UNIVERSITY of WASHINGTON

Livable City Year 2018–2019
in partnership with
City of Bellevue

CITY OF BELLEVUE

In Partnership with the
University of Washington

CLIMATE CHANGE VULNERABILITY ASSESSMENT FOR BELLEVUE

City of Bellevue Project Leads
Jennifer Ewing
Brian Landau

University Instructor: Bob Freitag

Student Authors
Kevin Lowe Pelstring
Helen Stanton

Winter–Spring 2019

LIVABLE
CITY YEAR

Livable City Year 2018–2019
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City of Bellevue
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Students in Bob Freitag's Hazard Mitigation class joined City staff in a field trip to Weowna Park on February 1, 2019. TERI THOMSON RANDALL

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Kids plant a tree at Bellevue's annual Arbor Day-Earth Day celebration. CITY OF BELLEVUE

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ABOUT LIVABLE CITY YEAR

The University of Washington's Livable City Year (LCY) initiative is a partnership between the university and one local government for one academic year. The program engages UW faculty and students across a broad range of disciplines to work on city-defined projects that promote local sustainability and livability goals. Each year hundreds of students work on high-priority projects, creating momentum on real-world challenges while serving and learning from communities. Partner cities benefit directly from bold and applied ideas that propel fresh thinking, improve livability for residents, and invigorate city staff. Focus areas include environmental sustainability; economic viability; population health; and social equity, inclusion and access. The program's 2018–2019 partner is the City of Bellevue; this follows partnerships with the City of Tacoma (2017–2018) and the City of Auburn (2016–2017).

LCY is modeled after the University of Oregon's Sustainable City Year Program, and is a member of the Educational Partnerships for Innovation in Communities Network (EPIC-N), an international network of institutions that have successfully adopted this new model for community innovation and change. For more information, contact the program at uwlcy@uw.edu.

LIVABLE CITY YEAR

ABOUT CITY OF BELLEVUE

Bellevue is the fifth largest city in Washington, with a population of more than 140,000. It's the high-tech and retail center of King County's Eastside, with more than 150,000 jobs and a skyline of gleaming high-rises. While business booms downtown, much of Bellevue retains a small-town feel, with thriving, woodsy neighborhoods and a vast network of green spaces, miles and miles of nature trails, public parks, and swim beaches. The community is known for its beautiful parks, top schools, and a vibrant economy. Bellevue is routinely ranked among the best mid-sized cities in the country.

The city spans more than 33 square miles between Lake Washington and Lake Sammamish and is a short drive from the Cascade Mountains. Bellevue prides itself on its diversity. Thirty-seven percent of its residents were born outside of the US and more than 50 percent of residents are people of color, making the city one of the most diverse in Washington state.

Bellevue is an emerging global city, home to some of the world's most innovative technology companies. It attracts top talent makers such as the University of Washington-Tsinghua University Global Innovation Exchange. Retail options abound in Bellevue and artists from around the country enter striking new works in the Bellwether arts festival. Bellevue's agrarian traditions are celebrated at popular seasonal fairs at the Kelsey Creek Farm Park.

Bellevue 2035, the City Council's 20-year vision for the city, outlines the city's commitment to its vision: "Bellevue welcomes the world. Our diversity is our strength. We embrace the future while respecting our past." Each project completed under the Livable City Year partnership ties to one of the plan's strategic areas and many directly support the three-year priorities identified by the council in 2018.

CITY OF BELLEVUE WASHINGTON

BELLEVUE 2035:
THE CITY WHERE YOU WANT TO BE

Climate Change Vulnerability Assessment for Bellevue supports the High Quality Built and Natural Environment target area of the Bellevue City Council Vision Priorities and was sponsored by the Community Development and Utilities departments.

HIGH QUALITY BUILT AND NATURAL ENVIRONMENT

Bellevue has it all. From a livable high-rise urban environment to large wooded lots in an equestrian setting, people can find exactly where they want to live and work in Bellevue. The diverse and well-balanced mix of business and commercial properties and wide variety of housing types attract workers and families who desire a safe, sustainable, and accessible community.

Bellevue has an abundance of parks and natural open space. Known as a "city in a park," our park system is one of the best in the nation due to its high park acreage-to-population ratio. From neighborhood walking paths and forested trails to a regional waterfront park, we enjoy a variety of recreational opportunities within walking distance of our homes and businesses. Bellevue is a "Smart City" with a clean, high-quality environment and excellent, reliable infrastructure that supports our vibrant and growing city, including high-tech connectivity. The city has a connected multi-modal transportation system that blends seamlessly with its buildings, plazas, and parks.

Whether it's an urban high rise, a classic Bellevue rambler, or a historic resource, the constant is our people. Our neighborhoods and businesses transcend age, ethnicity, and culture to create safe, welcoming places to live and work.

BELLEVUE 2035:
THE CITY WHERE YOU WANT TO BE

Bellevue welcomes the world. Our diversity is our strength.
We embrace the future while respecting our past.

The seven strategic target areas identified in the Bellevue City Council Vision Priorities are:

ECONOMIC DEVELOPMENT
Bellevue business is global and local.

TRANSPORTATION AND MOBILITY
Transportation is both reliable and predictable. Mode choices are abundant and safe.

HIGH QUALITY BUILT AND NATURAL ENVIRONMENT
From a livable high-rise urban environment to large wooded lots in an equestrian setting, people can find exactly where they want to live and work.

BELLEVUE: GREAT PLACES WHERE YOU WANT TO BE
Bellevue is a place to be inspired by cuilture, entertainment, and nature.

REGIONAL LEADERSHIP AND INFLUENCE
Bellevue will lead, catalyze, and partner with our neighbors throughout the region.

ACHIEVING HUMAN POTENTIAL
Bellevue is caring community where all residents enjoy a high quality life.

HIGH PERFORMANCE GOVERNMENT
People are attracted to live here because they see that city government is well managed.

For more information please visit: https://bellevuewa.gov/city-government/city-council/council-vision

FOREWORD

We are pleased to have had the opportunity to formulate the suggestions presented in this document and to demonstrate the value of applying a scenario planning process. This process, and the ideas included within this report, are written to help guide a future rigorous public planning effort.

Please realize that the ideas offered within this report represent the efforts of student teams, as well as the research of two students who expanded each team's initial findings. This project stands as one of several assignments students completed over a ten-week period.

The suggestions of this report are not the result of a public planning process. Therefore, this report cannot be considered a plan. Students did not hold public meetings, nor did they rigorously analyze the consequences of their suggestions. However, the ideas contained within this report can be thought of as a starting point for such a plan to be carried out by the City of Bellevue.

We would be pleased to discuss any aspect of this report in order to further support the City as it explores strategies to adapt to a changing climate within the context of a changing Bellevue.

Hazard Mitigation Planning students present their project findings to City of Bellevue staff. TERI THOMSON RANDALL

Jennifer Ewing, Community Development, and Jerry Shuster, Utilities Department, offer feedback to students during their final presentation.
TERI THOMSON RANDALL

EXECUTIVE SUMMARY

Scenario planning is a systematic method for envisioning potential outcomes produced by complex and uncertain factors set in the future.

Bellevue anticipates great change in coming years and decades as a result of climate change and population growth. Uncertainty and potentially catastrophic consequences related to the compounding effects of climate change and increased urbanization are important for the City of Bellevue to evaluate and incorporate into its long-term planning now. University of Washington (UW) graduate students taking a Hazard Mitigation Planning course considered three topics of particular concern to the City of Bellevue:

1. The tangible effects of climate change on the well-being of current and future residents of Bellevue
2. The vulnerability induced by rapid urban development and more frequent and intense storms
3. The role of urban tree canopy culturally and aesthetically, as well as for developing resilience to climate change

We applied scenario planning to each of these three topics to see how changes in precipitation and heat interact with urban systems. Scenario planning is a systematic method for envisioning potential outcomes produced by complex and uncertain factors set in the future (Peterson, et al. 2003). Each scenario is the result of plausible events and environmental drivers, and would require different courses of action and strategic decision making to occur (Wilburn 2011). Thus, scenario planning serves as a lens for planners to envision possible, probable, or plausible future outcomes of climate change and urbanization. Equipped with such information, planners can attend to possible future events and conceptualize plans and course of action accordingly.

Bellevue's parks promote public health and livability. CITY OF BELLEVUE

Students visited Weowna Park to consider how through strategic maintenance and redesign of parks the City may mitigate effects of climate change. CITY OF BELLEVUE

While attending to urban growth projections, resilience to climate change should be considered a primary goal for Bellevue over the next few decades. This is because resilience to climate change is essential for maintaining the city's livability. To prepare for climate change, the City of Bellevue may need to modify or replace infrastructure, protect or reinforce features of the natural environment, and accommodate new needs and vulnerabilities of residents. Starting points for the City to become resilient to climate change include:

- Providing access to shelters for people in need of refuge
- Increasing access to medical care
- Incentivizing renewable energy opportunities
- Promoting and dispersing mixed-use social infrastructures
- Retrofitting aging development
- Expanding the use of low impact development
- Redesigning parks
- Installing onsite water detention features in up-zoned areas
- Creating a comprehensive tree inventory
- Establishing a regional urban tree canopy climate stressors research organization
- Facilitating assisted species migration
- Improving wildland fire mitigation and adaptation

This document has been produced to encourage rigorous public planning efforts. The suggestions offered represent the efforts of student teams, as well as the work of two individual students who further expanded the scope of research. The suggestions are not the result of a public planning process, and, therefore, this document cannot be considered a plan. Rather, this document may be considered as a starting point for subsequent planning efforts.

INTRODUCTION

As a result of climate change and increased urbanization, the City of Bellevue and surrounding Puget Sound region are likely to encounter sweeping change in coming years and decades. Bellevue, like countless other cities and towns throughout the region, is presented with challenges and opportunities which require comprehensive, long-range planning. Rather than considering itself powerless to the potential effects of climate change, the City of Bellevue can assume itself capable of taking direct action to plan and prepare for a range of potential scenarios.

This Livable City Year project (LCY) explores three topics related to climate change and urbanization, all of which are critical to the future livability of the City of Bellevue:

1. Human well-being
2. Urban flooding
3. Urban tree canopy (UTC)

These topics were captured originally within three distinct reports generated by graduate students enrolled in a Hazard Mitigation Planning course at the UW during Winter Quarter of 2019. Student teams received support and guidance from City of Bellevue staff. The original reports generated by each student team are presented as three main sections within this document.

Rather than considering itself powerless to the potential effects of climate change, the City of Bellevue can assume itself capable of taking direct action to plan and prepare for a range of potential scenarios.

IDENTIFYING THE CITY'S CHALLENGE

Bellevue, like cities everywhere, experiences change over time. There are two primary modes of change cities encounter: intrinsic (changes influenced to large degree by decisions made by the City) and extrinsic (changes which occur regardless of City decision making). Intrinsic changes in population, urban density, and economy are somewhat within the City's control; extrinsic change, like climate change, is not. Accounting for these two sets of changes (intrinsic change as a result of urban growth, and extrinsic change related to global climate change), students involved in this LCY project evaluated several potential future scenarios within their reports related to human well-being, urban flooding, and urban tree canopy.

This view from Bellevue City Center toward Lake Washington and Seattle captures Bellevue's "city in a park" motto. CURT SMITH

VALUES OF BELLEVUE

RECREATE WHERE YOU LIVE

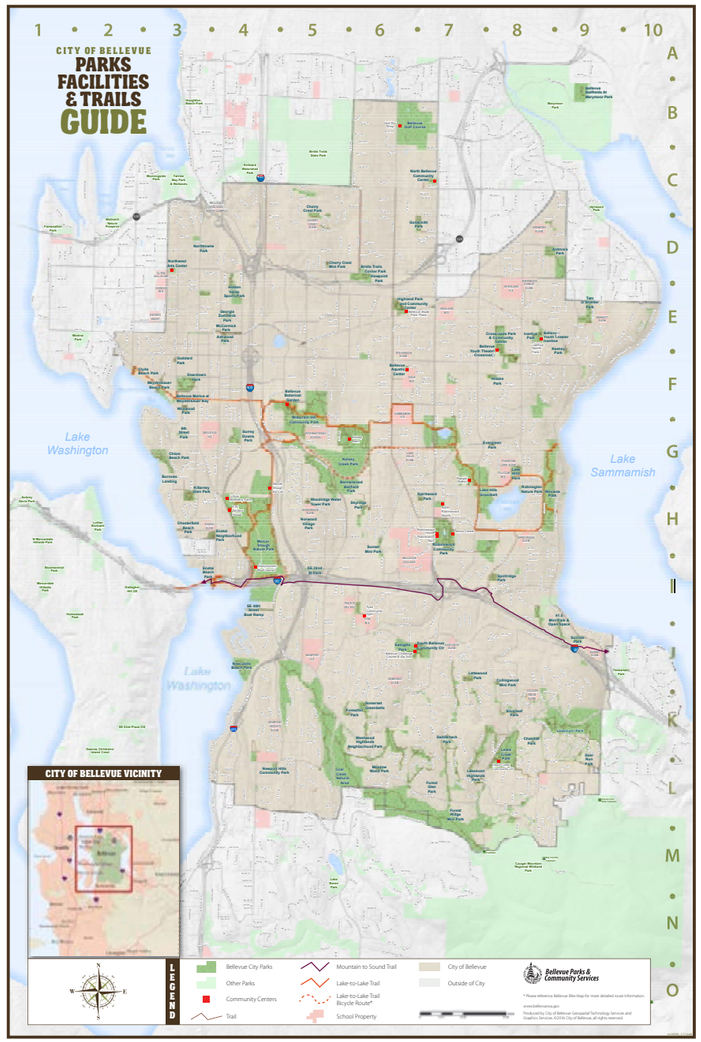
The City of Bellevue offers a range of recreational opportunities in natural settings to support its value, “recreate where you live.” This value stems from Bellevue’s motto: “A City in a Park.” Scattered throughout the City of Bellevue are 2,700 acres of parks and open spaces which offer a range of recreational opportunities for residents and visitors alike. City-owned parks are shown in the map to the right. Ongoing work to protect Bellevue’s existing network of parks and open spaces informs the city culturally and in terms of policymaking. The City’s parks are known for enhancing human well-being and for promote learning. Their continued presence is key to supporting the City’s core value of access to recreational spaces.

The continued presence of parks and open spaces is key to supporting the City’s core value of access to recreational spaces.

ACCESS AND PROXIMITY TO NATURAL LANDSCAPES

Access and close proximity from residential areas to parks and open spaces ensure residents’ ability to recreate outdoors. Public transportation systems can support and increase access to parks and open spaces for residents from across the City. By designing road networks to accommodate all modes of transportation and by constructing those networks to withstand anticipated natural hazards related to climate change, the City can become more climate resilient and ensure residents are able to visit and enjoy natural spaces long into the future.

BELLEVUE PARKS GUIDE



CITY OF BELLEVUE

SAFE AND FUNCTIONING NATURAL AND BUILT ENVIRONMENTS

Just as natural environments may struggle to adapt to climatic change and to altered land uses, built systems may also become overwhelmed by similar change processes. As a result, built systems may no longer function optimally or serve their intended purposes. As climate change results in increased frequency of storm events, for example, older systems must be adapted or upgraded to provide more pervious surface coverage to support increased stormwater runoff. Natural environments may also require additional support to handle increased stormwater volumes and to adapt more quickly to climate change.

A CITY THAT SUPPORTS HUMAN WELL-BEING

An environment that promotes human health, well-being, and livability is of high value to all residents. Human well-being (HWB) encompasses security, basic materials for a good life, health, good social relations, and freedom of choice (Millennium Eco Assessment 2005).

COMMUNITY ASSETS SUPPORT THESE VALUES

The values embraced by Bellevue have associated assets. These assets include the existing urban tree canopy and flora; parks, such as Weowna Park, Kelsey Creek Park, and Phantom Lake; stormwater facilities which protect natural and built environments from hazards that could significantly damage them; and transportation networks and supportive infrastructure such as parking, bus systems, roadways, and pedestrian and bike facilities. This multitude of assets combines to allow residents and visitors alike to access parks and open spaces.

The first report presented in this document (focused on human well-being) hones in on how the City can continue to support human well-being by implementing a set of mitigation strategies that protect and enhance assets like shelter/housing, medical facilities, and social infrastructure. The second two reports (focused on urban flooding and urban tree canopy) outline potential mitigation strategies for protecting assets that support the core value of access to open space.

Open space, trees, and streams characterize Weowna Park, one site in which students conducted field observations. LCY STUDENT TEAM

Blueberry plants along Kelsey Creek are an important local landmark vulnerable to flooding. KEVIN LOWE PELSTRING

METHODOLOGY

SCENARIO PLANNING

For each of the three reports combined in this document, student teams applied a scenario planning framework to explore four plausible futures for Bellevue. In each case, students considered intrinsic and extrinsic change factors as key drivers.

Scenario planning is a systematic method for envisioning possible complex and uncertain futures (scenarios) (Peterson, Cumming, and Carterpenter 2003). Scenarios are based on plausible consequences of events and environmental drivers that could occur. A primary goal in scenario planning is to consider likely impacts possible situations would have on strategic decision making processes (Wilburn 2011). Within scenario planning, a range of possible futures is considered, with no single scenario receiving prioritization over another, regardless of their relative probability (Enzmann, Beauchamp, and Norbash 2011). Scenario planning is considered a useful tool for planners to envision a range of possible/plausible scenarios and to devise plans accordingly. When applied, scenario planning helps widen perspectives on what the future may entail and can make it easier to recognize a range of potential challenges and opportunities (Gunnarsson-Östling, and Höjer 2011).

DRIVERS

For each framework in a scenario planning model, two drivers are measured against each other. Each of the three reports combined in this document refer to the same drivers of climate change and urbanization. The first driver addresses climate change, an extrinsic force. Since Bellevue is subject to other change, a second driver introduces urbanization, an intrinsic force. While the general drivers of climate change and urbanization remain the same in each of the three reports, students determined distinct variables to account for the drivers in their work and created four distinct scenarios for each report.

THREE REPORTS WITH SELECT CLIMATE CHANGE AND URBANIZATION VARIABLES

Report	Climate change variable	Urbanization variable
Human well-being	Extreme weather events	Population increase
Flooding	Large storm events	Impervious surface coverage
Urban tree canopy	Climate stressors	Population increase

HELEN STANTON

CLIMATE CHANGE

Climate change is already occurring in the area. In the coming years and decades, as a result of climate change, increased frequency of extreme weather events is likely. What we conceived of in the past as representing 10-year or 100-year storm events are poised to become annual or semiannual events by midcentury. These storms will impact a different Bellevue from the one we know today. Among other changes Bellevue will endure, the city will be home to a larger at-risk population as a result of population growth and increased urbanization. Herein lie both opportunities and risks. A future Bellevue could experience less flood damage because of careful planning and design targeting the introduction of more permeable surfaces, and less vulnerability to drought as a result of increased water storage availability; or, the city could face more flood damage as a result of increased presence of impervious surfaces, and more vulnerability to drought as a result of not creating more storage space for water. One thing is certain: The way in which the City prepares for and manages future weather events is critical for supporting the livelihood of residents of Bellevue.

The climate change driver describes, for the most part, a future based on one of two scenarios:

1. Scenario A: Carbon emissions increase.
2. Scenario B: Carbon emissions remain constant.

URBANIZATION

Urbanization, like climate change, is also already occurring in Bellevue, reflective of the city's steadily growing population. As a result, the City must plan for continued development and redevelopment to meet the needs of more people. Population growth is accounted for in Bellevue's Comprehensive Plan. This plan outlines designated growth areas throughout the city and directs preservation of Bellevue's natural assets, which include its parks and open spaces. The plan introduces a set of policies to preserve parks and green spaces.

The urbanization driver is aspirational and reflective of Bellevue's Comprehensive Plan, which presents a future in which:

1. New growth is concentrated in designated high-density areas.
2. The City of Bellevue remains single family in character.
3. Jobs are available to local residents.

MODELING THE EFFECTS OF CLIMATE CHANGE IN BELLEVUE

By 2080, the reliability ensemble averaging value (REA) of temperature change is calculated at almost 3.4°C (6.1°F) for scenario A (carbon emissions increase) and at 2.5°C (4.5°F) for the scenario B (carbon emissions remain constant). The range for these two scenarios is from 1.5 to 5.8°C (2.8 to 9.7°F). Individual precipitation models produce varied changes ranging from a -10% decrease to a +20% increase in annual precipitation by the 2080s in the Puget Sound region. These changes in climate direct the following aspects of this project:

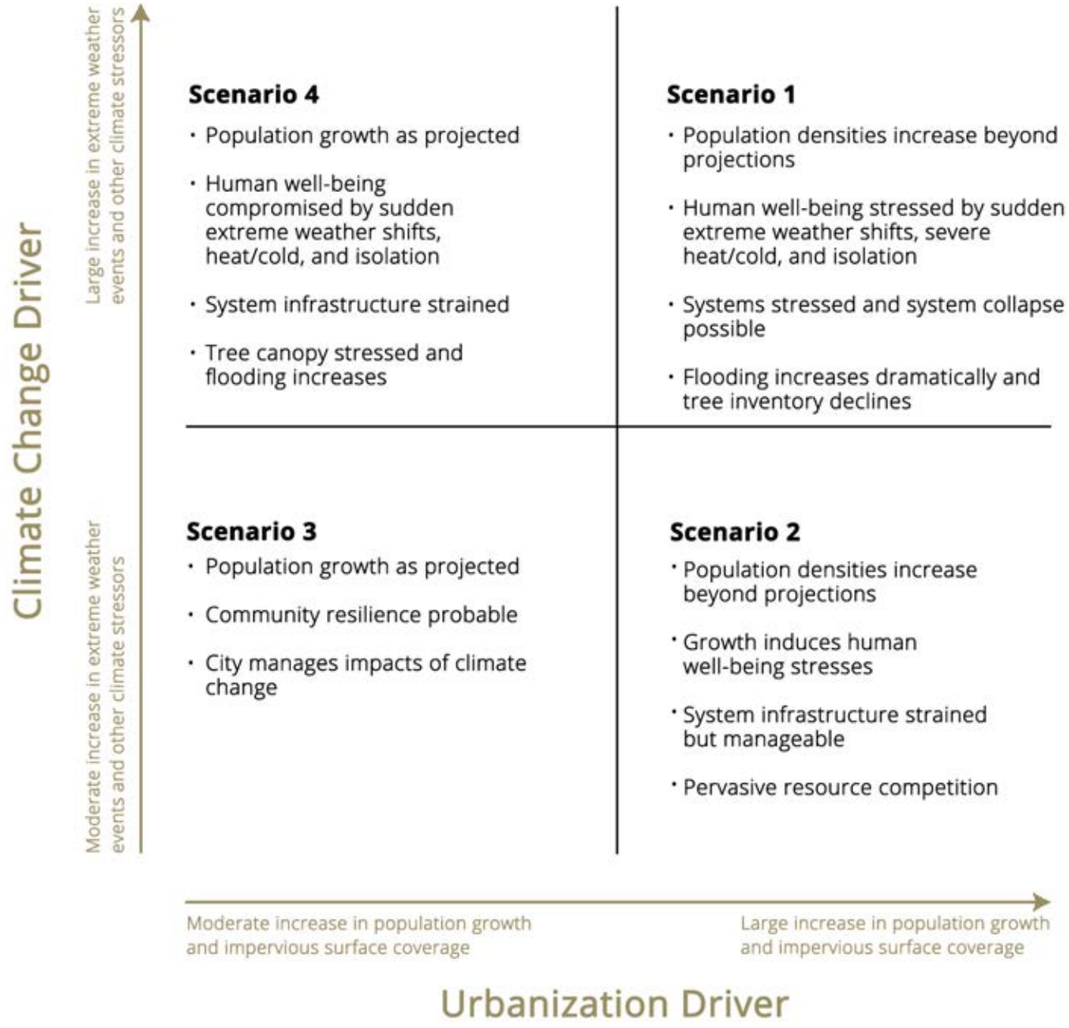
1. The tangible effects of climate change on the current and future well-being of Bellevue residents.
2. The expected vulnerability resultant from rapid urbanization and increasingly frequent storms.
3. The integral role of urban tree canopy culturally and aesthetically, as well as for creating climate resilience.

By evaluating the 12 scenarios presented within this document (four from each of the three reports), we illustrate how changes in extreme weather events are likely to compound with the effects of urban growth and interact with select systems of public and private built environments. To determine precise measures to mitigate the effects of climate change and urbanization, the City of Bellevue can engage in further study.

RELIABILITY ENSEMBLE AVERAGING (REA)

REA refers to the temperate changes of each season and decade. REA values are calculated by weighing each model by its variance and distance from the average of all models.

SCENARIO PLANNING FRAMEWORK



HELEN STANTON AND LIZA HIGBEE-ROBINSON

HUMAN WELL-BEING

CLIMATE CHANGE IMPACTS BELLEVUE'S HUMAN WELL-BEING

Climate change impacts in the Pacific Northwest are upon us, with increased heat events and more frequent and intense winter weather events occurring in recent years. These types of extreme weather events are expected to continue to increase into the future (Climate Change Impacts Group 2019).

Along with increased frequency of severe weather events, Bellevue's population has grown, from 122,363 residents in 2010 to 147,000 in 2017 (City of Bellevue 2017). The City anticipates more growth to accompany the introduction of Sound Transit Link light rail in 2023. This transportation option will increase access to and from Bellevue, and could contribute to growth which exceeds the current projection of a 1% annual increase (City of Bellevue 2017). This section reviews how increased extreme weather events attributed to climate change will impact human well-being as Bellevue grows.

The Millennium Ecosystem Assessment (2005) identifies five characteristics of human well-being: security, basic material for good life, health, good social relations, and freedom of choice and action. In this section, we assess each of these in view of possible impacts of climate change in conjunction with increased urbanization in Bellevue. Then, we propose strategies to mitigate adverse impacts of climate change and urbanization in order to support human well-being.

We propose strategies to mitigate adverse impacts of climate change and urbanization in order to support human well-being.

FIVE COMPONENTS OF HUMAN WELL-BEING

Each component of human well-being is supported and sustained by the provision of particular assets, referred to within this section. The five components of human well-being are described below:

1. **Security** includes safe access to natural resources, such as parks, recreation areas, and general safety resources like emergency and fire services. General safety of persons and possessions also factors into security (Millennium Ecosystem Assessment 2005). For Bellevue, assets which support security include the City's police force, fire department, emergency medical services, and safe public spaces. Security from natural disasters is addressed by the City's Comprehensive Emergency Management Plan (2013), which presents management and hazard mitigation strategies for specific hazards, especially flooding, earthquakes, and landslides.
2. **Basic material for good life** entails income and assets, food security, adequate shelter, furniture, clothing, and access to other goods and services (Millennium Ecosystem Assessment 2005). Assets which support this component include adequate affordable housing supply; employment, education, and job training opportunities; emergency accommodations and homeless shelters; retail and grocery stores; farmers markets, community gardens, and soup kitchens.
3. The **health** component refers to one's physical strength and wellness. It also involves a healthy environment with provides people with access to clean air and water (Millennium Ecosystem Assessment 2005). Assets in Bellevue that support this component include medical centers, hospitals, nursing and treatment facilities, water treatment facilities, drainage systems, recreation areas, parks, and green space.
4. **Good social relations** encompasses qualities of social cohesion, mutual respect for one another, and one's ability to help others (Millennium Ecosystem Assessment 2005). This component is supported through intangible assets, including bonding, social networks, and community norms and values (OECD 2009). Tangible assets that support good social relations include community gathering spaces like churches, schools, civic clubs, sports clubs, community centers, neighborhood associations, and volunteer groups, all of which bring people together around common interests or purpose and foster one's sense of belonging within a group (Bolton 2011).
5. **Freedom of choice** refers to one's sense of autonomy and control over what happens in their life. It includes feeling able to pursue and achieve goals aligned with one's core values (Millennium Ecosystem Assessment 2005). Local government agencies can support this component by ensuring basic human rights and freedom of lifestyle choices.

Two of the five components of human well-being stand to be especially impacted by the compounding effects of climate change and increased urbanization: **basic material for a good life** and **health**. Thus, these are focused on within this section. Both population growth and more frequent and severe weather events are likely to produce stress and pressure related to providing adequate housing supply and temporary shelters to residents of Bellevue. According to the United States Global Change Research Program (2016), human health is likely to be impacted by climate change in two main ways:

1. Increased severity and/or frequency of certain health problems
2. Creation of new health threats

SCENARIO PLANNING

DRIVER: CLIMATE CHANGE

The City of Bellevue is not immune to effects of climate change. Climatologists suggest that extreme weather events (periods of extreme heat and cold) will become more frequent and longer-lasting. The primary impacts of these events will be felt by densely populated cities and metropolitan regions that have historically experienced mild summers and whose residents are not set up with air conditioning (Jackson, Yost, Karr, Fitzpatrick, Lamb, Chung, Chen, Avise, Rosenblatt, and Fenske 2009). Cities and regions that match these characteristics, such as the Seattle area, are very likely to experience increased morbidity and mortality rates (Isaksen, Yost, Hom, Ren, Lyons, and Fenske 2015).

GREATER SEATTLE AREA PROJECTED SUMMER WARMING AND POPULATION MORTALITY FOR 2025, 2045, AND 2085

Low summer warming scenario	Moderate summer warming scenario	High summer warming scenario
The greater Seattle area can expect **68** excess deaths in 2025, **89** excess deaths in 2045, and **107** excess deaths in 2085.	The greater Seattle area can expect **101** excess deaths in 2025, **156** excess deaths in 2045, and **280** excess deaths in 2085.	The greater Seattle area can expect **211** excess deaths in 2025, **401** excess deaths in 2045, and **988** excess deaths in 2085.

HELEN STANTON

The moderate summer warming scenario represents what experts consider to be the most reliable projection for the greater Seattle area. According to this scenario, in 2025, the greater Seattle area can expect to endure "3.6 heat events with a mean duration of 2.3 days, and in 2085 this will increase to 7.2 heat events of 2.9 days mean duration" (Jackson, et al. 2009). Extreme weather episodes link to a multitude of health complications that impact different populations. An aging population, in particular, is more likely to include more at-risk individuals. In part, this is because hotter temperatures reduce the effectiveness of many medications (Jackson, et al. 2009).

Extreme weather events refer not just to periods of intense heat, but also to periods of severe cold. While winters in the Puget Sound area are predicted to be warmer and wetter in the future, episodic cold snaps will feature temperatures that plummet suddenly. It is possible that extreme cold weather events will be more common in the future as a result of warmer temperatures in the arctic region pushing cold air southward as a polar vortex weather pattern (Kretschmer, Coumou, Agel, Barlow, Tziperman, and Cohen 2018). Extreme cold weather events featuring heavy snowfall can cause significant damage to infrastructure and create power outages. Severe cold also increases the risk of people contracting hypothermia; in particular, this threatens people who are experiencing homelessness and others who lack adequate, reliable shelter.

Attribute: Extreme Weather Event Frequency Climate change impacts currently experienced in Bellevue, and research which suggests increased occurrence of extreme weather events in the future, create the two end points for this variable:

1. Moderate increases in frequency of extreme weather events
2. Large increases in frequency of extreme weather events

Population growth and more frequent and severe weather events are likely to produce pressure related to providing housing and temporary shelters to residents of Bellevue.

DRIVER: URBANIZATION

In 2017, Bellevue reported having a population of 140,700 people, making it the fifth largest city in the State of Washington (City of Bellevue 2017). As the overall Seattle metropolitan area continues to grow, with the ever-evolving technology sector expanding throughout the Puget Sound region, the City of Bellevue prepares for population growth that could exceed the current projection of a 1% rate of annual growth (Levy 2018). As baby boomers age, the proportion of older adults in Bellevue is increasing, further evening out the age distribution within the city (City of Bellevue 2017).

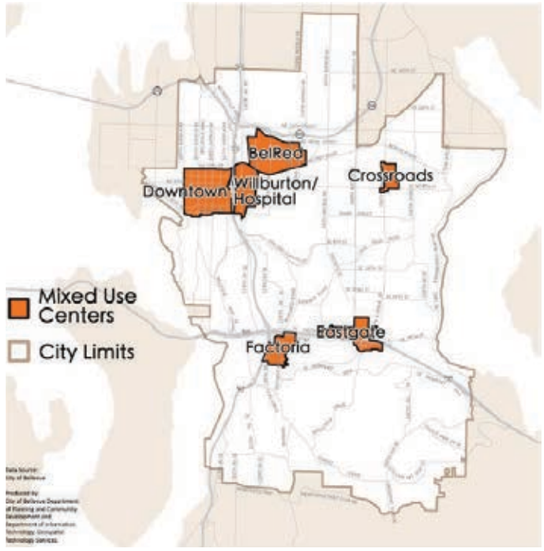
The City of Bellevue also faces effects of increased transportation connectivity and accessibility between Seattle and Bellevue as a result of Sound Transit projects. The Link light rail will provide a reliable, 20-minute (each way) commuter option to people who travel between Bellevue and Seattle. This will reduce travel times between the two cities substantially and make Bellevue more attractive to people who work in downtown Seattle (Sound Transit 2019).

The City has built into its urban planning framework ways to account for anticipated population growth. For example, the City has six designated mixed-use centers. These are planned to accommodate a significant portion of the city's growth (City of Bellevue Comprehensive Plan 2015).

Attribute: Population Growth Two end points for the population growth attribute frame the four scenarios for this report: at one end, the 1% predicted annual population growth rate; at the other end, a rate that exceeds the anticipated 1% annual growth rate.

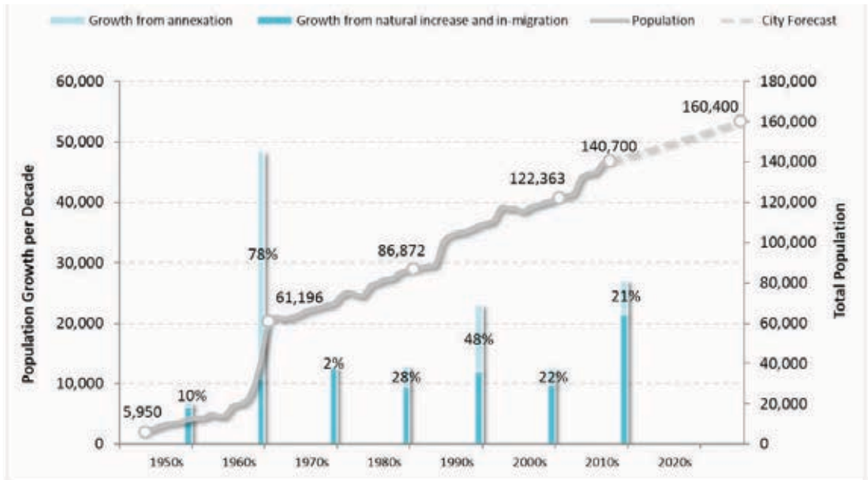
1. Projected increase in Bellevue's population and distribution (1% annual rate of growth)
2. Larger than anticipated increase in population and distribution

BELLEVUE'S SIX MIXED-USE CENTERS



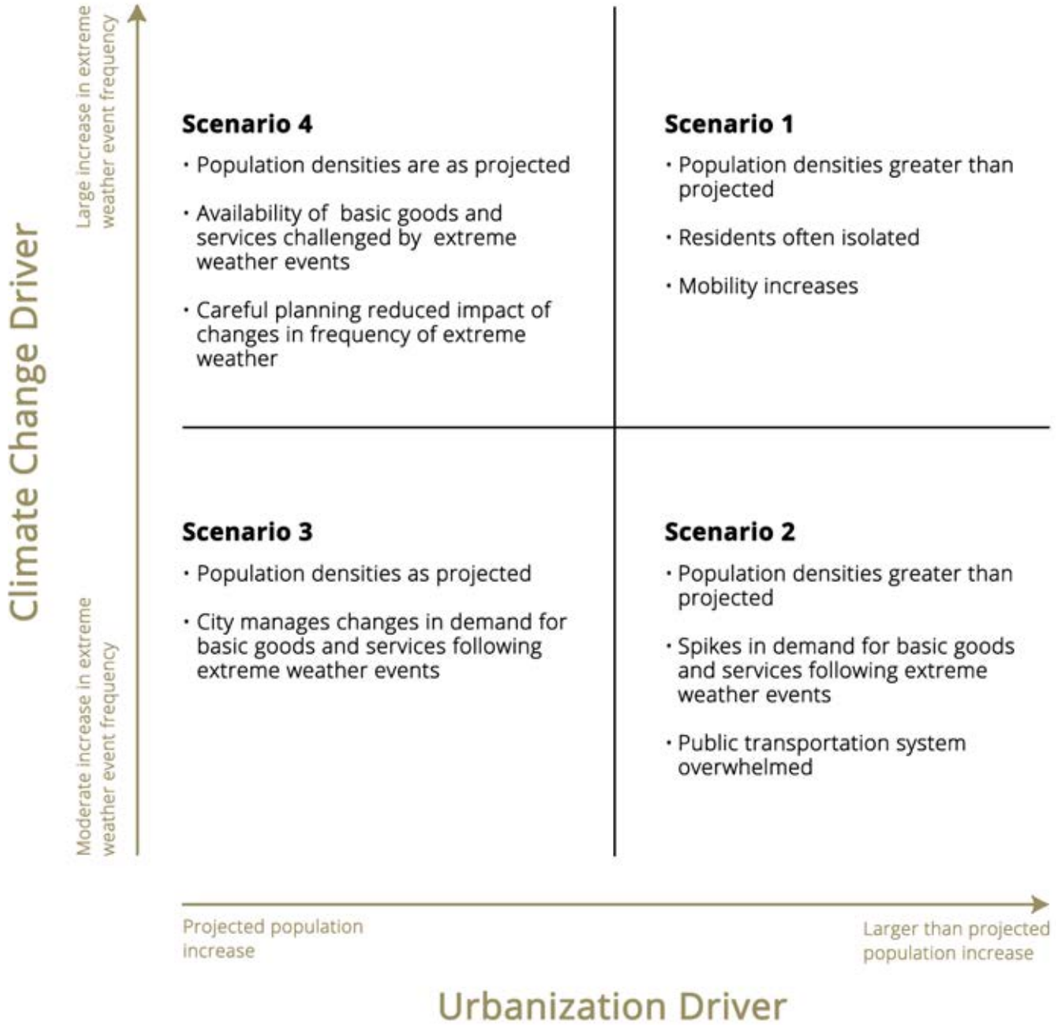
CITY OF BELLEVUE

BELLEVUE POPULATION 1953 TO 2017, FORECAST TO 2035 WITH PERCENT SHARE OF GROWTH FROM ANNEXATION AND NATURAL INCREASE OR IMMIGRATION



CITY OF BELLEVUE

HUMAN WELL-BEING SCENARIO PLANNING FRAMEWORK



HELEN STANTON AND LIZA HIGBEE-ROBINSON

SCENARIO 1. LARGE INCREASE IN EXTREME WEATHER EVENT FREQUENCY AND LARGER THAN PROJECTED POPULATION INCREASE

More people reside in Bellevue than the City accounted for in its Comprehensive Plan. This places excess demand on assets that are essential for human well-being, like shelter and access to medical care. There is also an increased occurrence of extreme weather events, indicated by bouts of severe cold in the winter months and severe heat in the summer months. Weather patterns change abruptly and stress assets that generate and sustain human well-being.

Local travel is frequently disrupted as a result of increased traffic and extreme weather events, such as snow storms. Some residents feel isolated and find themselves unable to access health care and other services. Booming population growth puts extra pressure on the housing market. In particular, the demand for affordable housing and for temporary shelters is at an all-time high. Increased urban density also puts pressure on existing infrastructure and human services. For example, emergency services to assist vulnerable populations are unable to meet the demand for them during extreme weather events. This results in increased morbidity, especially among vulnerable populations, which include elderly, disabled, and homeless populations (Eric Klinenberg 2002).

The combined effects of population growth and extreme weather events presented in this scenario refer to the most plausible future pressures and challenges the City of Bellevue will face. Mitigating this scenario also requires the most drastic action. Although Bellevue is planning for a 1% annual population increase, it behooves the City to prepare for the potential for even more growth. This is especially crucial for the City to plan and strategize for emergency situations.

Although Bellevue is planning for a 1% annual population increase, it behooves the City to prepare for the potential for even more growth.

SCENARIO 2. MODERATE INCREASE IN EXTREME WEATHER EVENT FREQUENCY AND LARGER THAN PROJECTED POPULATION INCREASE

Bellevue experiences greater population increase than it accounted for in its Comprehensive Plan. Moderate increases in extreme weather events bring severe heat events in the summer and severe cold events in the winter, but these events occur less frequently. The increase in population, beyond what the City planned for, places more pressure on assets that support human well-being. This jeopardizes human health and quality of life.

Future residents may find accessing goods and services more difficult as increased traffic and crowding may deter them from leaving their homes. Spikes in demand for basic goods due to extreme weather events will exacerbate congestion and overwhelm the public transportation system, making it even more difficult for some residents to access basic goods and services.

A moderate increase in the occurrence of extreme weather events is somewhat manageable with emergency services. Medical care providers and shelters help manage periodic peaks in demand during extreme weather events.

SCENARIO 3. MODERATE INCREASE IN EXTREME WEATHER EVENT FREQUENCY AND PROJECTED POPULATION INCREASE

This scenario invokes the least possible adverse impacts. It reflects anticipated population growth and only a moderate increase in the occurrence of extreme weather events. Although this scenario is possible, it is the least probable of the four considered in this section. The rate of change is gradual and the City is able to plan and accommodate it fairly easily, relative to other scenarios.

Even so, residents will be inconvenienced as the frequency, magnitude, and length of extreme weather events will still increase from present rates and conditions. When extreme heat and extreme cold weather events strike, increased demand for emergency services, like shelter and medical care, will result. The City is able to manage the needs of its population since less overall growth has occurred. Currently, Bellevue planning documents are in line with this scenario.

SCENARIO 4. LARGE INCREASE IN EXTREME WEATHER EVENT FREQUENCY AND PROJECTED POPULATION INCREASE

Significant increases in the frequency of extreme weather events bring bouts of extreme heat and extreme cold to Bellevue, and there is less time in between such events. With population growth in line with current projections, the City is prepared to meet the demand for emergency resources through much of the year. However, challenges arise during and in the aftermath of extreme weather events. At times many residents struggle to access essential resources.

Demand for shelter from extreme cold and extreme heat occurs more frequently, especially in areas which have been planned to accommodate population growth (e.g., the six mixed-use centers). While the impacts of extreme weather events featured in this scenario match those of scenario one, it is likely that emergency management resources will be less strained since population growth reflects current projections, which the City now plans to accommodate. With careful planning and by accounting for increased demand for human resources during extreme weather events, this scenario can be managed.

In scenarios characterized by more frequent and intense extreme weather events, the need for refuge during periods of crisis also increases.

IMPACTS

Human well-being impacts described in scenarios one and four above, as well as mitigation strategies for those potential impacts, are the focus of this section. Scenarios one and four have been selected because both involve large increases in the frequency of extreme weather events that will affect human well-being. In scenario one, the impacts on human well-being are more severe since increased population growth, beyond what the City of Bellevue is prepared to accommodate, occurs. This places greater strain on human well-being resources and prevents supply of goods and emergency services from meeting the demand of residents, especially during and after extreme weather events. Of the five components of human well-being referred to earlier in this section (security, basic material for good life, health, good social relations, and freedom of choice), the two that become most threatened by climate change are basic material for good life and health.

Basic material for good life includes "secure and adequate livelihood, including income and assets, enough food and water at all times, shelter, ability to have energy to keep warm and cool, and access to goods" (Millennium Ecosystem Assessment 2005). In scenarios characterized by more frequent and intense extreme weather events, the need for refuge during periods of crisis also increases. This may be true for diverse individuals and communities, regardless of whether one owns a home, rents a home, or is experiencing homelessness. Indoor climate control (i.e., air conditioning and heating) will be necessary for all residents, and will require more energy consumption. Access to other basic materials, such as food and clothing, may also be impacted by extreme weather events, during which residents may be advised to stay home. This is particularly problematic for residents who lack permanent shelters, for those who live in isolation, and for those without access to private vehicles or other reliable transportation.

The health component includes physical strength and wellness as well as access to clean air and water (Millennium Ecosystem Assessment 2005). With increased occurrence of extreme weather events and population growth, Bellevue will experience spikes in demand for health services. Heat events can lead to dehydration and other heat-related complications, increasing demand for medical services. Medical services will be particularly strained when wildfires break out. As a result of wildfires, more people will suffer the effects of chronic health problems related to heavily polluted air. Winter storms will also strain the healthcare system, as incidence of illness is found to increase when populations are exposed to conditions of extreme cold. It will be particularly challenging to provide services to individuals and households set in isolated areas. These people may struggle to access the medical assistance they require.

2014 Carlton Complex Fire burning in Washington State JASON KRIESS

Two members of the Human Well-Being Team during their final presentation, from left to right: Rawan Hasan, Mariko Kobayashi TERI THOMSON RANDALL

STRATEGIES

Bellevue's Comprehensive Plan seeks to address and prepare the city for projected population growth. We recommend the City also consider how human well-being will be impacted by climate change, especially as a result of increased frequency of extreme weather events. Strategies and recommendations to address the effects of climate change on human well-being in a growing Bellevue follow.

1. Increase access to shelters during extreme heat and extreme cold weather events

Related to the basic material for good life component of human well-being, the City's ability to guarantee residents' access to adequate shelter during extreme heat and extreme cold weather events is of utmost importance for supporting human health and quality of life. To address this, the City of Bellevue will need to ensure there is sufficient housing supply for residents and enough temporary shelters to accommodate homeless populations as well as others who may become displaced by extreme weather events. Shelters should be scattered throughout the city, with more concentrated in areas where homeless people live.

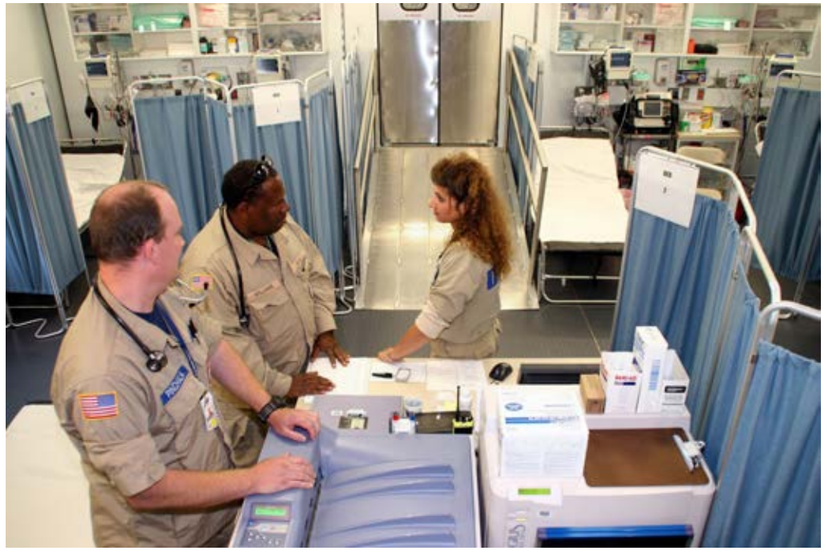
The Bellevue Comprehensive Plan addresses the city's need for affordable housing and how this need stands to increase as the city grows. Tools to help create more affordable housing stock can be adopted, such as requiring developers to set aside a minimum number of affordable units. This would be similar to Seattle's Mandatory Affordable Housing (MHA) policy. In addition to creating more affordable housing, the provision of shelters and public buildings with heating and air conditioning is crucial for supporting vulnerable community members.

By scattering medical services throughout areas planned to accommodate growth, the City can prevent central hospitals from becoming overwhelmed during periods of crisis.

2. Increase access to medical care

For the health component of human well-being, the most significant climate change-induced stress will revolve around access to health service providers, care facilities, and emergency medical supplies. Extreme heat events often lead to heat-related illnesses, such as heat stroke and dehydration. Exposure to poor air can also threaten one's health. On the other hand, extreme cold events often lead to hyperthermia and flu outbreaks. Spikes in these health issues will place greater demand on medical services and health care providers. As Bellevue's population grows and as it faces increased frequency of severe weather events, the city is likely to struggle to provide adequate health services.

To help mitigate this, Bellevue can decentralize its medical system and create scattered medical services throughout the areas planned to accommodate population growth. This will ensure medical services are accessible to more people and prevent central hospitals from becoming overwhelmed during periods of crisis. Dispersal of medical services throughout the city can occur incrementally and can be accompanied by the use of temporary climate relief centers for members of the public to access climate-controlled spaces as needed. To address isolated populations, the City can invest in setting up online consultations with medical doctors.



A mobile medical unit in Belle Chase, Louisiana ROBERT KAUFFMAN

3. Incentivize renewable energy opportunities

Bellevue's Comprehensive Plan designates six mixed-use centers to accommodate anticipated population growth. Ensuring housing stock is sufficient in these areas is essential for a future, denser Bellevue. With increased population and increased climate control technology requirements to heat and cool homes, it is likely that energy providers will experience increased pressure to keep up with energy demand, especially during extreme weather events.

To help compensate for the adverse effects related to increased energy use, Bellevue can encourage and incentivize use of green energies. For example, the City could offer subsidies to developers and homeowners who install solar panels.

To help compensate for the adverse effects related to increased energy use, Bellevue can encourage and incentivize use of green energies.

Students recommend the City of Bellevue incentivize homeowners to use solar panels and other renewable energy sources. TERRY COMBS

4. Promote and disperse mixed-use infrastructure

In line with the theme of decentralizing medical care, areas designated to accommodate population growth should be equipped with adequate amenities for residents. In addition to providing housing units, these areas can play host to social infrastructure: libraries, coffee shops, schools, parks, social clubs, and other places where human bonding occurs. Social infrastructure supports good social relations, one of the five components of human well-being. This is important to cultivate as a defense against the stress residents will experience in the face of more extreme and frequent weather events. By providing more spaces for people to socialize and network, community members are also more likely to look out for one another during times of crisis. Thus, communities can become more resilient through their access to spaces where they come into close contact with one another.

Human Well-Being team members, Rawan Hasan, Mariko Kobayashi TERI THOMSON RANDALL

URBAN FLOODING

CLIMATE CHANGE EXACERBATES URBAN FLOODING IN BELLEVUE

Described as a "City-in-a-Park," Bellevue, Washington places high value on its natural environment. Bellevue's many parks and open spaces are central to the high quality of life enjoyed by residents. The City of Bellevue takes pride in providing outstanding recreational opportunities through its network of parks and streams. This is why protecting natural assets has guided the City in comprehensive planning.

While the City of Bellevue seeks to protect its network of 2,700 acres of parks and open spaces, it also actively encourages large companies to expand in or re-locate within its city limits. Associated development, along with the extension of the Sound Transit Link light rail network, will inevitably impact the City's built and natural environments, including its parks and open spaces.

In addition to these urban development changes, more frequent and intense natural hazards associated with climate change will impact Bellevue's parks. In particular, 100-year storms will become more common. More frequent storm events will compound with the city's existing impervious surface coverage to overwhelm stormwater infrastructure. This will result in flooding of local waterways which could devastate not only parks and open spaces but also key roadways, businesses, and residential areas (Beekman 2018).

Urban growth is likely to intensify the adverse impacts of climate change unless careful planning and appropriate mitigation measures are in place. The City can continue to preserve its parks and natural resources while responding to population growth and accommodating new development. Importantly, the City may view urban development and population growth as important opportunities, rather than as threats.

Students in a Hazard Mitigation Planning course visit Weowna Park accompanied by City of Bellevue staff. The park encompasses 90 acres of open space and offers miles of trails through forested areas alongside Lake Sammamish. TERI THOMSON RANDALL

Compounding effects of climate change and urban development could lead to increased flooding and soil erosion in Weowna Park. KEVIN LOWE PELSTRING

Urban growth is likely to intensify the adverse impacts of climate change unless careful planning and appropriate mitigation measures are in place.

SCENARIO PLANNING

Scenario planning is applied as a framework to imagine four possible futures for the City of Bellevue. Each scenario presented in this section considers flooding hazards in the context of climate change and urbanization. Specific attributes to measure these two drivers are listed below:

DRIVER: CLIMATE CHANGE

***Attribute**: 24-hour storm events*

- Large increase in rainfall events representing 24-hour storm events with >1 inch of rainfall with 3+ events each year
- Moderate increases in rainfall, with 24-hour storm events occurring 1-2 times each year

DRIVER: URBANIZATION

Attribute: Impervious surface coverage

- Lower coverage, equal to current impervious surface coverage of 42%
- Higher coverage, greater than 50% of current impervious surface coverage

Members of the Urban Flooding Team during their final presentation, from left to right: Kevin Lowe Pelstring, Cate Kraska, Bob Freitag (course instructor, in background), and Helen Stanton. TERI THOMSON RANDALL

URBAN FLOODING SCENARIO PLANNING FRAMEWORK

HELEN STANTON AND LIZA HIGBEE-ROBINSON

SCENARIO 1: GREATEST INCREASE IN FREQUENCY OF LARGE STORM EVENTS AND INCREASED IMPERVIOUS SURFACE COVERAGE

In this scenario, the impacts of climate change have arrived quickly and produced more frequent and intense 24-hour storm events. Rapid urban growth, as a result of the Sound Transit Link light rail extension and growth in the business sector have contributed to an increase in impervious surface coverage, to above 50% of the city's total land area.

This is a worst-case scenario, with features of the built environment contributing to extensive adverse impacts which further compound with the effects of intense rainfall resultant from climate change. Bellevue becomes subject to destructive and persistent flooding. In the winter, it is very common for parks to regularly flood, and most are overgrown and unused for half the year. Roads are also prone to flooding, which disrupts school and work days. As a result, the economy struggles, becoming reactive to erratic seasons. Several large flooding events every year can grind the city to a halt for days. Increased flooding also brings more pollutants into the waterways, threatening keystone species like salmon and native flora. Flooding leads to streambank erosion, permanently reshaping the parks and open spaces of the area.

SCENARIO 2: MODERATE INCREASE IN FREQUENCY OF LARGE STORM EVENTS AND INCREASED IMPERVIOUS SURFACE COVERAGE

In this scenario, while expected growth still results in an increase in impervious surfaces, climate change impacts are modest and occur gradually.

While the changes do place increased pressure on stormwater facilities, the levels are manageable as a result of infrastructure improvements made possible by drawing from state and federal funding sources. Occasionally, after particularly intense storms, flooded roadways disrupt school and work days. However, this occurs infrequently and economic effects are minimal. Parks experience increased flooding, but they are carefully maintained to accommodate the impacts of water retention without disrupting public use of them. Water regularly pools in parts of the city where drainage is particularly poor and where impervious surfaces are prevalent, like the downtown area. Overall, the city maintains normal operations and manages the effects of climate change.

SCENARIO 3: LESS INCREASE IN FREQUENCY OF LARGE STORM EVENTS AND MAINTAINED IMPERVIOUS SURFACE COVERAGE

This scenario impacts the city least of all, as current impervious surface coverage is maintained or reduced while intense rainfall events progress less rapidly, with only one or two major storms occurring each year. While some flooding occurs, most impacts have been mitigated by an improved stormwater management system and by implementing low impact development (LID) features, like pervious surfaces which allow water to be absorbed by the earth. As a result of LID, which integrates with natural systems, it is uncommon for flooding to impact roads. Thus, in this scenario, school and work days are almost never affected by severe weather events and parks remain in use during all months of the year. Strategic stormwater design and management prevent flooding from wreaking havoc throughout the city.

SCENARIO 4: GREAT INCREASE IN LARGE STORM EVENTS AND MAINTAINED IMPERVIOUS SURFACE COVERAGE

In this scenario, although substantial urban growth has occurred, stricter planning regulations lead to maintained impervious surface coverage (i.e., approximately 42%). This helps mitigate the most intense effects of flooding. Heavy 24-hour periods of rainfall have become very common, but the impacts of storms vary. At times, severe flooding of roadways forces businesses and schools to close. In many cases, only the lowest drainages of the city are affected by storms, and the city continues to operate as normal. The stormwater management system is always teetering on the edge of failure during winter months, but it typically withstands weather events thanks to recent, strategic planning and infrastructure improvements. Parks are subject to flooding during winter months and put to greater use during the summertime, with residents taking full advantage of the shade provided by tree canopies on hot days.

STRATEGIES

Bellevue is currently considering several mitigation strategies for flooding as outlined in the City's Comprehensive Plan as well as in the City of Bellevue Stormwater Management Guide (2015). However, there are opportunities for the City to build upon existing climate change-influenced strategies. Strategies may involve accommodation, protection, or retreat techniques, and may be combined with specific planning, policymaking, and enforcement procedures. The City can apply for grant funding to cover associated costs. The three strategies discussed in this section are based on Bellevue's current conditions and anticipated urban growth.

1. Retrofitting Aging Development

Aging infrastructure contributes to Bellevue's high levels of impervious surface coverage and vulnerability to more severe and frequent flooding events. This includes the supportive infrastructures of private single-family homes, as well as commercial properties, such as shopping centers and parking lots. These portions of the built environment were developed before the City imposed development restrictions on impervious surface coverage in December of 2016.

Addressing Bellevue's current impervious surface coverage is especially important for the City to manage scenarios in which population increases beyond expected projections and the frequency of severe storms and flooding also increases. Several opportunities may exist for the City to incentivize property owners to retrofit or redevelop lands to increase pervious surface coverage and, therefore, flooding-resilience.

Aging infrastructure contributes to Bellevue's high levels of impervious surface coverage and vulnerability to more severe and frequent flooding events.

The City can offer grants or subsidies to help cover the cost of a full retrofit or consider waiving property or certain utility taxes for a period of time if property owners consent to make changes themselves (Freitag 2011). Another option is to apply land easements or to purchase redevelopment rights for impervious parcels, requiring owners to retrofit impervious surfaces to improve their land's stormwater management capacity (Freitag 2011). With regard to more vulnerable properties, directly proximate to flood-prone areas, the City could strategically acquire the properties and designate them as part of a natural flood path (Freitag 2011).

Dillenbough Creek floods I-5 in Chehalis, Washington. US GEOLOGICAL SURVEY

2. Low Impact Development (LID)

Low impact development (LID) involves stormwater management facilities and infrastructural features and designs which reduce stormwater runoff and improve water quality. LID methods, which support water infiltration, filtration, storage, evaporation, detention, and retention, can achieve restoring hydrological functions to pre-development conditions (Washington State Department of Ecology 2012). Many LID technologies integrate with natural systems, improving the aesthetics of a place while also reducing impervious surface coverage. LID can also reduce costs associated with maintaining pavement, detention basins, and pipe networks (Washington State Department of Ecology 2012). Examples of LID features include bioswales, permeable paving, green roofs, and rain gardens. Seattle's Street Edge Alternatives Project (SEA Streets) is one example of successful LID implementation and road redesign (Matsuno, et. al. 2001). The design combines traditional drainage infrastructure with newer technologies, like bioswales, to enhance the natural landscape visually and functionally. It reduces the site's total volume of stormwater runoff by 99% (Matsuno, et. al. 2001).

LID strategies can help mitigate consequences of increased impervious surface coverage in Bellevue and reduce the effects of increased frequency and intensity of rainfall events, as described previously. Integration of natural elements with LID projects also reinforces Bellevue's "City-in-a-park" motto.

Integration of natural elements with low impact development projects reinforces Bellevue's "city-in-a-park" motto.

Bellevue already requires implementation of LID for some new development and redevelopment projects and has adopted Washington State Department of Ecology's 2012 Stormwater Management Manual for Western Washington. These efforts will help the City of Bellevue offset impacts associated with urban growth, like increased impervious surface coverage. Another way to implement LID broadly is by creating improvement districts. These are essentially neighborhoods which decide on an approach (e.g., SEA Streets) to redeveloping their roads and sidewalks that incorporates LID strategies. Loans or grants issued by the local government can help cover associated costs. After covering initial redevelopment costs, the City of Bellevue would recapture the value of loans through higher returns on property taxes over a period of time (Freitag 2011). Benefits to the community would include a more livable neighborhood. Care would need to be taken to avoid displacement of current residents as a result of increased property values and rent costs.

LID strategies can help reduce the effects of more frequent and intense rainfall events. AARON VOLKENING

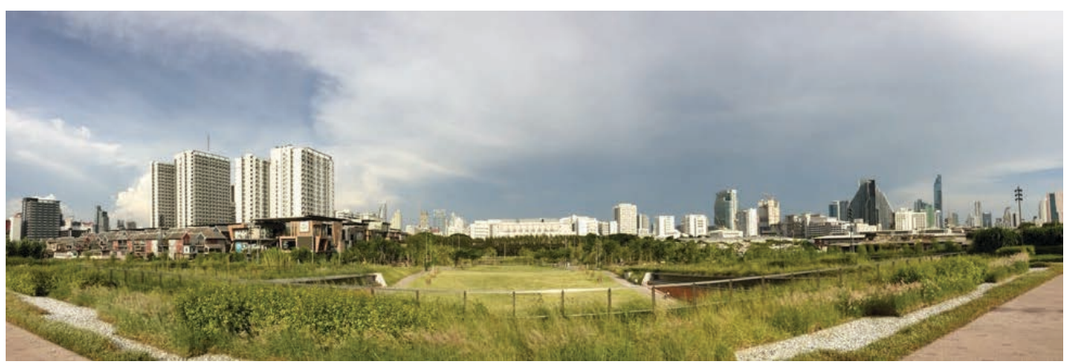
Park redesign represents a strategic, large-scale investment to accommodate future storm events and maintain the utility and desirability of parks for residents and visitors of Bellevue.

3. Park Redesign

By redesigning parks, potential damage to recreational sites from increased frequency and intensity of storms can be mitigated. Flooding, in particular, can be managed by designing and installing features to capture or redirect water. This can be done in a way that is aesthetically pleasing and ecologically sound. The intent would be to make the additional water from winter storms work for the City of Bellevue, rather than against it.

Parks in Bellevue are often flooded during the winter, discouraging park use and socialization. Redesign of parks will not completely change their character, but will instead support the natural collection and flow of water and account for increased water quantity as a result of more frequent and intense storms. Park redesign represents a strategic, large-scale investment to accommodate future storm events and maintain the utility and desirability of parks for residents and visitors of Bellevue.

Funding for flood mitigation could be drawn from grants sourced from the Federal Emergency Management Agency (FEMA). Inspiration for park redesign could be drawn locally from public input and design competitions, as well as from international examples, including Chulalongkorn University Centenary Park in Bangkok, Thailand. There, by retrofitting an 11-acre central park the sequestration of power from nearly one million gallons of water during a flooding event is made possible (Garfield 2018). Another promising example to learn from is Hans Tavsens Park in Copenhagen, Denmark, where the installation of retention ponds and greenways enables up to 18,000 cubic meters of water to be held (Mairs 2016).



Chulalongkorn University Centenary Park in Bangkok, Thailand, was redesigned to handle storm events. BUNBN

4. Onsite Detention in Up-Zoned Areas

One approach for accommodating greater urban density while also increasing permeability is the use of onsite water detention and retention. Onsite detention could include underground storage that allows water to travel via drainage or rain catchment systems (Federal Highway Administration n.d.). As a burgeoning design concept, Bellevue could easily become a model for other cities by adopting such an approach.
It is likely that Bellevue will experience both more frequent and intense rainfall events and urban growth over the next few decades, so a plan to accommodate both, like onsite detention and retention, is key to ensuring the city's resilience. By investing in infrastructure that accounts for the effects of increased storm events and urbanization, the City will save money in the long-term. Additionally, onsite water detention can be viewed as a conservation measure which reduces pressure on stormwater systems during times of inundation and which also guards against the consequences of extended periods of drought, also more likely to occur in the future (Federal Highway Administration n.d.). This approach can be applied to the redesign of existing developments, especially in parts of Bellevue experiencing growth. To encourage developers to incorporate these designs in their plans, the City could offer subsidies or change zoning regulations to permit denser development (Freitag 2011).

SEA Streets is an example of low impact development practiced in Seattle. NATIONAL ASSOCIATION OF CITY TRANSPORTATION OFFICIALS

By investing in infrastructure that accounts for the effects of increased storm events and urbanization, the City will save money in the long-term.

URBAN TREE CANOPY

To meet its 40% target for total tree canopy coverage, the City of Bellevue will need to invest in planting 670 acres of trees.

CLIMATE CHANGE THREATENS BELLEVUE'S URBAN TREE CANOPY

This section focuses on climate change as it will impact urban tree canopy (UTC) within the context of a growing Bellevue. The climate change driver looks at how four distinct scenarios stress or threaten the city's UTC and how this will affect Bellevue and its residents. The urbanization driver follows expected growth in targeted areas as growth interacts with varying degrees of severity of climate change. We outline Bellevue's current UTC, explain why trees matter in an urban environment, review potential impacts of each climate change/urban growth scenario, and outline strategies and recommendations for the City to consider. In view of anticipated hotter temperatures and heat waves induced by climate change, Bellevue's urban tree canopy will play an even more vital role as a source of cooling for residents. This is particularly the case as the city also becomes denser.

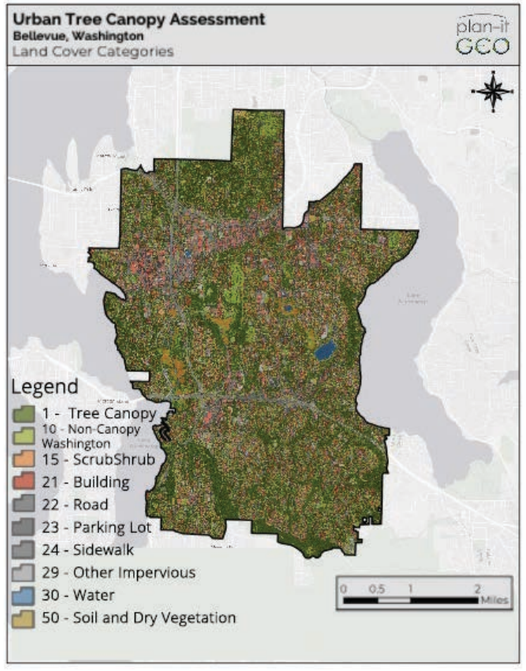
The second driver reflects an objective stated by the City of Bellevue in its Comprehensive Plan, to maintain its single-family character, overall, while accommodating growth in designated, up-zoned areas. We do not foresee a future Bellevue that does not experience some degree of pressure to increase density which means it is important to consider population growth in all planning processes.

UTC IMPORTANCE AND STRESSORS

Since 1986, the City of Bellevue has conducted a tree canopy assessment every 10 years (City of Bellevue 2017). In the City's first assessment, published three decades ago, the City reported its tree canopy to cover 40% of Bellevue's total land area. Reports published before 2007 demonstrate a decline in total tree coverage, from 40% in 1999 to 37% in 2007, for example (Pappas 2018). As a result of this trend, Bellevue's City Council passed a goal to increase tree canopy coverage to 40% in Bellevue's Comprehensive Plan (City of Bellevue 2015).

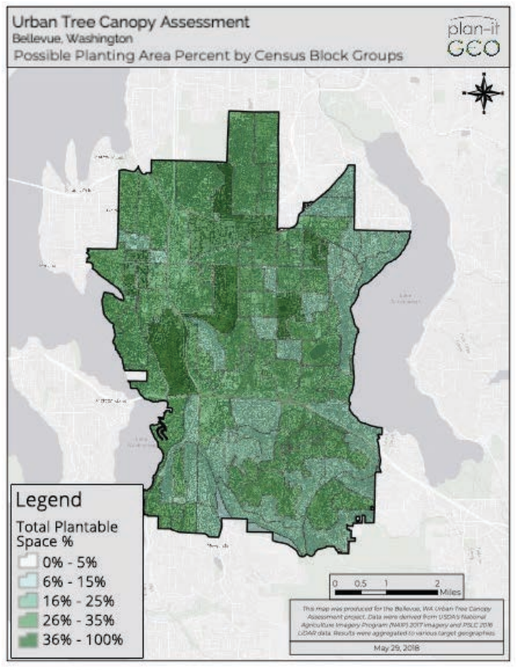
In recent years, tree canopy coverage decline has leveled off. The City's 2017 report measured 37% tree canopy coverage, demonstrating no further decline since the 2007 report (City of Bellevue 2017). Of four categories used to classify tree health — where class one indicates excellent health and class four indicates poor health — 72% of Bellevue's UTC is labeled class one or class two (Plan-It Geo 2018).

BELLEVUE'S EXISTING URBAN TREE CANOPY



PLAN-IT GEO

BELLEVUE'S POTENTIAL URBAN TREE CANOPY



PLAN-IT GEO

Currently, of the estimated 1.4 million trees in Bellevue, 65% are located on suburban residential properties, and 20% are located in parks and open spaces (Plan-It Geo 2018). To meet the City's 40% target for total tree canopy coverage, the City will need to invest in planting an additional 670 acres of trees (Pappas 2018). Currently, 28% of Bellevue's total land area is suitable for trees; this includes some areas which are covered with impervious surfaces, like parking lots, as well as areas covered by other vegetation (Plan-It Geo 2018). The remaining 35% of the city is not suitable for planting trees; this includes spaces that have already been built up with buildings, roads, and parking lots, as well as areas with bare soil and dry vegetation (Plan-It Geo 2018).

Since being recognized as "Tree City USA" by the national Arbor Day Foundation more than two decades ago, the City of Bellevue has maintained a steady focus on the importance of maintaining its UTC. People and wildlife of Bellevue, as well as the whole region, depend on the ecosystem services provided by a robust tree canopy. Climate change is expected to both amplify the effects of existing weather events, like heavy rainfall, severe windstorms, and extreme cold spells; and also introduce new stressors, like heat waves and sustained periods of drought. The following four scenarios reflect the range of climate change projections and gesture toward potentialities that the City can plan and prepare for now.

URBAN TREE CANOPY FAST FACTS

PLAN-IT GEO

URBAN TREE CANOPY BENEFITS

There is great potential for the City to increase overall tree health while also expanding the total percentage of its tree canopy coverage. However, increasing UTC may be a more important focus than that of improving tree health due to the innumerable benefits of UTC, listed below.

Economic: Bellevue's UTC saves the City $39 million in pollution mitigation, sequesters $51 million worth of carbon, and obviates $2.8 million in infrastructure development and maintenance (Plan-It Geo 2018). Planting and maintaining trees improves aesthetics and engenders sense of place, qualities linked to higher property values (Enelow 2015). Trees improve water quality and reduce stormwater runoff, reducing costs associated with retaining and treating water. One of the biggest benefits of UTC for cities is the cooling effect of tree canopies. The shade offered by trees makes cities more livable through periods of sustained heat, and may contribute to reducing need to emit greenhouse gasses to cool indoor spaces (Enelow 2015).

Ecological: In the Pacific Northwest, tree canopy coverage contributes to stream health, required by Pacific salmon (a keystone species). Trees also prevent soil erosion, reduce runoff, and promote biodiversity (US Forest Service 2018). Abundant trees remove great quantities of pollutants from the air which helps cities like Bellevue meet federal air quality standards (US Forest Service 2018).

Social: Lastly, urban tree canopy increases social capital. Trees as associated with places like parks, patios, and plazas which provide places for people to gather in urban settings. Trees are also linked to improved psychological and cognitive functions (Holtan et al. 2014).

People and wildlife of Bellevue, as well as the whole region, depend on the ecosystem services provided by a robust tree canopy.

SCENARIO PLANNING

As before, scenario planning is applied as a framework to imagine four possible futures for the City of Bellevue. Each scenario considers urban tree canopy in view of attributes of two drivers: climate change and urbanization.

Nearly all climate change models predict increased precipitation in the northern third of North America and decreased precipitation in the southern third. However, Bellevue and the Pacific Northwest fall in an in-between space. This results in a greater degree of uncertainty about our region's future. For example, individual models predict changes in annual precipitation that range from a -10% decrease to a +20% increase by 2080. Because the City now anticipates a certain amount of population growth and urban density within targeted areas of Bellevue, our urbanization driver compares current population with a substantial increase in population.

DRIVER: CLIMATE CHANGE

Attribute: Urban tree canopy (UTC) stressors induced by climate change

- Lower stressors, with UTC self-organizing/adapting to stressors
- Higher stressors, with UTC collapsing

DRIVER: URBANIZATION

Attribute: Increased urban density in targeted up-zoned areas with infill in single-family neighborhoods

- Moderate levels of density in targeted areas and infill within sin-gle-family neighborhoods
- Accelerated levels of density in targeted areas and infill within single-family neighborhoods

URBAN TREE CANOPY SCENARIO PLANNING FRAMEWORK

HELEN STANTON AND LIZA HIGBEE-ROBINSON

SCENARIO 1: GREAT INCREASE IN CLIMATE STRESSORS AND SUBSTANTIAL POPULATION GROWTH

In the first scenario, summers in Bellevue have quickly become much hotter and drier, while winters have become shorter, warmer, and wetter. Increased wildfires in California have triggered migration to the Puget Sound region and Bellevue's population has spiked. The physical removal of trees to make room for housing and other urban services and the stress of sudden environmental change cause a reduction of total tree canopy. As a result of swift environmental change, even the more resilient trees struggle to reproduce. The tree canopy becomes sparse. Over time, the residents of Bellevue can access only a few shaded parks. Community ties and residents' attachment to communal spaces decline. Wildlife, like birds and squirrels, which rely on trees, begin to disappear. Eventually, ecosystem benefits of cleaner air and water retention are no longer provided by trees, and the urban heat island effect becomes routine. Soon, property values plummet and energy demands soar, as a result of far greater need to cool buildings. With decreased precipitation in summer months and shorter winters, the reservoirs the city relied upon in the past are not replenished and water shortages become a threat.

However, some opportunities may arise. Gaps in the tree canopy could allow for the most resilient and adaptable species to survive and eventually replace other species. A reduction in overall annual stormwater runoff would also reduce the burden placed on Bellevue's stormwater management system.

SCENARIO 2: MODERATE INCREASE IN CLIMATE STRESSORS AND SUBSTANTIAL POPULATION GROWTH

The second scenario includes both increased population and increased presence of climate stressors, but changes in precipitation and temperatures are more moderate than in the first scenario. These factors lead to a reduction in total tree canopy. Trees are removed to make room for new housing. Gradual environmental change causes less resilient species to die. Despite these challenges, opportunities abound to increase community awareness about the importance of the many ecosystem services provided by urban trees. Additionally, slightly wetter winters yield opportunities to introduce new tree species which may be better adapted to the altered climatic conditions.

SCENARIO 3: MODERATE INCREASE IN CLIMATE STRESSORS AND MODERATE POPULATION GROWTH

The third scenario accounts for less population growth and for gradual, modest climatic change. Summers are hotter and drier and winters are slightly wetter and warmer. These changes put some new pressures on the city's urban tree canopy. With less population growth, less tree removal occurs. With maintained levels of UTC and minimal effects of climate change, stormwater management is possible, properties retain their values, and the economy remains stable. The city avoids the worst impacts of climate change and its UTC flourishes.

SCENARIO 4: GREAT INCREASE IN CLIMATE STRESSORS AND MODERATE POPULATION GROWTH

In the fourth scenario, population growth occurs slowly and the effects of climate change are rapid and drastic. The residents of Bellevue experience hotter summers with regular heat waves, and short, warmer winters with intense periods of rainfall. These impacts impede the rate of urban growth and disrupt plans to complete the Sound Transit Link light rail extension. As extreme weather patterns persist, Bellevue's UTC struggles to adapt. Substantial die-off of native trees ensues. With increased rainfall in the winter and with fewer trees, there are fewer opportunities for people to gather outside and socialize. With fewer trees to retain water, stormwater runoff carries contaminants into streams, degrading stream health and threatening salmon populations. Stormwater facilities throughout the city become overwhelmed and costs to treat and store water soon become a burden. Increased flooding damages roads and buildings, and residents lose access to outdoor recreational spaces. Property values throughout the city decline, reflecting a crippled economy.

During drought periods, trees may lose their ability to transport water to their leaves, which prevents them from photosynthesizing and causes them to starve to death.

CLIMATE CHANGE DRIVEN TREE MORTALITY

In all four scenarios, in order to respond to stressors incurred, Bellevue needs to assess risks and threats to its UTC and build resiliency however possible. Research and understandings related to how climate change affects tree canopy is rapidly developing. However, most resources focus on wildland tree canopies, especially of tropical and subtropical environments, and not on urban tree canopies. The latter are more susceptible to environmental change because they do not exist in pristine conditions. Urban conditions are also associated with higher carbon dioxide levels, hotter temperatures, and greater nitrogen deposition than natural forest ecosystems (O'Brien, Ettinger, and HilleRisLambers 2012). These qualities of urban environments allude to reasons trees are particularly important for making them livable.

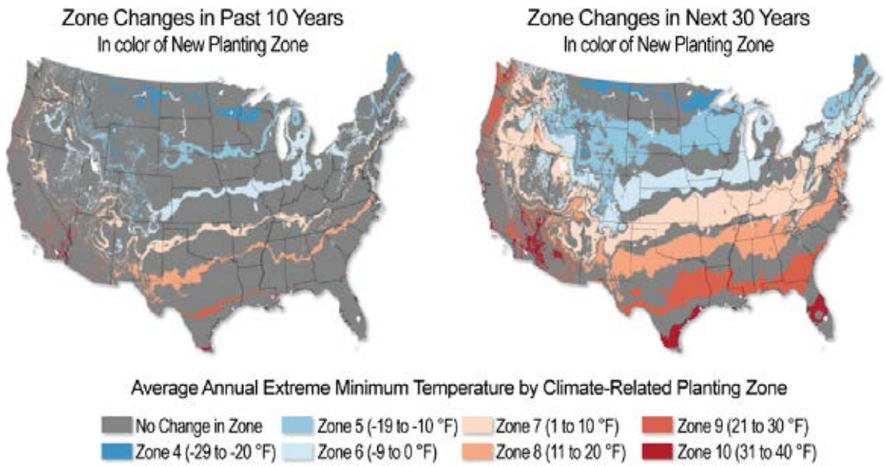
To understand how to mitigate the effects of climate change on urban tree canopy, we should first understand tree mortality and how it intersects with climate. The primary factor which incites or accelerates tree vulnerability and decline is heat, with drought often compounding with the effects of increased temperatures (van Mantgem, et al. 2009; Whyte, Howard, Hardy, and Burgess 2016). Predicting which trees will be affected by heat and drought remains challenging because concepts of tree mortality are not advanced enough to predict regional die-off patterns (Allen, et al. 2010; McDowell, et al. 2008). Tree mortality may occur gradually, with periods of growth, stress, and recovery. The primary cause of tree mortality during drought periods stems from trees losing the ability to transport water to their leaves (McDowell et al. 2008). This prevents them from photosynthesizing, causing their carbon reserves to decline (Allen et al. 2010; van Mantgem et al. 2009. Ultimately, drought causes trees to starve to death.

Drought resilience in trees tends to be inherited. The Pacific Decadal Oscillation (PDO) is a long-term fluctuation of the Pacific Ocean. It causes alternating long periods of wet and dry conditions along the west coast of the US. This phenomenon inhibits native trees from passing on drought tolerance and predisposes them to water stress (McDowell et al. 2008). One native tree of concern is Douglas-fir (Pseudotsuga menziesii), with a current range extending from Canada to Mexico. Douglas-fir populations found in Mexico and in the southern United States appear to be less affected by dry summers, suggesting that assisted species migration of drought resilient subspecies could help other regions maintain Douglas-fir throughout the tree's traditional native range (Chen, Welsh, and Hamann 2010).

One of the most visible factors linked to tree stress and mortality are pest and pathogen infestations. While mild to moderate infestations are normal, large scale, year after year infestations tend to occur when trees are stressed over a prolonged period and when conditions particularly encourage pest proliferation (Raffa, et al. 2008). These could be wet or dry conditions, depending on the pest. Increased frequency of severe weather events in the Pacific Northwest will encourage pest proliferation and trigger tree death. It is important to note that proximity to a global port (e.g., nearby Port of Seattle and Port of Tacoma) is correlated with an increase in importation of exotic pests (Gulick 2014).

Another significant concern is wildfire. By midcentury, lands at risk of experiencing wildfire in the northwest are projected to increase by 200-300% of their historic records (Halofsky and Peterson 2016). The majority of forest fires start in wildlands (79%) and spread through the wildland urban interface (WUI), where wild spaces and urban spaces merge (Ager, Day, Short, and Evers 2016). While wildfires in the WUI have yet to be a problem for western Washington, climate change and increased urban development will exacerbate risks of wildfires occurring in the WUI. Such wildfires could be devastating as a result of the substantial amount of fuel for fires present in semi-urbanized and suburban developments (Holdeman 2017; Keeton,W.S, Mote, P.W, and Franklin, J.F 2007; Radeloff, et al. 2018).

PROJECTED PLANTING ZONE CHANGES IN NEXT 30 YEARS



NOAA

STRATEGIES AND RECOMMENDATIONS

Given the significant role trees play in urban settings and the potential threats to Bellevue's urban tree canopy, it is urgent that the City take action to protect its trees now and in the future. All measures and strategies must be carefully considered to avoid creating new risks to UTC.

1. Comprehensive Tree Inventory

A comprehensive tree inventory involves accounting for all tree species found throughout Bellevue. In scenarios with increased pressure on UTC, the host-specific nature of tree pests and diseases, susceptibility to fire, and varying urban conditions, all loom as substantial threats. Together they point to the need for a comprehensive tree inventory to understand and mitigate tree mortality risks (Gulick 2014).

While complete ground inventories are typically cost-prohibitive, windshield surveys (rough observational surveys conducted from within cars) can be used to identify trees based on their unique characteristics (e.g., flower color, bark, fall color). Remote sensing and aerial imaging can also be used to identify target features (Gulick 2014). These methods are quickly becoming more sophisticated and accessible. A less traditional approach to monitoring urban tree populations is to crowdsource information by providing each tree with an email address linked to an identification number; this is already practiced in Melbourne, Australia (LaFrance 2015). These email addresses could easily link to imaging software and give forest managers feedback on which trees are stressed or requiring maintenance. This would enable them to focus their efforts broadly to support tree resilience and ensure trees continue to provide a range of ecosystem services.

Increased frequency of severe weather events in the Pacific Northwest will encourage pest proliferation and trigger tree death.

2. Share Knowledge and Research

Bellevue possesses significant institutional knowledge about its urban tree canopy and is already investigating ways to adapt to climate change. Unfortunately, many of the City's strategies are not well documented or available to the public. The City could organize a group whose purpose is to gather and share knowledge on tree canopy stressors resultant from both climate change and urbanization. Knowledge generated by this group could be used to develop planting mitigation strategies. The group could share resources and build a knowledge base to benefit tree canopy managers across the region. In forming such a group, the City of Bellevue could partner with the University Washington's School of Environmental and Forest Sciences and other environmental research groups interested in sharing information related to tree canopy stressors and mitigation strategies. Documenting experimental projects and existing knowledge legitimizes projects and justifies reproducing or expanding successful strategies, while also making space for recognizing and understanding failed techniques. Cumulatively, this augments institutional knowledge and enables urban foresters to hone their skills.

HARDINESS ZONES AND CLIMATE CHANGE

A hardiness zone is a geographic region where specific plant life is capable of growing. The United States Department of Agriculture (USDA)'s cold hardiness zones, which are determined based on average annual absolute minimum temperatures, are shifting quickly (Parker and Abatzoglou 2016). Bellevue is currently designated as belonging to zone 8b; by 2050, the city is expected to become reclassified as zone 9. As the city and broader region face climate change, plants adapted to zones 8b, 9, and 10 should be included in planting designs. To ensure that future plantings are viable and reflective of Pacific Northwest ecology, a variety of tree planting lists can be generated and used by public and private institutions, as well as residents. Lists can be derived from restoration ecology's Kuchler zones, which focus on regional plant communities. By ensuring information on trees is publicly available and easy to access, community members will be more likely to support tree planting initiatives.

3. Assisted Species Migration

Another way to protect species with wide geographical ranges is through assisted species migration. This would involve identifying and introducing trees that grow in areas with climates similar to expected future conditions. In theory, those species would be capable of withstanding or thriving in future conditions. Assisted species migration could be accomplished by partnering with climate and forest research organizations, such as the UW's School of Environmental and Forest Sciences. Native plant nurseries may serve as sources for trees adapted to different climatic conditions which could be transplanted in Bellevue and elsewhere throughout the Puget Sound region. Because introduced species can impact and even disrupt ecological systems, it is important that the City work with experts to manage the introduction of new species.

By assisting in the migration of Douglas fir found in southern United States, the iconic tree may continue to live throughout its historic range.
PATTE DAVID, US FISH AND WILDLIFE SERVICE

4. Wildland Fire Mitigation

Another way to protect species with wide geographical ranges is through assisted species migration. This would involve identifying and introducing trees that grow in areas with climates similar to expected future conditions. In theory, those species would be capable of withstanding or thriving in future conditions. Assisted species migration could be accomplished by partnering with climate and forest research organizations, such as the UW's School of Environmental and Forest Sciences. Native plant nurseries may serve as sources for trees adapted to different climatic conditions which could be transplanted in Bellevue and elsewhere throughout the Puget Sound region. Because introduced species can impact and even disrupt ecological systems, it is important that the City work with experts to manage the introduction of new species.

In the scenario characterized by rapid effects of climate change and accelerated urban development, threats posed by fires in the wildland urban interface (WUI) are significant. There are, fortunately, several strategies to prevent fire from impacting UTC:

1. The City can begin planning and updating FireWise, an educational program that teaches people to adapt to living in areas prone to wildfires.
2. The City can avoid planting flammable species (those with a high oil content and those that dry out in the summer months) and remove invasive species like English ivy (Hedera helix), which is oily and acts as a ladder fuel.
3. The City can simulate burns using mechanical thinning. This prevents fires from spreading. Simulated burns also mitigate the dispersal of pests and help maintain a balanced plant community.

Because many of these strategies require significant labor, we suggest that the City of Bellevue's Parks and Community Services department expand its volunteer activities to include shorter-term options, rather than year-long commitments. Many of these strategies could be incorporated into partnerships with the UW's School of Environmental and Forest Sciences and help the City protect and enhance UTC and Bellevue's "City-in-a-Park" aesthetic at less cost.

NFPA
FIREWISE USA™
Residents reducing wildfire risks
NATIONAL FIRE PROTECTION ASSOCIATION

CONCLUSION

The City of Bellevue is changing, as is the environment that sustains its rich network of parks and open spaces. In view of climate change and projected population growth, the opportunity looms to reimagine urban planning and align development practices with natural systems which support human well-being and livability.It is essential that the City consider how it can generate climate resilience while also accommodating urban growth. The stakes are high, as climate change will not only stress Bellevue's built environment and threaten its urban tree canopy, but also physically and emotionally stress the residents of Bellevue. The approaches and tools recommended in this report respond to likely scenarios, set in the future. Each of the focused sections offers starting points for the City to consider mitigation strategies and solutions, including:

- Providing access to shelters for people in need of refuge
- Increasing access to medical care
- Incentivizing renewable energy opportunities
- Promoting and dispersing mixed-use social infrastructures
- Retrofitting aging development
- Expanding the use of low impact development
- Redesigning parks
- Installing onsite water detention features in up-zoned areas
- Creating a comprehensive tree inventory
- Establishing a regional urban tree canopy climate stressors research organization
- Facilitating assisted species migration
- Improving wildland fire mitigation and adaptation

In view of climate change and projected population growth, the opportunity looms to reimagine urban planning and align development practices with natural systems which support human well-being and livability.

These recommendations emerged from three reports completed over the course of one academic quarter by graduate students enrolled in a Hazard Mitigation Planning course at the University of Washington. Each topic requires further investigation and investment. More time should be devoted to flushing out ideas and to exploring potential solutions. By combining various mitigation strategies, Bellevue can build resilience and face the compounding effects of climate change and urbanization. To cultivate equity and resilience, the City can dedicate resources to further study and develop an action plan to include and expand on many of our recommendations.

In the face of climate change and increased urbanization, Bellevue's parks will help pave the way toward a livable future. JOE MABEL

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