Spatial Analysis of Hazard Risk Factors for Vulnerable Populations in Portland, Oregon

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Executive Summary

In the late 1990's, the concept of "disaster" became redefined as a natural event coupled with the vulnerability of the area. The concept of vulnerability takes into account the role of man-made structures and their exposure, resistance and resilience to natural hazards. The term is multi-faceted and includes structural, economic, psychological, and social effects.

The changing view towards evaluating and mitigating disaster based on vulnerability provides a renewed motivation for proactive hazard mitigation. Developments in mapping software, particularly geographical information systems (GIS), have complemented the renewed focus. These two converging trends have inspired increased spatial analysis in disaster mitigation and management planning.

This intent of this project was to use GIS-based analysis, HAZUS-MH software, and localized data to contribute to the renewed discussion of vulnerability and disaster planning. The goal of the specific analysis was to identify Portland neighborhoods with both high hazard risk and one or more vulnerable populations that would need special attention from responders at the neighborhood level.

The primary sources of the data used in the study were the U.S. Census, Metro's Regional Land Information System (RLIS), and HAZUS-MH. Additional sources include Toxic Release Inventory (TRI) locations from the EPA and transitional housing and shelter facilities drawn from a community services database. For the purpose of this study, vulnerability includes households below the poverty level and/or without access to vehicles and persons who are disabled and/or over the age of 65. The study utilized a specific scenario in the Portland region as a starting point for spatial analysis. Maps were developed to reflect a magnitude 7.0 Portland Hills earthquake event with 100 year flood plain and TRI sites. The model was used to determine the potential areas where vulnerable populations are exposed to increased risk and which neighborhoods are threatened by all three potential hazards.

The analysis showed that thirteen neighborhoods are at risk in a "triple hazard area" (THA), which combines the highest rates of peak ground acceleration from the 7.0 Portland Hills event, 100-year flood risk and potential toxic release sites. With the exception of seniors, which had highest concentrations in the NE neighborhoods, the highest percentage of vulnerable populations by census tract was located in the triple hazard area – with notable concentrations of vulnerable populations within the dense City Center. The Buckman, Northwest District, and St. Johns neighborhoods were analyzed in further detail for locations of potential resources for both outreach and incident management.

This project provides a framework for undertaking the mapping of vulnerable populations and a basic neighborhood map template that could be utilized to focus neighborhood emergency teams being trained by the City as the first-line emergency responders.

Neighborhoods in the triple hazard area

Brooklyn
Buckman
Cathedral Park
Corbet Terwilliger/ Lair Hill
Downtown
Hosford-Abernathy
Linnton
Northwest District
Overlook
Sellwood-Moreland
St. Johns
University Park

Introduction

The pairing of recent high profile natural disasters and a proliferation of mapping software has inspired the increased use of spatial analysis in disaster mitigation and management planning. The catastrophic losses of the 2004 Sumatra-Andaman earthquake catalyzed many countries to (re)evaluate their disaster management strategies and warning systems (Oloruntoba, 2005). The 9.0 earthquake took the lives of more than 150,000 people with tens of thousands still missing and presumed dead. The resultant deaths occurred as far as 4,500 km from the quake's epicenter (Oloruntoba, 2005). Notably in the United States, Hurricane Katrina fueled conversation around disaster planning. The hurricane made landfall between a category three and five, taking the lives of 1,200 people and taking on the title as one of the most deadly natural disasters in U.S. history (Roberts, 2005). But this is a source of contention. The majority of the deaths were due to drowning and structural failures as water rushed into New Orleans through breached levees. Post-mortem, the levee breaks in the face of Katrina were attributed to design flaws, a man-made disaster rather than a natural disaster (Warrwick, 2005). The majority of those that perished in New Orleans were poor and African-American who lived in the lower areas of the city (Pastor, 2006). The disproportionate loss of life suffered in the disaster was not a unique occurrence (Pastor, 2006). What was unique to Katrina was the media's real time coverage of the saga. Households across the globe witnessed the levee failure and the ensuing crawl to rescue to those left behind.

This very public display of disaster management's failure came as the disaster community was in the midst of a theory and practice based upheaval. In the 1990's the focus of disaster management began to shift from a reactive military based approach to a more proactive localized approach (Bankoff, et al, 2004). To this point, disaster planning in the United States

reflected Burton and Kates (1964) definition of natural disaster as an element of the physical environment which is harmful to man and caused by forces extraneous to him (from Pelling, 2002). This deference to environmental determinism yielded decades of response-based disaster planning.

More recently, the concept of "disaster" has been redefined as a natural event coupled with the vulnerability of the area. The concept of vulnerability takes into account the role of man-made structures and their exposure, resistance and resilience to natural hazards. The term is multi-faceted and includes structural, economic, psychological, and social effects. The focus on vulnerability empowers communities and organizations to engage in proactive hazard mitigation. Alexander (1997) called the reorientation "one of the most salient achievements in the field in the last decade" (from Bankoff, et al, 2004).

Developments in mapping software, particularly geographical information systems (GIS), have complemented the renewed focus on hazard mitigation. The Federal Emergency Management Agency (FEMA)'s supplies a modeling tool called Hazard U.S. Multi-Hazard (HAZUS) that extends ESRI's ArcGIS software. HAZUS allows localities to develop scenario-based maps that assess structural, economic and social vulnerability in the face of particular natural disasters. This localized approach to disaster management yields site-specific strategies to minimize exposure and improve resistance and resilience.

Problem Statement

Questions and Intent

Our GIS-based analysis utilizes HAZUS-MH software and localized data to contribute to renewed discussion of vulnerability and disaster planning. Inspired by social ecology theory which poses that social spatial relationships mirror the larger social structure, the study maps vulnerable populations in Portland, Oregon, in relation to hazard proximity (Zakour and Harrell,

2003). It expands upon previous work on the topic through a more inclusive definition of "vulnerable populations" and "hazard". Previous hazard management analysis utilizing HAZUS software defined vulnerable populations as those over 65 years of age and/ or living below the poverty level. For the purpose of this analysis, vulnerability includes households below the poverty level, carless, disabled and/or over age 65 population. The expanded definition of hazard includes toxic release in addition to earthquake and flood. This understanding takes into account the possibility of secondary hazards that could result from a primary hazard such as an earthquake.

Employing these definitions of hazard and vulnerability, the study addresses four questions through spatial analysis. First, the study seeks to pin-point what areas of Portland are at greatest risk for hazards. Of these hazard prone areas, we determine which have the greatest concentrations of vulnerable populations. A second tier of analysis identifies the neighborhoods with the largest concentrations of vulnerable populations within the high-risk area and what emergency amenities are available in these neighborhoods.

The intent of the analysis is to contribute to the development of a methodology which more closely examines the needs of vulnerable residents in hazard mitigation planning. By identifying vulnerable populations most at risk of disaster, the community will be better able to plan for the delivery of post-disaster services at the neighborhood level. Through proactive planning, the data may be used to tailor outreach programs and materials to address the needs of these specific populations.

Previous Analysis

This analysis builds upon work completed by the City of Portland's Office of Emergency Management (POEM) in a 2003 pilot project supported by the FEMA (Portland, 2003). The project employed HAZUS-MH and ArcGIS software to produce a risk assessment which

inventoried assets and projected losses based on identified hazards.

The City analyzed four hazards out of 12 potential hazards that can be modeled with HAZUS: earthquake, flood, wildland fire, and landslide. Based on historical and researched data, each hazard was profiled and ranked on a priority scale (low/no concern to severe concern). Flood ranked as a hazard of "high" concern. Earthquake, wildland fire and landslide were ranked as hazards of severe concern. As legislated by the Disaster Management Act of 2000, the assessment mapped vulnerable populations in relation to earthquake hazard on the city level. The elderly and low-income residents constituted this population.

The GIS-based risk assessment examined the effects of 100-year MRP and 500-year MRP events. The MRP, Mean Return Period "considers the severity of a hazard event that can occur within a given time period." Each year there is a 1% chance that there will be an earthquake of a given magnitude in the Portland area. This event is likely to take place within 100 years. For the purposes of the HAZUS-MH analysis, the 100-year earthquake was assumed to be a 5.8 magnitude earthquake originating along the Portland Hills fault or a 7.0 earthquake originating in the ocean (Portland, 2003).

The HAZUS study offered a detailed and localized vulnerability assessment in relation to specific and separate hazards. Further work by Wood, Good, and Godwin (2004) utilized GIS to assess social vulnerability in relation to an earthquake and subsequent tsunami in Yaquina River, OR. This assessment builds upon this concept of primary and secondary hazards and their effect upon social vulnerability in a localized setting.

Data Summary

The primary sources of the data used in our study of hazard risk and vulnerability were the U.S. Census, Metro's Regional Land Information System (RLIS), and HAZUS-MH. Only

vector and attribute data was used. Table 1 below provides a listing of all data sources and Figure 1 in the appendix depicts the processing and analysis methodology.

Table 1. Data sources, grouped by data source. *Only vector and attribute data was used. Detailed notes where indicated are at the bottom of the table.*

Source	Data Set Category	Layer Description	Date	Feature Type	Notes
PRIMARY SOURCES					
RLIS	Boundary	Metro Region Boundaries	a	Polygon	4
RLIS	Boundary	County Region Boundaries	a	Polygon	4
RLIS	Boundary	Census Tract Boundaries	a	Polygon	4
RLIS	Boundary	Regional Neighborhoods	a	Polygon	4
RLIS	Land Use	Parks	a	Polygon	4
RLIS	Land Use	Zoning	a	Polygon	4
RLIS	Water	Rivers	a	Polygon	4
RLIS	Water	Floodplain	a	Polygon	4
RLIS	Streets	Streets	a	Line	4
RLIS	Streets	Arterials	a	Line	4
RLIS	Transit	Railroads	a	Line	4
RLIS	Places	Fire Stations	a	Point	4
RLIS	Places	Hospital	a	Point	4
Hazus (FEMA)	Geology	Earthquake Peak Ground Accel.	b	Polygon	5
Hazus (FEMA)	Geology	Earthquake Historical Epicenters	b	Point	5
Hazus (FEMA)	Geology	Earthquake Faults	b	Line	5
Hazus (FEMA)	Hazard	Hazardous Material Sites	2003_b	Point	5
Hazus (FEMA)	Emerg. Facil.	Fire Stations	2003_b	Point	2, 5
Hazus (FEMA)	Emerg. Facil.	Police Stations	2001_b	Point	5
Hazus (FEMA)	Emerg. Facil.	School	2000_b	Point	2, 5
EPA	-	Toxic Release Inventory	2004	Point	1, 6
ODOT	-	Freight Routes	2002	Line	
Census	Demographic	Table H44: Vehicle Ownership by Tenure	2000	Table	3
Census	Demographic	Table P119: Imputed Disabled Pop.	2000	Table	3
Census	Demographic	Table P80: Population by Age	2000	Table	3
Census	Demographic	Table P92: Hholds below poverty	2000	Table	3
SECONDARY SOURCES					
211 Info	-	Transitional Housing and Shelters		Point	1, 7
Multnomah Cty.	-	Adult Care Facilities		Point	1, 8
City of Portland	-	Community Centers		Point	1, 9

Source	Data Set Category	Layer Description	Date	Feature Type	Notes

General Notes:

1. Geocoded
2. Used a Hazus feature class; in future work would prefer to draw from the RLIS data set.
3. American Factfinder website accessed from http://www.census.gov.
4. Accessed from the Portland State University RLIS repository.
5. HAZUS was obtained from FEMA on CD/DVD-ROM media, using http://www.fema.gov/plan/prevent/hazus/hz_orderform.shtm.
6. TRI data obtained from http://www.epa.gov/tri/tridata/tri03/index.htm.
7. Transitional housing and shelter data obtained from http://www.211info.org.
8. Multnomah Cty Aging and Disability Services, http://multnomah.or.networkofcare.org/aging/resource/searchbycat.cfm?cat=8589
9. Obtained from http://www.portlandonline.com/parks/finder/

Date Notes:

a. RLIS February 2007 Data Set
b. Hazus Data October 2006; Hazus Program: Hazus-MH MR2 (v. 1.2) May 2006

The following sections describe both the primary and secondary data sources in further detail.

U.S. Census

The 2000 U.S. Census provided the demographic data for our study, including the following. variables from the Census Summary File 3 (short form):

- Carless households (number of occupied housing units without access to a vehicle)
- Households with incomes below the poverty level
- Population over age 65
- Population over age five with one or more disabilities (imputed)

We obtained data at the census tract level for the three Metro region counties – Clackamas, Multnomah, and Washington. Data for the imputed population with disabilities was only available for census tracts, so for consistency we chose to use this scale for all demographic variables, as opposed to more disaggregated block group data.

RLIS

Metro's Regional Land Information System (RLIS) provided many of the data sources used in our mapping and analysis. Metro, county, and neighborhood polygon feature classes were used as boundaries. A variety of line, polygon, and point feature classes were primarily used for thematic display purposes. Floodplains were utilized in our primary analysis, while

railroads and zoning (industrial) were used to identify neighborhoods to map at a larger scale.

HAZUS

HAZUS-MH generates GIS feature classes based on user-selected hazard models and parameters. HAZUS was the only source able to provide the earthquake vector data that we needed for our analysis. We used historical earthquake epicenters and known fault lines for thematic purposes, but the principal analysis layer was polygons of peak ground acceleration (PGA) for a 7.0 earthquake on the Portland Hills fault, modeled using HAZUS. The feature class comprised census tract polygons with a PGA attribute for each tract. The PGA factors approximate the severity of shaking and resultant damage.

Toxic Release Inventory (TRI)

TRI data from the federal Environmental Protection Agency (EPA) consists of sites for which a toxic release emission in excess of federal guidelines has been reported. We used this data to identify potential areas of secondary hazards. The data was "cleaned" by manipulating the data tables to consistently reflect the location and name of facilities. An interpretation "key" that is available from the EPA website assisted with this process. The data was then geocoded for representation in the GIS.

Secondary Sources

All of the following secondary data sources were also geocoded.

Transitional housing and shelter facilities were drawn from a community services database, 211info.org.

Adult care facilities data provided by Multnomah County Aging and Disability Services included adult residential care homes, assisted living facilities, nursing facilities, independent living facilities, and continued care facilities.

Deleted: was geocoded. These facilities

Community center locations were obtained from the Portland Parks and Recreation

department. These facilities are possible staging areas for Portland Neighborhood Emergency Teams (NETs) in the event of a disaster event, particularly when located in parks. Assessing the suitability of community centers to serve as NET staging areas would be a step for future work.

Projections

RLIS data sets are projected in the state plane geographical coordinate system, GCS_North_American_1983_HARN, and we used this projection as the base for all our project files. HAZUS data sets are projected in GCS_North_American_1983. The optimum result was to let ArcGIS transform any HAZUS layer "on-the-fly," rather than re-project it to HARN. We believe that the result was accurate; however future work should validate this.

Data Limitations

Census

Demographic shifts since the 2000 census was conducted may affect the accuracy of representation and analysis. The short form samples one out of every six people and is weighted to represent the total population. Finally, census tracts sometimes overlap the Portland neighborhood boundaries.

HAZUS

HAZUS is a modeling tool, and hazards, and earthquakes in particular, are not completely understood and or predictable in their exact effects. The HAZUS model can be used to estimate building damage or the number of people displaced at a census tract level, however given our limited time frame, we focused on PGA as a sufficient approximation. It can also estimate 100-year MRP and 500-year MRP events, used in the 2003 pilot project.

The data is developed at a national scale, and certain layers may not be as comprehensive as locally produced data. FEMA data also identifies locations of features but does not describe

them. For these reasons, we used RLIS data instead of HAZUS data where available. Finally, the metadata for feature classes generated from HAZUS models does not document the underlying model.

TRI

Given the attributes of the data which were reported, within the scope of this project it was difficult to determine an adequate buffer size for the potential hazard; data on storage capacity and chemical output would be useful. The information is also self-reported and therefore potentially incomplete. Future work should use the existing literature on this topic to more accurately determine an impact buffer around TRI sites based on specific attributes of the sites.

Secondary Sources

The transitional housing and shelter data is self-reported by facilities and some facilities, such as battered women's shelters, do not report data for security reasons. In the future, it would be helpful to have social service agencies verify and supplement addresses. It may be possible to overcome confidentially concerns with assurances that information will be kept within the city so that facilities remain undisclosed.

The Multnomah County adult care facilities data lists some facilities that may not actually house people on-site but may be clearinghouses for information. It would be advisable to field check the information by telephone, verifying location and housing capacity.

Methodology

The goal of this project was to identify Portland neighborhoods with both high hazard risk and one or more vulnerable populations that would need special attention from responders at the neighborhood level. The desired final product was a neighborhood-level map that would identify potential gaps in services and provide neighborhood response teams with locations of

vulnerable populations and services. This section details the methodology behind the analysis used and highlights the assumptions that should be reexamined in the future.

Our basic approach was to map hazards in the Portland region, concentrating on a magnitude 7.0 Portland Hills event that we modeled with HAZUS, a 100-year flood, and TRI data. While by no means a comprehensive set of possible events, earthquakes represent a scenario where a disaster cuts off the population from outside resources and self-sufficiency is required. On the other hand, a flood may render the human environment unsafe or uninhabitable and require evacuation of the population. Toxic releases may occur independently of any other event or may be a secondary concern of a primary event.

For both scenarios, we sought to identify the impact zones of possible of natural hazards, including earthquakes and flooding, and of industrial incidents. In both cases we attempted to develop GIS layers of risk areas and analyze these areas with the identified populations. Having identified this confluence of risk and vulnerability, we planned to focus on key neighborhoods exhibiting this overlap.

Hazards

To create an analysis layer representing high risk of multiple types of hazards, we followed the following general steps:

- We created 0.5 mile buffers around TRI sites, dissolved when they overlapped. As discussed in the "Data Summary" section, additional information would allow a more precise buffer to be placed around each site.
- We selected and created a feature class of all census tracts in the HAZUS PGA (representing level of intensity) polygon feature class with a PGA of > 0.70.
- We intersected the floodplain, TRI, and high-intensity PGA feature classes to identify the census tracts vulnerable to all three threats. We later intersected this with Portland neighborhoods. (An alternative approach would have been to intersect the Portland

neighborhoods polygon layer and a feature class containing census tracts, and then to join the PGA and Neighborhoods based on Census tract number.)

Maps of hazards in the Portland region are shown in Figure 1a of the appendix.

Vulnerable Populations

In order to identify the vulnerable populations in these tracts at highest hazard risk, we first mapped vulnerable populations citywide, and also included the Metro region.

Two of our vulnerability variables are measured in household units. Households below the poverty level – the count of households with income in 1999 under the federal poverty level – are displayed in a choropleth map of Portland showing these households as a percentage of total households (Appendix, Figure 4). Carless households, defined as the count of occupied housing units with no vehicle available to occupants, are similarly represented as a percentage of the total number of households in Figure 5 of the appendix.

The other two variables are population counts. Figure 6 in the appendix shows a map of total imputed disabilities – converted to percentage of the population. The "Over 65" population was converted to a percentage of the total population and represented in a choropleth map (Figure 7).

We elected to represent the vulnerable population as a percentage of a total on the overall maps of vulnerable populations (Figures 4-7), useful for identifying the census tracts in Portland with the highest levels of each population. However, on the neighborhood-level maps (Figures 8-10) we showed population counts. Our rationale is that a count of people to be assisted will be more useful to responders.

Neighborhood Identification

To incorporate neighborhoods into the selection process, we assessed all Portland neighborhoods intersecting the Triple Hazard area. Using a qualitative process, we created a

table listing the top neighborhoods in the selection area for each vulnerability population.

While not included in our primary analysis, we also qualitatively looked at railroads and freight routes, where train derailments and truck accidents could occur, when making neighborhood selections. In the future, buffers could be created around them and incorporated into the analysis. We also incorporated areas zoned for industrial use and hazardous materials sites from HAZUS. These sites are shown in Figure 1b of the appendix.

We attempted to identify neighborhoods representing different scenarios and characteristics. St. Johns is at the confluence of the Columbia and Willamette Rivers, on Portland's east side. Buckman is also on the east side. The Northwest District is on the west side. The Analysis section will provide more details about these neighborhoods.

Neighborhood Response Resources

At the neighborhood level, we mapped both the vulnerable populations and resources to serve them (Appendix, Figures 8-10). These maps include neighborhood boundaries from RLIS, which, as described in the Hazards section above, we intersected with the HAZUS PGA feature class containing Census tract polygons.

Analysis Results

Hazards

As noted in the methodology section, the first phase in the analysis identified Portland census tracts that are at risk for multiple hazards under two potential 'natural disaster' scenarios. The potential peak ground acceleration (PGA) after a 7.0 magnitude earthquake event on the Portland Hills Fault and the 100-year floodplain from the Colombia and Willamette Rivers were mapped along with locations of TRI industrial sites with known toxic release events. Figures 2 and 3 show almost the entire City of Portland within a zone of PGA that exceeds 0.40. This value indicates a potential for moderate to extensive damage due to the shaking intensity of the

earthquake event.

Eighteen TRI sites are located within the area of the highest potential PGA (over 7.0). Flood zones are present in the entire north-south extent of the highest PGA area within Portland.

Table 2: Neighborhoods in the triple hazard area

Brooklyn
Buckman
Cathedral Park
Corbet/Terwilliger/Lair Hill
Downtown
Hosford-Abernathy
Linnton
Northwest District
Northwest Industrial
Overlook
Sellwood-Moreland
St. Johns
University Park

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The analysis showed that thirteen neighborhoods are at risk in a 'triple hazard area' (THA), which combines the highest rates of peak ground acceleration, 100-year flood risk and potential toxic release sites. Figure 3 shows neighborhoods in relation to the hazard risk zones. The 13 neighborhoods shown in Table 2 span the length of the Portland City limits from north to south and have varying demographic characteristics.

Vulnerable Populations

A brief analysis of census data within these neighborhoods showed that with the exception of seniors, all of the census tracts with the highest percentage of vulnerable populations were located in the triple hazard area. The spatial analysis highlights notable concentrations of vulnerable populations within the dense City Center. The downtown neighborhood was singled out as having the highest concentrations for all vulnerable populations within the triple hazard area. Table 3 presents the top three tracts for each vulnerable population and neighborhood location.

Table 3: Top three census tracts for vulnerable population in neighborhoods within the triple hazard area

	% of Total Population	Cenusus Tract #	Neighborhood
Below Poverty Level Households			
	58%	54	Downtown
	47%	53	Downtown
	31%	56	Downtown
Carless Housing Units			
	90%	53	Downtown
	83%	54	Downtown
	55%	56	Downtown
Disabled persons			
	36%	54	Downtown
	28%	53	Downtown
	27%	44	Overlook
Persons over age 65			
	20%	57	Downtown
	19%	44	Overlook
	16%	53	Downtown

Figure 4 in the appendix shows households below poverty level in the Metro region. This figure illustrates that 15 of the 20 census tracts with the highest percentage of households below the poverty level are in neighborhoods identified in the THA during the first phase of analysis. Figure 5 in the appendix shows a similar trend for carless households with 18 of the 22 highest percentage tracts located in the THA.

The senior and disabled populations are more dispersed throughout Portland and the

Metro region. Figure 6 (appendix) does show notable concentrations of disabled persons in THA neighborhoods, with high percentages in the Downtown and Overlook neighborhoods. Concentrations of seniors are seen throughout the City, with a notable area in northeast neighborhoods. Figure 7 (appendix) shows that while the areas in the THA may not have the largest proportions of seniors, there are still significant numbers there.

Overall regional trends show that neighborhoods towards central Portland and the THA have high percentages of vulnerable populations relative to the total population.

Neighborhood Study

The addition of point data showing community services allowed a first-run analysis of potential resources within the neighborhoods. In all three neighborhoods schools may provide the best centralized response centers in a disaster event. Only the Northwest District has a hospital located in the immediate vicinity. Both the Buckman and Northwest District neighborhoods have multiple homeless and transitional shelters. Residents of these facilities may have complex vulnerabilities and few alternatives for transportation and alternate housing. This is the case in other neighborhoods in the THA – particularly the Downtown neighborhood. St. Johns is susceptible to isolation from services in the event of a bridge collapse.

Results from our comparison of the three neighborhoods show high or equal rates of vulnerable populations relative to Portland as a whole. Table 4 and Figures A-D below compare the levels of vulnerable populations relative to greater Portland.

Buckman and the Northwest District have rates of carless households significantly larger than the average in Portland, while St. Johns is equal to that average. This is likely due to the location of the neighborhoods and the necessity of owning a car – rather than preference or socio-economic status.

All three study areas have relatively low levels of seniors over 65.

Table 4: Comparison of percentage of vulnerable populations in select neighborhoods within the triple hazard area

	Buckman	Northwest District	St. Johns	Portland
Below Poverty Level Households				
Top Census Tract	18%	20%	16%	58%
Neighborhood Total	21%	17%	15%	12%
Carless Households				
Top Census Tract	19%	46%	25%	90%
Neighborhood Total	26%	30%	14%	14%
Disabled Persons				
Top Census Tract	11%	14%	14%	36%
Neighborhood Total	13%	11%	13%	13%
Persons over age 65				
Top Census Tract	6%	8%	8%	32%
Neighborhood Total	5%	14%	8%	16%

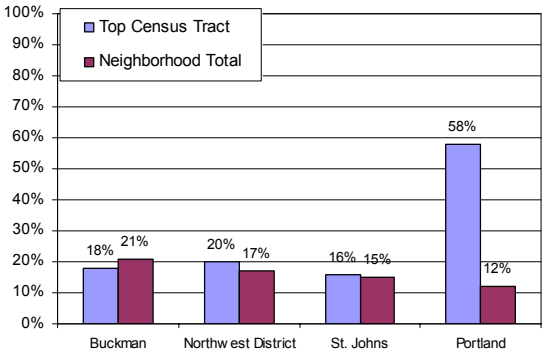

Figure A: Percentage of households below the federal poverty level (based on 1999 income)

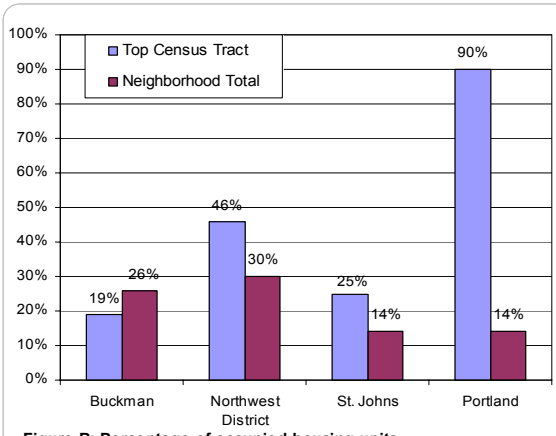

Figure B: Percentage of occupied housing units with no access to vehicles (Carless Households)

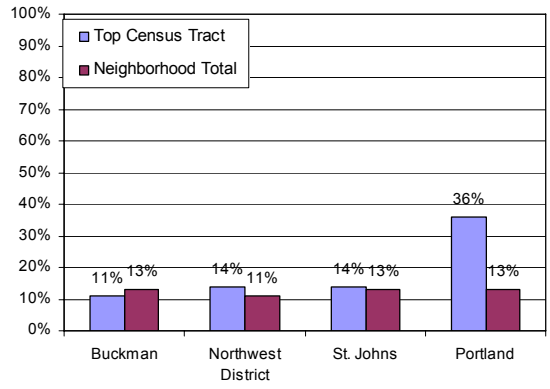

Figure C: Percentage of population with one or more disabilites

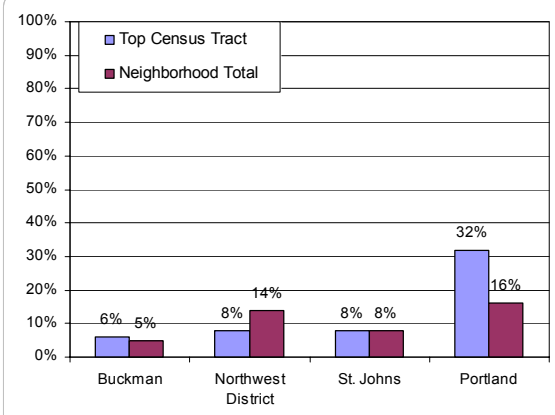

Figure D: Percentage of population over 65

Conclusions

This project intended to advance the development of a methodology for more carefully considering the needs of vulnerable populations in hazard mitigation planning. Only one potential scenario was included in our analysis for clarity.

Specific disaster events can cut off the population from outside resources due to failures of the transportation network. To this end, our objective was to assess the geographic distribution of services across Portland and examine the self-sufficiency of local neighborhoods and populations. The neighborhood maps are a first step in assessing neighborhood capacity and existing resources. By mapping community services and resources at the neighborhood level along with the data related to vulnerable populations, emergency response planners have a better tool for understanding potential scenarios and possible mitigation. The maps created for this project can serve as a template.

Other disasters render the human environment unsafe or uninhabitable and require evacuation of the population. Our goal in this scenario was to identify concentrations of the local population whose ability to self-evacuate may be limited due to a lack of resources or capability. We began this task by mapping the location of vulnerable populations and identifying areas of likely extensive damage that could require evacuation. The scope of this analysis was narrow and to get a more definitive answer additional information regarding potential evacuation routes, transportation route failure and transit access should be analyzed in future projects.

This project provides Portland Office of Emergency Management with both new geocoded data on the location of services for vulnerable populations and a basic neighborhood map template that would be useful to the neighborhood emergency teams being trained by the City as the first-line emergency responders. These maps can be used to further the discussion of hazard mitigation which considers the unique needs of residents on a human scale. Future

conversation may involve targeted emergency preparedness campaigns, the location of social service agencies with disaster response capabilities, and infrastructure evaluation.

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Please see the Appendix in a separate document for additional diagrams and maps.