end-users, which may be prohibitive for some. Most municipalities do not have room for discretionary spending in their budgets. CAP itself has limited core funding for research and relies on external project funding. In-kind contributions will likely be available from both end-users and CAP, the nature of which will depend on the phase II workplan and the final product. To assess interest in Phase II and to determine what matching funds will be available, CAP will meet with potential project collaborators in late May or early June of 2008.

Neither CAP nor participating municipalities have the technical capacity to develop a GDSS. Therefore, the services of an external consultant must be retained. In order to cost the construction of the GDSS, and to develop a phase II budget, potential software developers must be identified as early as possible. CAP has previously worked with a variety of environmental consultants in the GTA who will be approached for proposals.

Questions of where a GDSS will be housed and who will be responsible for maintaining it were only briefly

discussed in this assessment. According to end-users, no one municipality has the funding or the staff resources to be responsible for maintaining and hosting the GDSS. One respondent suggested it be housed at the Provincial level, perhaps with the Public Health Agency of Ontario. However, the tool must be accessible to both public health units and planning staff, so this may not be a good solution. Ideally, the GDSS should be housed with an organization that has core funding, a compatible mandate, and the capacity to manage and maintain it on a long-term basis. One end-user proposed that municipalities share responsibility for developing the tool, but host and maintain independent versions of it on their own servers. However, the development of a consistent regional approach to heat requires a commitment among municipalities to share data and other resources. Furthermore, to ensure that municipalities who are not early-adopters are able to take advantage of a GDSS in the future, one centralized tool is preferable. As this question will likely be complicated to resolve, it will be addressed with collaborators and developers as early on as possible.

Contingent upon GeoConnections support for proceeding with Phase II of this project, CAP will develop a project proposal, in collaboration with project partners, to be submitted in June, 2008.

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APPENDIX I – LIST OF WORKSHOP PARTICIPANTS AND INTERVIEWEES

Workshop Attendees:

Toronto:

1. Helen Iardas (Urban Design)
2. Allison Reid (Urban Design)
3. Mike Mulqueen (Environmental Planning)
4. Lisa King (Environmental Planning)
5. Melanie Lelanie (Public Health)
6. Marco Vittiglio (Public Health)
7. Monica Bienefeld (Public Health)
8. Bill Warren (City Planning, Research and Information)
9. Perry Korouyenis (Community Planning)
10. Norman DeFraeye (Urban Forestry)
11. Nancy Day (Epidemiologist)
12. Marco Vittiglio (Public Health)
13. Stephanie Gower (Public Health)
14. Kate Bassil (Epidemiologist)
15. Joe Da'Abramo (Environmental Planning)
16. Monica Campbell (Public Health)
17. Matt Maloley (NRCan)
18. Phil Hill (NRCan)
19. Dan Jakubek (Ryerson University)

Halton Region:

1. Phillippa Holowaty (Epidemiologist)
2. Chris Lui (Technology Services - Project Manager)
3. Anthony Campese (Planning & Transportation GIS Analyst)
4. Jacinth Miller (Health Department - Environmental Health Specialist)
5. Trisha Leczynski, Environmental Coordinator
6. Anthony Campese (Planning and Transportation Services)
7. Dimitra Kasimos (Public Health)
8. Joanna Oliver (Epidemiologist)
9. Kim Perrotta (Public Health)
10. Sonya Muntwyler (Public Health)

Peel:

1. Lori Greco (Public Health)
2. Kiran Ghai (Public Health)
3. Jacquelyn Gulati (Mississauga Transportation)
4. Julie Stratton (Public Health)
5. Craig Moffitt (Planner) Planning, Policy and Research
6. Gavin Bailey (Planner) Development Planning
7. Alain Normand (Brampton Emergency Measures)
8. David Marion (Mississauga Geomatics)

Interview Subjects:

1. Monica Campbell (Toronto Environmental Protection Office, Public Health)
2. Bill Warren (Toronto City Planning, Research and Information)
3. Elaine Pacheco (Toronto Public Health)
4. Christopher Morgan (Toronto Environment Office)
5. Julie Stratton (Peel Public Health)
6. Derek Yee (Peel Public Health)
7. David Marion (Mississauga Geomatics)
8. Kevin Tierney (Toronto Survey and Mapping)
9. John Rampal (Peel Information & Technology Services)
10. Scott Webb (Land Information Toronto)

APPENDIX II – WORKSHOP PRESENTATION

(See attached presentation file)

APPENDIX III – WORKSHOP QUESTIONS

WORKSHOP QUESTIONS:

1. How does your department currently address heat issues?
2. What long-term goals do you have with respect to heat mitigation/heat response?
3. What spatial information is important for understanding heat-related issues?
4. What data do you currently have access to/use in thinking about or implementing heat-related programs?
 - What heat-related data does your department collect and analyze?
 - Do you have concerns about quality of the data you use?
 - What resolution is necessary for local analysis and decision-making?
5. What additional data would you like to have?
6. What are the barriers and challenges to getting and using spatial data/GIS in heat-related work?
 - Human resources?
 - Capacity?
 - Financial?
 - Lack of standardization?
 - Other?
7. If a geospatial decision support system was created for the GTA:
 - What data should be available on it?
 - Where should it be housed?
 - How should it be accessed?
 - Who should have access?
 - How could it be maintained/ updated?
8. Can we contact you to follow up on the information from this workshop?

APPENDIX IV – INFORMATION SHEET

Thank you for agreeing to participate in the Clean Air Partnership initiative: *Using GIS to Address Extreme Heat and the Urban Heat Island Effect in the GTA.*

In order to gather some preliminary information, we ask that you take a few minutes to complete and return the questionnaire below. Where there is a multiple-choice question, please circle the answer that most closely reflects your experience.

1. NAME
2. Position and Department
3. In your current position, what are your primary responsibilities?
4. Do you have experience using Geographic Information Systems (GIS)?
 - I have considerable GIS experience
 - I have working knowledge of GIS
 - I have minimal GIS experience
 - I have no GIS experience
5. Do you use Geographic Information Systems (GIS) in your current position?
 - Often
 - Sometimes
 - Never (Skip to Question 9)
6. Please specify which GIS software functions do you primarily use?
 - Viewing Spatial Data
 - Producing thematic maps
 - Analyzing data/ Decision-making
 - Other, please specify
7. Which, if any data sets do you routinely use (ex. land cover/ land use, census tract data)? Please indicate the source(s)
8. Which GIS/ Remote Sensing software(s)/ applications do you currently use?
9. Are you familiar with the Canadian Geospatial Data Infrastructure (CGDI)?
 - YES
 - NO
10. Have you ever accessed any of the free GIS resources available through the public health information network of Canada or GeoConnections?
 - YES
 - NO
11. Can we contact you to follow up on the information from this workshop? YES/ NO