APPENDIX C
CLIMATE CHANGE VULNERABILITY ASSESSMENT

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MEMORANDUM

Date: March 17, 2016

Re: Climate Change Vulnerability Assessment for the City of Pasadena

INTRODUCTION

This memorandum provides a climate change vulnerability assessment for the City of Pasadena. The purpose of this assessment is to provide a preliminary evaluation of the potential impacts of climate change on community resources. This report categorizes community resources as people, structures, and functions. Understanding the vulnerabilities that Pasadena may face due to climate change hazards is a first step in identifying strategies aimed at improving Pasadena's resilience to climate change.

BACKGROUND

This vulnerability assessment is intended to help develop an understanding of the potential primary impacts of climate change on the community and was completed to begin to evaluate the degree to which physical, socioeconomic, and natural factors are susceptible to, or unable to accommodate, the anticipated effects of climate change. According to the Intergovernmental Panel on Climate Change (IPCC), in its Fifth Assessment Report, vulnerability is defined as "the propensity or predisposition to be adversely affected." It further adds that vulnerability "encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2013). Consistent with the Climate Adaptation Planning Guide (California Emergency Management Agency (CEMA) and California Natural Resources Agency (CNRA), 2012), this assessment is comprised of five primary components:

- **Exposure** – the nature and degree to which the community experiences a stress or hazard;
- **Sensitivity** – the aspects of the community (i.e., people, structures, and functions) most affected by the identified exposures;
- **Potential Impacts** – the nature and degree to which the community is affected by a given stressor, change, or disturbance;

- **Adaptive Capacity** – the ability to cope with extreme events, to make changes, or to transform to a greater extent, including the ability to moderate potential damages and to take advantage of opportunities; and
- **Risk and Onset** – the likeliness and expected timing of impacts.

It is anticipated that Pasadena will be exposed to a variety of unavoidable climate change effects. However, exposure to climate change hazards does not necessarily mean that the community will be sensitive to the effect. Whether individuals, property, and the environment are affected and to what degree depends on a number of factors, such as the ones listed above. Typically, climate change hazards would impact those people, structures, and functions that have the greatest exposure and sensitivity to climate change impacts the most, as well as the lowest adaptive capacity. For each climate related hazard, the population and economic sector that would be most vulnerable depends on the unique combination of these three factors (people, structures, and functions). For this vulnerability assessment, the years 1990, 2015, 2035, 2050, and 2100 were examined. The years 1990 and 2015 provide historic and current recorded data, while the years 2035, 2050 and 2100 present projections of expected change in the future.

Exploring California's Climate Change Research

There are a number of resources available and scientific groups attempting to more accurately define the potential risks of climate change. One of these tools specific to California is Cal-Adapt (cal-adapt.org), a web-based climate adaptation planning tool that allows the user to identify potential climate change risks in specific geographic areas throughout the state. Cal-Adapt was designed by University of California Berkeley's Geospatial Innovation Facility (GIF) with funding and oversight provided by the California Energy Commission (CEC) to provide access to data and information produced by the State's scientific and research community which offers a view of how climate change might affect California at the local level. Users can either search by location or use an interactive map to explore what climate impacts are projected to occur in a specific area of interest. Cal-Adapt synthesizes volumes of existing climate change scenarios and climate impact research and presents it in an easily available, graphical layout that is intended to benefit local planning efforts. Much of the information found at Cal-Adapt is based on downscaled Intergovernmental Panel on Climate Change (IPCC) models to describe how the climate may evolve in California. The source data used within the tool are available for download, as well as further information including research organizations that have developed the data, and relevant scientific publications. It is important to note that Cal-Adapt does not provide forecasts; however it does provide potential scenarios based on the most currently available science which can be used to inform local adaptation planning such as the development of climate action plan.

EXPOSURE: WHAT CLIMATE CHANGE EFFECTS WILL THE COMMUNITY EXPERIENCE?

Climate change is a global phenomenon that has the potential to impact local health, natural resources, infrastructure, emergency response, tourism, and many other facets of society. The direct changes projected for California include sea level rise, changed temperature and/or precipitation patterns, increased temperature, and wildfires. Secondary impacts occur as a result of primary impacts as shown in Table 1.

Table 1: Primary and Secondary Climate Change Impacts

Primary Impact	Associated Secondary Impacts
Sea level rise	Inundation, waterline change, extreme high tide, coastal erosion, saltwater intrusion
Changed temperature and/or precipitation patterns	Changed seasonal patterns
Increased temperature	Heat wave
Increased temperature and/or changed precipitation	Intense rainstorms, floods
Wildfire and/or increased precipitation	Landslide
Increased temperature and/or reduced precipitation	Drought, wildfire, reduced snowpack, reduced air quality

Source: CEMA and CNRA, 2012

Exposure to climate change is primarily a function of geography as such projected changes to the climate vary based on location. For example, coastal communities will have a higher exposure to sea level rise, while communities in the dessert may be more exposed to drought. According to Cal-Adapt, Pasadena can expect to experience extreme temperatures, changes in precipitation patterns, and increased storm frequency and intensity. Pasadena can also expect to experience hazards related to wildfires and sea level rise.

Extreme Temperatures

Average temperatures in Pasadena are expected to become 3.5°F to 6.0°F warmer by the end of the century, depending on emission levels (CEC, 2015). Greater warming is expected to occur in the early spring and late fall months compared to summer and winter. Pasadena is also expected to experience more extreme heat conditions. The annual number of heat waves, defined as four or more days over 96° F, is projected to increase from four to five heat waves per

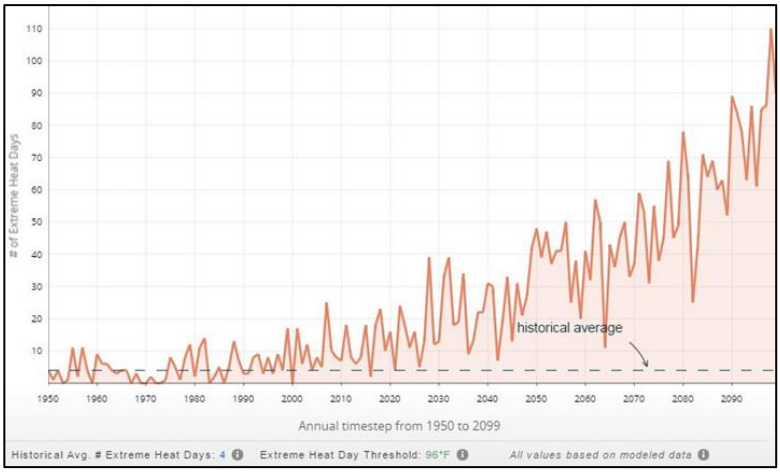

Figure 1: Number of Days with Extreme Heat (CEC, 2015)

year by 2050 and nearly 15 heat waves per year by 2100 (CEC, 2015). In addition, the annual number of extreme heat days, with temperatures greater than 96°F, is projected to increase from approximately 18 to 48 by 2050, and roughly 90 by the end of the century (refer to Figure 1). This combination could result in longer heat waves. It is predicted that the maximum duration of a heat wave would increase. In 2015, the maximum duration of a heat wave was approximately 5 days and by 2050 it is expected to increase to 8 days and by the end of the century to 26 days. The annual high temperature is also expected to increase. In 1990, the annual high temperature was 97°F, in 2015 it increased to approximately 103°F, by 2050 it is expected to increase to 105°F and further to 111°F by the end of the century.

Table 2: Temperature Extremes

Effect	1990	2015	2035	2050	2100[1]
# Days Extreme Heat per year	3	18	34	48	90
# Warm Nights per year	1	21	35	47	90
# Heat Waves per year	0	0	2	5	15
Max Duration of Heat Wave	0	4	5	8	26
Annual High Temperature °F	97	103	103	105	111
Period of Extreme Heat Days	July 27	July 10	Apr 24	June 16	May 28
	Sept 01	Sept 27	Sept 05	Oct 04	Oct 05

[1] 2099 data was used when 2100 data was unavailable.
Source: CEC, 2015

In addition, the timing of extreme heat days is expected to change. In 1990, the earliest day of extreme heat was July 27th and the latest day was September 1st; by the end of the century, the earliest day of extreme heat is expected to occur on May 28th with the latest day of extreme heat occurring on October 5th (CEC, 2015). This change would extend the period of extreme heat days by nearly three months.

Changes in Precipitation

Precipitation, except during winter months, is anticipated to change little in the near future. However, climate models forecast drier conditions in Pasadena by 2050, and even drier conditions by 2100. Average annual rainfall in Pasadena is expected to decrease from approximately 21 inches to 18 inches in 2050, and approximately 15 inches by the end of the century (Figure 2).[1] Based on the climate models, it appears that the timing of the rainy season may change as well.

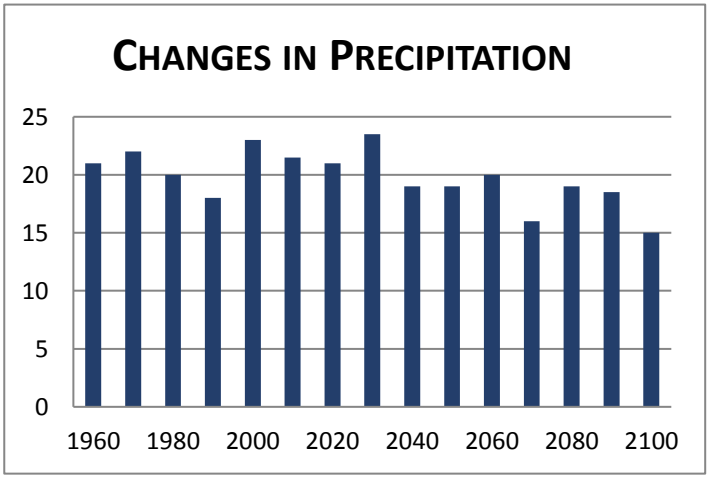

Figure 2: Precipitation: Decadal Averages Chart (CEC, 2015)

[1] Figure 2 is based on high emissions scenario.

The greatest amount of rainfall currently occurs between the months of December and March in Pasadena; the amount of rain during these months is expected to decrease by the end of the century. Likewise, in the future, the amount of rainfall may increase slightly over existing rates during the months of August and September. As a result of decreased rainfall, droughts may become more frequent, longer, and more severe. It is also projected that when rainfall does occur, it may be more likely to come in the form of intense downpours.

Increased Storm Frequency and Intensity

In combination with increased temperatures and changed precipitation, Pasadena is likely to experience altered seasons and intense rainstorms. Forecasts for these phenomena are currently unavailable in Cal-Adapt, but are acknowledged as possible outcomes. Intense rainstorms might result in increased flooding or trigger intense landslides that could impact infrastructure and human health and safety in Pasadena.

Fires

Although fire predictions in Cal-Adapt suggest a slight decrease in wildfire risk, with the implications of changes in temperature and precipitation, Pasadena would remain at risk. In particular, areas near the San Rafael Hills and the San Gabriel Mountains and other areas along the wildland-urban interface are subject to fire hazards. In addition, fires can also be generated by hazardous spills, earthquakes, and other natural disasters in areas that are not generally considered high-risk areas. These induced fires can pose additional risks to the developed and downtown areas of Pasadena that may be impacted by downed power lines, broken gas mains, and over turned appliances. Further, decreased water in the local reservoirs would exacerbate the problem and create challenges when fighting these urban and wildland fires.

Sea Level Rise

Pasadena is approximately 22 miles northeast of the Pacific Ocean and will not be directly affected by sea level rise. Overall, Los Angeles County has 3,951.7 acres that are currently vulnerable to a 100-year flood event and an additional 7,293.9 acres that would be vulnerable with 140 cm of sea-level-rise (CEC, 2015). Although sea level rise may not result in a direct physical impact to the city, Pasadena may be impacted by the indirect effects of sea level rise including population change, shift in jobs, and/or increased need for healthcare.

SENSITIVITY: WHAT ASPECTS OF THE COMMUNITY (STRUCTURES, FUNCTIONS, AND POPULATIONS) WILL BE AFFECTED?

Sensitivity is the degree to which a given community or ecosystem is affected by climatic stresses. For example, arid or semi-arid communities will be more sensitive than a tropical one to a decrease in rainfall, due to the subsequent impact on water flows.

Community Structures

Structures
☒ Residential
☒ Commercial
☒ Industrial
☒ Government
☒ Institutional (schools, churches, hospitals, prisons, etc.)
☒ Parks and open space
☒ Recreational facilities
☒ Transportation facilities and infrastructure
☐ Marine facilities
☒ Communication infrastructure
☐ Dikes and levees
☒ Water treatment plant and delivery infrastructure
☒ Wastewater treatment plant and collection infrastructure

Essential facilities such as hospitals and other medical facilities, police and fire stations, emergency operations centers, evacuation shelters, and schools are essential to the health and welfare of the population of Pasadena and are especially important following climate-influenced hazard events. The following community structures within Pasadena would be particularly sensitive to climate change:

- City Hall and all other municipal buildings, including 10 branch libraries throughout the City
- Huntington Memorial Hospital, Las Encinas Hospital, and various doctors' offices and medical entities
- Educational facilities, including Pasadena Unified School District's schools as well the Art Center College of Design, Caltech, and Pasadena Community College
- Rose Bowl Stadium, the 18th largest stadium in the world with a capacity for approximately 88,000 people
- Homeless shelters
- Pasadena's eight fire stations and five Police Department service areas.
- 2,400 acres of open space, including city parks, City-owned and privately owned golf courses, including Annandale and Brookside, and Arroyo Seco and Eaton Canyons, including utility owned lands in Eaton Canyon (City of Pasadena, 2012).

Sensitive facilities, such as dams, reservoirs, water treatment plants, and facilities that manage a large amount of hazardous waste, where damage would have large environmental, economic, or public safety consequences, are also considered particularly vulnerable to climate change including:

- Devil's Gate Dam, the first flood control dam in Los Angeles County built by the Los Angeles County Flood Control District in 1920, is used as a flood control dam between the communities of Pasadena, La Cañada Flintridge, and Altadena.

- City reservoirs (14) and wells (16), including: Sunset Treatment Plant and Reservoir, Jones Reservoir, and Eaton Reservoir
- Eaton Canyon stormwater detention/debris basin in the hills above Pasadena managed by Los Angeles County Department of Public Works (LACDPW) and U.S. Army Corps of Engineers (USACE). In addition, property owners in the hillside areas have constructed numerous small dikes to impound water.
- NASA's Jet Propulsion Laboratory (JPL) managed by California Institute of Technology (Caltech), located just outside the city boundaries, is a leading laboratory for construction and operation of planetary robotic spacecraft. This facility is leading the world in space exploration and is also considered a large-quantity hazardous waste generator. JPL is located within the recommended fault hazard management zone for Sierra Madre, and within a fire hazard area. According to the *Safety Element* of the General Plan, since JPL is also the largest user of hazardous materials in the area, there is a real potential for this site to negatively impact the surrounding area should an earthquake on the Sierra Madre fault, a wildfire, or alternative natural disaster cause hazardous materials to be released.
- Monk Hill Treatment Plant, a state-of-the-art water treatment plant established to remove perchlorate and volatile organic compounds (VOCs) from the groundwater near NASA-owned JPL, was funded by NASA and backed by the U.S. Environmental Protection Agency (EPA), California Department of Toxic Substances Control, and the Los Angeles Regional Water Quality Board.
- Pasadena Water and Power (PWP) facilities which provide water and power to the City of Pasadena and areas outside the city boundaries including unincorporated areas of southern Altadena, East Pasadena, Chapman Woods, and East San Gabriel. In 2014, PWP supplied over 30,000 acre-feet (approximately 10.50 billion gallons) of water, to serve more than 160,000 consumers and over 1 million megawatt hours (MWh) of electricity to serve more than 140,000 consumers (PWP, 2015).

Community Functions

Functions

☒ Government continuity
☒ Water/sewer/solid waste
☒ Energy delivery
☒ Emergency services
☒ Public safety
☒ Emotional and mental health
☒ Business continuity
☒ Housing access
☒ Employment and job access
☒ Food security
☒ Mobility, transportation, & access
☒ Quality of life
☒ Social services
☒ Ecological function
☒ Tourism
☒ Recreation
☒ Agriculture, forest, and fishery productivity
☒ Industrial Operations

Transportation Systems such as airways (airports, heliports, highways); bridges; tunnels; road beds; overpasses; transfer centers; and railways (tracks, tunnels, bridges, rail yards, depots) may be threatened by the impacts of climate change as well. Pasadena sits in the heart of Los Angeles County, located adjacent to State Route 134 (SR 134) and Interstates 210 and 710 (I-210 and I-710). State Route 110 (SR 110) also runs through Pasadena. In addition to vehicular transportation, Pasadena relies on a robust public transit system that may also be vulnerable to impacts of climate change. Pasadena is currently served by seven transportation agencies: Commuter Express, Foothill Transit, Glendale Bee Line, Metro, Montebello Bus Lines, Pasadena Area Rapid Transit System (ARTS), and South Pasadena Gold Link. As mentioned in the Mobility Element of the General Plan, Pasadena's local system connects with the larger regional system, and the operation of the two systems is interdependent. Impacts to the regional transportation system could therefore impact Pasadena. In 2004, Pasadena was recognized as the most bike-friendly city in Los Angeles County. Pasadena has 82 miles of bike routes that lead to jobs, shopping centers, schools, and Metro Gold Line Stations (City of Pasadena, 2015b). Pasadena has also prioritized pedestrian access by creating connectivity to neighborhoods through linking commercial areas to residential neighborhoods and other districts. Although highly popular among residents and tourists, use of the bike and pedestrian routes may decrease if temperatures increase to the point where active transportation is uncomfortable or unsafe in extreme heat conditions.

Lifeline utility systems such as potable water, wastewater, fuel, natural gas, electric power, and communication systems may also be particularly sensitive to a changing climate. Pasadena currently relies on PWP, a municipal utility which supplies power to a service population of 140,879 and water to a service population of 162,011 (PWP, 2015). Approximately 41 percent of PWP's water supply is groundwater from the Raymond Groundwater Basin, and is pumped from wells throughout the city; 58 percent of the water is imported from the Metropolitan Water District of Southern California (MWD), which acquires water from Northern California and the Colorado River; and the remaining 1 percent is purchased from neighboring water agencies, and is a combination of surface and groundwater (City of Pasadena, 2015g). The water distribution system consists of 520 miles of water mains, ranging from 2 to 36 inches in diameter; 17 booster stations; and 14 distribution reservoirs (PWP, 2015). Pasadena also has five service connections with MWD. Water from MWD is stored in reservoirs with a total capacity of 110 million gallons before it is put into the water distribution system. PWP owns and operates 16 wells that draw water from the Raymond Groundwater Basin and has developed 11

interconnections with neighboring water agencies to enhance the reliability of Pasadena's system and to use as emergency back-up (City of Pasadena, 2015c). The majority of Pasadena's wastewater is collected, treated, and disposed by the County Sanitation Districts of Los Angeles County No. 16, while a small portion of the southwest hillside area of Pasadena, comprised exclusively of single family homes, is tributary to the waste water collection, treatment, and disposal system owned and operated by the City of Los Angeles (City of Pasadena, 2015c); increased flooding could impact these wastewater management facilities.

Electricity provided by PWP increasingly comes from renewable sources of energy; however PWP also currently relies on traditional, non-renewable sources of energy as well. In 2013, PWP achieved a renewable portfolio standard of over 27 percent (PWP, 2015). Energy is moved from sources to substations over Pasadena's transmission system. At present, that system operates at 34 Kilovolts and is approximately 95% underground. Future transmission facilities, which may be of a higher voltage, will all be underground (City of Pasadena, 2015c). Energy is delivered to Pasadena at two locations: the Water and Power Department generating plants near the SR 110 Freeway, in the south-central portion of the city, and at the T. M. Goodrich Receiving Station in the eastern side of Pasadena, where energy is imported from sources outside the city.

Changes in climate could also have a substantial impact on Pasadena's economy, as tourism is a driving force, generating $475.4 million and supported 2,383 jobs in 2011 alone (City of Pasadena, 2015e). Pasadena's tourism is driven in part due to the temperate, Mediterranean climate and exciting annual events which draw millions each year, including the Tournament of Roses, Rose Parade, Rose Bowl, Doo Dah Parade, and Pasadena Chalk Festival (City of Pasadena, 2015e).

Populations

Some populations are more vulnerable than others to climate related exposures such as people who may require special response assistance or special medical care after a climate-influenced disaster. The 2009 California Climate Adaptation Strategy identifies those most at risk and vulnerable to climate-related illness as the elderly, individuals with chronic conditions such as heart and lung disease, diabetes, and mental illnesses, infants, the socially or economically disadvantaged, and those who work outdoors (CNRA, 2009). Of the non-elderly adult population in Pasadena, nearly 25 percent does not have medical insurance (City of Pasadena PHD, 2012); these individuals may face unique climate change impacts if they become ill or are injured in an extreme weather event.

Populations

☒ Seniors
☒ Children
☒ Individuals with disabilities
☒ Individuals with compromised immune systems or who are chronically ill
☒ Individuals without access lifelines (e.g. car or transit, telephones)
☒ Non-white communities
☒ Low-income, unemployed, or underemployed communities
☒ Individuals with limited English skills
☒ Renters
☒ Students
☒ Seasonal residents
☒ Individuals uncertain about available resources

The current population of Pasadena is 141,510 (DOF, 2015). Based on the 2014 U.S. Census, 14 percent of the population is 65 years or older and 19 percent of the population is under the age of 18 (with 6 percent under the age of 5) (Figure 3). These individuals may face unique impacts related to climate change. According to the findings from a recent United Nations Children's Fund (UNICEF) study, children are "physiologically and metabolically less able than adults at adapting to heat. The study recognizes that geography plays a role on the impacts of climate change that may affect specific populations, and acknowledges the fact that those with fewer resources have a more difficult time adapting.

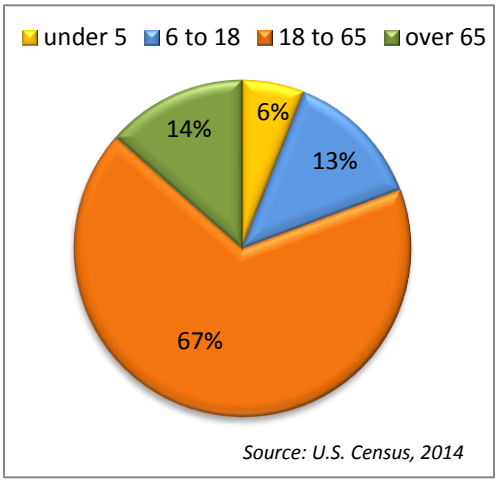

Figure 3: Pasadena Age Demographic

Financial wellbeing also impacts climate change sensitivity, as well as preparation, because those with a greater access to resources have a greater ability to prepare and adapt. While Pasadena has an average household income above the California average, over 10 percent of the population lives below the poverty line. According to the Pasadena Public Health Department, there is a broad geographic earning disparity within the city; on the northeast side of the city (91103 zip code), the 2012 median income was $44,358, compared to the southwest side of the city (91105 zip code), with a median income of $91,587 (City of Pasadena PHD, 2012).

In addition, many Pasadena residents speak a language other than English at home (44.6 percent vs. the California average of 43.7 percent) (U.S. Census, 2014), which may result in a language barriers in dissemination of information related to climate change preparation and emergency response.

POTENTIAL IMPACTS: HOW WILL CLIMATE CHANGE AFFECT THE POINTS OF SENSITIVITY?

As climate change continues to progress, increased stress to vulnerable populations and sectors of society are expected. In Pasadena, the most likely primary impacts of climate change include temperature extremes, changes in precipitation, and increased storm frequency and intensity. There is currently no recorded snowpack in Pasadena, and that is not expected to change over the next century. However, decreased snowpack in other areas of California will likely impact the water supply in the city due to a decrease in snowpack melt that supplies much of Southern California with potable water. Likewise, Pasadena is approximately 22 miles northeast of the Pacific Ocean and will not be directly affected by sea level rise; however, indirect effects (population change, shift in jobs, increased need for healthcare, etc.) of sea level rise may impact the city. The potential impacts of temperature extremes, changed precipitation, and increased storm frequency and intensity are discussed below.

Temperature Extremes

As describe above, Pasadena may experience a variety of impacts from climate change, which include an increase of 3.5°F to 6.0°F by the end of the century (CEC, 2015). This increase in temperature (which may result in changes in seasonal patterns, potential heat waves, drought, and increased storm frequency and intensity) has the potential to affect Pasadena through decreased public health, potential infrastructure damage, decreased economic viability, and decreased water supply.

Decreased Public Health

Public health may be negatively impacted by a changing climate as a result of changing environmental conditions (e.g., extreme weather events; changes in temperature and rainfall that decrease water supply; worsening air quality; and increases in allergens and air pollutants). This could lead to hazardous conditions, such as heat stroke and respiratory ailments for athletes, children playing outdoors, tourists attending community events, and construction laborers or others working outdoors. Potential impacts to public health include cardiovascular disease; exacerbation of asthma, allergies, and chronic obstructive pulmonary disease (COPD); increased risk of skin cancer and cataracts; premature death; cardiovascular stress and failure; and heat-related illnesses such as heat stroke, heat exhaustion, and kidney stones (CEMA and CNRA, 2012). Those in the community without health insurance, which includes nearly 25 percent of the non-elderly adult population, are particularly vulnerable. As described above, more than 10 percent of all Pasadena residents live below the poverty line (U.S. Census, 2014). With anticipated increases in temperature, these economically disadvantaged residents may find it more difficult to afford the additional costs of cooling their homes. Likewise, those without access to public transit or who do not own vehicles may be at increased risk because they may be unable to go to cooler areas or community cooling centers (Shonkoff et al. 2009). Consequently, many low-income households, especially those of seniors and the disabled may become physically vulnerable to the effects of extreme heat events.

Changing temperatures may also impact vulnerable youth populations as nearly 20 percent of the population within Pasadena is under the age of 18 (U.S. Census, 2014). In particular, children are "especially susceptible to air and water quality, temperature, humidity and vector-borne infections due to their less-developed physiology and immune system." These health concerns are not just physical; children can be impacted psychologically as well, which could result in a loss of self-confidence, nervousness, and insomnia (UNICEF, 2011). This additional stress on children's systems could affect them into adulthood and result in lifelong ailments. Climate change impacts on the youth populations may extend past their personal development and into their family and social lives through the impacts of increased food prices, spread of disease and illness, and potential competition over natural resources (Jones, 2011).

Changes in temperature may also indirectly impact human health through impacts to biological species and natural habitat, such as increases in the incidence of vectorborne disease (World Health Organization, 2015). According to the World Health Organization (WHO), insects have no internal control over their body temperature, and as ambient temperatures rise, the

distribution of insects may expand through increased reproductive rate, biting behavior, and survival (2015). Additionally, they state that the incubation period for pathogens within vectors is also temperature-dependent, and the period often becomes shorter as conditions warm (WHO, 2015). This will result in pathogens developing and spreading more quickly; susceptibility to disease may increase.

As rising temperature impacts public health, community resources such as Huntington Memorial Hospital, Las Encinas Hospital, and various doctors' offices and medical entities may be impacted by an increased need for various health care services including heat and respiratory care. Although Pasadena currently has a strong healthcare sector, climate driven health concerns may necessitate additional growth and expansion.

Infrastructure Damage

Community infrastructure including PWP facilities and the Pasadena's transportation system may also be impacted by increased temperatures. Long periods of intense heat may result in an increase use of electricity for home cooling purposes that could tax the system and result in electricity restrictions or black-outs. In addition, cyclists and active-commuters could be impacted by increased temperatures and could suffer from heat related illnesses and be less inclined to ride their bikes for transportation if the temperatures continue to climb. This would increase demand on other aspects of the transportation system including public transit and city roadways, which may also exacerbate worsening air quality conditions.

Decreased Economic Viability

As mentioned above, increases in temperature could also have a substantial impact to Pasadena's economy, as tourism is a driving force, generating $475.4 million and supporting 2,383 jobs in 2011 alone (City of Pasadena, 2015e). Increased temperatures may result in uncomfortable and unsafe conditions for tourists, athletes, and event staff, thus reducing the attendance at and associated income generated by outdoor recreational activities and events within the city.

Decreased Water Supply

High temperatures may also contribute to a reduced water supply. For instance, higher temperatures will melt the Sierra snowpack earlier and drive the snowline higher, in addition to the reduction in precipitation, which will result in less snowpack to supply water to California users (CNRA, 2009). Increased temperatures could therefore result in decreased potable water supply for the city which relies on local groundwater as well as imported water from water projects. Currently, many water supply wells and reservoirs in Pasadena are operating at seriously diminished capacities, including two wells which were taken out of service in 2014 due to low groundwater levels (PWP, 2015). As mentioned, there are a total of 14 reservoirs throughout Pasadena that range in capacity from the Jones Reservoir, which can hold approximately 50 million gallons of water to the Lida Reservoir, which has the smallest capacity of Pasadena's reservoirs and can hold approximately 0.43 million gallons of water (City of Pasadena, 2015d). Impacts of a decreased water supply are discussed in greater detail below.

Changes in Precipitation

Decreased precipitation will result in more frequent and persistent droughts, especially in combination with increased temperatures which would result in decreased water supply, decreased water quality, decreased public health, reduced viability of natural landscapes, and increased risk of wildfires.

Decreased Water Supply

Approximately 41 percent of PWP's water supply is groundwater from the Raymond Groundwater Basin, and is pumped from wells throughout the city; 58 percent of the water is imported from the Metropolitan Water District of Southern California (MWD), which acquires water from Northern California and the Colorado River; and the remaining 1 percent is purchased from neighboring water agencies, and is a combination of surface and groundwater (City of Pasadena, 2015g). Based on the current water supply, without intervention, Pasadena may expect a 17 percent shortfall in water supply by 2035 (City of Pasadena Public Health Department (PHD), 2012). Further decreases in precipitation and Sierra snow pack may directly impact the city's water supply and could cause water prices to increase. Increased water prices would impact potable water used in residential, retail, and commercial uses. Additionally, increased prices and decreased water supply would affect emergency response availability. The current drought has already impacted the Pasadena's water supply; groundwater levels have dropped 20 to 60 feet and two wells have been taken out of service due to low groundwater levels (City of Pasadena, 2015g).

Decreased Water Quality

In addition to the decrease in Pasadena's groundwater levels, some residents have noticed that their tap water has been unusually hard and/or cloudy (City of Pasadena, 2015g). Decreased water quality or supply during drought is more likely to affect Pasadena because a large portion of the community's water is supplied by groundwater or imported from other water projects. Drought may cause a decrease in water quality and increase the levels of chemical concentration, nutrients, or solid particulates, or decrease the dissolved oxygen level (Stanke, et. al., 2013). Water quality can decrease further when rainfall follows a prolonged period of low-precipitation because chemicals accumulate on the ground and roads and are washed into the rivers. If water quality decreases to a level where it is no longer potable, a shortage would ensure. Bottled drinking water could be purchased, however, as with all impacts, risk is not dispersed evenly. Poor water quality would likely impact the economically disadvantaged sector of the community to a greater extent than it would the affluent, because bottled water is sold at a much higher price per gallon than water provided by the municipal provider.

Decreased Public Health

Although not currently a health risk, a continued decrease in water supply and quality may result in community health impacts or a shortage of potable water. This decrease in water availability could cause health effects associated with drought that include impacts on nutrition, water-related disease, airborne and dust-related disease, vector-borne disease, and other health impacts. One of the greatest risks of prolonged drought are impacts on nutrition, however,

populations in developed countries do not usually experience drought-associated malnutrition because food is sourced from geographically diverse suppliers and can be purchased from different locations if drought-driven problems with agricultural production arise (Stanke, et. al., 2013). Nonetheless, reduced water availability may result in an increase in the price of produce, thus potentially affecting the nutritional availability for the community, particularly for the economically disadvantaged.

Reduced Viability of Natural Landscapes

Decreased precipitation and drought would also impact Pasadena's 2,400 acres of open space, including city parks, city-owned and privately owned golf courses, such as Annandale and Brookside, and Arroyo Seco and Eaton Canyons, including utility owned lands in Eaton Canyon. Without sufficient water the native environment may not be able to sustain itself, resulting in disease or death of natural landscapes as well reduced opportunities for community recreation. Decreased community recreation opportunities may drive residents and tourists to visit other communities for recreational outlets and reduce the amount of activity-driven tourism.

Increased Risk of Wildfires

Decreased precipitation and drought may indirectly result in increased risk of wildfires through drier natural landscapes in close proximity to the community. As mentioned above, Pasadena is bordered by Angeles National Forest and is vulnerable to wildfire hazards. Portions of the San Rafael Hills and the San Gabriel Mountains within city limits are mapped as having fire hazards due to the steep topography of the area and the presence of flammable vegetation. Decreased precipitation may result in increased dry, flammable vegetation and combined with increased temperatures, could result in increased wildfires. Additionally, wildfires often precede other events including landslides, which could further impact the city. According to the General Plan, JPL has the potential to negatively impact the surrounding area should an earthquake on the Sierra Madre fault or a wildfire cause hazardous materials to be released (City of Pasadena, 2002). Proper maintenance of dry vegetation and JPL facilities will be increasingly important into the future. Further, decreased water in the local reservoirs would exacerbate the problem and create challenges when fighting these urban and wildland fires. In addition to the direct impacts of fires, poor air quality due to smoke would further impact the community if fire frequency increased.

Increased Frequency and Severity of Storm Events

As mentioned above, the frequency and severity of storm events could increase, even if precipitation levels do not. This could result in impacts to community infrastructure and well as human health and safety particularly related to flooding and landslides.

Flooding and Landslides

The region may see more severe (but not necessarily more frequent) rainfall events, leading to quick pulses of runoff. Within developed cities such as Pasadena, large amounts of impervious pavement prevent much of the rain from infiltrating into the ground. More rain falling in a

shorter time frame, in combination with large amounts of impervious surfaces increases the risk of flooding. In addition, since Pasadena is located in the foothills, the frequency and intensity of landslides may also increase. Hillside areas within Pasadena may be vulnerable to slope instability due primarily to the fractured, crushed, and weathered condition of the bedrock and steep terrain (City of Pasadena, 2002). The Arroyo Seco, on the west, and Eaton Wash on the east, are the two major stream channels that transect the city. Landslides have occurred previously in many of the canyons near the Pasadena area, in the upper reaches of the watersheds; specifically, Zachau, Rubio, and Shields Canyons have flooded in the past, and are likely to occur again (City of Pasadena, 2002). As would be predicted, landslides are more likely to occur in wet years following wildland fires. According to the *Safety Element* of the General Plan, if Devil's Gate Reservoir fails catastrophically, most of the water will be confined to the Arroyo Seco channel, but it may impact the Rose Bowl and other developed areas both north and south of the I-210. If Eaton Wash Dam failed, the inundation may impact residential and commercial areas located downstream of the dam, north of the I-210.

Infrastructure

Increased flooding may result in septic systems and sewage treatment plants being unable to handle increases in intense rainfall events and associated runoff. This could impede the proper functioning of on-site septic systems or overwhelm sewers and centralized sewage treatment plants. As a result, untreated water, with a full load of toxics and organic waste, could enter streams and coastal waters.

Infrastructure located within or adjacent to floodplains could be more susceptible to damage or disruption by larger than average precipitation events. Devil's Gate Dam is located between the communities of Pasadena, La Cañada Flintridge, and Altadena. The flood basin located above the dam, which captures the water that flows from the mountain, was filled with debris after the 2009 Station Fire and subsequent rains. In 2014, a five-year project was approved to remove 2.4 million cubic yards of sediment from the basin to reduce flood risk for most major storms. Although the project is currently underway, prior to completion of the project, an intense flood may result in an increased risk of flooding.

Flooding and landsides may also impact Pasadena's transportation network inhibiting movement of people and goods throughout the city. Emergency response systems would similarly be affected by flooding and landslides through restricted access to and from emergency response systems, increasing wait times for these crucial services. Communication to these entities may also be impacted if electricity transmission is interrupted or water/other natural resources are unavailable.

Decreased Public Health and Safety

Public health and safety may be directly impacted by injury and or death of community members resulting from large floods and/or landslides. Public health may also be indirectly impacted by reduced access to emergency response and health centers resulting from infrastructure impacts discussed above.

ADAPTIVE CAPACITY: WHAT IS CURRENTLY BEING DONE TO ADDRESS THE IMPACTS?

Adaptive capacity is the current ability to address the potential impacts of climate change (CEMA and CNRA, 2012) and includes adjustments in behavior, resources, and technologies (IPCC, 2007). Pasadena recognizes its role of leadership and has actively taken steps to increase the city's adaptive capacity, which include promoting disaster preparedness. Adaptive capacity also includes recognizing opportunities to take advantage of impacts from climate change. Pasadena uses a set of guiding documents with underlying emphasis on adaptive capacity which include but are not limited to:

Table 3: Pasadena Guiding Planning Documents

Document	Year Established
General Plan[1]	2002, 2007, 2015
Water System Master Plan	2002
Hahamongna Watershed Park Master Plan	2003
Specific Plans: Central District, South Fair Oaks, West Gateway, East Pasadena, East Colorado Boulevard, North Lake, Fair Oaks/Orange Grove, and Lincoln Avenue	2004
Neighborhood Traffic Management Plan	2004
Arroyo Seco Master Plans	2003, 2005
Green City Action Plan/Report	2006 - 2010
Pasadena Pedestrian Plan	2006
Safe Routes to School Plan	2006
Cultural Nexus Implementation Report	2007 - 2008
Central Park Master Plan	2007
Green Space, Recreation and Parks Master Plan	2007
Master Sewer Plan	2007
Recreation and Parks Master Plan	2007
Pasadena Groundwater Storage Program	2008
Green City Indicator Report	2008 - 2010
PWP Annual Report	2008 – 2014
Intelligent Transportation System Master Plan	2009
Comprehensive Water Conservation Plan	2009
Urban Water Management Plan	2011
Plastic Bag Ordinance 7214	2011
PWP's 25-year Water Integrated Resource Plan (WIRP)	2011
Emergency Operations Plan	2011
Economic Development Strategic Plan	2012
Power Integrated Resource Plan	2012
City of Pasadena Greenhouse Gas Inventory	2013
Short Range Transit Plan	2013
Community Health Improvement Plan	2014
Bicycle Transportation Action Plan	2015

[1] The General Plan was originally approved in 2002. The Green Space, Recreation, and Parks Element was completed in 207 and the Land Use and Planning and Mobility Elements were updated in 2015.

Several examples of adaptive planning are outlined in detail in the Pasadena General Plan *Safety Element*. This section of the General Plan sets forth policies and programs to minimize fatalities and injuries, the burden on public and emergency response resources, public and private costs for clean-up, repair, and recovery, and long-term impacts caused by displaced households, business disruption, and reduced fiscal resources (City of Pasadena, 2002). Policy S-4 of the *Safety Element* states that, "*the City will ensure to the fullest extent possible that, in the event of a major disaster, essential structures and facilities remain safe and functional, as required by current law. Essential facilities include hospitals, police stations, fire stations, emergency operation centers, communication centers, generators and substations, and reservoirs.*" This policy would apply to impacts from climate change identified above including heat waves, drought, flooding, fire, and storm events. Further, the *Safety Element* specifically outlines policies and programs to reduce impacts from various hazards that may impact the community such as seismic hazards, geologic hazards, flood hazards, fire hazards, hazardous materials, and disaster response planning.

Long-term projects to improve adaptive capacity and promote water security in the city include the Non-Potable Water Project, Eastside Well Collector and Centralized Disinfection Facility Project, and the Arroyo Seco Canyon Project, which are all outlined in PWP's 25-year Water Integrated Resource Plan (WIRP), adopted by City Council in 2011. The non-potable water pipeline will supply treated, recycled water from the Los Angeles-Glendale Water Reclamation plant and/or tunnel water to the city for irrigating public landscaped areas. This project will save the city 700 acre-feet of potable water per year in the first phase, and could save the city over 3,000 acre-feet of water per year upon build-out (City of Pasadena, 2015g). PWP has installed over 23,000 linear feet of pipeline in conjunction with the Eastside Well Collector and Centralized Disinfection Facility Project, which increases the reliability of groundwater well production and provides a more consistent water supply. The Collector pipeline and connections to five wells are completed and will allow flow to the Jones Reservoir for centralized disinfection (City of Pasadena, 2015g). These measures will help ensure PWP is able to supply a sustainable water supply to the City of Pasadena into the future, despite a predicted decrease in precipitation. Pasadena is also working on the Arroyo Seco Canyon Project which is an integrated resource project that includes restoring a portion of the Arroyo Seco Stream and increasing diversion of the Pasadena's water rights during large storm events when stream water is more readily available. The goal is to increase the local recharge that could result in an increase of 600 acre-feet per year of additional groundwater.

Additional improvements are outlined in the WIRP that will enhance Pasadena's adaptive capacity, including replacing approximately 3.0 miles of aging water mains and 2,000 water meters with Automatic Meter Read devices per year, upgrades to multiple facilities, and completion of new disinfection facilities. These initiatives enable the city to reduce its dependency on the imported water, and provide a reliable long-term water supply for the city. PWP, in conjunction with MWD, offers a variety of incentives and rebates that help expand the community's adaptive capacity as well, and encourage residents to replace their ornamental turf lawns with drought tolerant gardens and take other active measures to reduce water

consumption. Programs include irrigation retrofits, turf removal, landscape surveys, greywater systems, and rain barrel programs which will become increasingly important in times of increased temperatures and decreased precipitation. On average, ornamental turf accounts for about 60% of the average residential customer's water bill (City of Pasadena, 2015g). Replacing this turf with drought tolerant landscaping, permeable groundcover, and mulch promotes groundwater recharge while avoiding excess water usage as the climate changes. The City of Pasadena's overall adaptive capacity would be considered medium to high. There is secure infrastructure in place to protect people and land as the climate changes which include a robust safety and protection services and health care sector. Pasadena may be most impacted by health and human safety concerns related to the increased temperature and decreased precipitation that may result in problems such as heat stroke, dehydration, and other health problems. In addition, the city has access to technology that may allow Pasadena to further adapt to the changes in climate. According to the IPCC, efficient cooling systems, improved seeds, desalination technologies, and other engineering solutions represent some of the options that can lead to improved outcomes and increased coping under conditions of climate change (IPCC, 2007). It's been noted that strong local and international support networks enable communities to recover from and prepare for storms (IPCC, 2007). Pasadena is founded on a strong network that will allow the city to prepare and encourage long-term solutions that improve adaptive capacity.

In addition to the measures currently being implemented by the city, additional measures should be adopted requiring unique actions going forward to maintain and improve upon the city's current adaptive capacity. Specifically, the areas related to climate change vulnerability that provide the greatest opportunity for growth in Pasadena include preparing for extreme heat events, changes in precipitation and wildfires, as well improving outreach to vulnerable populations such as the elderly, youth, and non-English speakers. In addition, the *Safety Element*'s discussion of disaster response planning could be updated to include a more robust discussion of the impacts of climate change and the preparation necessary to adapt to a changing climate.

RISK AND ONSET: HOW LIKELY ARE THE IMPACTS AND HOW QUICKLY WILL THEY OCCUR?

Risk is defined as the likelihood or probability that a certain magnitude/extent/scale of potential impact will occur (CEMA and CNRA, 2012). For each impact, a level of uncertainty, based on the probability of the primary or secondary exposures is assigned.

Table 4: Probability Based on Global Models

Driver	% Probability (IPCC)	Certainty Rating
Temperature Change	>90%	High
Precipitation Change	>66%	Medium

Source: IPCC 2007

For each secondary impact, a low, medium, or high uncertainty was estimated based on the most conservative driver from Table 4 above.

Table 5: Probability of Secondary Impacts Based on Global Models

Primary Impact	Associated Secondary Impacts	Certainty Rating	Timeline for Expected Impacts[1]
Changed temperature and/or precipitation patterns	Changed seasonal patterns	Medium	Near-term
Increased temperature	Heat wave	High	Mid-term
Increased temperature and/or changed precipitation	Intense rainstorms	Medium	Mid-term
Increased temperature and/or reduced precipitation	Drought, wildfire, reduced snowpack	Medium	Near-term

Source: CEMA and CNRA, 2012
1 Timeline: Current: impacts currently going on; Near-term: 2020-2040; Mid-term: 2040-2070; and Long-term: 2070-2100.

CONCLUSION

Climate change will affect populations throughout the state, nation, and the world differently based on their actual and perceived vulnerabilities. The major impacts of climate change that are expected to affect Pasadena include temperature extremes, changes in precipitation, increased frequency and severity of storm events, and increased fires. Identifying potential hazards and understanding Pasadena's potential vulnerabilities is a first step towards improving the community's resiliency.

REFERENCES

California Energy Commission, State of. (2015). Cal-Adapt: Exploring California's Climate Change Research. Retrieved from: http://resources.ca.gov/docs/climate/01APG_Planning_for_Adaptive_Communities.pdf

California Emergency Management Agency, State of and California Natural Resources Agency, State of. (2012). *California Adaptation Planning Guide*. Retrieved from: http://resources.ca.gov/docs/climate/01APG_Planning_for_Adaptive_Communities.pdf

California Natural Resources Agency, State of. (2009). *2009 California Climate Adaptation Strategy*. Retrieved from: http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF

Department of Finance (DOF). (2015). *New State Population Report: California Grew by 358,000 Residents in 2014*. Retrieved from: http://www.dof.ca.gov/research/demographic/reports/estimates/e-1/documents/E-1_2015PressRelease.pdf

Intergovernmental Panel on Climate Change (IPCC). (2013*). IPCC Fifth Assessment Report: Climate Change 2013. Working Group I: The Physical Science Basis*. Retrieved from: http://www.ipcc.ch/report/ar5/wg1/

Pasadena, City of. (2015a). City of Pasadena General Plan *Land Use Element*. Retrieved from: http://cityofpasadena.net/GeneralPlan/

Pasadena, City of. (2012). *General Plan Update: Draft Open Space and Conservation Element.* Retrieved from: http://cityofpasadena.net/Planning/CommunityPlanning/Open_Space/

Pasadena, City of. (2015b). *Getting Around Pasadena Without Your Car.* Retrieved from: http://cityofpasadena.net/Getting_Around_Pasadena_Without_A_Car/

Pasadena, City of. (2015c). *Mobility Element: Department of Transportation*. Retrieved from: http://cityofpasadena.net/GeneralPlan/

Pasadena, City of. (2015d). *Pasadena Facts*. Retrieved from: http://cityofpasadena.net/Pasadena_Facts_and_Statistics/

Pasadena, City of. (2015e). *Pasadena Tourism Helps Boost Local Economy*. Retrieved from: http://www.cityofpasadena.net/EkContent.aspx?theme=Navy&id=8589937388&bid=0&style=news

Pasadena, City of. (2015f). *Planning Community Development.* Retrieved from: http://cityofpasadena.net/GreenCity/

Pasadena, City of. (2002). *Safety Element of the General Plan*. Retrieved from: http://cityofpasadena.net/planning/CommunityPlanning/General_Plan_Safety_Element/

Pasadena, City of. (2015g). *Water Quality Reports.* Retrieved from: http://www.cityofpasadena.net/waterandpower/waterquality/

Pasadena Water and Power (PWP). (2015). 2014 Annual Report. Retrieved from: file:///C:/Users/hmize/Downloads/2014%20Annual%20Report%20-%20Revised%201-20-15%20(2).pdf

Public Health Department, Pasadena, City of. (2012). Pasadena Altadena Quality of Life Index 2012. Retrieved from: http://www.naccho.org/topics/infrastructure/accreditation/upload/pasadena-cha-quality-of-life-index.pdf

United Nations Children's Fund (UNICEF). (2011). *Children and Climate Change: Children's Vulnerability to Climate Change and Disaster Impacts in East Asia and the Pacific.* Retrieved from: http://www.unicef.org/media/files/Climate_Change_Regional_Report_14_Nov_final.pdf

United States Bureau of the Census. (2013). *American Community Survey.* 2009 – 2013. Retrieved from: http://quickfacts.census.gov/qfd/states/06/0656000.html

World Health Organization. (2015). *Malaria, other vectorborne and parasitic diseases programme.* Retrieved from: http://www.wpro.who.int/mvp/climate_change/about/en/