Rosemount Climate Adaptation

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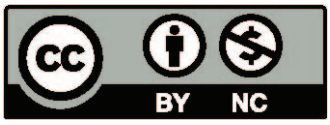

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Introduction

The University of Minnesota – Humphrey School of Public Affairs graduate student research team, through the 2014-2015 Resilient Communities Project and the City of Rosemount, compiled this climate vulnerability assessment report. Using the Minnesota Department of Health's Vulnerability Assessment, and two different regions in the United States as a case study, this report discusses how the City of Rosemount can use a vulnerability assessment in terms of being adaptable in the face of climate change. This report seeks to identify several overall activities that can be implemented in order for the City to be adaptable and able to conduct its own vulnerability assessment. This report will not provide a complete vulnerability assessment. Instead, it will attempt to give an overview of different approaches that the City of Rosemount can use in order to be more resilient.

According to the Inter-Governmental Panel on Climate Change (IPCC) Climate adaptability is defined as

> "an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities[1]."

Vulnerability is defined as the inability to withstand the effects of a hostile environment. There are problems that occur as a City looks to develop. Common problems that will potentially occur with development include, loss of woodlands, loss of remnant ecosystems, erosion, and impairment of surface waters by runoff[2]. Damage to the natural environment could cause decreases in the non-market value residents place on the natural environment, as well as a reduction in individual property values.

This report will be divided into six primary components, followed by appendices. The report initially discusses the problem setting, which will identify the land use type, presence of agricultural land and a basic overview of the demographics for the City of Rosemount. The next component will talk about what a vulnerability assessment is, followed by climate impact descriptions. The climate impact descriptions will be divided into six sections; flood plains, utilities, infrastructure, impervious surfaces, tree canopy, and age distribution.

The next two components discuss the planning process, strategies to reduce susceptibility, and recommendation for next steps. The planning process will identify how the vulnerability assessment will prioritize areas in the City of Rosemount that are particularly vulnerable; particularly areas related to tree canopy, impervious cover, the 100 year flood plain, and the number of elderly residents living alone.

The section for strategies to reduce susceptibility will discuss the strategies for climate resiliency currently in use by other municipalities. These strategies will provide a base for future actions by the City of Rosemount to reduce vulnerability to climate change. In addition, these strategies may assist in conducting a vulnerability assessment in the future.

The City of Rosemount requested that a report be done to find out how a climate vulnerability assessment could be done. Based on this report, the hope is that the City will look to conduct its own climate vulnerability assessment to be more resilient towards climate change.

Problem Setting

The City of Rosemount is located approximately 15 miles south of the Twin Cities Metropolitan Area. Additionally, the City of Rosemount has a surface area of nearly 36 miles with a vibrant community. The City has an industrial park, agricultural land as well as a thriving business sector. As of 2013 Rosemount has a population of 22,666, which consists of majority 87% whites, and with minorities being the remaining 13%. The people of Rosemount are very well educated with approximately 95% holding a high school degree, and 42% holding a bachelor's degree or higher. The percentage of those who hold a bachelor's degree are 10% higher than the state of Minnesota. The City is expanding at a rate of 73 new housing units per year. The City has over 250 commercial ventures providing various services to residents. The Rosemount Business Park has been designated as a "shovel ready site" meaning that Rosemount is welcoming new businesses to invest in the City and develop office spaces. In addition, the City of Rosemount has devoted 467 acres to passive and active recreational uses. The information mentioned above lends itself to the fact that Rosemount is, like many municipalities, trying to develop its economy. However, the City has recognized that in order to develop, they need to address climate change and the potential impacts it may have going forward. This is important because if there are businesses that develop on land that is meant for cover and is supposed to be impervious, then it could harm the environment by preventing soil nourishment, and groundwater recharge. On the other hand if the land is not being developed for environmental reasons, then the City loses a potential tax base. The growth of the City of Rosemount depends on the balance between the environmental and business sectors.

The City has eight main sectors of land use: agricultural, industrial, residential, public and institutional, commercial, waste management, and flood plains. In addition, there is also a large portion of land dedicated for use as an agricultural preserve. The University of Minnesota conducts research on

the preserved agricultural land and has a partnership with the City which does not allow the City to develop on that land. The land dedicated to the business park is located in the South West section of the City. The zoning map for the city can be found in Appendix 4[3]. The North West section of the city is dedicated towards agricultural use (non-agricultural preserve), that is allocated to the City.

In 2005 the City of Rosemount had 9,270 acres dedicated to agriculture. This consisted of 41% of the Cities Land. However, the City has planned to reduce the amount acreage dedicated to agriculture. In 2020 for instance, the acreage for agriculture is projected to drop to 8,540 acres (38% of the Cities land). In 2030 the City plans to decrease the acreage even further to 6,990 acres (31% of the Cities land). This is important because the amount of land dedicated to agriculture shouldn't be ignored when it comes to climate adaptability. For instance, agricultural land impacts the amount of agricultural run-off, the amount of land available for development, and the available tax base for the City.

FIGURE 1: ROSEMOUNT WATER TOWER AS PHOTOGRAPHED BY THE TWIN CITIES DAILY (2008)

SOURCE: HTTP://WWW.TWINCITIESDAILYPHOTO.COM/2008/07/ROSEMOUNT-WATER-TOWER.HTML ACCESSED MAY 4TH, 2015.

In order to write a report on how a vulnerability assessment could be done for the City of Rosemount, six sections need to be considered. As mentioned in the introduction, the six sections that this report considers as impact areas need to be assessed if a vulnerability assessment is conducted. The section on flood plains will discuss the flood plains in and surrounding the City of Rosemount and what needs to be done in order for a vulnerability assessment to be conducted. This is important because with climate change the severity, duration, and impact of the 100 year flood could increase than what has been seen previously. This will have consequences on agriculture, local businesses, and anyone who is looking to invest in the City.

The section on utilities discusses how a vulnerability assessment could assist utilities with preparing for climate adaptation. Utilities are affected because any new development that occurs will be potential revenue for utilities, due to the increase in energy and water usage. Additionally, with the new development comes additional infrastructure expenses that the utilities would need to account for through taxes or some other methods. Climate change could impact utilities by reducing revenue streams if for instance, land that is developed is also on the 100 year flood plain. Therefore, without doing a vulnerability assessment utilities would not know which land is safe for infrastructure expansions, as well as development in general.

The section on infrastructure explains how a vulnerability assessment could assist with infrastructure development. For this report infrastructure is defined as built infrastructure as opposed to social infrastructure. Built infrastructure consists of urban buildings and spaces, energy systems, transportation systems, water systems, wastewater and drainage systems, communication systems, health-care systems, industrial structures, and other products of human design and construction that are intended to deliver services in support of human quality of life[4].

The section on impervious surfaces will discuss how impervious surfaces will impact the development of the City. Impervious cover for this report is defined as any surface on the landscape that cannot effectively absorb or infiltrate rainfall[5]. Lack of impervious cover could harm a city's ability to absorb enough water into the soil to recharge groundwater sources, increase agricultural run-off into rivers that could contaminate water sources, increase the urban heat island effect, and have adverse impacts on ecosystems that rely on groundwater. A vulnerability assessment will inform city planners and developers of where impervious cover could be built, and areas where it shouldn't be developed. This report will provide the city with a method for conducting a vulnerability assessment on impervious surfaces.

Tree Canopy would help with reducing the Urban Heat Island (UHI) effect. The Environmental Protection Agency (EPA) defines the Heat Island Effect as built up areas that are hotter than nearby rural areas due to human activity[6]. Heat islands can affect Cities by increasing peak summer energy demand, air conditioning costs, air pollution, greenhouse gas emissions, heat related illness and mortality, and water quality. If not dealt with appropriately the City of Rosemount might see an increase in the above factors that could prove disadvantageous for a City that is planning to develop further. By increasing the amount of tree canopy it would naturally reduce the amount of heat generated by urban development.

FIGURE 2: TREE CANOPY AND THE MITIGATION OF THE URBAN HEAT ISLAND EFFECT, NEW JERSEY (2014).

SOURCE: HEAT ISLAND MITIGATION IN NEW JERSEY, KELSEY BRIDGES, MAY 2ND, 2014. BYCICLE AND PEDESTRIAN RESOURCE CENTER, NEW JERSEY. HTTP://NJBIKEPED.ORG/HEAT-ISLAND-MITIGATION-IN-NEW-JERSEY/. DATE ACCESSED: MAY 2015.

Finally, age distribution is seen as a factor that needs to be addressed with regard to climate change. Typically the most vulnerable populations to climate change are the elderly (64 years of age and older), and children (under 18 years of age). If these vulnerable populations are not provided with adequate resources to adapt to climate change, then the City could be seeing an increase in heat related diseases as well as mortality with these populations. According to the 2010 census 8% of the population of Rosemount is 64 and older. In addition, 31% of the population is below 18 years of age[7]. In total 39% of the population of Rosemount are potentially vulnerable to the impacts of climate change. Addressing the needs of this sector of the population is an important step for Rosemount to assist in adaptation strategies. The next component of this report will discuss what a vulnerability assessment is and how the assessment has been used in other cities.

Vulnerability Assessment Description

A vulnerability assessment is an attempt to identify and address the potential hazards that a community will face from climate change. This document will outline some key terminology that will be relevant to stakeholders in the future planning process. It provides a framework for policy makers to address climate change concerns that may be affecting their particular community. Therefore, a vulnerability assessment can then be used to implement a more targeted policy response that reduces harm to people and assets. Different federal agencies and local governments have created vulnerability assessments to combat climate change, but in general each assessment follows the same broad methodology; all cities should identify their current priority planning areas that they seek to address, create a planning process to address those areas, and determine the effectiveness of the program, adjusting policies and implementation as needed.

Climate change priority planning areas are the planning areas which a community or government determines to be most important given their estimated vulnerabilities to climate change and the associated risks. The authors of the MDH climate change vulnerability assessment did an exhaustive review of other vulnerability assessments to compile a master list of priority planning areas, so the authors of this assessment will rely on that master list to avoid a duplication of effort. Several of these priority planning areas were deemed particularly relevant to Rosemount, and will be discussed at length later in the document; the area of impervious surface; the area of tree cover; the number of elderly residents living alone; the 100-year floodplain; and the infrastructure dependence, measured as the debt-to-revenue ratio for the county.

Although the layperson may use the term “vulnerability” and “risk” interchangeably, they are two very distinct terms. Vulnerability is the inability to withstand the effects of a hostile environment. Risk is the potential of losing something of value; it differs from vulnerability because risk is the level of

vulnerability times the probability of loss. Because vulnerability is determined irrespective of probability, the vulnerability process is concerned with identifying, quantifying, and prioritizing the vulnerabilities of a system based on the severity of the impacts, not on the likelihood of those impacts happening. Therefore, some communities opt to do a separate analysis of best-case or worst-case scenarios to take into account the likelihood of risk in addition to the vulnerability assessment. In the future, the city of Rosemount could conduct a risk assessment based for the priority planning areas identified in the vulnerability assessment to determine which issues will be of greatest concern in the future.

FIGURE 3: MATRIX SHOWING THE RELATIONSHIP BETWEEN RISK AND VULNARABILITY

PLANNING AREAS WITH SYSTEMS THAT ARE...

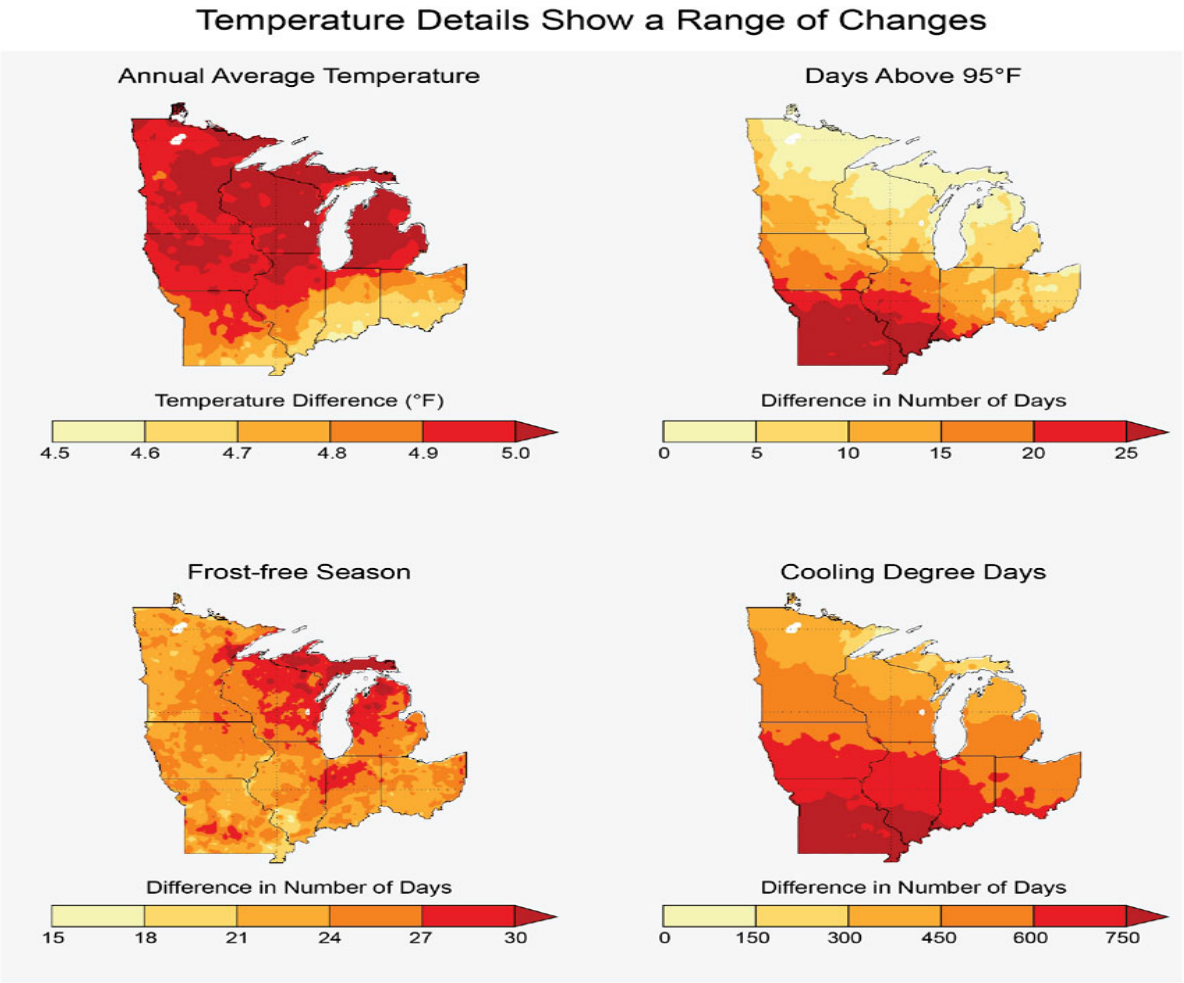
	Low Vulnerability	High Vulnerability
High Risk	*May be priority planning areas*	*Should be priority planning areas*
Low Risk	*Are unlikely to be priority planning areas*	*May be priority planning areas*

Mitigation refers to the human intervention used to reduce the impact on our climate system; for example, it includes strategies to reduce greenhouse gas emissions or to enhance the capacity of greenhouse gas sinks to absorb greenhouse gases. While the current level of greenhouse gases in the atmosphere is doing demonstrable harm, some impacts of climate change will only worsen as the parts per million of carbon dioxide in the atmosphere increases. In order to minimize the future impacts, mitigation efforts aim to reduce carbon dioxide levels in the present to avoid the compounding effects of greenhouse gas emissions in the future. Mitigation measures could also be taken to reduce vulnerability in a number of priority planning areas like the amount of tree canopy area that covers the city; the city of

Rosemount could mitigate that factor by planting more trees in places where the canopy coverage is thin.

Adaptation signifies an adjustment or preparation of natural or human systems to a new or changing environment which minimizes harm or maximizes beneficial outcomes. As opposed to mitigation, adaptation policies are designed to react to the impacts of climate change, but do not work to lessen the impact of greenhouse gases. One analogy would be like paying off credit card debt; mitigation measures are like paying off the principal of the debt, whereas adaptation measures are more like making the interest payments. The adaptation measures that we would need to take in order to address our climate change vulnerability are the "size" of the interest payments that need to be made on our greenhouse gas account to keep the same balance. For the example of infrastructure dependence, if the debt-to-revenue ratio for the county makes it difficult for the city to justify spending money on infrastructure upgrades, the city could adapt by alleviating some of its financial burdens of maintaining sections of the highway through the Adopt-A-Highway program with the Department of transportation.

FIGURE 4: PROJECTED TEMPERATURE CHANGES IN MINNESOTA DUE TO CLIMATE CHANGE



SOURCE: SUSTAINABILITY INSTITUTE. DATE ACCESSED MAY 2015

Resiliency is the capability to anticipate, prepare for, respond to, and recover from significant threats with minimum damage to social well-being, the economy, and the environment. It is a measure of the city's ability to adapt to the changing climate. The city could improve its resilience, for example, by anticipating the likelihood of flooding areas along its eastern edge on the Mississippi River and prepare for such flooding events by educating the public on where to go during extreme weather events. Having an emergency response plan in place would improve the resiliency of Rosemount to climate change-induced weather events.

Climate sensitivity is the temperature change in response to changes of greenhouse gas levels. Areas of the world that are highly sensitive of climate tend to require the greatest adaptation response. Adaptive capacity is the ability of a system to adapt when exposed to a changing environment. For example, some governments are better able to afford the greater maintenance costs of public infrastructure in response to more frequent episodes of inclement weather. Therefore, adaptive capacity is a measure of how resilient a community is against climate change. These terms are by no means an exhaustive list of terms, and for further reference, consult the bibliography to read more information about other vulnerability assessments.

The Minnesota Department of Health's (MDH) climate change vulnerability assessment was the primary document used as a template in the creation of this vulnerability assessment description for the city of Rosemount. The project from the MDH does not address adaptation nor resiliency, nor does it predict future vulnerability; it uses historical data to assess the current areas of vulnerability in the state of the Minnesota. Similarly, this vulnerability assessment will focus on the current areas of vulnerability using the most recent available demographic data available. While data sources like the U.S. Census Bureau may be the most accessible and widely-known place to gather information, some of the information from the site was collected in 2010, and therefore may be out-of-date. However, the authors assumed that the data will suffice for the purpose of identifying trends such as the area of tree cover in Rosemount, since that figure is not likely to change significantly within 5 years.

The scale of a vulnerability assessment can vary based on the needs of the community, but typically, the assessment should be used in conjunction with the city's comprehensive plan. The assessment should identify priority planning areas of local climate change impacts that the city of Rosemount will likely face in the next 20 to 25 years. This assessment should also be capable of identifying the severity or intensity of the impacts and the duration or scope of each impact through the

next 20 to 25 years. The assessment could benefit from a risk assessment that uses a middle-of-the-road model, given that the best case scenario belies the reality of climate change as much as the worst case scenario would. Determining where a middle-of-the-road estimate lies would likely be managed in future risk assessments after priority planning areas have been identified.

The assessment should support the decision-making process on how the city can reduce its susceptibility to climate change. Particularly of interest are the priority planning areas identified in the MDH climate change vulnerability assessment since much of their work at the state level would still apply on a city-level for Rosemount since data on the census tract or census block level is available and this would make it possible to do a vulnerability assessment for neighborhoods within a city just as easily as counties within a state. Based on the analysis done by the MDH, the city of Rosemount will likely face a number of stresses in the coming years such as extreme precipitation events in the fall and spring. Extreme heat events could also be of concern for Rosemount in the summer months as well as extreme freezing events in the winter months. Extreme precipitation events can put strains on local infrastructure such as roads or utilities; higher force winds could do greater damage to trees and power lines, making them more susceptible to damage during storms; intense rain could exacerbate erosion and bring down trees or flood roads, decreasing accessibility.

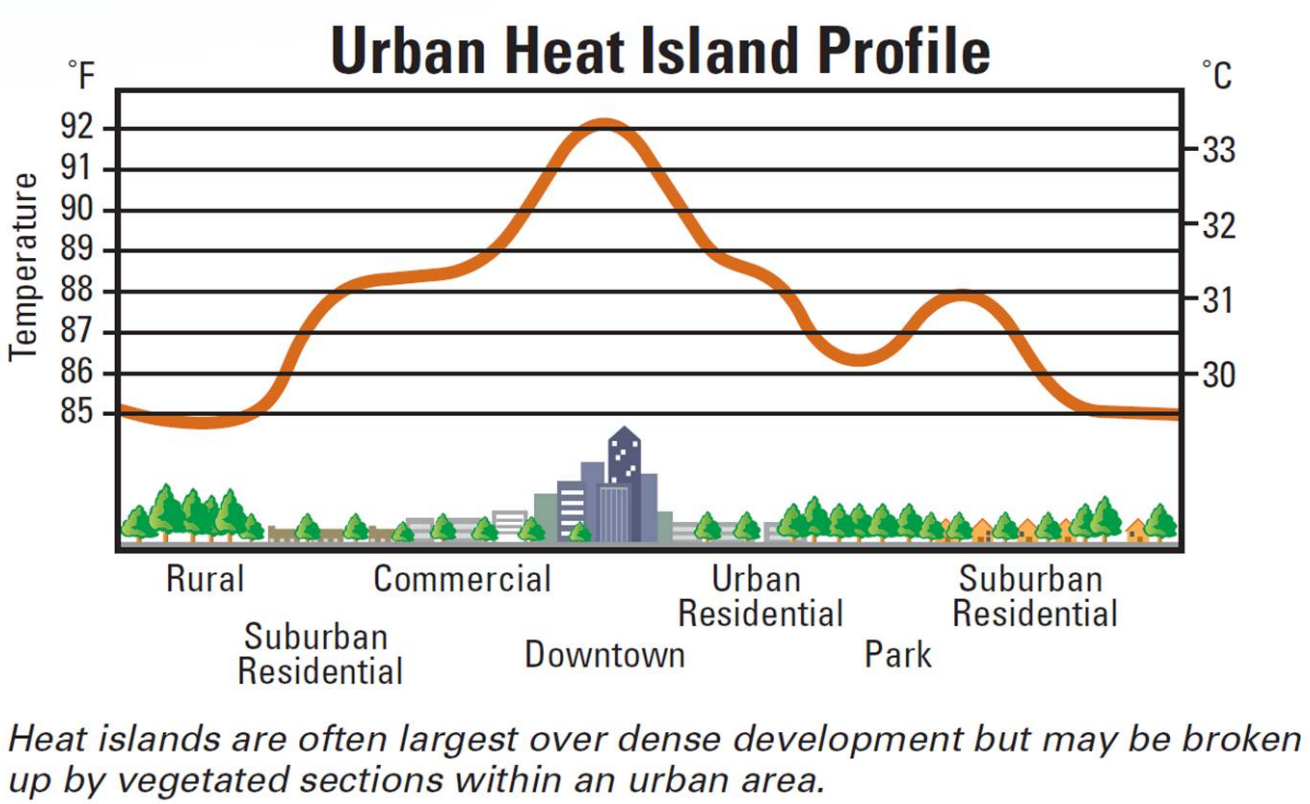
Climate Impact Descriptions

The Environmental Justice Screening method included climate change vulnerability indicators including area of impervious surfaces, area of tree canopy, and percentage of elderly living alone. Our vulnerability assessment will consider these indicators as well as the area likely to be inundated during a 100 year-flood, the number of electric transmission lines between Rosemount and another city, and the percentage roads in Rosemount in need of repair.

Area of impervious surfaces is defined by the National Land Cover Database (NLCD) Percent Developed Imperviousness data, which can be found at the NLCD website for the year 2011. A greater percentage of impervious surface represents a greater vulnerability to local flooding in high-precipitation events. Precipitation runs off of impervious surfaces and contributes to the risk of flooding events during the spring. Areas with lower levels of impervious surface would permit the percolation of groundwater and cut down on the number of flooding events in the city. A map of imperviousness in the city of Rosemount could highlight areas that are in need of more green space, which would help the city adapt to extreme precipitation events.

Area of tree canopy is defined by the NLCD 2011 USFS Tree Canopy cartographic data, which can be found at the National Land Cover Database 2011. A higher percentage of tree canopy represents a lower vulnerability to heat waves and droughts given that trees are able to provide shade for individuals and their property during the summer months. This could cut down on the number of heat-related hospitalizations during the hottest months of the year. Trees would also assist in soil retention during extreme precipitation events, which may minimize the likelihood of flooding in the area. And finally, there is research to suggest a positive relationship between the number of trees within a community and its walkability, which is itself an indicator of positive health outcomes.

FIGURE 5: SKETCH DESCRIBING AN URBAN HEAT ISLAND PROFILE



SOURCE: US-EPA. HTTP://WWW.EPA.GOV/HIRI/RESOURCES/PDF/HIRIBROCHURE.PDF. ACCESSED MAY 2015.

Percentage of elderly living alone is defined by the U.S. Census Bureau from the 2010 U.S. census data on the American FactFinder website. Looking at the 2010 census data from the level of individual block groups within a census tract, the Census Bureau defines households where are people living alone the same as households which do not have any members related to the householder. The Minnesota Climate Change Vulnerability Assessment identified extreme heat events as one of the biggest impacts of climate change to hit Rosemount. The elderly population is especially vulnerable to heat waves and face a greater risk to heat stroke and other related ailments during the hottest months in the summer, if they are not able to contact others for help or seek relief from the heat. The city could

concentrate its adaptation efforts on the elderly population based on neighborhoods on the map where their concentration is greatest.

A 100-year Floodplain map produced using GIS likely already exists for the city of Rosemount, and would be the easiest layer of the thematic map to create. The 100-year floodplain map would indicate to the city which neighborhoods are most susceptible to climate change-related storms and extreme precipitation events. Because greenhouse gases trap heat-energy in the atmosphere and because our greenhouse gas emissions have been rising, severe storms that historically would only hit Rosemount once every 5 years, could become the norm for every year hereafter. And storms that once only hit Rosemount every 50 years could occur nearly once every decade.

Public Utilities like electrical transmission lines and substations will be more susceptible to extreme weather events like storms and flooding in the future. Because Rosemount's energy grid is connected to a larger energy infrastructure in Minnesota and the Upper Midwest, Rosemount can be impacted by events that hit any one of the 11 transmission-owning utilities in Minnesota and the surrounding region. Mapping the nearby electrical transmission lines and substations will give leaders in Rosemount a better understanding of the extent to which Rosemount would be impacted if one or more of these electrical transmission lines and substations went down. This information is available at the Minnesota Geospatial Information Office

The city could also consider a map of wellhead protection areas to determine the quality of drinking water in the city Rosemount. Wellhead protection is a way to prevent drinking water from becoming polluted by managing the number of potential sources of contamination, which will likely increase as the economy of Rosemount takes off with population growth. Information about wellheads in the metropolitan area are available through the Minnesota Department of Health and the United States Geological Survey. A map of municipal water demand and the supply of water to the community could

be of particular concern for Rosemount since it would indicate how much drinkable water is available to the city currently and projected into the future. Both information on the municipal water demand and the supply of water available to the community is available through MetroGIS' DataFinder Catalog.

Infrastructure in Rosemount will likely face increased wear-and-tear due to extreme weather and this could mean that the city of Rosemount will be required to pay increased maintenance costs in the future in order to sustain a the same level of reliable service currently. A map of streets in the city will show how much area needs to be routinely maintained, and the map could be color-coded to show how recently that a stretch of road had been repaved. By estimating the area of road in need of repaving, the city could estimate the amount of money needed to maintain the road infrastructure. the city could also map the This could predict infrastructure dependence, measured as the debt-to-revenue ratio for the city; if the debt-to-revenue ratio for the city is large, then the city should focus on reducing spending on infrastructure or finding ways to increase revenue for the city such as the Adopt-a-Highway program.

FIGURE 6: ROBERT TRAIL LIBRARY, CITY OF ROSEMOUNT, MINNESOTA

SOURCE: HTTP://WIKIMAPIA.ORG/28434388/ROBERT-TRAIL-LIBRARY, DATE ACCESSED: MAY 4TH, 2015.

Using information taken from the U.S. Census Bureau and other sources, the city can map the average scores of each census tract using GIS to determine which sections of the neighborhood are most vulnerable to the effects of climate change. These areas would be featured in an overlay map of sensitive land use area. These are tracts of land that are associated with sensitive populations such as schools, nursing homes, hospitals, parks, daycare centers, and other facilities. Where sensitive areas and vulnerable areas on the map do overlap, the city should focus its planning process on those areas to develop climate adaptation strategies that reduce the community's susceptibility to climate change.

Each indicator would be quantified and then broken up into five quintiles associated to the severity of vulnerability. To create a final composite climate change population vulnerability score for each census tract, the scores of each indicator are averaged for each census tract. The average scores are then divided into quintiles and re-ranked 1 to 5, representing a final composite score for population vulnerability to climate change. In the Association of State and Territorial Health Officials' Climate Change Population Vulnerability Screening Tool, the authors suggest that dividing the values of each indicator into quintiles is best because it's easier to explain that information to the public.

This model does have some limitations, too. Because it relies on published data, the information may not be accurate since the U.S. Census Bureau tends to publish their data two years after it was originally collected. Therefore, in a developing city like Rosemount where the population is changing rapidly, the census bureau statistics may not be applicable since they would be two-years out-of-date the moment they were published. Also, while the Census Bureau does provide information on individual cities and county subdivisions, the most comprehensive information is at the census tract level. The U.S. Census Bureau largely collects data on the census tract level, but further resolution might be necessary to craft effective policy. Since Rosemount is divided into five census tracts, the information may not be precise enough to detect patterns that occur within a census tract. For example, within a census tract,

there could be profound economic inequality in household income, but the census would only report the average household income, which tells us nothing about the minimum or maximum household income or even the standard deviation. Future projects could include a research project on a street or household level.

Community Methodology and Planning Process

In order for the city of Rosemount to effectively implement climate change adaptation plan, it will need the support of the community to ensure that the strategies it pursues will be long-lasting and impactful. According to the International Council for Local Environmental Initiatives (ICLEI),

> The planning process most effective at implementing a climate change adaptation plan begins with the creation of a climate change adaptation team that works to set climate adaptation goals, create and implement a preparedness plan and serve as the agency responsible for continuously monitoring, evaluating and assessing the success of the plan through each step in the process.

The climate change adaptation team should be representative of the community as a whole, with an appropriate mix of legal and technical advisors as well as community leaders and concerned citizens. External scientific advisors can also be a valuable asset to the team, especially if they are trained to communicate scientific knowledge in a way that is easily digestible to the public. The team makeup will be largely determined by the direction the community opts to take in the climate change adaptation plan and which specific strategies the team decides to pursue. The number of members appropriate for the committee can vary based on the scope of the plan and the level of interest for the project.

FIGURE 7: THE CLIMATE ADAPTATION TEAM SHOULD BE A REPRESENTATIVE OF THE COMMUNITY AS A WHOLE

FIGURE 8: WORD COMPILATION SHOWING THE WORDS THAT MOST RESEMBLE WHAT PEOPLE THINK OF CLIMATE CHANGE. THE LARGER THE SIZE OF THE WORD THE MORE PEOPLE THINK OF IT WHEN DISCUSSING CLIMATE CHANGE.

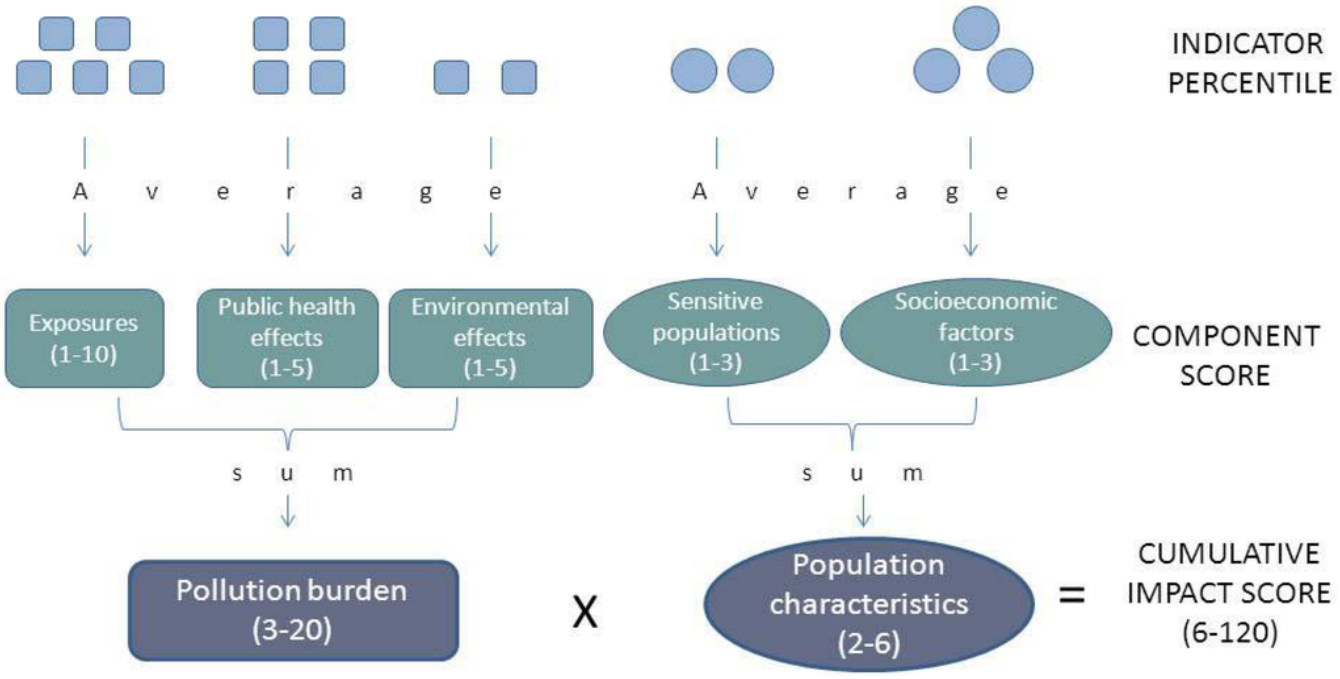
The first goal of the climate change adaptation team would be to research and implement a climate change vulnerability assessment, such as the methodology mentioned above. As part of the research for the vulnerability assessment, members of the team could gather data from the U.S. census

bureau website create a thematic map in GIS. The map would elucidate areas vulnerable to the impacts of climate change, such as areas that lack sufficient shade or green space that could exacerbate the number of heat-related illnesses during extreme summer temperatures. These vulnerable areas on the map could be compared with areas where sensitive populations could be found, such as elderly individuals who live alone. By creating a thematic map that shows layers outlining where vulnerable areas can overlap layers of sensitive populations, the city can begin to direct their climate change adaptation strategies in areas most in need of action. A thematic map is useful because it can be produced cheaply and easily in GIS and it can be modified as necessary to better reflect the needs of the community; for example, additional layers showing socioeconomic background or age could be added to the thematic map to highlight how different demographics can be vulnerable to climate change.

Once the team has identified these areas where climate change adaptation are needed, the team would set out to prioritize which areas are most in need of assistance. This will be based on a calculation of the risks that each area could potentially face from the effects of climate change. Risk is determined by the consequences of a particular climate change impact multiplied by the probability. The consequences of a particular climate change impact could be determined by the size of the geographic area that would be influenced by impacted, the time scale in which the city would be impacted, or the number of people who might be impacted as one possibility. The impact could be determined by the cumulative cost of minor impacts that occur frequently such as heavy rains or extended droughts. Another possibility is that the team could focus solely on the financial costs that the city would incur for each climate change impact and rank the effects based on how costly it would be to address the changes. The team would also need to consider the likelihood of the effect occurring. For example, increasing temperatures are almost virtually certain whereas prolonged droughts may not be as likely. Any or all of these criteria could be considered by the team.

Based on the Minnesota Climate Change Vulnerability Assessment, our group would recommend that the city of Rosemount use the Environmental Justice Screening model outlined by *Saad et al* to develop a future local climate change vulnerability assessment. The model uses key indicators of justice and health to estimate the cumulative impact of climate change on the built environment. The key to this model is to map the vulnerability indicators and show the geographic extent of where the cumulative impacts of climate change lie in the community. By mapping areas within the city of Rosemount that are sensitive to the effects of climate change, meaning areas of the city where sensitive populations are likely to congregate, the city can identify where their attention is needed most. That map can be cross-referenced with the areas most vulnerable to the effects of climate change; areas vulnerable to climate may not necessary overlap with sensitive areas, but the nexus where these two maps do overlap would be of greatest concern. The city of Rosemount could also look at this model through the lens of race, ethnicity, and socioeconomic status as well, since there is evidence communities of color tend to be more vulnerable to the effects of climate change.

FIGURE 9: STRUCTURE OF THE CUMULATIVE IMPACTS SCREENING MODEL (2012)



SOURCE: MEEHAN AUGUST, LAURA, ET AL. 2012, HTTP://WWW.MDPI.COM/1660-4601/9/9/3069/HTM. DATE ACCESSED: MAY 2015.

This model is also more transparent than most other models and robust enough to benefit both policy-makers and communities. If designed properly, the map could be easily understood by the public and easy for a city official to explain at a public meeting. Because this thematic map could be created using ArcGIS software, it could be assembled in a matter of days or weeks without the need to hire an outside consultant to complete the work. These variables were chosen because they were previously identified by the Association of State and Territorial Health Officials in their Climate Change Population Vulnerability Screening Tool. This information also is readily accessible on the internet, which helps to make the process simplified and transparent. Over time, more variables could be added, removed, or amended from the original map to better fit the scope of the community.

Once these impacts have been quantified and ranked, the team should implement the climate change adaptation plan, preferably with support from the community. Public outreach is essential at this stage in the planning process because broad support for the plan will give it further legitimacy and can

be used to entice change at the government level for changes in policy and procedures that can reduce institutional vulnerability to climate change. Also, educating the public on the importance of having a climate change adaptation plan can also inspire collective action against climate change in the form of mitigation or adaptation, once the community understands the potential risks of climate change. By implementing climate change education directed within the offices of the city of Rosemount, the team can highlight the need to increase technical capacity for climate change on a local government scale. Education can also motivate new partnerships within the community of organizations can identify a common concern or realize the benefits that could come by cooperating or pooling resources.

The team should next identify potential goals that they would want to meet when addressing the impacts identified previously. Goals should be specific, meaning the goal is framed in a way that people can identify what needs to be accomplished; it should measurable meaning that the team should be able to identify whether the goal has been met; it should be attainable meaning that the goal should be within the resources of the team to accomplish given a modest investment of time or money; it should be relevant meaning sensitive to the context of the community concern; and time-sensitive meaning that the action can be carried out in a reasonable amount of time. It can be helpful to reach out to help outside of the team since public input can be invaluable in providing feedback on whether goals are relevant or attainable to the community. Identifying potential goals is an iterative process since the risks and probabilities identified earlier may change over time and goals should be adjusted to react to those changes.

After goals have been identified, the team should develop a candidate list of actions that can address the impacts and satisfy the goals. Actions may include modifying existing practices, policies, or procedures to incorporate climate adaptation, such as updating zoning codes to restrict development along flood plains. Or the team could pursue actions that increase adaptation capacity such as moving

the community tax base away from economic sectors like tourism that could be more vulnerable to climate change than other revenue sources. The city could look into upgrading the physical infrastructure of the city since these may not currently be able to accommodate the anticipated needs of future generations given the predicted impacts of climate change.

Given resource constraints of time and money, each action should further be separated into low, middle, and high tiers based on a cost-benefit analysis of which actions present the most efficient use of the city's resources. Oftentimes, high-tier actions that can address multiple goals or impacts tend to be the most cost-effective measures such as planting urban trees to retain soil during the rainy spring and fall months while providing shade during the hot summer months. The city could also focus on actions with the fewest drawbacks or actions with the greatest certainty of benefits such as reducing leakage from water utility infrastructure which can improve water efficiency. The team should also rank actions based on the time frame that it would take to implement the action and the extent to which an action could be adjusted as conditions change. Also, the team may want to consider whether the action will result in a socially or economically equitable outcome.

The climate change adaptation team must periodically re-assess their climate change vulnerability plan as well as the analysis of their impacts, goals, and actions identified in the planning process to assure that their assumptions within the planning process still hold true. Given climate change is inherently a dynamic and on-going process, the adaptation team should revise their plans as necessary when more accurate climate change data is published. The team should devise quantitative measures of how successful their actions have been at addressing their identified goals such as the number of plans or other governing documents that address climate change on a local level or the amount of money saved by implementing a new policy or upgrading the infrastructure of a building. Throughout the planning process, the team should document their progress wherever possible to ensure transparency and

accountability as well as replicability. Successful actions should analyzed to better understand what aspects of their planning or implementation made them especially fruitful and these insights should be shared both within the community to celebrate innovation and outside of the community as a tool for other communities to use.

The city of Rosemount should consider the use of publicly available data such as the U.S. Census Bureau's American Factfinder site, and a transparent method to increase the accessibility and adaptability by outside stakeholders. Developing a simplified transparent tool with no weighted averages allows future stakeholders to use the screening tool as is, or to adjust it to best fit their needs. Building upon existing emergency plans limits the data workload necessary to complete a screening tool, while avoiding duplicative efforts. Ideally, processed data layers could be held and maintained by a central source, such as the city website, making the content easy for users to find. For example, the Metropolitan Council has an application called "Make-a-Map" available on its website that allows users to create their own thematic map of Minnesota with layers that highlight demographics and zoning maps at a census tract level.

Reviewing and revising the screening tool with input from other departments within the city, community groups, planning agencies, and other relevant stakeholders will produce a more robust model. This will also help the city to tailor the model to best meet the needs of the community. Ideally, the data could be accessed online at the city website and be readily available for download. Future efforts could be made to include the data in a dynamic online mapping tool, such as Google Fusion, and allow stakeholders to easily change weights and/or turn data layers off and on, and zoom in and out of specific areas. This would greatly increase accessibility, and the data management could be done by an outside contractor or possibly by someone within the city.

The importance of creating a climate change adaptation team first in the planning process cannot be overstated because the team serves as the driving force responsible research, outreach and implementation of a climate change adaptation plan. A climate change vulnerability assessment allows the city of Rosemount to target their response to those areas and populations that are in most need of climate change adaptation policy. Once the team has created a vulnerability assessment, it should identify the goals that the city should aim for and develop the actions necessary to meet those goals. Actions should be based on criteria established by the team into tiers which are used to determine which actions the city should consider their highest priority. Throughout the planning process, the team should re-assess their actions and goals to ensure they are still relevant to the context of their community. The team should document their progress as they go and develop metrics for determining how successful they have been throughout the process.

Strategies to Reduce Susceptibility

Low Impact Development (LID) methods are a climate adaptation tool that can be used to redistribute increases of stormwater runoff resulting from changing weather patterns. Examples of this practice would include retaining native vegetation, minimizing impervious surfaces, pervious pavement, vegetated (green) roofs, rain gardens and bioretention.[8] Currently, the city of Tacoma, Washington is promoting the use of low impact stormwater construction projects as a way to add storage to the infrastructure landscape and maintain the balance of natural systems while contributing to the sustainability of the city.

FIGURE 10: LOW IMPACT DEVELOPMENT, PHILADELPHIA, PENNSYLVANIA (2011)

SOURCE: PHILADELPHIA LOW IMPACT DEVELOPMENT SYMPOSIUM. HTTP://WWW.BAE.NCSU.EDU/STORMWATER/2011LID/. DATE ACCESSED: MAY 2015.

The State of Washington Department of Ecology defines low impact development as a stormwater and land use management strategy that strives to mimic natural hydrologic processes of infiltration, filtration, storage, evaporation and transpiration by emphasizing conservation, use of on-site natural features, site planning, and distributed stormwater management practices that are integrated into a project design.[9] With the ambition to improve stormwater management in a natural and green manner, the city is bolstering incentives with hopes of encouraging LID in current and upcoming construction plans.

In November 2014 The City of Tacoma, Metro Parks Tacoma, and the Port of Tacoma began holding a design contest under the name of the "Tacoma Green Infrastructure Challenge". The contest invited teams to compete for a $5,000 cash prize by presenting real-world site designs with the goals of conserving natural resources, enhancing the quality of life and reducing maintenance costs, providing a traditional and green infrastructure, and promoting creativity in design and green infrastructure strategies.[10] Design challenge categories included industrial and urban redevelopments as well as a

green roadway sites, all encompassed under requirements such as a diverse interdisciplinary team, in-depth cost and benefit presentations, and aesthetic creativity.[11] The finalists were selected and presented in the beginning of March 2015, and the city is currently considering such designs for implementation into their port, parks, and within the city itself.

FIGURE 11: CITY OF TACOMA. WASHINGTON. GREEN INFRASTRUCTURE CHALLENGE

SOURCE: CITY OF TACOMA, WASHINGTON. HTTP://WWW.CITYOFTACOMA.ORG/CMS/ONE.ASPX?OBJECTID=68259. DATE ACCESSED: MAY 2015.

To prepare for implementation of the winning green stormwater infrastructure, in May 2014, Tacoma updated their Stormwater Management Program (SWMP) plan to meet 2013-2018 National Pollutant Discharge Eliminations System (NPDES) Permit requirements. This process included steps such as reviewing all development codes and guidance documents, partnering with the planning department to use the existing process for code adoption, using their Standards Committee existing process to update a Public Works Design Manual, creating internal work groups, and public outreach.[12]

In addition, during a code update meeting held in April of 2014, it was announced that in order to continue the implementation of low impact development designs, the city would need additional training and technical support, additional details and pre-engineered site assessment and design guidance,

guidance for minimizing impervious surfaces, tree retention and protection specifications, methods for retaining native vegetation, soil testing assistance, training workshops, and online information.[13]

Climate change effects around the globe are an issue of constantly changing debate. Projected changes in climate through this century and their impacts should be considered when planning for development. Not only does the size and cost of projects create major decision points for municipalities considering LID, but also the scope of construction designs and their relative risks or impacts on future developments.[14] In the case of Tacoma, Washington, local environment and development characteristics are the main cause for urgency in climate adaptation developments. As a coastal state, Washington already has a high need for water circulation assistance. Tacoma, a lowland of Puget Sound, has an especially slow process of interception, storage, and conveyance of stormwater throughout the vegetation and bodies of water within their ecosystem. As much as 50 percent of the stormwater entering these forests is stopped and evaporated through vegetation alone.[15]

According to the Earth Economics board of Seattle, Washington, the Puget Sound Basin is, and will continue to be, seeing higher costs due to a loss of "natural capital". These losses encompass damage to human health from pollution, rising costs for more effective stormwater systems, climate change impacts, and the loss of beauty in aesthetic and recreational value. This, in turn, is degrading citizens' quality of life. "Rainwater once flowed into Puget Sound through natural systems recharging [the] groundwater. Impermeable surfaces and other structures now prevent water from recharging the aquifer".[16]

Keeping this in mind within the context of Rosemount, as new development within city limits occurs, the quantity of impervious surfaces, such as those present in roadways, will increase in the watershed. The increased runoff from rainfall events into the stormwater systems may exceed the designed capacity, which often leads to flooding of streets and low, basin-like areas. Additionally,

pollution in the watershed may result after chemicals present on the impervious surface are washed into the stormwater system.

In addition, it is challenging to develop consistent and integrated climate adaptation approaches for large geographic regions due to complexities in modeling climate impacts and anticipating vulnerabilities at regional, state, county, city, and neighborhood scales, and the difficulty in developing appropriate adaptation approaches that can be used at each of those scales. In this sense, the fact that both the Tacoma project and the Rosemount project are at the city level would make Tacoma a good model for Rosemount to follow. On the other hand, projects may need to be scaled down in consideration of the population differences between the two cities. Lastly, since there is a difference in ecosystems and water circulation loads, it may be wise to simply start with an incentive program to persuade Rosemount developers towards the use of LID instead of strictly following the actual projects being implemented within Tacoma.

Area vulnerability is also an important aspect of climate adaptation. Many cities deliberating the use of such projects will need to undergo a vulnerability assessment in order to build maps and data which will point out the more vulnerable areas of land to be focused on. In 2006, the Northern Virginia Regional Hazard Mitigation Plan was developed. One of the mitigation strategies put into motion was the creation of improvements and continued enforcement of zoning ordinances so that damage from environmental hazards would be minimized. Examples of how this was done include keeping development away from flood hazard areas, encouraging cluster development, and protecting underground utilities[17].

FIGURE 12: CITY OF ROSEMOUNT FARMER'S MARKET. PHOTO CREDIT: CITY OF ROSEMOUNT

Using various grants from the U.S. Small Business Administration, U.S. Department of Agriculture, U.S. Department of Homeland Security, U.S. Environmental Protection Agency, U.S. Department of Defense, and other various flood and fire emergency act funding sources[18], the Northern Virginia region was able to administer a vulnerability assessment using HAZUS methodology from the Federal Emergency Management Agency (see Figure 1), and subsequently take action on a plan to protect their cities from environmental emergencies. This plan was modified at the local level in each city where areas of vulnerability varied; from fires to wind or flood damage.

In 2000, a Federal Disaster Mitigation policy was enacted which required all localities to develop a hazard mitigation plan in order to be eligible for grants and funding under the Federal Emergency Management Agency's Hazard Mitigation Grant Program and Pre-Disaster Mitigation Grant Program[19], such as those mentioned in the previous section. Even though this plan has a regional foundation, it relies on the individual communities and their members to act as collaborators and resource managers.

Ensuring education and observance of the plan's goals is of the utmost importance in such a situation. Such disaster mitigation is important for all areas of the United States, but this importance can be seen especially in ecological economics within Virginia. Northern Virginia boasts many tourist destinations, but rising sea levels and an increase in runoff in the Chesapeake Bay area threaten this and many other economic foundations.

As noted in the Tacoma practice, it is important to consider the difference in scale between the Northern Virginia region involved in this climate adaptation practice, and the scale which would be present in any Rosemount projects. Since a regional plan has the benefit of including funding from several local government areas, while Rosemount may be depending on their own budget and resources; hence the plan will need to be appropriately proportioned.

According to the United States Environmental Protection Agency, "throughout the year, precipitation in the Midwest is likely to become more intense, leading to increased flood damage, strained drainage systems, and reduced summer water availability"[20]. This means that variances from the Northern Virginia would also have to include areas of focus. While Northern Virginia had a heavy focus on keeping new developments away from sea surge prone areas, cities located in the Midwest would more likely need to place emphasis on denying proposed developments in flood prone regions.

Even with the contextual and vulnerability differences between the city of Rosemount and those existing in the best practices presented above, both would be practical options for Rosemount to consider. If the practice itself is not deemed useful, many of the steps taken precluding the practice would be beneficial for any region or city considering climate adaptation projects.

Recommendation for Next Steps

By relying on their own assets, municipalities are able to pursue a goal of supporting city climate resilience. The City of Rosemount can use its available resources to promote efforts of increased resiliency within their buildings, infrastructure, energy use, and citizens. This could occur through the implementation of a vulnerability assessment and the pursuance of best practices. The scope of success will be limited, however, because without requirements for buildings to implement resilience measures, Rosemount must rely upon community support and attractive adaptation methods. Without a legal requirement, only those with a strong interest in increasing local resiliency would participate. This group would likely include new builders that are already trying to increase resiliency, and community members with a personal interest in the issue. Still, by providing resources and incentives, the city could encourage its residents to take part.

The effectiveness of any of the aforementioned approaches will vary depending on the incentives and the accuracy of the resources provided. Yet, by determining the level of need and availability of finances, the City of Rosemount will be able to decide which specific standards or areas of vulnerability portrayed in a vulnerability assessment best suit the needs and goals of their municipality.

Appendix 1: Glossary of Terms

- **Mitigation** refers to a human intervention to reduce the human impact on the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.
- **Adaptation** signifies an adjustment of natural or human systems to a new or changing environment which moderates harm or exploits beneficial opportunities.
- **Resiliency** is a capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.
- **Vulnerability** is the inability to withstand the effects of a hostile environment.
- **Risk** is the potential of losing something of value; vulnerability times probability.
- **Ecosystem** signifies any natural unit or entity including living and nonliving parts that interact to produce a stable system through cyclic exchange of materials.
- **Climate** in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands of years. Climate in a wider sense is the state, including a statistical description, of the climate system.
- **Climate System** represents the five physical components (atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere) that are responsible for the climate and its variations.
- **Climate change** refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer.
- **Climate sensitivity** is the temperature change in response to changes of greenhouse gas levels.

- **Adaptive capacity** is the ability of a system to adapt when the environment where the system exists is changing, for example the maintenance of social capital and economic prosperity.
- **Climate change priority planning areas** are the planning areas which your community or government determine to be most important given your community's vulnerabilities to climate change and the associated risks.
- **Climate change vulnerability assessment** is the identification of existing stressors facing built and natural systems and how climate change will impact and/or introduce new stressors in the future.

Appendix 2: Additional Best Practices

A report to advise the City of Minneapolis on climate change impacts and adaptive strategies was created by Andrew Emanuele, Andrew Rockway, Georgia Rubenstein, and Kelly Schmitt as part of a capstone project in Sustainability Planning (coordinated by the Humphrey School of Public Affairs at the University of Minnesota and the Minneapolis Sustainability Office). The group compiled climate adaptation best practice strategies into a table format, "marked by both its primary benefit – or which type of climate adaptation it contributes to the most – as well as any co-benefits"[21].

	Manage Heat	*Natural*	*Stormwater*	*Energy/Water*
1.1 Improve methods of tracking heat-related illness and death to ensure ability to accommodate more patients and appropriately target extreme heat responses	✔			
1.2 Expand access to pools, misting stations, and other cooling opportunities for those particularly at risk of suffering from heat-related illness	✔			
1.3 Implement cool pavements to reduce urban heat island effect	✔			✔
1.4 Increase green roofs to reduce urban heat island effect	✔	✔	✔	✔
2.1 Adapt recreation opportunities to the changing climate		✔		
2.2 Increase urban tree canopy	✔	✔	✔	✔
2.3 Conduct vulnerability study of natural ecosystems		✔		
2.4 Conserve urban plant and animal habitat		✔		
2.5 Manage invasive and native species		✔		
2.6 Initiate Programs to Engage the Private Sector				
3.1 Control runoff with rain gardens and bioretention		✔	✔	
3.2 Harvest rainwater to control runoff and decrease water		✔	✔	✔
3.3 Expand surface detention capacity to reduce runoff volumes			✔	
3.4 Reduce impervious surface coverage with permeable	✔	✔	✔	
3.5 Maintain and expand traditional infrastructure to control			✔	
4.1 Understand the energy use patterns and needs of homeowners in order to implement comprehensive smart grid technology on a localized scale				✔
4.2 Incentivize microgrid projects				✔
4.3 Incentivize cool roofs on new/existing buildings	✔			✔
4.4 Pursue an "urban cap-and-trade" policy to encourage energy	✔			✔
4.5 Encourage energy efficiency and conservation in both new and existing buildings through the identification of a geographic district	✔			✔
4.6 Mandate 100% renewable energy use	✔			✔
4.7 Encourage residential water conservation			✔	✔
4.8 Diversify water supply and plan for potential supply				✔

Appendix 3: Notes

[1] http://www.vcccar.org.au/climate-change-adaptation-definitions
[2] Minnesota Environmental Quality Board, 2012
[3] http://ci.rosemount.mn.us/DocumentCenter/View/128
[4] http://www.esd.ornl.gov/eess/Infrastructure.pdf
[5] http://nemo.udel.edu/manual/chap2web.pdf
[6] http://www.epa.gov/heatisland/
[7] http://www.ci.rosemount.mn.us/index.aspx?nid=153
[8] http://www.cityoftacoma.org/cms/One.aspx?portalId=169&pageId=68271
[9] http://www.ecy.wa.gov/programs/wq/stormwater/municipal/LID/Resources.html
[10] http://www.cityoftacoma.org/cms/One.aspx?portalId=169&pageId=68271
[11] http://stormwater.wef.org/2014/11/tacoma-green-infrastructure-challenge-now-accepting-entries/
[12] http://cms.cityoftacoma.org/surfacewater/SWMP.pdf
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[14] http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/docs/FTL_Chapter5%20LR.pdf
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[17] http://www.novaregion.org/DocumentCenter/Home/View/1741
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[19] https://www.fema.gov/policies
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