APPENDIX B




CLIMATE CHANGE VULNERABILITY ASSESSMENT MATRICES & PRIORITY VULNERABILITIES

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Climate Change Vulnerability Assessment Matrices & Priority Vulnerabilities
City of Salem, Massachusetts

Approach

VULNERABILITY ASSESSMENT:

The first half of the matrices in this document (columns labeled as "Vulnerability Assessment") constitute the data for the vulnerability assessment. The rows in each matrix identify unique stresses on components in the sector (column called "Current and future stresses to this component as a result of climate impact") for each of the projected climate change impacts. In each row, the sensitivity, adaptive capacity, and overall vulnerability of the component to this climate impact have been identified and given a preliminary ranking. The source information for these data are interviews with several City Staff, GIS data collected by the City and CDM Smith, and sector-specific analyses of projected impacts to known components within a sector. These data and rankings will be validated, allowing a final analysis that will sort the climate vulnerabilities by priority.

There are a number of common themes throughout the sectors and impacts, most notably flooding. Two or more different climate impacts can both yield the same types of stresses impacting the same components, for example, extreme precipitation and storm surge both can cause flooding that stresses the stormwater drainage system. The repetition of similar information for each impact/stress/asset combination is necessary for querying and sorting of the data.

PRIORITY VULNERABILITIES:

The second half of the matrices (columns labeled as "Priority Vulnerabilities") prioritize the vulnerabilities, based on two methods: 1) a risk assessment and 2) evaluation criteria.

Risk Assessment:

The risk assessment determines the risk of a climate impact and stress to the component based on the economic, health and safety, cultural and historical, and ecological and environmental consequences to the component and the likelihood that the climate impact will occur. Vulnerabilities that are determined to be at high risk and are high vulnerability will be consi dered for adaptation strategies.

Evaluation Criteria:

The second method for prioritizing vulnerabilities is incorporating the City's particular opportunities and concerns. If a particular vulnerability that has not been ranked high risk/high vulnerability, but instead aligns with existing plans, policies, or programs, funding availability, or the city has control over the implementation, these vulnerabilities may also be considered for adaptation strategies.

Next Steps ADAPTATION STRATEGIES:

The next phase of the project are to develop Adaptation Strategies for the Prioritized Vulnerabilities. These will include stresses that are determined to: 1) have a high risk and high vulnerability to the climate impact, and 2) fit within the City's priority areas based on the evaluation criteria. The details may be found in Appendix C, Climate Change Adaptation Strategies.

Climate Impacts Appendix A, Technical Memorandum on Potential Climate Change Impacts in Salem, MA, described the possible climate change impacts that the City faces. Based on that information, the City and the Working Group decided to focus on four key climate change impacts that inform the vulnerability assessment and priority vulnerabilities. They are:

- Extreme heat events: The number of days over 90˚F will increase from 7 days per year to 18 days per year by 2050.
- Extreme precipitation events: The frequency of a storm as intense as the current 100-year storm will increase by 2050, making it roughly a 77-year storm.
- Sea level rise: The mean high high water will be 9.03ft, an increase of 4.27 ft above the baseline by 2100.
- Storm surge: With sea level rise, storm surge will be 13.03ft for a 100-year storm. This is an increase of 4.23ft from baseline by 2100.

Sectors The following sectors are included in this analysis:

- *Critical Building Infrastructure (CB):* Critical City Facilities (Department of Public Works facility, South Essex Sewerage District, City Hall, recreational facilities), emergency facilities (police, fire, hospitals, schools), historical and culturally significant buildings and areas, Salem State University, seawalls, tide gates
- *Water (W):* Plants, pumping stations, supply, distribution
- *Energy (E):* Electricity supply, transmission and distribution equipment, power lines, substations, natural gas supply, transmission and distribution lines, iquefied natural gas storage (LNG), renewable energy installations, emergency back-up power, streetlights
- *Stormwater (SW):* Stormwater pipes, drainage areas, pump stations, discharge locations
- *Transportation (T):* Roadways, rail, bus lines, ferry service, sidewalks, bike paths
- *Vulnerable Populations (VP):* Disproportionally impacted people within the City, including (elderly, children, low-income, homeless, disabled, non-native English speakers)

Definitions *The following terms are used in the Vulnerability Assessment:*

- Sector: A cohesive system within the City that may be impacted by climate change. It is made up of many components. In Salem, sectors included in this Plan are critical building infrastructure, water, energy, stormwater, transportation, and vulnerable populations.
- Component: An individual item in a sector, including the infrastructure, policies, and programs that people in the City use and rely on. They may be owned and operated by the City, or they may be run by a third party - such as a state agency or private company.
- Stress: A problem arising to a sector or component due to one or more climate change impacts.

- Sensitivity: The degree to which a component is directly or indirectly affected by the stresses resulting from climate change impacts. Sensitivity is composed of a component's exposure to the climate change impact and the known or predicted effects of the impact on the component.

- Adaptive Capacity: The component’s ability to accommodate to the stresses resulting from climate change impacts. It also considers the ability of the component to return to normalcy after a disruption. It is closely related to resiliency.

The following terms are used in the Risk Assessment:

• Consequence: The known and estimated impact due to climate change. In Salem, economic, health and safety, cultural and historical, and ecological and environmental consequences were assessed as part of the risk assessment. All consequences will be ranked using the same low (1) - high (5) scale as was used for ranking the sensitivity and adaptive capacity of each component.
• Economic Consequences: the known and estimated consequences both to the City government's finances and city-wide economic consequences. On the City government side, they include changes to city-owned property, tax base/income, and costs for capital and maintenance projects. City-wide economic consequences include change in business revenues, private property capital and maintenance projects, changes in tourism spending.
• Health and Safety Consequences: the known and estimated impacts to the well-being of the people who live, work, and visit Salem in both day-to-day public health and emergency situations.

• Cultural and Historical Consequences: the known and estimated impacts to buildings and areas that hold cultural or historical significance; these are the areas that define Salem's identity.

• Ecological and Environmental Consequences: the known and estimated consequences that cause alternations to natural resources, habitats, organisms, and open spaces.
• Likelihood: The probability of the climate change impact occurring based on the IPCC. They are based on the type, amount, quality, and consistency of evidence that a given climate change impact will occur. Climate change impacts are categorized with "Level of Confidence" rankings of virtually certain (99-100%), extremely likely (95-100%), very likely (90-100%), likely (66-100%), more likely than not (>50-100%), about as likely as not (33-66%), unlikely (0-33%), very unlikely (0-10%), extremely unlikely (0-5%), and exceptionally unlikely (0-1%).

• Risk: A function of the consequences of climate change times the likelihood of climate change. This is used to prioritize the vulnerabilities.

The following terms are used to determine the Evaluation Criteria/City Priority Areas:
• Alignment with existing plans, policies, or programs: the city has current plans, policies, or programs related to the vulnerable component, and a related adaptation strategy would further existing City goals.
• Funding availability: known outside funding is available (especially through grants) at the time of the evaluation.
• City control over implementation: the City has a high level (if not total control) over the component, and therefore can implement an adaptation strategy with fewer institutional barriers.

			VULNERABILITY ASSESSMENT								
			Sensitivity				Adaptive Capacity			Vulnerability	
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	How is this climate impact currently stressing the component?	How will this climate impact stress the component in the future?	If no action is taken, how much will climate impact worsen the stress to the component?	What is the overall sensitivity of this component?	Ability of the component to accommodate future impacts with minimum disruption or cost	What are the barriers to the component to accommodate impacts?	What is the overall adaptive capacity of this component?	Explanation/summary of vulnerability rating.	What is the overall vulnerability of the component?
CB1	Extreme heat events	**Property damage to historic properties**	No current stress.	Extreme heat events may impact historic building materials and historical artifacts, such as those at the Peabody Essex Museum.	Damage of historically and culturally significant property.	2 - Medium-low	Air temperature and humidity controls may be installed at some properties.	Cost, feasibility of installations at some facilities.	5 - High	Heat may cause additional damage to historic properties, which may be addressed with current cooling technologies.	1 - Low
CB2	Extreme precipitation events	**Property damage or loss of emergency and critical city facilities**	Flooding currently occurs near the DPW and Police headquarters near Canal Street. DPW has flooded from extreme precipitation events.	Flooding from extreme precipitation events may impact more critical facilities, in addition to those that currently experience problems including: the SESD Wastewater Treatment Facility, City Hall, and Fire Department Headquarters.	Flooded emergency facilities may impact public safety by increasing the response time and communications. The emergency response plan may need to address how to access to areas cut-off by flooding. There may be potential public health and ecological impacts if other critical facilities flood such as the SESD Wastewater Treatment Facility. Impacts may occur beyond the storm event, depending on the severity of the damage.	4 - Medium-high	Salem is conducting flood control/drainage projects, including a $15M-$20M phased project underway at Canal Street. Facilities have currently managed during flooding while providing service. Other fire stations and the hospital are not at risk for flooding from extreme precipitation events.	Cost of retrofitting buildings and communication services, continuing to provide services with more frequent and severe flooding.	2 - Medium-low	If flooding becomes more severe at these critical facilities, providing the needed level of service will become impaired. This may put public safety at risk.	3 - Medium
CB3	Extreme precipitation events	**Property damage or loss of power infrastructure**	Flooding currently occurs at Collins Cove near the LNG station and tanks at Collins Cove.	Flooding from extreme precipitation events may impact more critical facilities including the power plant.	There may be potential public health and ecological impacts if the power plant and LNG tanks are flooded. Depending on the regional impacts of the event, electricity reliability may be impacted.	3 - Medium	Unclear.	Cost, design standards, minimal re-siting flexibility, coordination with Footprint Power and others would be necessary.	2 - Medium-low	If flooding becomes more severe at these facilities, providing the needed level of service will become impaired.	3 - Medium
CB4	Extreme precipitation events	**Property damage or loss to historic properties**	Flooding currently occurs in the historic areas of: Willows near Fort Lee, Salem Common, Emerton and Forester Streets, Derby Wharf, and Bridge Street.	Flooding from extreme precipitation events may flood these areas more severely and frequently and may flood other historically significant properties in the future. These are important assets for economic development and tourism.	Loss of historically and culturally significant property	4 - Medium-high	Historic properties are not easily renovated to accommodate flooding; they are grandfathered from complying with current building codes.	Cost, limited ability to redesign property, many properties are managed/owned by entities other than the City.	2 - Medium-low	There are many important historic properties in Salem, that will be difficult to retrofit to handle extreme precipitation.	3 - Medium
CB5	Extreme precipitation events	**Back up power failure at critical city facilities.**	No current stress.	Diesel-fired emergency generators are located at 2 of the fire stations and at the schools. These are located at street-level or in basements, which are the most vulnerable to flooding.	Flooded emergency power presents a public safety risk and may make emergency shelters inoperable.	4 - Medium-high	It is technically feasible to resite or protect emergency generators.	Cost of resiting or flood proofing emergency generators.	2 - Medium-low	Emergency power is critical for public safety.	3 - Medium
CB6	Sea level rise	**Property damage or loss of emergency and critical city facilities**	Emergency and critical facilities have not experienced flooding related to sea level rise.	Flooding from sea level may impact coastal critical facilities including: the SESD Wastewater Treatment Facility, and Fire Department's Headquarters and possibly Station 5. Salem Academy Charter School is at risk for sea level rise flooding.	Flooded emergency facilities may impact public safety by increasing the response time and communications. The emergency response plan may need to address how to access to areas cut-off by flooding. There may be potential public health and ecological impacts if other critical facilities flood such as the SESD Wastewater Treatment Facility. Salem Academy Charter School may experience lost school days if it is sufficiently damaged.	4 - Medium-high	Salem is conducting flood control/drainage projects, including a $15M-$20M phased project underway at Canal Street. Facilities have currently managed during flooding while providing service. Other fire stations, the hospital, and schools are not at risk for flooding from storm surge.	Cost of retrofitting buildings and communication services, continuing to provide services with more frequent and severe flooding. The seawalls and tide gates in Salem are in need of maintenance to be more effective (approx. $5-6M), including those on the Forest River, South River.	1 - Low	If flooding becomes more severe at these critical facilities, providing the needed level of service will become impaired. This may put public safety at risk.	4 - Medium-high
CB7	Sea level rise	**Property damage or loss at Salem State University**	Salem State University has not experienced flooding related to sea level rise (North, Central, and South Campuses, and the O'Keefe Center).	Flooding from sea level rise may impact the Central Campus and O'Keefe Center. Flooding is possible near the South campus, and very unlikely at the North Campus.	Sea level rise may result in the loss of the O'Keefe Center and possible property damage to the Central and South campuses.	4 - Medium-high	Unknown.	Cost of retrofitting buildings, ability to re-site facilities, ability for some campuses to continue to serve as a functioning college facilities.	2 - Medium-low	If flooding occurs at the O'Keefe Center and the Central Campus, their ability to serve as functioning facilities will become impaired.	3 - Medium

			Sensitivity				Adaptive Capacity			Vulnerability	
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	How is this climate impact currently stressing the component?	How will this climate impact stress the component in the future?	If no action is taken, how much will climate impact worsen the stress to the component?	What is the overall sensitivity of this component?	Ability of the component to accommodate future impacts with minimum disruption or cost	What are the barriers to the component to accommodate impacts?	What is the overall adaptive capacity of this component?	Explanation/summary of vulnerability rating.	What is the overall vulnerability of the component?
CB8	Sea level rise	**Property damage or loss of power infrastructure**	Flooding currently occurs at Collins Cove near the LNG tanks.	Flooding from sea level rise may impact more critical facilities including the power plant.	There may be potential public health and ecological impacts if the power plant and LNG tanks are flooded. Depending on the regional impacts of the event, electricity reliability may be impacted.	4 - Medium-high	Footprint Power plans to raise the power plant by 16 feet to account for sea level rise.	Cost, design standards, minimal re-siting flexibility, coordination with Footprint Power and others would be necessary.	2 - Medium-low	If flooding becomes more severe at these facilities, providing the needed level of service will become impaired. Footprint Power is addressing the issue; it is unclear if the LNG facility is taking sea level rise into account.	2 - Medium-low
CB9	Sea level rise	**Property damage or loss to historic properties**	Flooding currently occurs in the historic areas of: Willows near Fort Lee, Emerton and Forester Streets, Derby Wharf, and Bridge Street.	Flooding from sea level rise may flood these areas more severely and frequently and may flood other historically significant properties in the future. These are important assets for economic development and tourism.	Loss of historically and culturally significant property.	4 - Medium-high	Salem is conducting flood control/drainage projects, including a $15M-$20M phased project underway at Canal Street. Historic properties are not easily renovated to accommodate flooding; they are grandfathered from complying with current building codes. Even with redesign, coastal properties may be lost with sea level rise.	Cost, limited ability to redesign property, many properties are managed/owned by entities other than the City. The seawalls and tide gates in Salem are in need of maintenance to be more effective (approx. $5-6M), including those on the Forest River, South River.	2 - Medium-low	There are many important historic properties in Salem, that will be difficult to retrofit to handle sea level rise. Coastal properties may be lost.	4 - Medium-high
CB10	Sea level rise	**Ineffective seawalls**	Seawalls currently overtop at some locations, including at Commercial Street. Many are aging and have serious damage.	More frequent seawall overtopping and flooding.	Flooding of surrounding property and further damage to the seawalls.	5 - High	Seawalls have been improved in the Willows neighborhood, Collins Cove, and Hubon Street. However, there is a huge need for improvements (approx. $5-6M).	Cost.	1 - Low	Seawalls are aging and damaged, further damage is likely. Improvements are necessary to prevent flooding in the surrounding areas.	5 - High
CB11	Sea level rise	**Ineffective tide gates**	Tide gates at the South and Forrest Rivers are in need of repair.	More frequent use, maintenance, and damage to tide gates.	Flooding of surrounding property and further damage to the tide gates.	5 - High	Tide gates have been improved at Webb Street.	Cost.	1 - Low	Aging and damaged tide gates need to be maintained to ensure they are operable. Improvements or new tide gates are necessary to prevent flooding in the surrounding areas.	5 - High
CB12	Sea level rise	**Back up power failure at critical city facilities**	No current stress.	Diesel-fired emergency generators are located at 2 of the fire stations and at the schools. These are located at street level or in basements, which are the most vulnerable to flooding.	Flooded emergency power presents a public safety risk and may make emergency shelters inoperable.	4 - Medium-high	It is technically feasible to resite or protect emergency generators.	Cost of resiting or flood proofing emergency generators.	2 - Medium-low	Emergency power is critical for public safety.	3 - Medium
CB13	Sea level rise	**Damage to moored boats, docks, and yacht club facilities**	No current stress.	The Palmer Cove Yacht Club and associated moored boats are at risk of property damage due to sea level rise. The Salem Willows Yacht Club may experience similar issues, although perhaps not as severe.	Loss of private property.	3 - Medium	It is technically feasible retrofit properties and remove boats prior to a storm.	Cost of retrofitting facilities.	3 - Medium	Loss or damage to the yacht clubs damages culturally significant assets and private property.	3 - Medium
CB14	Storm surge	**Property damage or loss of emergency and critical city facilities**	Emergency and critical facilities have not experienced flooding related to storm surge.	Flooding from storm surge may impact coastal critical facilities including: the SESD Wastewater Treatment Facility, Police Department and Fire Department's Headquarters and Station 5. Some schools (which serve as emergency shelters) are also at risk for storm surge flooding, including: Carlton School, Bentley School, Salem Early Childhood School, and Salem Academy Charter School.	Flooded emergency facilities may impact public safety by increasing the response time and communications. The emergency response plan may need to address how to access to areas cut-off by flooding. There may be potential public health and ecological impacts if other critical facilities flood such as the SESD Wastewater Treatment Facility. If the schools that serve as emergency shelters are flooded, there will be less capacity to house residents. It also may result in lost school days if the schools are sufficiently damaged. Impacts may occur beyond the storm event, including loss of property, depending on the severity of the damage.	5 - High	Salem is conducting flood control/drainage projects, including a $15M-$20M phased project underway at Canal Street. Facilities have currently managed during flooding while providing service. Other fire stations, the hospital, and schools are not at risk for flooding from storm surge.	Cost of retrofitting buildings and communication services, continuing to provide services with more frequent and severe flooding. The seawalls and tide gates in Salem are in need of maintenance to be more effective (approx. $5-6M), including those on the Forest River, South River.	1 - Low	If flooding becomes more severe at these critical facilities, providing the needed level of service will become impaired. This may put public safety at risk.	5 - High

			Sensitivity				Adaptive Capacity			Vulnerability	
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	How is this climate impact currently stressing the component?	How will this climate impact stress the component in the future?	If no action is taken, how much will climate impact worsen the stress to the component?	What is the overall sensitivity of this component?	Ability of the component to accommodate future impacts with minimum disruption or cost	What are the barriers to the component to accommodate impacts?	What is the overall adaptive capacity of this component?	Explanation/summary of vulnerability rating.	What is the overall vulnerability of the component?
CB15	Storm surge	**Property damage or loss at Salem State University**	Salem State University has not experienced flooding related to storm surge (North, Central, and South Campuses, and the O'Keefe Center).	Flooding from storm surge may impact the North and South campuses of Salem State. The Central Campus and O'Keefe Center may experience significant losses.	Impacts may occur beyond the storm event, including loss of property, depending on the severity of the damage. This may impact emergency shelters for students and staff and result in lost school days if the schools are sufficiently damaged.	5 - High	Unknown.	Cost of retrofitting buildings, ability to continue to serve as a functioning college, economic and cultural resource for the city, with more frequent and severe flooding.	1 - Low	If flooding occurs at Salem State, continue to function as a college, economic and cultural resource will become impaired.	5 - High
CB16	Storm surge	**Property damage or loss of power infrastructure**	Flooding currently occurs at Collins Cove near the LNG tanks.	Flooding from storm surge may impact more critical facilities including the power plant.	There may be potential public health and ecological impacts if the power plant and LNG tanks are flooded. Depending on the regional impacts of the event, electricity reliability may be impacted.	5 - High	Footprint Power plans to raise the power plant by 16 feet to account for sea level rise.	Cost, design standards, minimal re-siting flexibility, coordination with Footprint Power and others would be necessary.	3 - Medium	If flooding becomes more severe at these facilities, providing the needed level of service will become impaired. Footprint Power is addressing the issue; it is unclear if the LNG facility is taking storm surge into account.	3 - Medium
CB17	Storm surge	**Property damage or loss to historic properties**	Flooding currently occurs in the historic areas of: Willows near Fort Lee, Emerton and Forester Streets, Derby Wharf/Maritime Historic Site, and Bridge Street.	Flooding from storm surge may flood these areas more severely and frequently and may flood other historically significant properties in the future. These are important assets for economic development and tourism.	Loss of historically and culturally significant property.	4 - Medium-high	Historic properties are not easily renovated to accommodate flooding; they are grandfathered from complying with current building codes. Even with redesign, coastal properties may be lost with storm surge.	Cost, limited ability to redesign property, many properties are managed/owned by entities other than the City. The seawalls and tide gates in Salem are in need of maintenance to be more effective (approx. $5-6M), including those on the Forest River, South River.	2 - Medium-low	There are many important historic properties in Salem, that will be difficult to retrofit to handle storm surge. Coastal properties may be lost.	4 - Medium-high
CB18	Storm surge	**Ineffective seawalls**	Seawalls currently overtop at some locations, including at Commercial Street. Many are aging and have serious damage.	More frequent seawall overtopping and flooding.	Flooding of surrounding property and further damage to the seawalls.	5 - High	Seawalls have been improved in the Willows neighborhood, Collins Cove, and Hubon Street. However, there is a huge need for improvements (approx. $5-6M).	Cost.	1 - Low	Seawalls are aging and damaged, further damage is likely. Improvements are necessary to prevent flooding in the surrounding areas.	5 - High
CB19	Storm surge	**Ineffective tide gates**	Tide gates at the South and Forrest Rivers are in need of repair.	More frequent use, maintenance, and damage to tide gates.	Flooding of surrounding property and further damage to the tide gates.	5 - High	Tide gates have been improved at Webb Street.	Cost.	1 - Low	Aging and damaged tide gates need to be maintained to ensure they are operable. Improvements or new tide gates are necessary to prevent flooding in the surrounding areas.	5 - High
CB20	Storm surge	**Back up power failure at critical city facilities**	No current stress.	Diesel-fired emergency generators are located at 2 of the fire stations and at the schools. These are located at street level or in basements, which are the most vulnerable to flooding.	Flooded emergency power presents a public safety risk and may make emergency shelters inoperable.	4 - Medium-high	It is technically feasible to resite or protect emergency generators.	Cost of resiting or flood proofing emergency generators.	2 - Medium-low	Emergency power is critical for public safety.	3 - Medium
CB21	Storm surge	**Damage to moored boats, docks, and yacht club facilities**	No current stress.	The Palmer Cove Yacht Club and associated moored boats are at risk of property damage due to storm surge. The Salem Willows Yacht Club may experience similar issues, although perhaps not as severe.	Loss of private property.	3 - Medium	It is technically feasible retrofit properties and remove boats prior to a storm.	Cost of retrofitting facilities.	3 - Medium	Loss or damage to the yacht clubs damages culturally significant assets and private property.	3 - Medium

			PRIORITY VULNERABILITIES										
			Risk Assessment							Evaluation Criteria			
			Consequences					Likelihood		Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact		Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
CB1	Extreme heat events	**Property damage to historic properties**	3	1	1	5	10	Virtually Certain (99-100% chance)	10	100				
CB2	Extreme precipitation events	**Property damage or loss of emergency and critical city facilities**	4	5	1	1	11	Very Likely (90-100% chance)	8	88	Yes			There is overlap with at least one high risk/high vulnerability stress.
CB3	Extreme precipitation events	**Property damage or loss of power infrastructure**	5	4	1	1	11	Very Likely (90-100% chance)	8	88				
CB4	Extreme precipitation events	**Property damage or loss to historic properties**	4	1	1	5	11	Very Likely (90-100% chance)	8	88				There is overlap with at least one high risk/high vulnerability stress.
CB5	Extreme precipitation events	**Back up power failure at critical city facilities.**	2	4	1	1	8	Very Likely (90-100% chance)	8	64	Yes		Yes	Priority Area
CB6	Sea level rise	**Property damage or loss of emergency and critical city facilities**	4	5	1	1	11	Very Likely (90-100% chance)	8	88				High risk/high vulnerability ranking
CB7	Sea level rise	**Property damage or loss at Salem State University**	5	3	1	3	12	Very Likely (90-100% chance)	8	96				

			Consequences					Likelihood		Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact		Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
CB8	Sea level rise	**Property damage or loss of power infrastructure**	5	4	1	1	11	Very Likely (90-100% chance)	8	88				
CB9	Sea level rise	**Property damage or loss to historic properties**	4	1	1	5	11	Very Likely (90-100% chance)	8	88				High risk/high vulnerability ranking
CB10	Sea level rise	**Ineffective seawalls**	5	4	2	1	12	Very Likely (90-100% chance)	8	96				High risk/high vulnerability ranking
CB11	Sea level rise	**Ineffective tide gates**	5	4	2	3	14	Very Likely (90-100% chance)	8	112				High risk/high vulnerability ranking
CB12	Sea level rise	**Back up power failure at critical city facilities**	2	4	1	1	8	Very Likely (90-100% chance)	8	64	Yes		Yes	Priority Area
CB13	Sea level rise	**Damage to moored boats, docks, and yacht club facilities**	2	1	1	3	7	Very Likely (90-100% chance)	8	56				
CB14	Storm surge	**Property damage or loss of emergency and critical city facilities**	4	5	1	1	11	Very Likely (90-100% chance)	8	88				High risk/high vulnerability ranking

			Consequences					Likelihood		Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact		Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
CB15	Storm surge	**Property damage or loss at Salem State University**	5	3	1	3	12	Very Likely (90-100% chance)	8	96				High risk/high vulnerability ranking
CB16	Storm surge	**Property damage or loss of power infrastructure**	5	4	1	1	11	Very Likely (90-100% chance)	8	88				
CB17	Storm surge	**Property damage or loss to historic properties**	4	1	1	5	11	Very Likely (90-100% chance)	8	88				High risk/high vulnerability ranking
CB18	Storm surge	**Ineffective seawalls**	5	4	2	3	14	Very Likely (90-100% chance)	8	112				High risk/high vulnerability ranking
CB19	Storm surge	**Ineffective tide gates**	5	4	2	3	14	Very Likely (90-100% chance)	8	112				High risk/high vulnerability ranking
CB20	Storm surge	**Back up power failure at critical city facilities**	2	4	1	1	8	Very Likely (90-100% chance)	8	64	Yes		Yes	Priority Area
CB21	Storm surge	**Damage to moored boats, docks, and yacht club facilities**	2	1	1	3	7	Very Likely (90-100% chance)	8	56				

			VULNERABILITY ASSESSMENT								
			Sensitivity Analysis				Adaptive Capacity			Vulnerability	
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	How is this climate impact currently stressing the component?	How will this climate impact stress the component in the future?	If no action is taken, how much will climate impact worsen the stress to the component?	What is the overall sensitivity of this component?	Ability of the component to accommodate future impacts with minimum disruption or cost	What are the barriers to the component to accommodate impacts?	What is the overall adaptive capacity of this component?	Explanation/summary of vulnerability rating.	What is the overall vulnerability of the component?
W1	Extreme heat events	**Increase demand for potable water**	The highest daily water demands during the year generally occur on the hottest days. There is currently no stress on the system, as Salem currently has sufficient supply and capacity. Salem has not needed to institute a water ban.	High daily water demands may occur more frequently.	More frequent high demand days could require additional distribution system capacity and require water use restrictions.	1 - Low	The City Engineer reports that existing water distribution system has sufficient reserve capacity to satisfy more frequent high demand days	Operating and maintenance costs to maintain the existing capacity in an aging water distribution system. Costs to implement a water conservation restriction or ban.	5 - High	The existing water distribution system reportedly has excess capacity to satisfy peak customer demand and does not appear vulnerable to increased frequency of extreme heat events.	1 - Low
W2	Extreme heat events	**Bacterial growth in the water distribution system**	Salem's current disinfection practices maintain high-quality drinking water.	Increased frequency of hot days may result in warmer water in the distribution system storage facilities. Water contained in above ground water storage tanks in the distribution system will warm up on hot days. Bacterial growth in the distribution is more likely with warmer water.	Summer time distribution system water temperatures may rise.	1 - Low	With normal disinfection practices and residual levels maintained, bacterial growth in the distribution system is unlikely.	Need to maintain disinfectant residual in the water storage facilities and to the extremities of the distribution system.	5 - High	A well operated water treatment and disinfection facility will limit the vulnerability to extreme heat events.	1 - Low
W3	Extreme heat events	**Power failure of the water supply system**	The water supply system in Salem does not currently experience frequent power issues.	Extremely hot days may cause brown-outs or black outs leading to power failure at the Water Filtration Plant and Pump Stations. Power failure can lead to interruption in water supply and cause pressure surges in the transmission and distribution systems when pumps abruptly trip off-line.	More frequent power failures could lead to more frequent pressure surges stressing pipes and possibly increasing the frequency of pipe breaks.	2 - Medium-low	Use standby power where available will reduce impact.	Availability of standby power facilities and surge control facilities. More frequent operation of standby power facilities.	4 - Medium-high	Standby power and adequate surge protection facilities limit the vulnerability to power failure events.	2 - Medium-low
W4	Extreme heat events	**Water Supply shortages via the Salem and Beverly Water Supply Board**	A portion of Salem's water is supplied from the Ipswich River, a critical source of water for hundreds of thousands of people. The river suffers from chronic low flow typically during summer months.	A change in seasonal rainfall patterns could exacerbate low flows in the Ipswich River.	Salem and Beverly Water Supply Board does not draw water from the Ipswich River during the summer months. Water is drawn during winter and spring and stored for use during the summer. Change in seasonal rainfall may cause shortages.	2 - Medium-low	The Salem and Beverly Water Supply Board operates three large reservoirs to store water collected in the winter and spring flows for summertime use.	Fixed water supply storage reservoir capacity. Coordination with Salem and Beverly Water Supply Board.	4 - Medium-high	Salem is partly supplied from a stressed Ipswich River. However, infrastructure is in place to harvest water during winter and spring high flow periods for summer use.	2 - Medium-low
W5	Extreme precipitation events	**Flooding of water supply system**	No current stress.	Minimal impact because water distribution lines are buried and subject to very limited damage from localized flooding.	Extreme storm events may affect surface-level infrastructure.	1 - Low	Gravity system does not rely greatly on pump stations that would need repair. Emergency response to severe storms is unknown.	Coordination with Salem Beverly Water Supply Board would be necessary. Water supply source and storage are located outside of Salem.	2 - Medium-low	Flooding of water supply system does not pose a significant risk.	2 - Medium-low
W6	Extreme precipitation events	**Flooding of wastewater system infrastructure**	Some pump stations and a trunk sewer currently flood during tidal and extreme precipitation events.	Pump stations and pipelines may suffer outages and/or damage.	Pumps and pipelines may become ineffective more frequently. Wastewater treatment facility is located outside of 100 year flood zone.	3 - Medium	Unknown.	Cost of pump station protection or system redesign is substantial. Coordination with SESD for emergency preparedness.	0 - Uncertain	Flooding from extreme precipitation may increase frequency pump station failure.	3 - Medium
W7	Extreme precipitation events	**Electric power failure to wastewater system**	No current stress.	Substations/transformers may fail to supply power during intense weather events.	Pump stations may lose power more frequently. Treatment facility may depend on backup power supply more frequently.	3 - Medium	Technology exists to reasonably proof pump stations for extreme precipitation events. Treatment facility possesses back-up power.	Cost for system upgrades.	5 - High	Emergency standby generators to supply back-up power to the treatment plant and pumping stations are technologically feasible and may be in place already.	2 - Medium-low

			Sensitivity Analysis				Adaptive Capacity			Vulnerability	
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W8	Sea level rise	**Flooding of water supply system**	No current stress.	Minimal impact because water distribution lines are buried and subject to very limited damage from localized flooding.	Minimal change will occur.	1 - Low	Gravity system does not rely greatly on pump stations that would need repair.	Coordination with Salem Beverly Water Supply Board would be necessary. Water supply source and storage are located outside of Salem.	2 - Medium-low	Flooding of water supply system does not pose a significant risk.	2 - Medium-low
W9	Sea level rise	**Saltwater intrusion to water supply**	No current stress.	Rising sea levels could introduce saltwater into water supply. However, likelihood is very low, as both Wenham Lake reservoir and Ipswich River supply intake are far from coastline and approximately 30 feet from sea level.	Minimal change will occur.	1 - Low	Geography of water supply provides protection and this to accommodate future sea level rise.	Unknown.	1 - Low	Likelihood of sea level rise Saltwater intrusion to water supply is minimal.	1 - Low
W10	Sea level rise	**Flooding of wastewater system infrastructure**	No current stress.	Rise in coastal sea level alone will not severely impact wastewater buried pipelines, pump stations or treatment facility.	Minimal impact from nuisance flooding to wastewater system infrastructure.	2 - Medium-low	Assessment of coastal infrastructure can determine components of the system that may be impacted by a greater extent of nuisance flooding.	Few barriers.	5 - High	Coastal nuisance flooding from sea level rise is not anticipated to significantly impact the wastewater system and treatment facility because of location and design.	1 - Low
W11	Storm surge	**Flooding of water supply system**	No current stress.	Minimal impact because water distribution lines are buried and subject to very limited damage from localized flooding.	Extreme storm events may affect surface-level infrastructure.	1 - Low	Gravity system does not rely greatly on pump stations that would need repair. Emergency response to severe storms is unknown.	Coordination with Salem Beverly Water Supply Board would be necessary. Water supply source and storage are located outside of Salem.	2 - Medium-low	Flooding of water supply system does not pose a significant risk.	2 - Medium-low
W12	Storm surge	**Flooding of the wastewater system infrastructure**	Unknown.	Pump stations may be flooded. Land and access routes near SESD treatment facility may be flooded.	Pumps and pipelines may become ineffective if flooded. Treatment facility may need to depend on backup power supply and adjust to influent pipeline disruptions.	3 - Medium	Unknown.	Cost of pump station protection or system redesign is substantial. Coordination with SESD for emergency preparedness.	1 - Low	Storm surge and sea level rise may increase the impact of flooding on wastewater infrastructure. Elevation of critical equipment located in the sea level rise and storm surge influence areas is unknown at this time.	3 - Medium
W13	Storm surge	**Property damage or loss of critical city facilities**	Many densely developed wharf areas in Salem contain residential and commercial properties with multiple water piping connections between the private and public water distribution system. Currently, there is no stress to the water distribution system.	Storm surges from storm events, may create severe erosion which may expose the subgrade piping. This piping is likely to fail in shifting geotechnical conditions.	Distribution pipelines may become ineffective if wharf area local failures/breaks, drop pressures and/or allow contamination, creating a public health and safety issue.	5 - High	Without the ability to quickly shut down and isolate the wharf area piping from the main water system, failures would jeopardize the ability to provide safe and reliable water to fire hydrants and water users in the other sections of the system.	Cost of retrofitting the distribution system. Solution not dependent on other parties. Could be performed in-line with other water system improvements already planned including recommendations in the update to Emergency Operating Procedures & Response Plan.	3 - Medium	Storm surges may create severe erosion which could expose the subgrade piping, causing failure. These failures may jeopardize the ability to provide safe and reliable water to fire hydrants and water users in the rest of the system.	4 - Medium - High

			PRIORITY VULNERABILITIES										
			Risk Assessment							Evaluation Criteria			
			Consequences					Likelihood		Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact		Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
W1	Extreme heat events	**Increase demand for potable water**	3	3	3	1	10	Virtually Certain (99-100% chance)	10	100				
W2	Extreme heat events	**Bacterial growth in the water distribution system**	3	5	3	1	12	Virtually Certain (99-100% chance)	10	120				
W3	Extreme heat events	**Power failure of the water supply system**	3	5	4	1	13	Virtually Certain (99-100% chance)	10	130				
W4	Extreme heat events	**Water Supply shortages via the Salem and Beverly Water Supply Board**	4	4	3	1	12	Very Likely (90-100% chance)	8	96				
W5	Extreme precipitation events	**Flooding of water supply system**	5	3	1	1	10	Very Likely (90-100% chance)	8	80				
W6	Extreme precipitation events	**Flooding of wastewater system infrastructure**	5	5	5	1	16	Very Likely (90-100% chance)	8	128				
W7	Extreme precipitation events	**Electric power failure to wastewater system**	5	5	5	1	16	Very Likely (90-100% chance)	8	128				

			Consequences					Likelihood		Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact		Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
W8	Sea level rise	**Flooding of water supply system**	5	3	1	1	10	Very Likely (90-100% chance)	8	80				
W9	Sea level rise	**Saltwater intrusion to water supply**	5	5	2	1	13	Very Likely (90-100% chance)	8	104				
W10	Sea level rise	**Flooding of wastewater system infrastructure**	5	5	5	1	16	Very Likely (90-100% chance)	8	128				
W11	Storm surge	**Flooding of water supply system**	5	3	1	1	10	Very Likely (90-100% chance)	8	80				
W12	Storm surge	**Flooding of the wastewater system infrastructure**	5	5	5	1	16	Very Likely (90-100% chance)	8	128				
W13	Storm surge	**Property damage or loss of critical city facilities**	4	5	2	2	13	Very Likely (90-100% chance)	8	104	1			High risk/high vulnerability ranking

			VULNERABILITY ASSESSMENT									
			Sensitivity				Adaptive Capacity			Vulnerability		
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E1	Extreme heat events	**Loss of power at critical city buildings**	Seldom occurs during increased electrical load during heat waves.	Increased frequency of brown-outs/black-outs and the inability to operate critical city buildings and facilities.	More frequent and lengthy power loss for residents and businesses; if occurs during a extreme weather conditions, public health may be at risk.	3 - Medium	Installation of generators at all critical city buildings and facilities to provide power during loss of power events would be necessary. Efforts to reduce demand during heat events can be expanded.	Cost, coordination with National Grid will be required.	4 - Medium-high	Current impact is very problematic. Having locations that do not have continuous operation that involve public safety or emergency management is a risk. New facilities that involve public safety or emergency management are required by Article 708 of the NEC (National Electrical Code) to have an alternate power source. Installations of generators at these locations would help prevent these problems.	4 - Medium-high
E2	Extreme precipitation events	**Flooding/submersion of electrical distribution equipment (transformer, switchgear, etc.)**	Infrequent equipment failure & power loss; Loring Avenue off Rt 1A, North Salem near Rt 114, and Marlborough Road are particularly sensitive.	Increased frequency of equipment failure and power loss in these areas and across the City. Canal Street, Rail yard, and Salem Harbor substations are at risk.	More frequent and lengthy power loss for residents and businesses; if occurs during a extreme weather conditions, public health may be at risk.	2 - Medium-low	Repair is possible but long term adaptation requires relocation of existing electrical distribution equipment above the 100 year flood elevation or hardening of current facilities. Installation of standby generators in more of the critical city buildings is partially underway.	Cost, coordination with National Grid will be required.	3 - Medium	Impacts to the electrical distribution equipment will increase as the number of extreme precipitation events increase. The increased frequency in these events will cause damage to the equipment over time and will likely cause failure. Locating the equipment above the 100 year flood elevation would reduce the probability of the equipment becoming submerged.	3 - Medium
E3	Extreme precipitation events	**Downed power lines**	Infrequent power loss; Loring Avenue off Rt 1A and North Salem near Rt 114 are particularly sensitive.	Increased frequency of downed power lines and outages due to high winds from extreme events.	More frequent and lengthy power loss for residents and businesses; if occurs during a extreme weather conditions, public health may be at risk.	2 - Medium-low	Relocation of power lines underground, however may increase the risk of flooded power lines. Installation of standby generators in more of the critical city buildings is partially underway.	Cost, coordination with National Grid will be required.	3 - Medium	Extreme precipitation events are often accompanied by strong winds. By locating the power lines underground, it would reduce the probability of downed power lines.	3 - Medium
E4	Extreme precipitation events	**Disruption to renewable energy installations**	No current stress.	Inability for future solar installations at the High School and Middle School, as well as wind/solar facilities on Derby Street to feed the grid with the renewable energy due to downed/flooded power lines.	Renewable energy installations in Salem are largely connected with net metering and are this not independent of grid electricity. The renewable energy is currently not able to be fed directly to the buildings/areas on which they are located to provide backup power.	3 - Medium	It is technically feasible to change the interconnection of the renewable energy systems so they could still provide emergency power, but the capital costs and operating costs may increase.	Cost, coordination with the renewable energy owners (if not the city).	4 - Medium-high	Because potential renewable energy installations in Salem are largely connected with net metering, they cannot be used for backup power during a power outage due to flooded or downed power lines. It is technically feasible to change the connections of these systems, but may have economic barriers.	2 - Medium-low
E5	Extreme precipitation events	**Flooding of natural gas lines**	No current stress.	May damage natural gas distribution piping and system appurtenances.	Damage to natural gas service could render gas service and subsequent heating/power needs unavailable.	3 - Medium	Current natural gas infrastructure may need to be replaced.	Cost, remaining life expectancy of existing gas systems, room for upgrades/expansion, decision making for any upgrades/improvements under National Grid's jurisdiction.	1 - Low	Cross-agency involvement is required to initiate the process of assessing engineering vulnerability and adaptability of infrastructure to climate change.	3 - Medium
E6	Extreme precipitation events	**Flooding of power lines**	Infrequent power loss; North Salem near Rt 114 and Marlborough Road are particularly sensitive.	Increased frequency of flooded power lines and outages, in these locations and others.	More frequent and lengthy power loss for residents and businesses; if occurs during a extreme weather conditions, public health may be at risk.	2 - Medium-low	Relocation of power lines above ground however may increase the downed lines due to high winds. Installation of standby generators in more of the critical city buildings is partially underway.	Cost, coordination with National Grid will be required.	3 - Medium	Extreme precipitation events are often accompanied by strong winds. By locating the power lines underground, it would reduce the probability of downed power lines.	3 - Medium
E7	Extreme precipitation events	**Damage to streetlights**	No current stress.	Flooding may render streetlights in downtown areas inoperable. Wind damage may destroy or damage streetlights.	More frequent loss of streetlights is possible.	3 - Medium	Streetlights are designed to withstand storms but are dependent on underlying power supply system.	With city ownership of streetlights, cost for rehabilitation would be high.	2 - Medium-low	Streetlights in downtown and Commercial Street corridor may lose power more frequently.	3 - Medium

			Sensitivity				Adaptive Capacity			Vulnerability	
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E8	Sea level rise	**Flooding/submersion of substation and power distribution**	No current stress.	Inability to operate and provide power to the city. Rail yard substation is located in flood-prone area.	Chronic power loss for residents and businesses; if occurs during a extreme weather conditions, public health may be at risk.	4 - Medium-high	A new location for the substations both above the new sea level should be coordinated with the utility/sub-station owner.	Cost, coordination with National Grid will be required.	1 - Low	Current impacts to the substations are low, but plans for future electrical infrastructure should be considered well in advance to take a phased approach for constructing and bringing the new substations online.	4 - Medium-high
E9	Sea level rise	**Corroding of electrical distribution equipment (transformer, switchgear, etc.)**	No current stress.	Sea water intrusion leads to increased frequency of equipment failure and power loss in these areas and across the City. Need to replace equipment more frequently.	More frequent and lengthy power loss for residents and businesses; if occurs during a extreme weather conditions, public health may be at risk.	3 - Medium	Limited ability to accommodate without relocation of equipment.	Cost, technical feasibility, coordination with National Grid will be required.	1 - Low	Impacts to the electrical distribution equipment will increase as the frequency of storm surge increases. This will cause damage to the equipment over time and will likely cause failure.	3 - Medium
E10	Sea level rise	**Disruption to renewable energy installations**	No current stress.	Potential solar installations at the High School and Middle School, as well as wind/solar facilities on Derby Street are not likely to be impacted from sea level rise, due to their elevated locations and building's location relative to the ocean.	Minimal impact due to location.	1 - Low	No likely future impact.	None.	5 - High	Potential solar installations at the High School and Middle School, as well as wind/solar facilities on Derby Street are not likely to be impacted from sea level rise.	1 - Low
E11	Sea level rise	**Flooding of natural gas lines and the Collins Cove LNG storage**	No current stress.	May damage natural gas distribution piping and system appurtenances near the coast.	Damage to natural gas service could render gas service and subsequent heating/power needs unavailable for coastal properties.	3 - Medium	Current natural gas infrastructure may need to be replaced.	Cost, remaining life expectancy of existing gas systems, room for upgrades/expansion, decision making for any upgrades/improvements under National Grid's jurisdiction.	1 - Low	Cross-agency involvement is required to initiate the process of assessing engineering vulnerability and adaptability of infrastructure to climate change.	3 - Medium
E12	Sea level rise	**Damage to streetlights**	No current stress.	Flooding may render streetlights in downtown areas inoperable.	Minimal impact on coastal areas.	3 - Medium	Streetlights are dependent on underlying power supply system.	With city ownership of streetlights, cost for rehabilitation would be high.	2 - Medium-low	Impact is minimal due to location of streetlights away from coastal areas.	3 - Medium
E13	Storm surge	**Flooding/submersion of substation and power distribution**	No current stress.	Inability to operate and provide power to the city. Rail yard substation is located in flood-prone area.	Chronic power loss for residents and businesses; if occurs during a extreme weather conditions, public health may be at risk.	5 - High	A new location for the substations both above the expected storm surge level should be coordinated with the utility/sub-station owner.	Cost, coordination with National Grid will be required.	1 - Low	Current impacts to the substations are low, but plans for future electrical infrastructure should be considered well in advance to take a phased approach for constructing and bringing the new substations online.	5 - High
E14	Storm surge	**Flooding/submersion of electrical distribution equipment (transformer, switchgear, etc.)**	Infrequent equipment failure & power loss; Loring Avenue off Rt 1A, North Salem near Rt 114, and Marlborough Road are particularly sensitive.	Increased frequency of equipment failure and power loss in these areas and across the City. Canal Street, Rail yard, and Salem Harbor substations are at risk.	More frequent and lengthy power loss for residents and businesses; if occurs during a extreme weather conditions, public health may be at risk.	2 - Medium-low	Repair is possible but long term adaptation requires relocation of existing electrical distribution equipment above the 100 year flood elevation. Installation of standby generators in more of the critical city buildings is partially underway.	Cost, coordination with National Grid will be required.	3 - Medium	Impacts to the electrical distribution equipment will increase as the frequency of storm surge increases. This will cause damage to the equipment over time and will likely cause failure.	3 - Medium
E15	Storm surge	**Corroding of electrical distribution equipment (transformer, switchgear, etc.)**	No current stress.	Sea water intrusion leads to increased frequency of equipment failure and power loss in these areas and across the City. Need to replace equipment more frequently.	More frequent and lengthy power loss for residents and businesses; if occurs during a extreme weather conditions, public health may be at risk.	2 - Medium-low	Limited ability to accommodate without relocation of equipment.	Cost, technical feasibility, coordination with National Grid will be required.	1 - Low	Impacts to the electrical distribution equipment will increase as the frequency of storm surge increases. This will cause damage to the equipment over time and will likely cause failure.	3 - Medium
E16	Storm surge	**Disruption to renewable energy installations**	No current stress.	Potential solar installations at the High School and Middle School, as well as wind/solar facilities on Derby Street are not likely to be impacted from sea level rise, due to their elevated locations and school's location relative to the ocean.	Minimal impact due to location.	1 - Low	No likely future impact.	None.	5 - High	Potential solar installations at the High School and Middle School, as well as wind/solar facilities on Derby Street are not likely to be impacted from storm surge.	1 - Low
E17	Storm surge	**Flooding of natural gas lines and the Collins Cove LNG storage**	No current stress.	May damage natural gas distribution piping and system appurtenances near the coast.	Damage to natural gas service could render gas service and subsequent heating/power needs unavailable for coastal properties.	3 - Medium	Current natural gas infrastructure may need to be replaced.	Cost, remaining life expectancy of existing gas systems, room for upgrades/expansion, decision making for any upgrades/improvements under National Grid's jurisdiction.	1 - Low	Cross-agency involvement is required to initiate the process of assessing engineering vulnerability and adaptability of infrastructure to climate change	3 - Medium
E18	Storm surge	**Damage to streetlights**	No current stress.	Flooding may render streetlights in downtown areas inoperable.	More frequent loss of streetlights is possible.	3 - Medium	Streetlights are designed to withstand storms but are dependent on underlying power supply system.	With city ownership of streetlights, cost for rehabilitation would be high.	2 - Medium-low	Streetlights in downtown and Commercial Street corridor may lose power more frequently.	3 - Medium

			PRIORITY VULNERABILITIES										
			Risk Assessment							Evaluation Criteria			
			Consequences					Likelihood		Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact		Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
E1	Extreme heat events	**Loss of power at critical city buildings**	5	5	1	1	12	Virtually Certain (99-100% chance)	10	120				High risk/high vulnerability ranking
E2	Extreme precipitation events	**Flooding/submersion of electrical distribution equipment (transformer, switchgear, etc.)**	5	3	1	1	10	Very Likely (90-100% chance)	8	80				
E3	Extreme precipitation events	**Downed power lines**	3	5	1	1	10	Very Likely (90-100% chance)	8	80	Yes			Priority Area
E4	Extreme precipitation events	**Disruption to renewable energy installations**	1	1	2	1	5	Very Likely (90-100% chance)	8	40				
E5	Extreme precipitation events	**Flooding of natural gas lines**	4	5	1	1	11	Very Likely (90-100% chance)	8	88				
E6	Extreme precipitation events	**Flooding of power lines**	5	5	2	1	13	Very Likely (90-100% chance)	8	104				
E7	Extreme precipitation events	**Damage to streetlights**	4	4	1	3	12	Very Likely (90-100% chance)	8	96				

			Consequences					Likelihood		Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact		Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
E8	Sea level rise	**Flooding/submersion of substation and power distribution**	5	3	1	1	10	Very Likely (90-100% chance)	8	80				
E9	Sea level rise	**Corroding of electrical distribution equipment (transformer, switchgear, etc.)**	5	3	1	1	10	Very Likely (90-100% chance)	8	80				
E10	Sea level rise	**Disruption to renewable energy installations**	3	1	2	1	7	Very Likely (90-100% chance)	8	56				
E11	Sea level rise	**Flooding of natural gas lines and the Collins Cove LNG storage**	4	5	1	1	11	Very Likely (90-100% chance)	8	88				
E12	Sea level rise	**Damage to streetlights**	4	4	1	3	12	Very Likely (90-100% chance)	8	96				
E13	Storm surge	**Flooding/submersion of substation and power distribution**	5	3	1	1	10	Very Likely (90-100% chance)	8	80				
E14	Storm surge	**Flooding/submersion of electrical distribution equipment (transformer, switchgear, etc.)**	5	3	1	1	10	Very Likely (90-100% chance)	8	80				
E15	Storm surge	**Corroding of electrical distribution equipment (transformer, switchgear, etc.)**	5	3	1	1	10	Very Likely (90-100% chance)	8	80				
E16	Storm surge	**Disruption to renewable energy installations**	1	1	2	1	5	Very Likely (90-100% chance)	8	40				
E17	Storm surge	**Flooding of natural gas lines and the Collins Cove LNG storage**	4	5	1	1	11	Very Likely (90-100% chance)	8	88				
E18	Storm surge	**Damage to streetlights**	4	4	1	3	12	Very Likely (90-100% chance)	8	96				

			VULNERABILITY ASSESSMENT								
			Sensitivity				Adaptive Capacity			Vulnerability	
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	How is this climate impact currently stressing the component?	How will this climate impact stress the component in the future?	If no action is taken, how much will climate impact worsen the stress to the component?	What is the overall sensitivity of this component?	Ability of the component to accommodate future impacts with minimum disruption or cost	What are the barriers to the component to accommodate impacts?	What is the overall adaptive capacity of this component?	Explanation/summary of vulnerability rating.	What is the overall vulnerability of the component?
SW1	Extreme precipitation events	**Clogged storm drains and catch basins**	Currently occurs during a predicted rainstorm and during high tides.	Flooding will occur more frequently. It may also occur in additional neighborhoods.	Cause more localized flooding because stormwater cannot enter the drainage system.	3 - Medium	Catch basins do not have much ability to accommodate the future impacts.	Cost and manpower.	1 - Low	Catch basin grates are a standard design; therefore, manually cleaning them is the only approach to managing the clogging problem.	3 - Medium
SW2	Extreme precipitation events	**Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods**	High tides coupled with significant precipitation events results in flooding. The following locations are currently experiencing flooding issues: Jackson Street/Jefferson Avenue area, the Willows neighborhood, the Point neighborhood, Loring Avenue Area, Commercial Street and Bridge Street, Emerton Street /Forester Street area, and Canal Street. There are no tides on the North River to mitigate flooding on Commercial and Bridge Streets.	Frequency of flooding and disruption to pump stations may increase.	It will cause more localized flooding, in part because the stormwater cannot be conveyed to the ocean.	5 - High	The ability of the stormwater system to accommodate these future impacts is low, with the exception of 1) the Emerton Street /Forester Street area due to the new tide gate on Webb Street and 2) Canal Street, which is undergoing a $22M flood mitigation program. Pumps are needed to convey stormwater in some locations.	Cost and the design of the current system.	2 - Medium - Low	The existing drainage system cannot accommodate large precipitation events coupled with high tides. The system would need to be redesigned and include pump stations to minimize flooding.	4 - Medium-high
SW3	Extreme precipitation events	**Ineffective tide gates (Lafayette Street)**	High tides coupled with significant precipitation events results in flooding. Therefore, tide gates at Lafayette Street are closed prior to storms. Overall, they are ineffective. This results in flooding around Loring Avenue.	Flooding in this area would be more frequent.	It will cause more localized flooding because the tide gates will continue to be ineffective.	5 - High	The ability of the stormwater system to accommodate these future impacts is low.	Costs to upgrade the tide gates at Lafayette Street.	1 - Low	To mitigate the flooding on Loring Avenue the tide gates need to be replaced; otherwise flooding will continue more frequently.	5 - High
SW4	Extreme precipitation events	**Overtopping of Rosie's Pond**	Significant precipitation events results in flooding around Rosie's Pond and South River basin.	It will occur more frequently. It may also extend into additional neighborhoods in the vicinity.	It will cause more localized flooding because the stormwater cannot be conveyed out of the area.	4 - Medium-high	The ability of the stormwater system to accommodate these future impacts is medium.	Cost to install stormwater pump stations to relieve flooding in the area.	2 - Medium - Low	This is a localized flooding problem around Rosie's Pond and South River basin.	4 - Medium-high
SW5	Extreme precipitation events	**Flooding of pump stations**	Pump stations along North River are frequently flooded.	Frequency of flooding and disruption to pump stations may increase.	Flooding will require more maintenance and repair. Localized flooding will be exacerbated.	3 - Medium	Flooding out of pump stations is currently a problem. However, there are only eight pump stations, as the system is mostly a gravity system.	Increased cost of maintenance and repair.	3 - Medium	Impacts to the overall stormwater drainage system are minimal because of the small number of pump stations.	3 - Medium
SW6	Sea level rise	**Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods**	No current impact.	Sea level rise coupled with significant precipitation events results in flooding. Flooding may occur at times other than high tide, with or without precipitation events, including at: Jackson Street/Jefferson Avenue Area, the Willows neighborhood, the Point neighborhood, Commercial Street and Bridge Street, Emerton Street /Forester Street area, and Canal Street. There are no tides on the North River to mitigate flooding on Commercial and Bridge Streets. It may also occur in additional neighborhoods.	It will cause more localized flooding because the stormwater cannot be conveyed to the ocean.	5 - High	The ability of the stormwater system to accommodate these future impacts is low with the exception of 1) the Emerton Street /Forester Street area due to the new tide gate on Webb Street and 2) Canal Street, which is undergoing a $22M flood mitigation program.	Cost and the design of the current system.	2 - Medium - Low	The existing drainage system currently backs up during high tide, typically with significant precipitation events. Without improvements to the drainage system, including pump stations to minimize flooding, the situation will become worse with sea level rise.	4 - Medium-high
SW7	Sea level rise	**Ineffective tide gates (Lafayette Street)**	No current impact.	Sea level rise coupled with significant precipitation events results in flooding. The tide gates at Lafayette Street are closed prior to storms but are ineffective. Flooding may occur at times other than high tide, with or without precipitation events and may also occur in additional neighborhoods.	It will cause more localized flooding because the tide gates will continue to be ineffective.	5 - High	The ability of the stormwater system to accommodate these future impacts is low.	Costs to upgrade the tide gates at Lafayette Street.	1 - Low	To mitigate the flooding on Loring Avenue the tide gates need to be replaced; otherwise flooding will continue more frequently.	5 - High
SW8	Sea level rise	**Flooding of pump stations**	No current impact.	Frequency of flooding and disruption to pump stations may increase.	Flooding will require more maintenance and repair. Localized flooding will be exacerbated.	3 - Medium	Flooding out of pump stations is currently a problem. However, there are only eight pump stations, as the system is mostly a gravity system.	Increased cost of maintenance and repair.	3 - Medium	Impacts to the overall stormwater drainage system are minimal because of the small number of pump stations.	3 - Medium

			Sensitivity				Adaptive Capacity			Vulnerability	
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SW9	Storm surge	**Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods**	A storm surge coupled with significant precipitation events results in flooding in several of the neighborhoods along the coast and along the rivers including: Jackson Street/Jefferson Avenue Area, the Willows neighborhood, the Point neighborhood, Commercial Street and Bridge Street, Emerton Street /Forester Street area, and Canal Street. There are no tides on the North River to mitigate flooding on Commercial and Bridge Streets.	The storm surge will extend further into these neighborhoods and will extend into additional neighborhoods.	It will cause more localized flooding because the stormwater cannot be conveyed to the ocean.	5 - High	The ability of the stormwater system to accommodate these future impacts is low with the exception of 1) the Emerton Street /Forester Street area due to the new tide gate on Webb Street and 2) Canal Street, which is undergoing a $22M flood mitigation program.	Cost and the design of the current system.	1 - Low	The existing drainage system cannot accommodate large precipitation events coupled with a storm surge. The system would need to be redesigned to minimize flooding.	5 - High
SW10	Storm surge	**Ineffective tide gates (Lafayette Street)**	A storm surge coupled with significant precipitation events results in flooding. Therefore, tide gates at Lafayette Street are closed prior to storms. Overall, they are ineffective. This results in flooding around Loring Avenue.	Flooding in this area would be more extensive may also occur in additional neighborhoods.	It will cause more localized flooding because the tide gates will continue to be ineffective.	5 - High	The ability of the stormwater system to accommodate these future impacts is low.	Costs to upgrade the tide gates at Lafayette Street.	1 - Low	To mitigate the flooding on Loring Avenue the tide gates need to be replaced; otherwise flooding will continue more frequently.	5 - High
SW11	Storm surge	**Flooding of pump stations**	Pump stations along North River are frequently flooded.	Frequency of flooding and disruption to pump stations may increase.	Flooding will require more maintenance and repair. Localized flooding will be exacerbated.	3 - Medium	Flooding out of pump stations is currently a problem. However, there are only eight pump stations, as the system is mostly a gravity system.	Increased cost of maintenance and repair.	3 - Medium	Impacts to the overall stormwater drainage system are minimal because of the small number of pump stations.	3 - Medium
SW12	Storm surge	**Ineffective seawalls**	A storm surge results in the seawalls and revetments being overtopped in some areas.	Future storm surges may overtop the seawalls and revetments in more areas and result in more extensive flooding.	It could result in more widespread overtopping and flooding.	5 - High	The ability of the seawall/revetment system to accommodate these future impacts is low.	Cost and ownership of the seawall/revetment system.	1 - Low	The existing seawall/revetment system is currently inadequate for storm surges. In the future, this will only get worse.	5 - High
SW13	Storm surge	**Overtopping of Rosie's Pond**	Storm surge exacerbates flooding in the South River basin and increases extent of flooding around Rosie's Pond.	Storm surge could further exacerbate flooding in the South River basin and increase extent of flooding around Rosie's Pond.	It could result in more overtopping of the pond and localized flooding.	5 - High	The ability of the stormwater system to accommodate these future impacts is medium.	Cost to install stormwater pump stations to relieve flooding in the area.	2 - Medium - Low	This is a localized flooding problem around Rosie's Pond and South River basin that may become worse with more extreme storm surge and sea level rise.	5 - High

			PRIORITY VULNERABILITIES											
			Risk Assessment							Evaluation Criteria				
			Consequences					Likelihood	Risk	City Priority Areas				
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact	Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking	
SW1	Extreme precipitation events	**Clogged storm drains and catch basins**	3	1	3	1	8	Very Likely (90-100% chance)	8	64				
SW2	Extreme precipitation events	**Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods**	5	5	3	3	16	Very Likely (90-100% chance)	8	128			High risk/high vulnerability ranking	
SW3	Extreme precipitation events	**Ineffective tide gates (Lafayette Street)**	5	4	2	3	14	Very Likely (90-100% chance)	8	112			High risk/high vulnerability ranking	
SW4	Extreme precipitation events	**Overtopping of Rosie's Pond**	3	3	3	1	10	Very Likely (90-100% chance)	8	80	Yes	Yes	Yes	Priority Area
SW5	Extreme precipitation events	**Flooding of pump stations**	3	2	2	1	8	Very Likely (90-100% chance)	8	64	Yes		Yes	Priority Area
SW6	Sea level rise	**Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods**	5	5	3	3	16	Very Likely (90-100% chance)	8	128			High risk/high vulnerability ranking	
SW7	Sea level rise	**Ineffective tide gates (Lafayette Street)**	5	4	2	3	14	Very Likely (90-100% chance)	8	112			High risk/high vulnerability ranking	
SW8	Sea level rise	**Flooding of pump stations**	3	2	2	1	8	Very Likely (90-100% chance)	8	64	Yes		Yes	Priority Area

			Consequences					Likelihood		Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact		Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
SW9	Storm surge	**Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods**	5	5	3	3	16	Very Likely (90-100% chance)	8	128				High risk/high vulnerability
SW10	Storm surge	**Ineffective tide gates (Lafayette Street)**	5	4	2	3	14	Very Likely (90-100% chance)	8	112				High risk/high vulnerability ranking
SW11	Storm surge	**Flooding of pump stations**	3	2	2	1	8	Very Likely (90-100% chance)	8	64	Yes		Yes	
SW12	Storm surge	**Ineffective seawalls**	5	4	2	3	14	Very Likely (90-100% chance)	8	112				High risk/high vulnerability ranking
SW13	Storm surge	**Overtopping of Rosie's Pond**	3	3	3	1	10	Very Likely (90-100% chance)	8	80	Yes	Yes	Yes	Priority Area

			VULNERABILITY ASSESSMENT								
			Sensitivity				Adaptive Capacity			Vulnerability	
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T1	Extreme heat events	**Sidewalk/roadway buckling, softening and rutting**	No current stress.	High temperatures for extended periods may cause buckling of concrete pavement, softening of asphalt and rutting of highway pavement.	Deterioration would decrease the safety and usability of the transportation network by degrading surfacing materials, resulting in cracking and potholing.	2 - Medium-low	More frequent maintenance and repaving with more heat-tolerant materials may be sufficient.	Some roads maintained by State. Cost, design standards, minimal re-siting flexibility.	3 - Medium	More heat-tolerant materials and more frequent resurfacing, while adhering to design standards, can be costly.	2 - Medium-low
T2	Extreme heat events	**Stress on bridges structural materials**	No current stresses to Kernwood Street. and Rt. 1A bridges.	Extreme heat events exact stress on bridge joints and steel, requiring more frequent repair and reconstruction.	Extreme heat quickens bridges' degradation and causes safety concerns.	2 - Medium-low	Monitoring, maintenance and use of heat-tolerant materials may be sufficient.	Cost, design standards, minimal re-siting flexibility.	4 - Medium-high	The lack of flexibility in siting the location of bridges leads to low adaptive capacity.	2 - Medium-low
T3	Extreme heat events	**Strain on transportation system equipment**	Extreme heat events could lead to failure of equipment, most notably street signals and commuter rail.	Service disruptions and required maintenance may increase.	Could cause system failure, leading to safety concerns and restricted mobility.	1 - Low	Systems in place now for emergency response and repair.	Cost if enhanced monitoring systems, more frequent maintenance, and use of heat-tolerant materials.	4 - Medium-high	Enhanced monitoring systems, more heat-tolerant materials and more frequent maintenance can be so costly as to discourage use.	3 - Medium
T4	Extreme heat events	**Rail tracks deformation**	No current stress.	High temperatures for extended periods cause tracks to become deformed.	Extreme heat would reduce the safety and usability of the MBTA commuter rail and freight rail lines.	3 - Medium	Monitoring, maintenance and use of heat-tolerant materials may be sufficient.	MBTA ownership of rail system. Cost, design standards, minimal re-siting flexibility.	3 - Medium	Enhanced monitoring systems, more heat-tolerant materials and more frequent maintenance can be so costly as to discourage use.	3 - Medium
T5	Extreme heat events	**Reduced bicycle and pedestrian activity**	Minimal stress.	Increased heat events may reduce viability of walking and cycling modes.	Pedestrian and bicycle use may decline.	2 - Medium-low	Pedestrian and bicycle facilities are exposed to heat, and may not be adapted to increase usage during heat events.	Very limited technology or resiting options.	1 - Low	Extreme heat discourages walking and cycling, but adaptation options are limited.	1 - Low
T6	Extreme precipitation events	**Increase need for road maintenance**	Extreme snow events require snow removal, deicing and salting.	Increased frequency of extreme snow events would require more frequent road clearing and maintenance.	More frequent deicing and salting further degrades roadways.	5 - High	More frequent maintenance, snow removal and repair may be necessary.	Cost.	4 - Medium-high	City has the ability to increase snow removal and street treatment as necessary, despite increased cost.	1 - Low
T7	Extreme precipitation events	**Soil saturation, erosion, and landslides lead to shifting and destabilizing transportation network infrastructure**	No current abnormal stresses.	Increased extreme precipitation may lead to increased shifting and destabilization of network infrastructure, including streets and commuter rail (see future flood-prone areas map).	Destabilization of structural foundations could compromise the safety of the transportation network.	5 - High	Current stormwater drainage capacity is limited leading to soil saturation, erosion, and landslides.	Technical and ecological feasibility of addressing this stress is costly.	2 - Medium-low	All potential measures to accommodate future impacts are costly, and are limited by the minimal flexibility in siting.	3 - Medium
T8	Extreme precipitation events	**Flooding from storm drain overflow and overwhelmed seawalls breaches undermines transportation network infrastructure**	Extreme snow and rain events lead to flooding of City streets and tunnels, notably Bridge Street, Canal Street, Commercial Street, Loring Avenue, Jefferson Street, streets in the Willows and Point neighborhoods, and commuter rail. Insufficient emergency parking during snow storms.	More frequent precipitation will flood roadways, the commuter rail, and the freight rail line; this will overwhelm the pumping capacity for tunnels. Access to Rt. 128 will be limited more frequently. Increased damage so signals and signs.	An increase of frequency of extreme precipitation events would lead to decreased roadway, commuter rail, and freight rail access.	5 - High	Current stormwater drainage capacity is limited leading to roadway, commuter rail, and freight rail flooding. Canal Street improvements will reduce impact in that area.	Cost, design standards, minimal re-siting flexibility.	1 - Low	All potential measures to accommodate future impacts are costly, and are limited by the minimal flexibility in siting.	5 - High
T9	Extreme precipitation events	**Reduced access to ferry and operation of service**	Extreme precipitation affects ferry operation and floods area surrounding terminal.	Flooding and operation disruptions will become more frequent.	Increased flooding levels could flood streets surrounding ferry station during storms, reducing transportation options in Salem.	3 - Medium	Current stormwater drainage capacity is limited, which causes flooding near the ferry.	Cost, design standards, minimal re-siting flexibility.	3 - Medium	Service and access disruptions to ferry will be more frequent.	3 - Medium

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T10	Sea level rise	**Nuisance flooding causes frequent disruption of roadways and transit**	No current stress.	Sea level rise may increase the extent of nuisance flooding on streets, the commuter rail line, and the freight rail line particularly along Commercial St., Canal Street, and the Point neighborhood. MBTA bus lines are minimally impacted.	Sea level rise may increase flooding, degrading infrastructure and disrupting mobility.	4 - Medium-high	Current stormwater drainage capacity is limited leading to roadway, the commuter rail, and the freight rail line flooding. However, City services are already experienced in dealing with nuisance flooding. Canal Street improvements will reduce impact in that area.	Cost, design standards, minimal re-siting flexibility.	2 - Medium-low	All potential measures to accommodate future impacts are costly, and are limited by the minimal flexibility in siting.	2 - Medium-low
T11	Sea level rise	**Flooding reduces access to ferry**	No current stress.	Coastal sea level rise may inundate ferry terminal and New Blaney Street Wharf.	Increased flooding levels could flood streets surrounding ferry station during storms, reducing transportation options in Salem.	2 - Medium-low	Ferry terminal relocation options are limited, though elevation of the terminal is possible.	Cost, design standards, minimal re-siting flexibility.	3 - Medium	Regular flooding may require relocation or elevation of ferry terminal.	3 - Medium
T12	Storm surge	**Flooding from storm drain overflow and overwhelmed seawalls breaches undermines transportation network infrastructure**	Storm surge increases impact of flooding of roadways - particularly Bridge Street (between Flint Street and the commuter rail station), Canal Street, North River Canal, Commercial Street, Loring Avenue, Jefferson Street.	Greater storm surge may overwhelm tunnel pumping capacity, notably the commuter rail tunnel. Increased need for evacuation places stress on infrastructure; access is reduced to evacuation via Rt. 128. Greater flooding from storm surge exacerbates flooding in certain roadways. Increased demand for already limited emergency parking. Increased storm surge would overwhelm the aging flood gates at Lafayette Street and Loring Avenue, increasing flooding on those streets. Several bus routes are disrupted by higher flooding levels.	Higher storm surge level increases roadways and transit that are flooded during storms, degrading infrastructure and disrupting mobility.	5 - High	Current stormwater drainage capacity is limited leading to roadway, commuter rail, and the freight rail line flooding. Canal Street improvements will reduce impact in that area.	Cost, design standards, minimal re-siting flexibility.	1 - Low	All potential measures to accommodate future impacts are costly, and are limited by the minimal flexibility in siting.	5 - High
T13	Storm surge	**Reduced access to ferry and operation of service**	Minor flooding.	Increased flooding levels could flood streets surrounding ferry terminal during storms.	Increased flooding levels could flood streets surrounding ferry station during storms, reducing transportation options in Salem.	3 - Medium	Current stormwater drainage capacity is limited, which causes flooding near the ferry.	Cost, design standards, minimal re-siting flexibility.	2 - Medium-low	Ferry terminal may be impacted, though access to ferry during storms is not needed.	3 - Medium
T14	Storm surge	**Inundated sidewalks and bicycle paths**	Coastal walkways and sidewalks in low-lying areas are flooded during storms.	Increased flooding levels may reduce access on more sidewalks. Marblehead rail-trial may be inundated.	Pedestrian and bicycle mobility may be reduced, particularly during storms.	4 - Medium-high	Current stormwater drainage capacity is limited.	Cost, design standards, minimal re-siting flexibility.	2 - Medium-low	Greater extent of flooding reduces bicycle and pedestrian access and mobility.	3 - Medium

			PRIORITY VULNERABILITIES										
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			Consequences					Likelihood		City Priority Areas			
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T1	Extreme heat events	**Sidewalk/roadway buckling, softening and rutting**	4	3	1	2	10	Virtually Certain (99-100% chance) 10	100				
T2	Extreme heat events	**Stress on bridges structural materials**	5	4	1	1	11	Virtually Certain (99-100% chance) 10	110				
T3	Extreme heat events	**Strain on transportation system equipment**	4	2	1	1	8	Virtually Certain (99-100% chance) 10	80				
T4	Extreme heat events	**Rail tracks deformation**	5	3	1	1	10	Virtually Certain (99-100% chance) 10	100				
T5	Extreme heat events	**Reduced bicycle and pedestrian activity**	1	4	1	3	9	Virtually Certain (99-100% chance) 10	90				
T6	Extreme precipitation events	**Increase need for road maintenance**	3	3	2	1	9	Very Likely (90-100% chance) 8	72				
T7	Extreme precipitation events	**Soil saturation, erosion, and landslides lead to shifting and destabilizing transportation network infrastructure**	5	3	2	2	12	Very Likely (90-100% chance) 8	96				
T8	Extreme precipitation events	**Flooding from storm drain overflow and overwhelmed seawalls breaches undermines transportation network infrastructure**	5	3	2	1	11	Very Likely (90-100% chance) 8	88				High risk/high vulnerability ranking
T9	Extreme precipitation events	**Reduced access to ferry and operation of service**	2	1	1	3	7	Very Likely (90-100% chance) 8	56				

			Consequences					Likelihood		Risk	City Priority Areas			
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T10	Sea level rise	**Nuisance flooding causes frequent disruption of roadways and transit**	3	3	1	1	8	Very Likely (90-100% chance)	8	64				
T11	Sea level rise	**Flooding reduces access to ferry**	4	1	1	3	9	Very Likely (90-100% chance)	8	72				
T12	Storm surge	**Flooding from storm drain overflow and overwhelmed seawalls breaches undermines transportation network infrastructure**	5	3	2	1	11	Very Likely (90-100% chance)	8	88				High risk/high vulnerability
T13	Storm surge	**Reduced access to ferry and operation of service**	2	1	1	3	7	Very Likely (90-100% chance)	8	56				
T14	Storm surge	**Inundated sidewalks and bicycle paths**	2	4	1	3	10	Very Likely (90-100% chance)	8	80				

			VULNERABILITY ASSESSMENT								
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VP1	Extreme heat events	**Cooling center space availability**	There is enough space currently at cooling center at Council on aging, but the very few people use the facility.	More extreme heat events will result in the need for more days with cooling centers and more people who need cooling centers. If this happens during the school year, could be lack of space. Current low demand may be due to communication or transportation barriers.	Greater need for cooling centers; more days and more space.	2 - Medium-low	There is ample capacity at cooling center at Council on Aging. Schools can also function as cooling centers during vacation months.	Cost and space availability if demand rises substantially.	1 - Low	Current impact does not seem to be large, but impacts under climate change could cause severe stress to vulnerable populations and adaptation has high costs.	3 - Medium
VP2	Extreme heat events	**Cooling center staff availability**	Cooling center staffing is currently an issue of concern, even with low demand.	More extreme heat events will result in the need for more cooling centers and more emergency response. This will be challenging if there is a lack of staff.	Salem may not be able to staff cooling centers as needed.	4 - Medium-high	Red Cross and City are not able to staff at necessary levels because of resources; if resources are allocated adaptation is readily achievable.	Cost and staff resources.	1 - Low	Staffing of cooling centers is major concern even at current low demand levels.	4 - Medium-high
VP3	Extreme heat events	**Power outages**	System is not currently strained.	More extreme heat days may stress the electrical system in the future.	Increased brownouts and blackouts caused by increased demand for cooling may pose risk to population.	3 - Medium	Most schools have back-up generators, but the Council on Aging does not.	Cost of improving system and transporting residents to cooling centers.	3 - Medium	There is some backup to accommodate increased demands under climate change.	3 - Medium
VP4	Extreme heat events	**Critical emergency preparedness communication**	There is currently a need for emergency information in more languages than English and Spanish. Elderly and disabled may not want to disclose contact information for emergency notifications.	This need will become greater with more extreme heat events.	More extreme heat events result in more need to communicate with and protect vulnerable populations.	3 - Medium	Current systems in place may need to be augmented. More communication could require more staff time and coordination among city departments which could be challenging.	Interdepartmental coordination, translation services or development of other forms of communication (picture-based signage), cooperation from vulnerable populations (giving out personal information).	3 - Medium	There could be some challenges, but the city is already taking some alternative communication measures such as developing picture-based signage for emergency response.	3 - Medium
VP5	Extreme heat events	**Poor air quality**	Vulnerable populations experience respiratory issues on peak hot days.	Increased concentrations of pollutants during more extreme hot and humid days. Increased demand for energy for cooling increases air pollution emissions.	Increased public health risk for people with respiratory illness. This may increase emergency response demand.	3 - Medium	Air pollution control regulations are in place. Air pollution control technologies exist and are likely in place to the extent feasible. Public Health Department does not currently have capacity for respiratory illness prevention.	Air pollution is a regional issue, and Salem has limited control. Cost and feasibility for additional technologies for pollution control. Cost for proactive public health programs.	1 - Low	Full extent of public health risk posed by increased air pollution is unknown; further action would require regional coordination.	3 - Medium
VP6	Extreme precipitation events	**Reduced access to commercial areas**	Areas of current flooding are mostly commercial.	Result in limiting access to commercial areas/needed goods, services and jobs.	More flooding with more extreme precipitation events may reduce access to some basic goods, services, and jobs.	3 - Medium	High cost to repair streets; many flood-prone areas.	Cost.	1 - Low	Flooding is a major issue and it is very costly to implement solutions.	4 - Medium-high
VP7	Extreme precipitation events	**Critical emergency preparedness communication**	There is currently a need for emergency information in more languages than English and Spanish. Elderly and disabled may not want to disclose contact information for emergency notifications.	This need will become greater with more extreme precipitation events.	More extreme precipitation events result in more need to communicate with and protect vulnerable populations.	3 - Medium	Current systems in place may need to be augmented. More communication could require more staff time and coordination among city departments which could be challenging.	Interdepartmental coordination, translation services or development of other forms of communication (picture-based signage), cooperation from vulnerable populations (giving out personal information).	3 - Medium	There could be some challenges, but the city is already taking some alternative communication measures such as developing picture-based signage for emergency response.	3 - Medium
VP8	Extreme precipitation events	**Flooding of and reduced access to public transportation**	Roads currently flood, but lack of access to public transportation is not a concern at this time.	Commuter rail station, tunnel, and rail lines are prone to flooding. Current MBTA bus routes do not overlap substantially with flood-prone areas, with the exception of the route that runs through The Point; Access on both ends of the route may be cut off.	Increased extreme precipitation combined with SLR could damage commuter rail and leave transit-dependent populations isolated during extreme events.	4 - Medium-high	Stormwater drainage system has limited capacity to accommodate greater flooding.	Cost. Accommodating impacts to commuter rail would involve major reconstruction. Coordination with MBTA would be necessary.	1 - Low	If transit is negatively affected by climate change, transit dependent populations will have trouble evacuating their neighborhoods and/or reaching necessary emergency services. Adapting public transit to climate change impacts is costly.	4 - Medium-high
VP9	Extreme precipitation events	**Lack of access by emergency vehicles**	Roads currently flood, but emergency responders can access flooded areas.	More extreme flooding could result in some areas being cut off from emergency response.	Increased flooding would put more vulnerable populations at risk during these weather events caused by climate change.	3 - Medium	Current systems may need to be augmented. Access to the hospital is severely disrupted.	Costs of more frequent emergency response.	4 - Medium-high	Current systems can be expanded to meet increased emergency response demand.	2 - Medium-low
VP10	Extreme precipitation events	**Sidewalk and roadway damage/buckling**	Several areas with heavy pedestrian activity are currently prone to flooding, including Bridge St, Commercial St, Canal St, areas near canals.	More frequent and severe flooding would cause more extensive roadway and sidewalk damage.	Road and sidewalk damage from increased flooding would exacerbate mobility challenges for vulnerable populations, particularly the elderly and the disabled.	5 - High	Sidewalks can be repaired but preventing damage is technologically complex.	Cost and logistics of rebuilding flood protection systems and moving/improving roadways and sidewalks.	2 - Medium-low	The sensitivity is high, roadways and developed coastal areas are already experiencing flooding. Adaptive capacity is low, the system is not capable of handling or adapting to increased flooding.	5 - High

			Sensitivity				Adaptive Capacity			Vulnerability	
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	How is this climate impact currently stressing the component?	How will this climate impact stress the component in the future?	If no action is taken, how much will climate impact worsen the stress to the component?	What is the overall sensitivity of this component?	Ability of the component to accommodate future impacts with minimum disruption or cost	What are the barriers to the component to accommodate impacts?	What is the overall adaptive capacity of this component?	Explanation/summary of vulnerability rating.	What is the overall vulnerability of the component?
VP11	Extreme precipitation events	**Neighborhood security**	No current stress.	More mobile populations vacate neighborhoods following storms creating safety issues for remaining residents.	More frequent flooding leads to more people vacating neighborhoods and not monitoring their property.	3 - Medium	Following flood events, city could establish programs to encourage residents to stay and to educate them about flood recovery and adaptation resources.	Costs to city to help residents and establish programs. Costs to residents to recover after flooding.	3 - Medium	Safety and security are important factors for vulnerable populations especially following extreme weather events. While the city can take action to encourage residents not to vacate their properties, these programs could require funds, and depending on the level of damage, it may not be feasible for people to stay in their homes or neighborhoods.	3 - Medium
VP12	Extreme precipitation events	**Damage to community recreational assets**	Current flooding impairs the use of recreational resources in the city.	Increased flooding and damage to these assets could result in their temporary or permanent closure. Salem State sports complex, OnPoint Community Center, marinas and yacht clubs, wharves and canals, beaches and coastal parks may be affected.	Increased flooding would cause more damage to these resources.	4 - Medium-high	Many recreational facilities are in flood-prone areas. Stormwater drainage system has limited capacity.	Unable to relocate these assets (including Maritime Historic Site and Derby Wharf). Cost of repairing assets.	1 - Low	Location of assets is fixed and damage or loss of assets would more severely impact vulnerable populations such as low income and less mobile residents who have less ability to enjoy recreational opportunities outside of Salem.	4 - Medium-high
VP13	Extreme precipitation events	**Flooding of evacuation routes**	Several major streets out of Salem experience flooding during major storm events, including Rt 1A, Lafayette Street, and Kernwood St. Minimal flooding on Rt. 107 and Boston Street.	Flooding of evacuation routes may become more frequent.	Increased flooding of evacuation routes would require earlier evacuation.	4 - Medium-high	Evacuation on flooded streets is not practical during extreme events. Earlier evacuation would allow for safe exit from Salem. Some routes will not flood, though there may be increased congestion. Canal Street improvements may reduce impact in that area.	Roadway and stormwater system improvements would be necessary.	2- Medium-Low	Several evacuation routes from Salem may flood more frequently. Evacuation may need to occur earlier to accommodate restricted capacity during storms.	4 - Medium-high
VP14	Extreme precipitation events	**Flooding of emergency response facilities**	Canal Street and Derby Street areas experience flooding.	Flooding of Police and Fire Station Headquarters may become more frequent.	Emergency response may be impaired during and immediately after storms.	3 - Medium	Emergency vehicles are capable of movement in extreme conditions, but operations may be affected.	Ability to resite major emergency response facilities is costly and space is limited.	2 - Medium-low	Some emergency response centers may experience flooding during storms, limiting their ability to respond to vulnerable residents.	3 - Medium
VP15	Sea level rise	**Flooding of residential areas**	No current stress.	Sea level rise will lead to increased flooding of coastal areas, particularly in the Point residential neighborhood.	More flooding in developed coastal areas on a regular basis.	5 - High	Transportation infrastructure and homes would need rebuilding after flood damage. Flood protection infrastructure needs rebuilding and repair. Stormwater infrastructure has limited capacity to accommodate current flooding levels. Residents in The Point neighborhood and other low-income populations may be displaced without a place to live if they are renters.	Costs for emergency preparedness, infrastructure, and reconstruction/elevation of homes, ability of low-income populations to pay for repairs or find alternate housing if they are renters.	1 - Low	Likelihood of continued flooding problems is high and adaptive capacity is low.	5 - High
VP16	Sea level rise	**Flooding of and reduced access to public transportation**	No current stress.	Commuter rail station, tunnel, and rail lines are prone to flooding. Current MBTA bus routes do not overlap substantially with coastal areas.	Roads and transit may flood more frequently, reducing mobility.	2 - Medium-low	Stormwater drainage system has limited capacity to accommodate greater flooding. Bus routes can be rerouted.	Cost. Coordination with MBTA would be necessary.	3 - Medium	Regular nuisance flooding may not substantially disrupt transit.	2 - Medium-low
VP17	Sea level rise	**Damage to community recreational assets**	Minor nuisance flooding of coastal resources.	Increased flooding and damage to these assets could result in their temporary or permanent closure. Salem State sports complex, wharves and canals, beaches and coastal parks may be affected.	Increased flooding would cause more damage to these resources.	4 - Medium-high	Many recreational facilities are in flood-prone areas. Stormwater drainage system has limited capacity.	Unable to relocate these assets (including Maritime Historic Site and Derby Wharf). Cost of repairing assets.	1 - Low	Location of assets is fixed and damage or loss of assets would more severely impact critical populations such as low income and less mobile residents who have less ability to enjoy recreational opportunities outside of Salem.	4 - Medium-high
VP18	Sea level rise	**Flooding of evacuation routes**	No current stress.	Many major routes out of Salem will remain passable, with the exception of Canal Street.	Increased sea level rise may increase the congestion of the evacuation routes, due to the flooding on Canal Street.	2 - Medium-low	Evacuation on flooded streets is not practical during extreme events. Earlier evacuation would allow for safe exit from Salem. Some routes will not flood, though there may be increased congestion. Canal Street improvements may reduce impact in that area.	Communicate the need to evacuate earlier.	4 - Medium-high	Increased sea level rise may increase the congestion of the evacuation routes, due to the flooding on Canal Street. However, Canal Street is undergoing flooding improvement projects which may help to mitigate flooding from sea level rise.	2 - Medium-low

			Sensitivity				Adaptive Capacity			Vulnerability	
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	How is this climate impact currently stressing the component?	How will this climate impact stress the component in the future?	If no action is taken, how much will climate impact worsen the stress to the component?	What is the overall sensitivity of this component?	Ability of the component to accommodate future impacts with minimum disruption or cost	What are the barriers to the component to accommodate impacts?	What is the overall adaptive capacity of this component?	Explanation/summary of vulnerability rating.	What is the overall vulnerability of the component?
VP19	Storm surge	**Critical emergency preparedness communication**	There is currently a need for emergency information in more languages than English and Spanish. Elderly and disabled may not want to disclose contact information for emergency notifications.	This need will become greater with more storm surge events.	More storm surge events result in more need to communicate with and protect vulnerable populations.	3 - Medium	Current systems in place may need to be augmented. More communication could require more staff time and coordination among city departments which could be challenging.	Interdepartmental coordination, translation services or development of other forms of communication (picture-based signage), cooperation from vulnerable populations (giving out personal information).	3 - Medium	There could be some challenges, but the city is already taking some alternative communication measures such as developing picture-based signage for emergency response.	3 - Medium
VP20	Storm surge	**Flooding of residential areas**	Anywhere between the canals and the ocean is vulnerable to flooding. This includes the Point neighborhood, Willows neighborhood, and Pioneer Terrace (senior housing). High tide flooding occurs frequently now.	Storm surge will result in greater flooding in at-risk areas. The Point neighborhood may experience a substantial increase in severe flooding.	Residents may be at greater risk for loss of property and safety during storms.	5 - High	Transportation infrastructure and homes would need rebuilding after flood damage. Flood protection infrastructure needs rebuilding and repair. Stormwater infrastructure has limited capacity to accommodate current flooding levels. Residents in The Point neighborhood and other low-income populations may be displaced without a place to live if they are renters.	Costs for emergency preparedness, infrastructure, and reconstruction/elevation of homes, ability of low-income populations to pay for repairs or find alternate housing if they are renters.	1 - Low	Storm surge may increase extent and severity of flooding in vulnerable residential neighborhoods.	5 - High
VP21	Storm surge	**Flooding of and reduced access to public transportation**	Roads currently flood, but lack of access to public transportation is not a concern at this time.	Commuter rail station, tunnel, and rail lines are prone to flooding. Current MBTA bus routes may be disrupted by storm surge flooding.	Increased extreme precipitation combined with sea level rise could damage commuter rail and leave transit-dependent populations isolated during extreme events.	4 - Medium-high	Stormwater drainage system has limited capacity to accommodate greater flooding. Commuter rail tunnel and line may be disabled. Bus routes can be rerouted.	Cost of protection and elevation of rail. Coordination with MBTA would be necessary.	4 - Medium-high	Storm surge may disrupt transit service and damage infrastructure, reducing mobility of transit users.	3 - Medium
VP22	Storm surge	**Damage to community recreational assets**	Flooding of coastal resources.	Increased flooding and damage to these assets could result in their temporary or permanent closure. Salem State sports complex, wharves and canals, beaches and coastal parks may be affected.	Increased flooding would cause more damage to these resources.	4 - Medium-high	Many recreational facilities are in flood-prone areas. Stormwater drainage system has limited capacity.	Unable to relocate these assets (including Maritime Historic Site and Derby Wharf). Cost of repairing assets.	1 - Low	Location of assets is fixed and damage or loss of assets would more severely impact vulnerable populations such as low income and less mobile residents who have less ability to enjoy recreational opportunities outside of Salem.	4 - Medium-high
VP23	Storm surge	**Flooding of evacuation routes**	No current stress.	Many major routes out of Salem will remain passable, with the exception of Canal Street.	Increased flooding of evacuation routes would require earlier evacuation.	4 - Medium-high	Evacuation on flooded streets is not practical during extreme events. Earlier evacuation would allow for safe exit from Salem. Some routes will not flood, though there may be increased congestion. Canal Street improvements may reduce impact in that area.	Roadway and stormwater system improvements would be necessary.	2- Medium-Low	Several evacuation routes from Salem may flood more frequently. Evacuation may need to occur earlier to accommodate restricted capacity during storms.	4 - Medium-high
VP24	Storm surge	**Flooding of emergency response facilities**	Canal Street and Derby Street areas experience flooding.	Flooding of Police and Fire Station Headquarters may become more intense.	Emergency response may be impaired during and immediately after storms.	3 - Medium	Emergency vehicles are capable of movement in extreme conditions, but operations may be affected.	Ability to resite major emergency response facilities is costly and space is limited.	2 - Medium-low	Some emergency response centers may experience flooding during storms, limiting their ability to respond to vulnerable residents.	3 - Medium

			PRIORITY VULNERABILITIES										
			Risk Assessment							Evaluation Criteria			
			Consequences					Likelihood	Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact	Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
VP1	Extreme heat events	**Cooling center space availability**	1	5	1	1	8	Virtually Certain (99-100% chance) 10	80				
VP2	Extreme heat events	**Cooling center staff availability**	3	5	1	1	10	Virtually Certain (99-100% chance) 10	100				
VP3	Extreme heat events	**Power outages**	1	4	1	1	7	Virtually Certain (99-100% chance) 10	70				
VP4	Extreme heat events	**Critical emergency preparedness communication**	1	5	1	1	8	Virtually Certain (99-100% chance) 10	80	Yes		Yes	Priority Area
VP5	Extreme heat events	**Poor air quality**	2	5	3	1	11	Virtually Certain (99-100% chance) 10	110	Yes			Priority Area
VP6	Extreme precipitation events	**Reduced access to commercial areas**	4	1	1	4	10	Very Likely (90-100% chance) 8	80				
VP7	Extreme precipitation events	**Critical emergency preparedness communication**	1	3	1	1	6	Very Likely (90-100% chance) 8	48	Yes		Yes	Priority Area
VP8	Extreme precipitation events	**Flooding of and reduced access to public transportation**	2	1	1	1	5	Very Likely (90-100% chance) 8	40				
VP9	Extreme precipitation events	**Lack of access by emergency vehicles**	1	5	1	1	8	Very Likely (90-100% chance) 8	64				
VP10	Extreme precipitation events	**Sidewalk and roadway damage/buckling**	4	3	1	2	10	Very Likely (90-100% chance) 8	80				

			Consequences					Likelihood		Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact		Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
VP11	Extreme precipitation events	**Neighborhood security**	2	5	1	3	11	Very Likely (90-100% chance)	8	88				
VP12	Extreme precipitation events	**Damage to community recreational assets**	3	1	2	3	9	Very Likely (90-100% chance)	8	72				
VP13	Extreme precipitation events	**Flooding of evacuation routes**	3	5	1	2	11	Very Likely (90-100% chance)	8	88				High risk/high vulnerability ranking
VP14	Extreme precipitation events	**Flooding of emergency response facilities**	3	5	1	1	10	Very Likely (90-100% chance)	8	80				There is overlap with at least one high risk/high vulnerability stress.
VP15	Sea level rise	**Flooding of residential areas**	4	5	3	3	15	Very Likely (90-100% chance)	8	120				High risk/high vulnerability ranking
VP16	Sea level rise	**Flooding of and reduced access to public transportation**	2	1	1	1	5	Very Likely (90-100% chance)	8	40				
VP17	Sea level rise	**Damage to community recreational assets**	3	1	2	3	9	Very Likely (90-100% chance)	8	72				
VP18	Sea level rise	**Flooding of evacuation routes**	3	5	1	2	11	Very Likely (90-100% chance)	8	88				There is overlap with at least one high risk/high vulnerability stress.

			Consequences					Likelihood		Risk	City Priority Areas			
ID No.	Climate Impact	Current and future stresses to this component as a result of climate impact	Economic	Health and Safety	Ecological and Environmental	Cultural and Historical	TOTAL Consequence	Likelihood of the Climate Impact		Risk = Consequence x Likelihood	Alignment with existing plans, policies, or programs	Funding availability	City control over implementation	Reason for Prioritized Vulnerability Ranking
VP19	Storm surge	**Critical emergency preparedness communication**	1	3	1	1	6	Very Likely (90-100% chance)	8	48	Yes		Yes	Priority Area
VP20	Storm surge	**Flooding of residential areas**	4	5	3	3	15	Very Likely (90-100% chance)	8	120				High risk/high vulnerability ranking
VP21	Storm surge	**Flooding of and reduced access to public transportation**	2	1	1	1	5	Very Likely (90-100% chance)	8	40				
VP22	Storm surge	**Damage to community recreational assets**	3	1	2	3	9	Very Likely (90-100% chance)	8	72				
VP23	Storm surge	**Flooding of evacuation routes**	3	5	1	2	11	Very Likely (90-100% chance)	8	88				High risk/high vulnerability ranking
VP24	Storm surge	**Flooding of emergency response facilities**	3	5	1	1	10	Very Likely (90-100% chance)	8	80				There is overlap with at least one high risk/high vulnerability stress.

Likelihood of Climate Impacts

The "Level of Confidence" rankings of each climate impact are determined by the International Panel on Climate Change. They are based on the type, amount, quality, and consistency of evidence that a given climate impact will occur. CDM Smith assigned a score to each "Level of Confidence" to use as the likelihood that any of the four climate impacts would occur.

Level of Confidence[1]	Score	Climate Impacts by the late 21st century (2081-2100)[2]			
		Extreme precipitation events	Extreme heat events	Sea level rise	Storm surge
Exceptionally Unlikely (0-1%)	1				
Extremely Unlikely (0-5%)	2				
Very Unlikely (0-10%)	3				
Unlikely (0-33%)	4				
About as likely as not (33-66%),	5				
More likely than not (>50-100%)	6				
Likely (66-100% chance)	7				
Very Likely (90-100% chance)	8	✓		✓	✓
Extremely Likely (95-100% chance)	9				
Virtually Certain (99-100% chance)	10		✓		

Notes:
1. International Panel on Climate Change, Working Group II. Fifth Assessment Report -Impacts, Adaptation, and Vulnerability - Summary for Policymakers (2014).
2. International Panel on Climate Change, Working Group I. Fifth Assessment Report - Physical Science Basis, Summary for Policymakers (2013).

Climate Change Vulnerability Assessment Matrices & Priority Vulnerabilities
City of Salem, Massachusetts

The results of the vulnerability assessment and the prioritized vulnerabilities based on two methods: 1) a risk assessment and 2) evaluation criteria established 17 distinct priority vulnerabilities, as shown in the table below. Adaptation strategies were developed for these in Appendix C, Climate Change Adaptation Strategies.

	Prioritized Vulnerabilities	Climate Change Impacts			
		Extreme heat events	Extreme precipitation events	Sea level rise	Storm surge
A	Ineffective seawalls (CB10, CB18, SW12)			x	x
B	Ineffective tide gates (CB11, CB19) and inadequate tide gates at Lafayette Street (SW7, SW10)		x	x	x
C	Insufficient capacity and drainage in the stormwater system to remove water from streets and neighborhoods (SW2, SW6, SW9)		x	x	x
D	Flooding disrupts operation of pump stations (SW5, SW8)		x	x	x
E	Flooding of transportation network infrastructure from storm drain overflow and overwhelmed seawalls (T8, T12)		x		x
F	Flooding of evacuation routes (VP13, VP18, VP23)		x	x	x
G	Loss of power at critical city buildings (E1)	x			
H	Backup power failure at critical city facilities (CB5, CB12, CB20)		x	x	x
I	Downed power lines (E3)		x		
J	Critical emergency preparedness communication (VP4, VP7, VP19)	x	x		x
K	Poor air quality (VP5)	x			
L	Property damage or loss of emergency and critical city facilities (CB2, CB6, CB13, W13)		x	x	x
M	Property damage or loss at Salem State University (CB15)				x
N	Flooding of emergency response facilities (VP14, VP24)		x		x
O	Property damage or loss of historic properties (CB4, CB9, CB17)		x	x	x
P	Flooding of residential areas (VP15, VP20)			x	x
Q	Overtopping of Rosie's Pond (SW4, SW13)		x		x