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Climate Resilience Action Plan for Pacific Northwest National Laboratory

SUMMARY OF APPROACH, RESULTS AND COMMITMENTS FOR THE DEPARTMENT OF ENERGY'S SUSTAINABILITY PERFORMANCE OFFICE

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U.S. DEPARTMENT OF
ENERGY

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Drivers for Resilience Planning at PNNL

Administrative Drivers for Climate Resilience Planning

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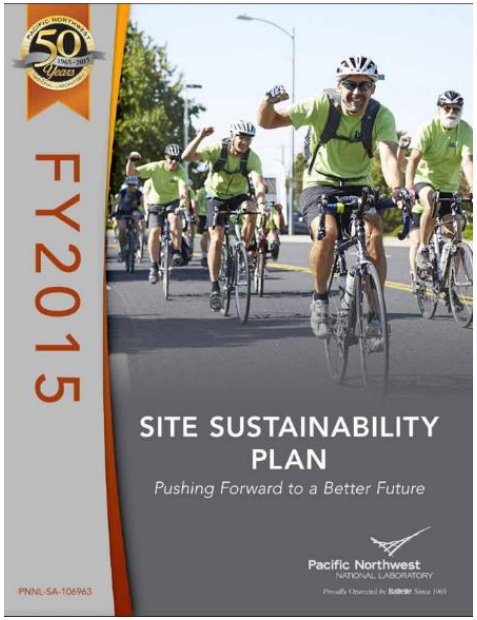
- Recent Executive Orders aim to make the federal government more resilient to climate impacts
  - EO 13514 (Oct 2009) – Develop Adaptation Plans
  - EO 13653 (Nov 2014) – Consider costs and benefits of improving climate adaptation and resilience
  - EO 13693 (Mar 2015) - Integrates previous orders
- DOE Climate Change Adaption Plan fulfills these requirements
- DOE sites must outline specific actions to understand risks and build resilience in annual Site Sustainability Plans (SSPs)



Regional Climate Trends and Projections as Drivers for Resilience Planning

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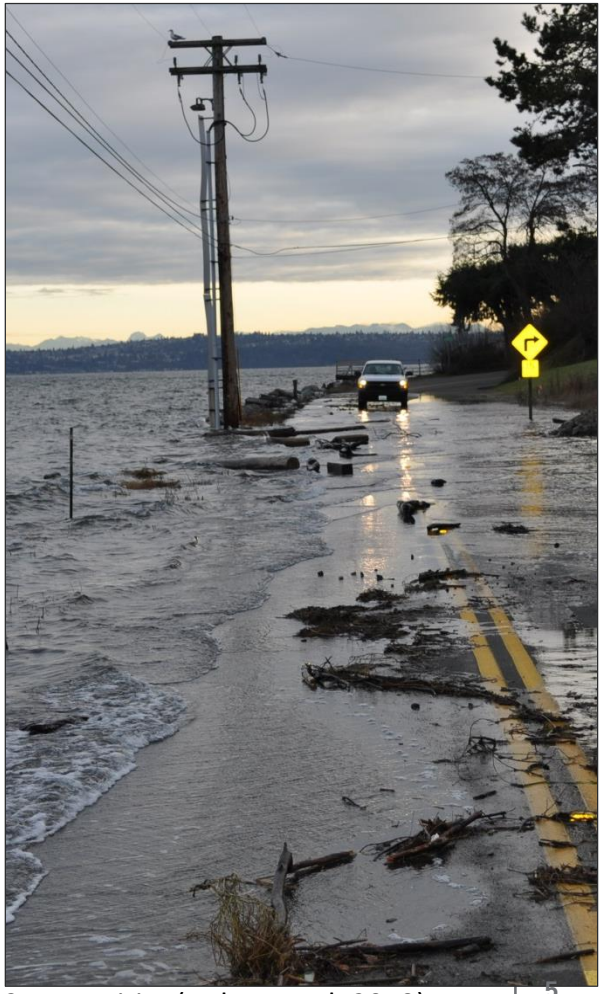
Drought
(less snow/shifting stream flows)

Wildfire

Intense Precipitation



As identified in *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities* (Dalton et al. 2013)
Available at: http://occri.net/wp-content/uploads/2013/11/ClimateChangeInTheNorthwest.pdf

Regional Projection: Less Snow

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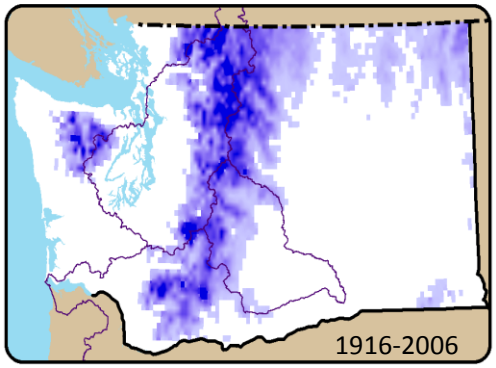
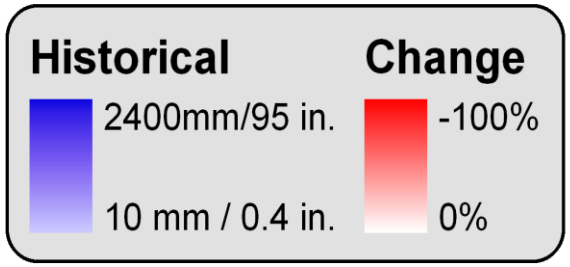
Historical



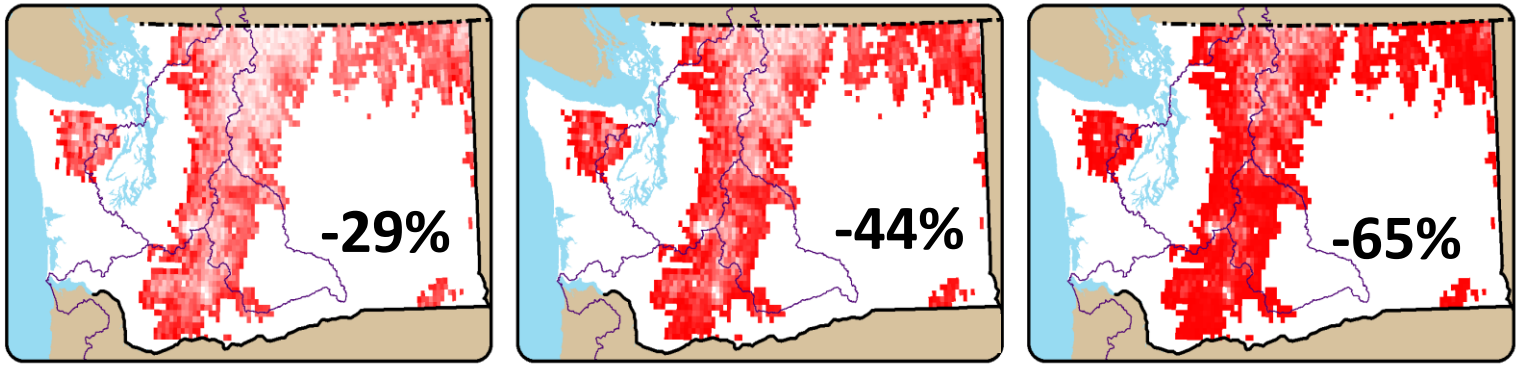


Apr. 1 Snow Water Equivalent

Medium Emissions Scenario

A1B

2020s **2040s** **2080s**

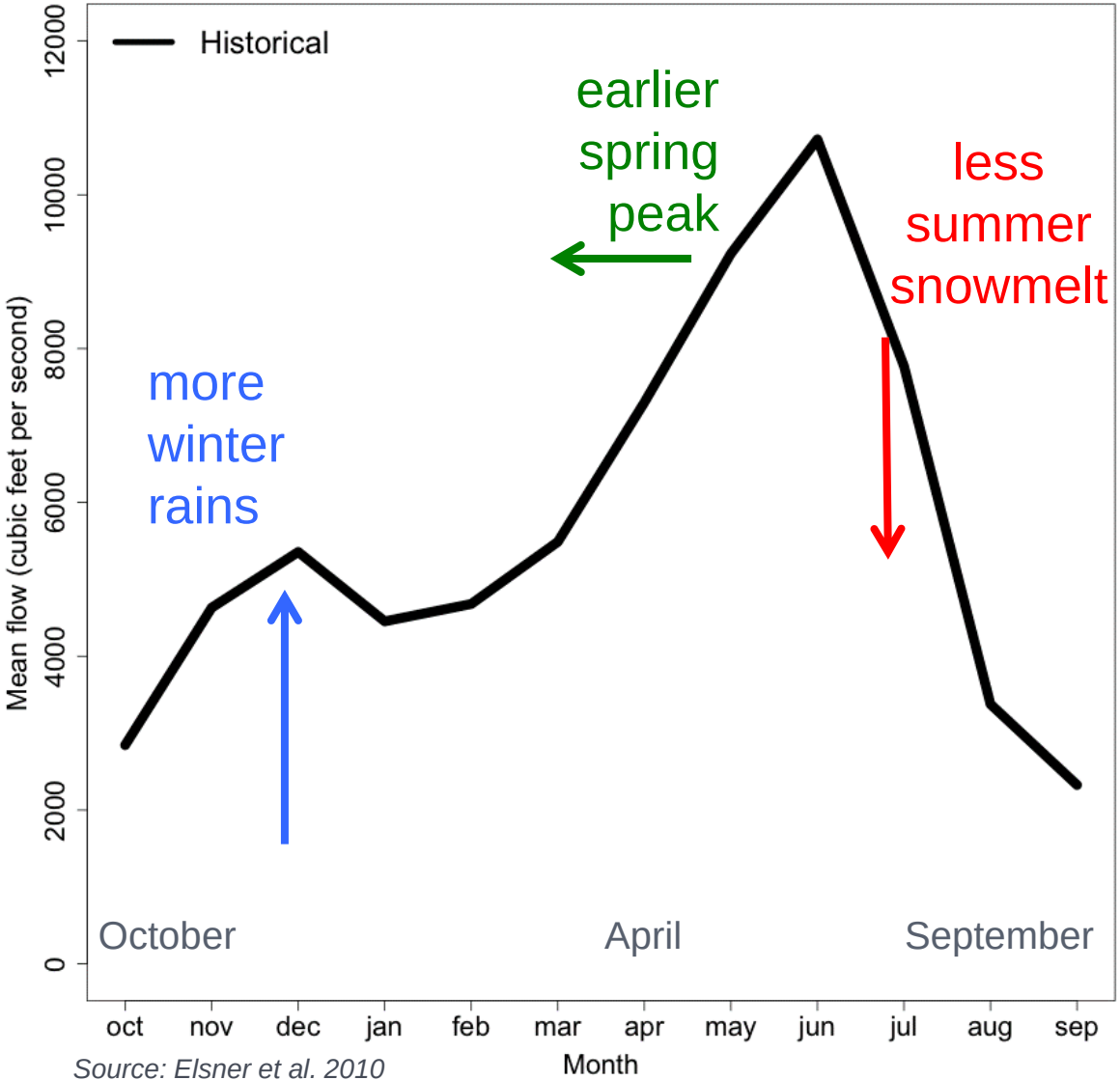


Source: Elsner et al. 2010. Implications of 21st century climate change for the hydrology of Washington State

Why? Spring snowpack is projected to decline as more winter precipitation falls as rain rather than snow, especially in warmer mid-elevation basins. Also, snowpack will melt earlier with warmer spring temperatures.

Regional Projection: Shifting Streamflows and Flood Risk

Naturalized flows (without the influence of dams)



Source: Elsner et al. 2010

Regional Projection: Increased Wildfire Risk

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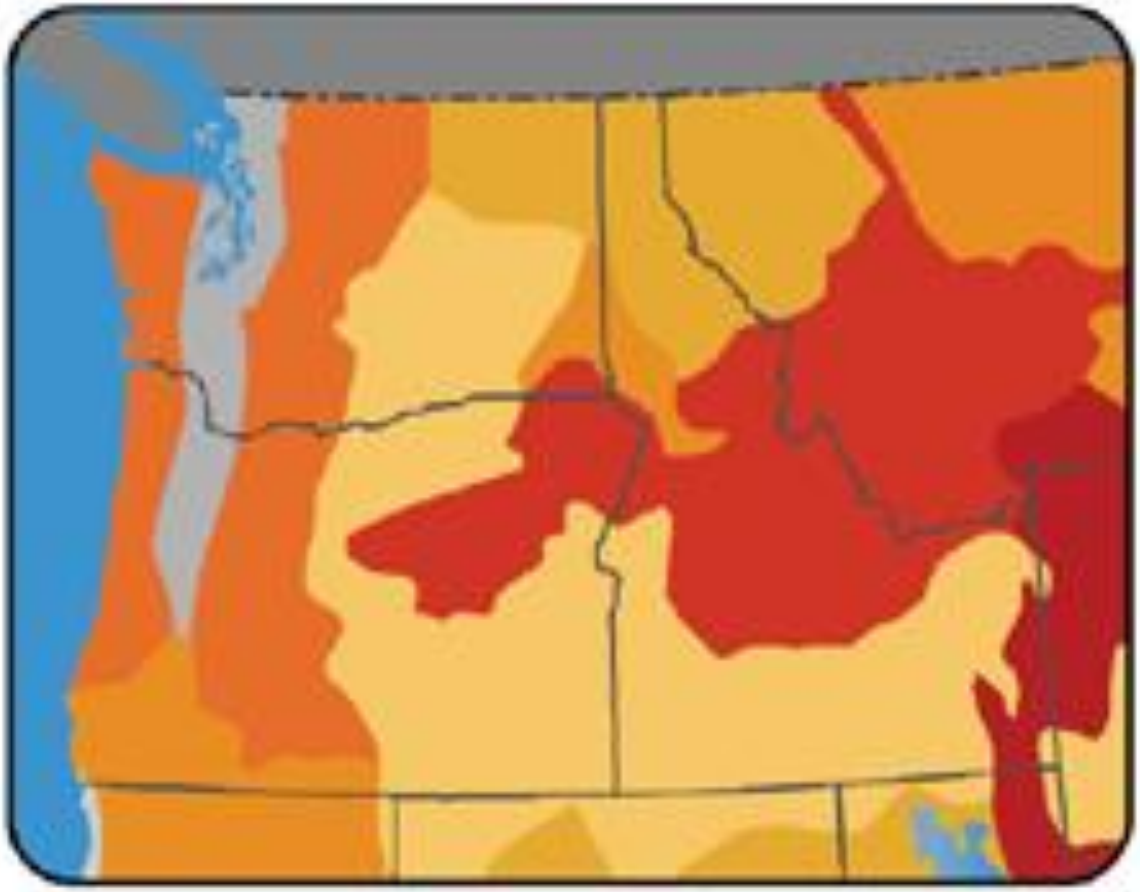


Projected Increase in Area Burned

- 600% to 700%
- 500% to 600%
- 400% to 500%
- 300% to 400%
- 200% to 300%
- 100% to 200%
- Not modeled

Source: 2014 National Climate Assessment, "Climate Impacts in the United States, Chapter 21 Northwest., p 496; Mote. et al
Available at: http://nca2014.globalchange.gov/report/regions/northwest

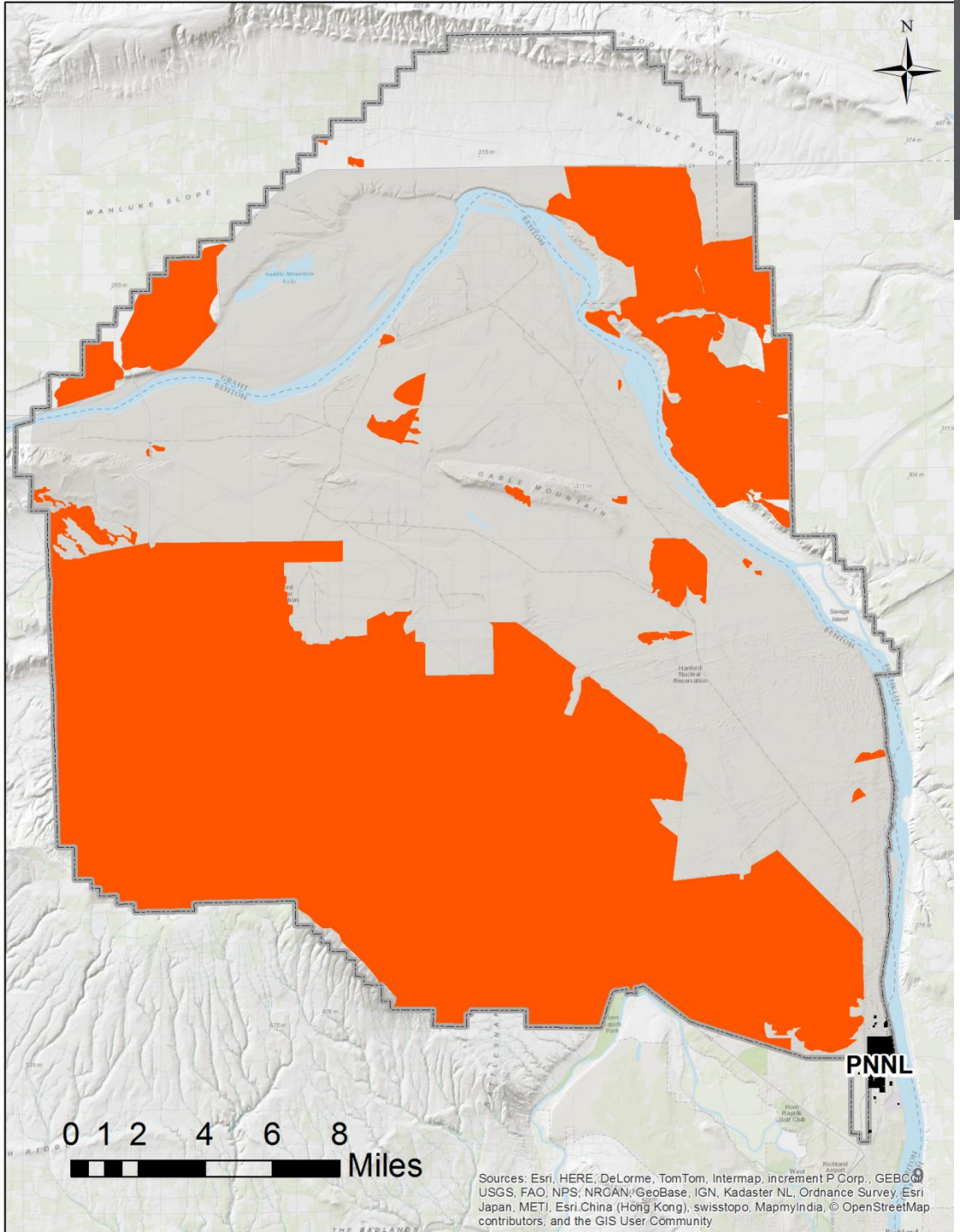
Regional Trends: Wildfires at Hanford

1970's

1980's

1990's

2000's



Regional Trends: Temperature and Precipitation at Hanford

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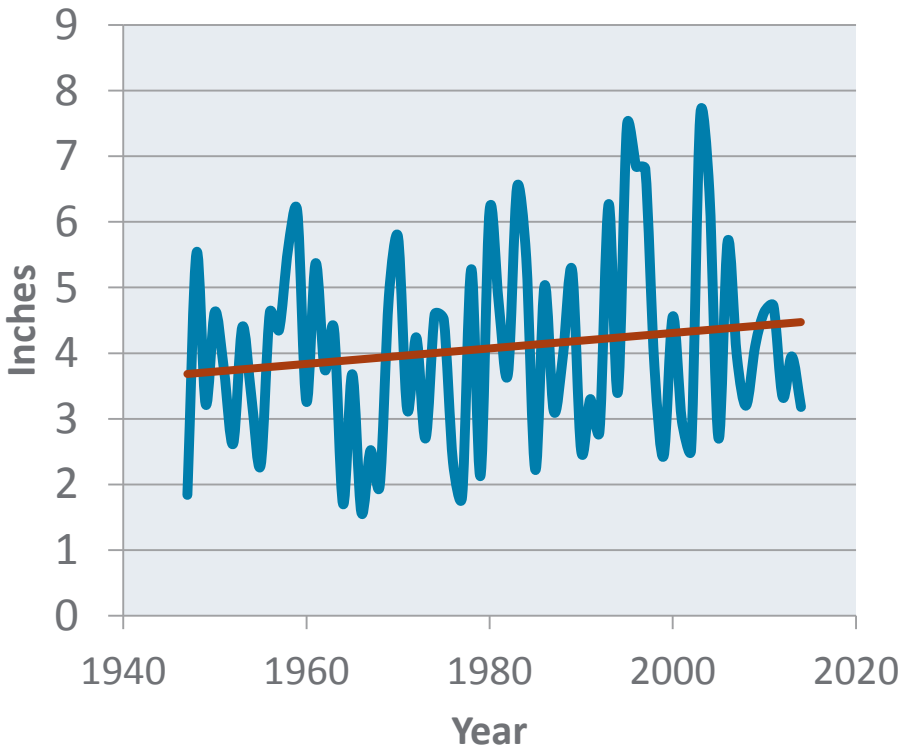
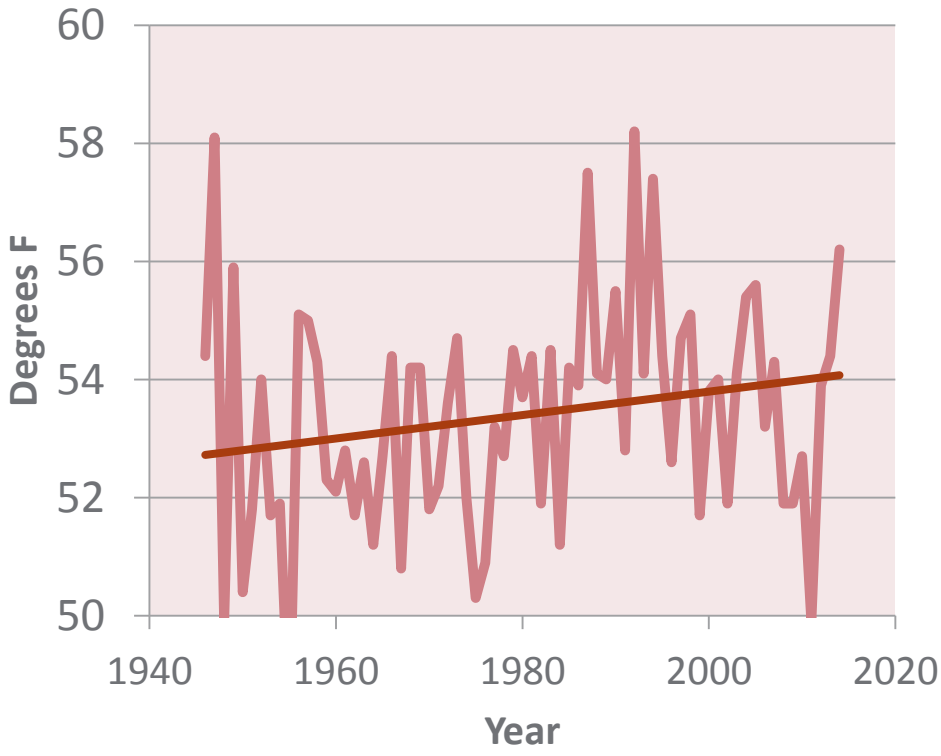
Increased winter rainfall and spring temperature influence the amount of flammable fuel (grasses)

Winter/Spring Precipitation 1945-2015



Spring Temperatures 1945-2015



Source: Hanford weather station data

Resilience Planning Approach

PNNL Climate Resilience Planning Process

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Establish core project team and scope

- Prepare detailed work plan

Secure stakeholder commitment

- Hold kickoff meeting with internal team discuss context for resilience planning, review process, and request input

Conduct exposure assessment

- Establish regional climate trends and projections
- Draft exposure worksheet to identify at-risk systems

Assess existing plans and ability to adapt

- Review existing plans to manage core systems
- Review external plans and models
- Interview site personnel to clarify plans
- Update exposure assessment worksheet

Prioritize vulnerabilities

- Hold workshop #1: Agree on vulnerabilities, identify current and new adaption actions
- Fill in information gaps (internal & external interviews)
- Draft climate exposures and core system vulnerability matrix

Establish resilience action plan

- Hold workshop #2: Finalize priority vulnerabilities and actions to build resilience
- Establish approach to integrate actions into operations
- Vet with key external stakeholders

Programs Represented on Internal Stakeholder Team

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- Sustainability Program
- Energy Operations
- Facilities Strategic Planning
- Facilities Engineering
- Facilities & Operations Strategic Projects
- Facilities & Grounds Maintenance
- Environmental Health & Safety
- Worker Safety & Health
- IT Services
- Water Resource Management
- DOE Pacific Northwest Site Office
- Research subject matter experts
  - Earth Systems/Climate Science
  - Sustainable Building Performance

Elements of Vulnerability Assessment

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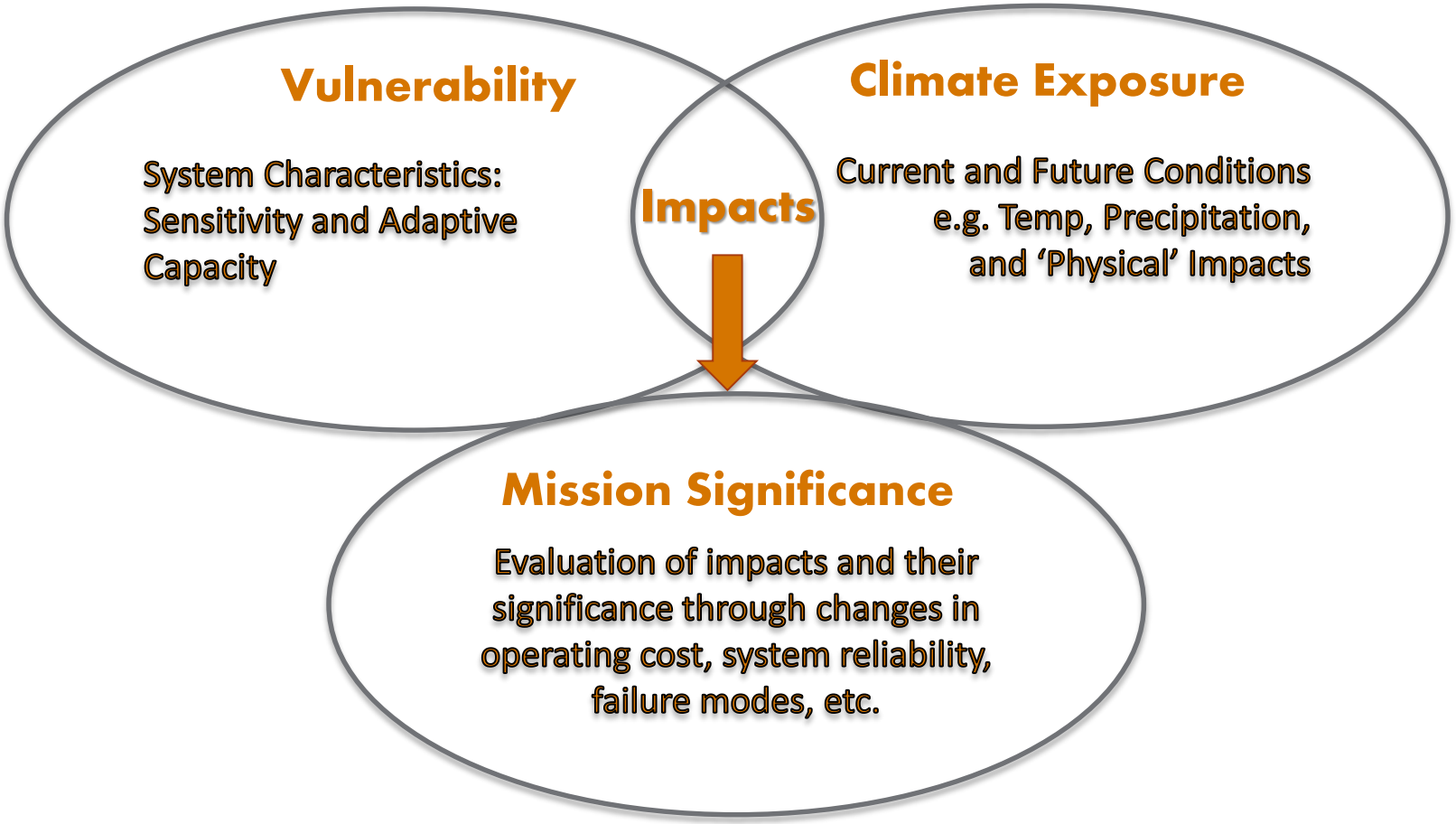
Vulnerabilities are caused by characteristics of infrastructure, such as their design, condition and placement. When an extreme event or change in climate occurs, it can exploit system vulnerabilities to produce impacts that affect mission attainment.



Source: Adapted from Moss et al, 2015. http://www.osti.gov/scitech/servlets/purl/1211559

Climate Resilience Planning Framework

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Internal Stakeholders

- Potential impacts?
- Existing/planned adaptation measures?
- New measures?
- Further information?
- Priorities for adaptation planning?

Core Systems

- Buildings
- Energy
- Water resources
- IT services
- Transportation
- Worker safety & health

Climate Exposure

- Intense precipitation
- Drought
- Wildfire
- High temperatures
- Storms and winds
- Ice storms

External Stakeholders

- Completed Assessments?
- Adaptation plans?
- Concerns or suggestions?

Prioritization – A Two-Step Process

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1. **Prioritization of Exposures and Vulnerabilities**
   - Probability of climate exposure occurring
   - Severity of impact and level of significance for core systems

2. **Prioritization of Actions –** For highest priority systems / exposures, expert judgment based assessment of
   - Impact on mission delivery
   - Cost
   - Technical feasibility / difficulty of alleviating the vulnerability
   - Health and safety risk
   - Impact on community
   - Time horizon for impact

System Vulnerabilities, Priority Exposures, and Resilience Measures

Priorities: Climate Exposures and Core System Vulnerabilities

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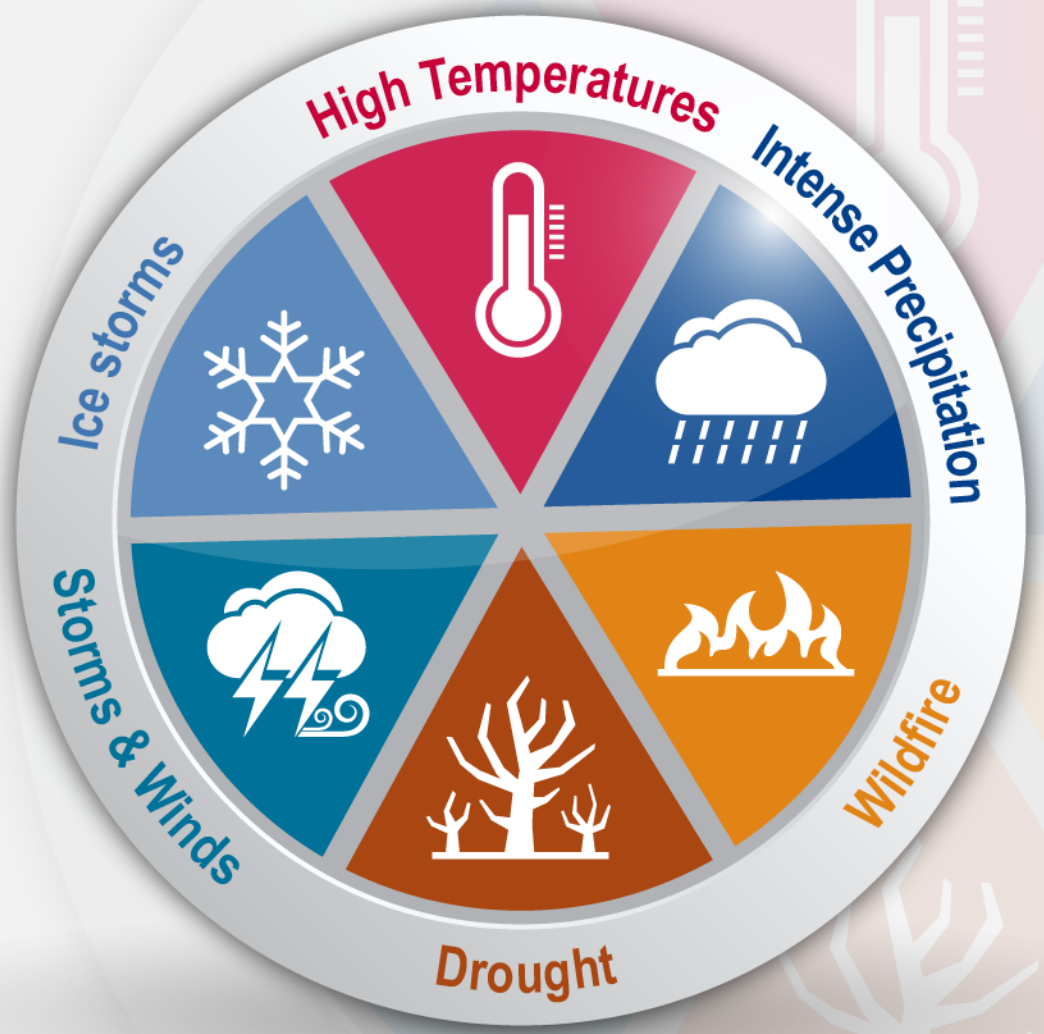
Climate Exposure / Core System	High Temperatures	Intense Precipitation	Wildfire	Drought	Storms and Winds	Ice Storms
Buildings	Higher	Higher	Medium	Medium	Medium	Medium
Energy	Higher	Lower	Lower	Medium	Medium	Lower
IT Services	Medium	Medium	Lower	Lower	Medium	Lower
Worker Safety & Health	Lower	Lower	Medium	Lower	Lower	Lower
Water Resources & Infrastructure	Lower	Lower	Lower	Lower	Lower	Lower
Transportation	Lower	Lower	Lower	Lower	Lower	Lower

Core System: Buildings



Buildings – Higher Priority

High temperatures

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Potential Vulnerabilities

- Increased degradation rate of building exterior and HVAC
- Increased costs for energy use and facility maintenance
  - Setbacks and evaporative cooling will be less effective
- Higher initial cost of building (envelope; HVAC)
- Utility could limit power distribution if taxed by higher demand/lower supply

Current Measures/Plans

- ✓ Preventative maintenance plans reviewed annually
- ✓ Cool roofs are the design default
- ✓ Maximize use of light-colored materials for roofs & hard-paved areas (CMP)
- ✓ Shade trees (CRGP)
- ✓ Building orientation (Design Guide)
- ✓ Considering a mobile chiller to boost systems stressed by heat

New Measures

- ✓ Integrate these vulnerabilities into preventative maintenance plans
- ✓ Add a check for remaining life expectancy in the 5 year condition assessment
- ✓ Track equipment life relative to life expectancy assumptions and adjust in LCC analyses if needed
- ✓ Use Metasys to alternate operating schedules to reduce power load if needed
- ✓ Model temp increases in new designs

Buildings – Higher Priority

Intense precipitation (including snow melt)

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Potential Vulnerabilities

- Flood damage to roofs, ground-level, and below-grade facilities

Current Measures/Plans

- ✓ Preventative maintenance (PM) to clean roof drains
- ✓ Current building drain systems are designed for 1" of rain in 24 hours

New Measures

- ✓ Revisit PM of building drainage systems (labor cost tradeoff)
- ✓ Include drains in facility condition assessments every 5 years
- ✓ Consider flood risk changes in building design and leasing decisions
- ✓ Assess risk of buildings with below-ground access (e.g. Building 318)
- ✓ Assess building and parking lot catch-basins annually to ensure effective infiltration

We discussed changing the building design for new structures to reduce the weed catching locations.

We discussed changing the building design for new structures to reduce the weed catching locations.

Buildings – Medium Priority

Wildfire

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Potential Vulnerabilities

- Particulates from fire and post-fire dust can increase HEPA and intake filter loading/failure and maintenance costs
- Damage to wood power poles (on campus or City of Richland poles)
- Structural damage to facilities from wind-blow embers that land on roofs
- Accumulation of tumbleweeds after wildfire, especially at PSF
- Radiological Processing Lab safety and spread of contamination (lower risk)

Current Measures/Plans

- ✓ Fire management plan requires stand-off distances (100' vegetation buffer)
- ✓ Grounds management controls fuel build-up by flail mowing around buildings
- ✓ Pre-filters to protect HEPA filters
- ✓ HEPA filters changed every 10 years or after big events (e.g. fire)
- ✓ Maintain a HEPA/intake filter inventory
- ✓ Use non-wood construction materials
- ✓ Bailer used to manage tumbleweed

New Measures

- ✓ Encourage City of Richland to replace wood power poles on/near site with steel
- ✓ Consider new building designs that reduce weed-catching locations

Buildings – Medium Priority

Drought

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Potential Vulnerabilities

- Water-intensive landscaping
- Use of BSF/CSF geothermal heat pump could be affected by lower water flows or changes to State discharge permit (lower risk)
- Compliance challenge if greater regulation of discharges from City of Richland sewer discharges (lower risk)
- Loss of access to Columbia River water right (lower risk)

Current Measures/Plans

- ✓ Water withdrawal is metered and capped
- ✓ Cooling towers at BSF/CSF to supplement GSHP
- ✓ New building landscaping standards require drought tolerant plants
- ✓ Consultant hired to develop more sustainable landscape design strategy
- ✓ Reinitiated use of well water

New Measures

- ✓ Implement alternate landscaping strategies (i.e. more native) around existing buildings on core campus

Buildings – Medium Priority

Storms and wind

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Potential Vulnerabilities

- Trees falling on buildings
- Windblown tumbleweeds create fire hazard

Current Measures/Plans

- ✓ Tumbleweeds removed after significant wind event
- ✓ Pruning of trees, removal of dead and/or diseased trees
- ✓ New trees are planted a safe distance from buildings per landscaping standards

New Measures

- ✓ Minimize areas where tumbleweeds can collect, example would be limiting “dead end” areas of building footprints

Buildings – Medium Priority

Ice storms

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Potential Vulnerabilities

- Frost can plug louvre screens and inlets
- Snow and ice can damage roofs and shorten envelope life span

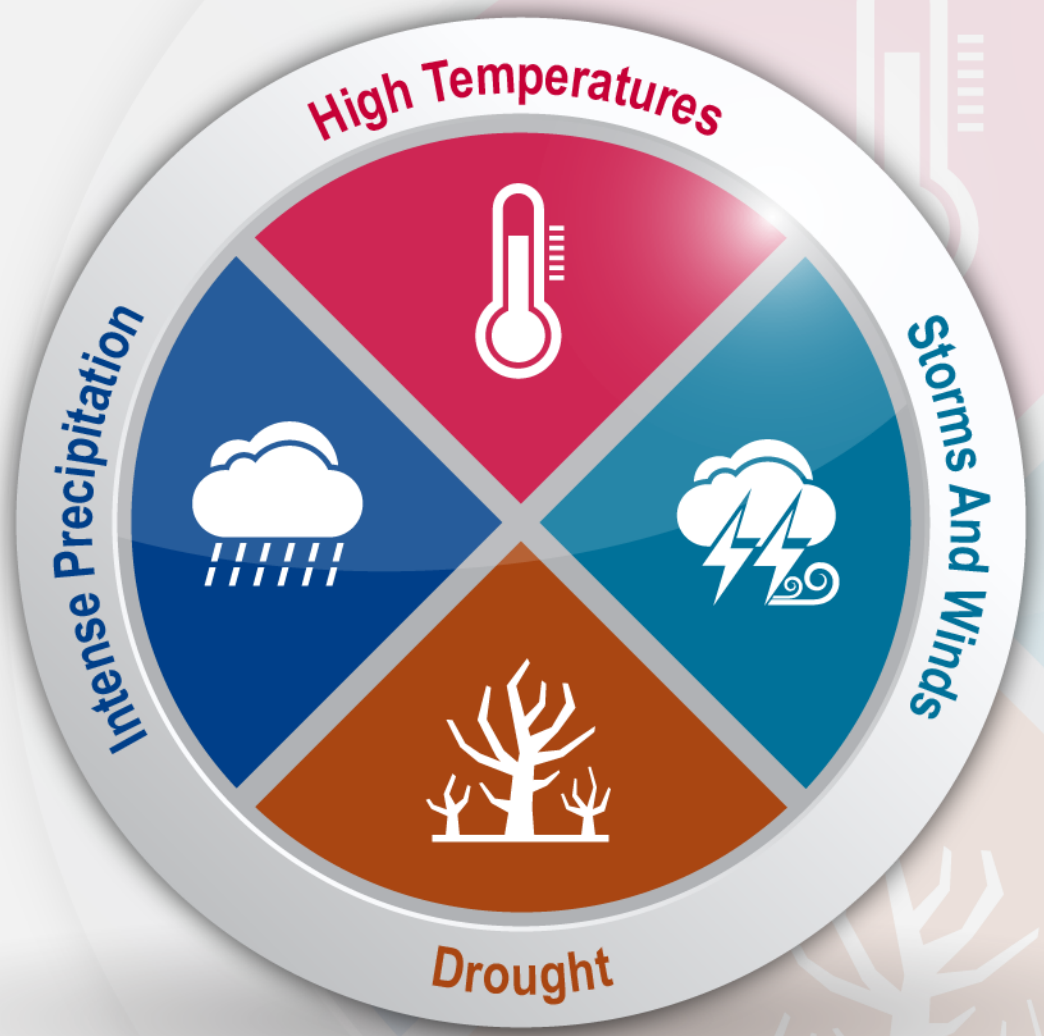
Current Measures/Plans

✓ Newer buildings have capabilities to relocate pre-filters downstream of heating coils to minimize frost potential

New Measures

✓ Ensure new building design standards incorporate this practice

Core System: Energy



Energy – Higher Priority

High temperatures

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Potential Vulnerabilities

- Higher initial cost for larger cooling equipment, other mitigation measures
- Higher O&M costs less effective cooling, systems working harder
- Higher energy prices with higher demand (medium risk)

Current Measures/Plans

- ✓ Three ESPCs will reduce energy demand (SSP)
- ✓ Ensure energy escalation rates reflect risk in facility design and operations planning (but need to ensure it's repeatable)

New Measures

- ✓ Implement continuous commissioning and facility retuning to reduce energy
- ✓ Add note in design standards to consider temp impact and cost-benefit tradeoff for envelope, HVAC system changes
- ✓ Alternate operating schedules to reduce power load (e.g., limit mid-day ops)

Energy – Medium Priority

Drought

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Potential Vulnerabilities

- Cost impact if BPA is having buy more power from the market
- Brownouts if BPA / City take measures to manage high regional energy demand relative to hydropower supply (lower risk)

Current Measures/Plans

- ✓ Onsite renewable (125 kW PV array) supports ~4% of EMSL's load (SSP)
- ✓ Implement comprehensive load-shedding at BSF/CSF

New Measures

- ✓ Extend load-shedding capability to all buildings
- ✓ Leverage PNNL research on flow batteries and smart appliances in PNNL facilities
- ✓ Establish plans for net zero buildings by 2030 (future SSP requirement)

Energy – Medium Priority

Storms and winds

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Potential Vulnerabilities

- Electricity supply interruption from transmission system damage
- Generators not designed to operate for periods of more than a few days or week

Current Measures/Plans

- ✓ Back-up power generators at some buildings 331, RTL, PSF
- ✓ Continuity of Ops considers R&D mission needs for sustained outages (i.e. 10 days)

New Measures

- ✓ None

Energy – Lower Priority

Intense precipitation

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Potential Vulnerabilities

- Damages to buried natural gas pipelines/conduits/tunnels
- Electrical and IT damage from flooded vaults

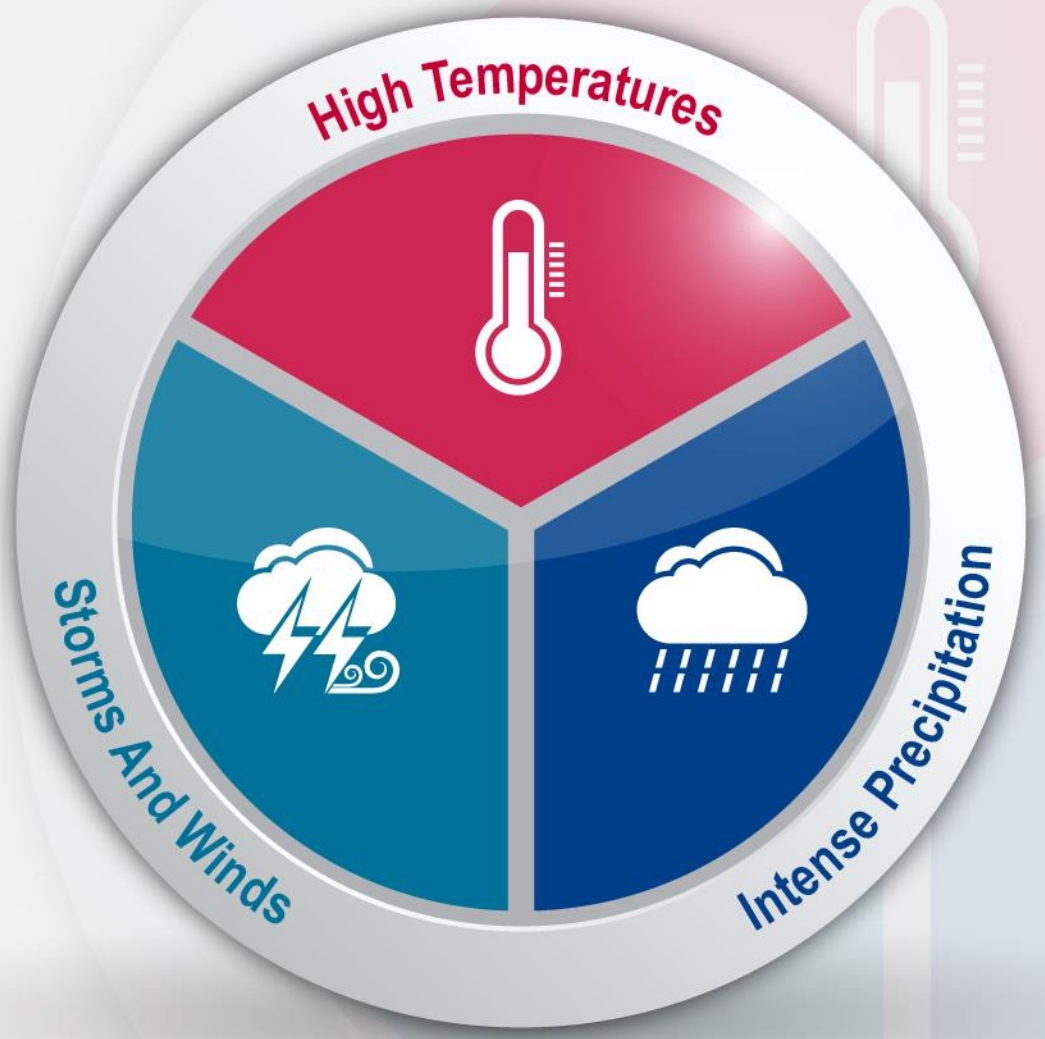
Current Measures/Plans

✓ Cascade Natural Gas identified needs for reinforcement in its distribution system

New Measures

✓ Consider flood risk in design and location of vaults

Core System: IT Services



IT Services – Medium Priority

High temperatures

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Potential Vulnerabilities

- Loss of cooling efficiency and capacity as temperatures increase
- Power loss due to electricity brownouts/blackouts
- Water use would increase for water cooled facilities

Current Measures/Plans

- ✓ Dual power feeds to ISB2 data center from different City substations
- ✓ Current design assumes temps of 101F, 1% of time
- ✓ Wet bulb temperature considered when planning facilities w/ water cooling

New Measures

- ✓ When modeling new data center cooling systems, account for more days of extreme temperatures (code + x days) to accurately assess HVAC demand
- ✓ Consider predictive changes in wet bulb temp/humidity when designing cooling systems

IT Services – Medium Priority

Intense precipitation

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Potential Vulnerabilities

- Flood risk to ISB2 basement (data center) through vault
- Damage to buried cables from flooded land settling and breaking conduits (lower risk)

Current Measures/Plans

- ✓ Redundant Internet connection with diverse routes
- ✓ Redundancy in campus telecom infrastructure
- ✓ Courtyard above data center has had weatherproofing
- ✓ Conduits entering data center below ground have been sealed
- ✓ Some IT infrastructure duplicated in EMSL MSCF for Continuity of Ops
- ✓ Dual power feeds to ISB2 data center from different City substations

New Measures

- ✓ Assess data center vulnerability to flood and effectiveness of current measures
- ✓ Add checking vaults to 5-yr condition assessment process

IT Services – Medium Priority

Storms and winds

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Potential Vulnerabilities

- Loss of internet service from trees falling on aerial lines (Internet providers and have some aerial lines)
- Loss of internet service from the root ball of a downed tree damaging buried fiber optic cable (lower risk)

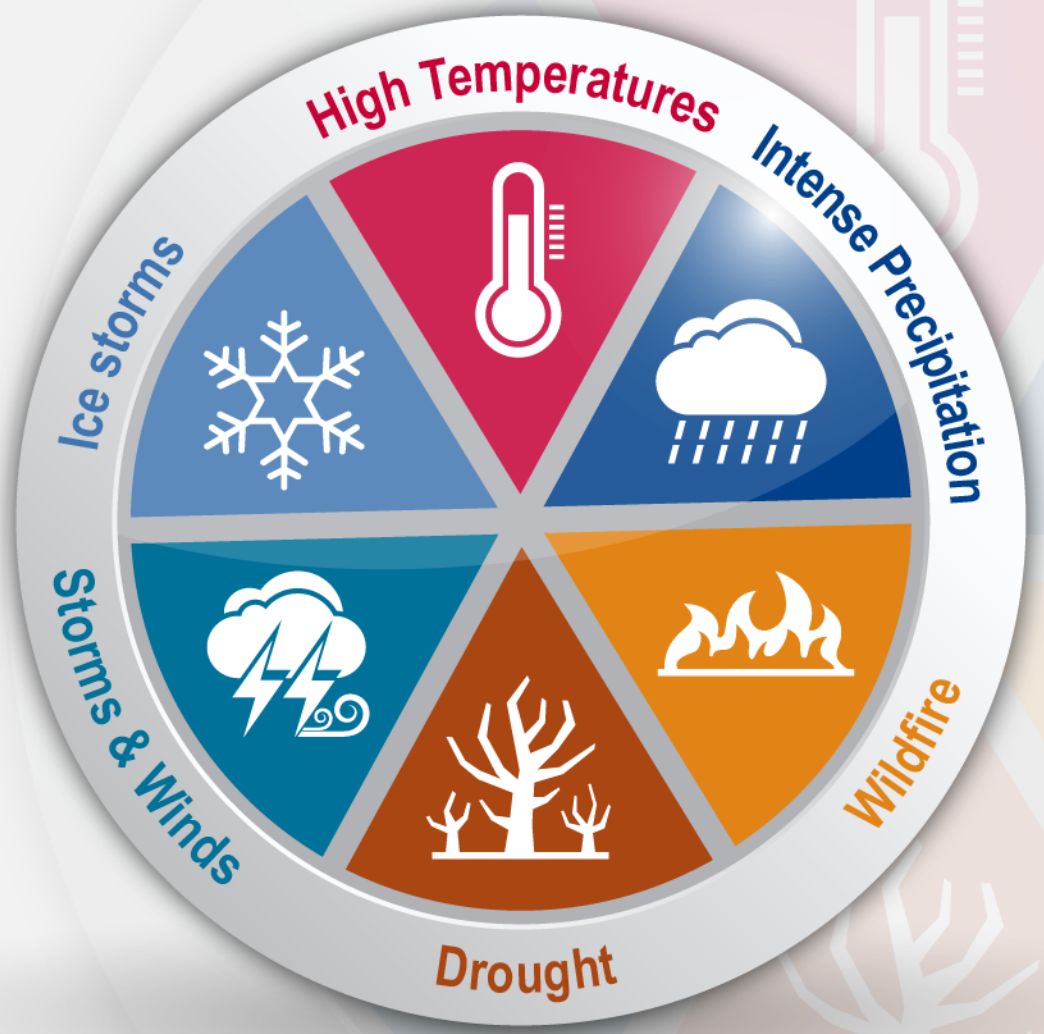
Current Measures/Plans

- ✓ Redundant Internet connection is in place with diverse routes
- ✓ Redundancy in campus telecom infrastructure is in place
- ✓ Dual power feeds to ISB2 data center from different City substations

New Measures

- ✓ Find out what providers are doing to manage risk

Core System: Worker Health & Safety



Worker Health & Safety – Medium Priority

Wildfire

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Potential Vulnerabilities

- Health effects from smoke pulled into buildings through ventilation systems
- Driving hazard posed by low visibility on campus roads

Current Measures/Plans

- ✓ Fire response plan includes filter loading during events
- ✓ Maintain a HEPA/intake filter inventory
- ✓ Hazard advisory system and lab workday closures/delays encourage staff to stay off roads when unsafe
- ✓ Flextime and telework policies help to reduce commuting risks when unsafe

New Measures

- ✓ Add air quality risk from wildfire to field work checklist signed by project management offices (PMODs)
- ✓ Consider monitoring or alert system for dust storms

Worker Health & Safety – Lower Priority

High temperatures

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Potential Vulnerabilities

- Heat stress, heat stroke, dehydration of outdoor maintenance personnel

Current Measures/Plans

- ✓ Provide staff with protection (sunscreen, hat, shaded glasses, bandana, fluids)
- ✓ Refer to heat stress link and wet bulb sensor during summer months
- ✓ Educate staff to take breaks, drink plenty of fluids, know symptoms of heat stress and heat stroke
- ✓ Adjust shifts (come in 2 hours early) in hot months

New Measures

- ✓ None noted

Worker Health & Safety – Lower Priority

Intense precipitation

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Potential Vulnerabilities

- Hazardous road conditions to employees while commuting
- Increased risk of flooding-related infectious diseases

Current Measures/Plans

✓ Flextime, telework, and lab workday closures/delays to manage commuting risks

New Measures

✓ None noted

Worker Health & Safety – Lower Priority

Storms and winds

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Potential Vulnerabilities

- Hazardous driving conditions due to low visibility from dust storms
- Breathing problems for outdoor personnel who have severe allergies and asthma

Current Measures/Plans

- ✓ Flextime, telework, and lab workday closures and delays to manage commuting risks

New Measures

- ✓ None noted

Worker Health & Safety – Lower Priority

Ice storms

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Potential Vulnerabilities

- Hazardous driving conditions to employees while commuting
- Pedestrian and auto safety risk on campus

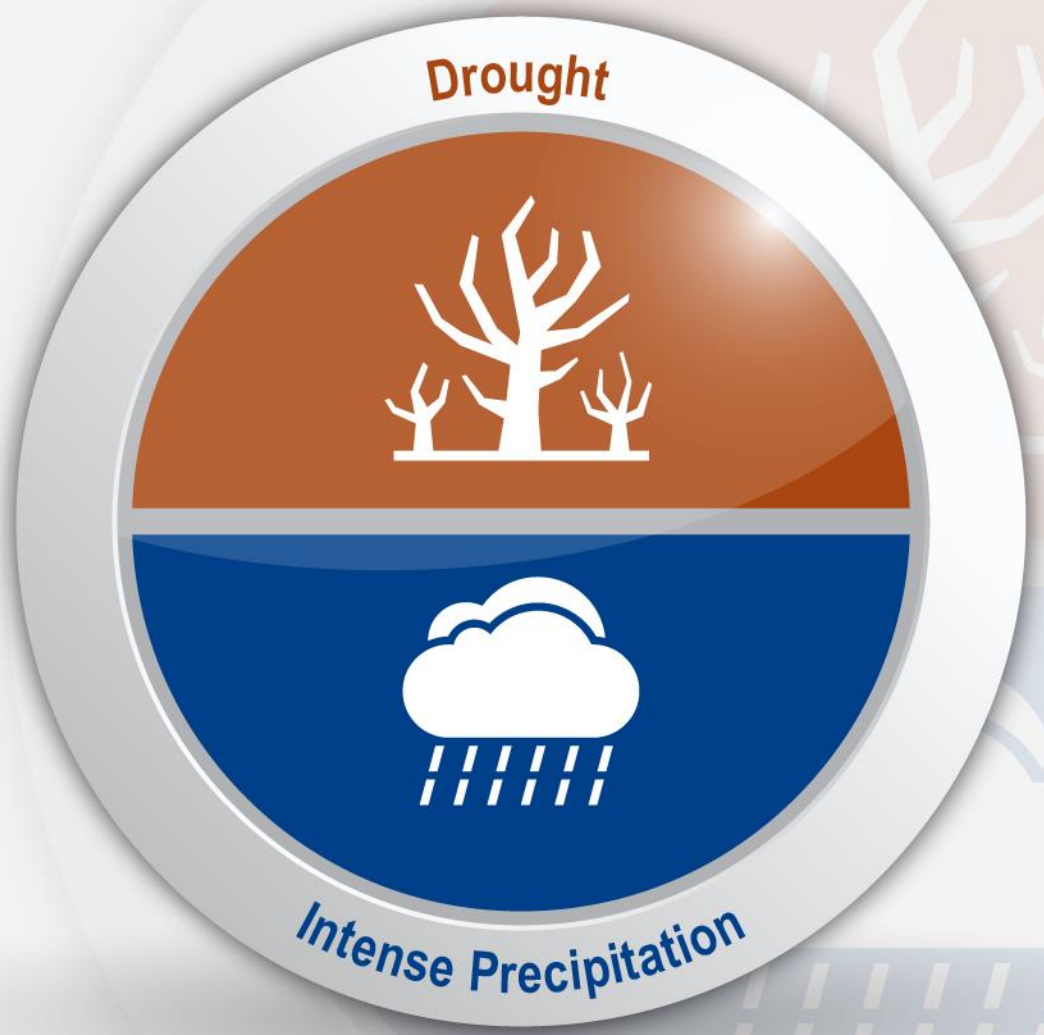
Current Measures/Plans

- ✓ Extensive use of deicer on campus sidewalks and roads
- ✓ Flextime, telework, and lab workday closures/delays to manage commuting risks

New Measures

- ✓ None noted

Core System: Water



Water – Lower Priority

Drought

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Potential Vulnerabilities

- Limited water supply for all uses during events

Current Measures/Plans

- ✓ Use native and adaptive vegetation to reduce water demand (CMP)
  - ✓ Fire prevention tradeoff
- ✓ Continue audits of all facilities to identify water conservation opportunities (SSP)

New Measures

- ✓ None noted

Water – Lower Priority

Intense precipitation

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Potential Vulnerabilities

- Damage to City of Richland's water treatment or intake facilities
- Flooding could cut off water supply
- Water table level changes could inundate Building 3425

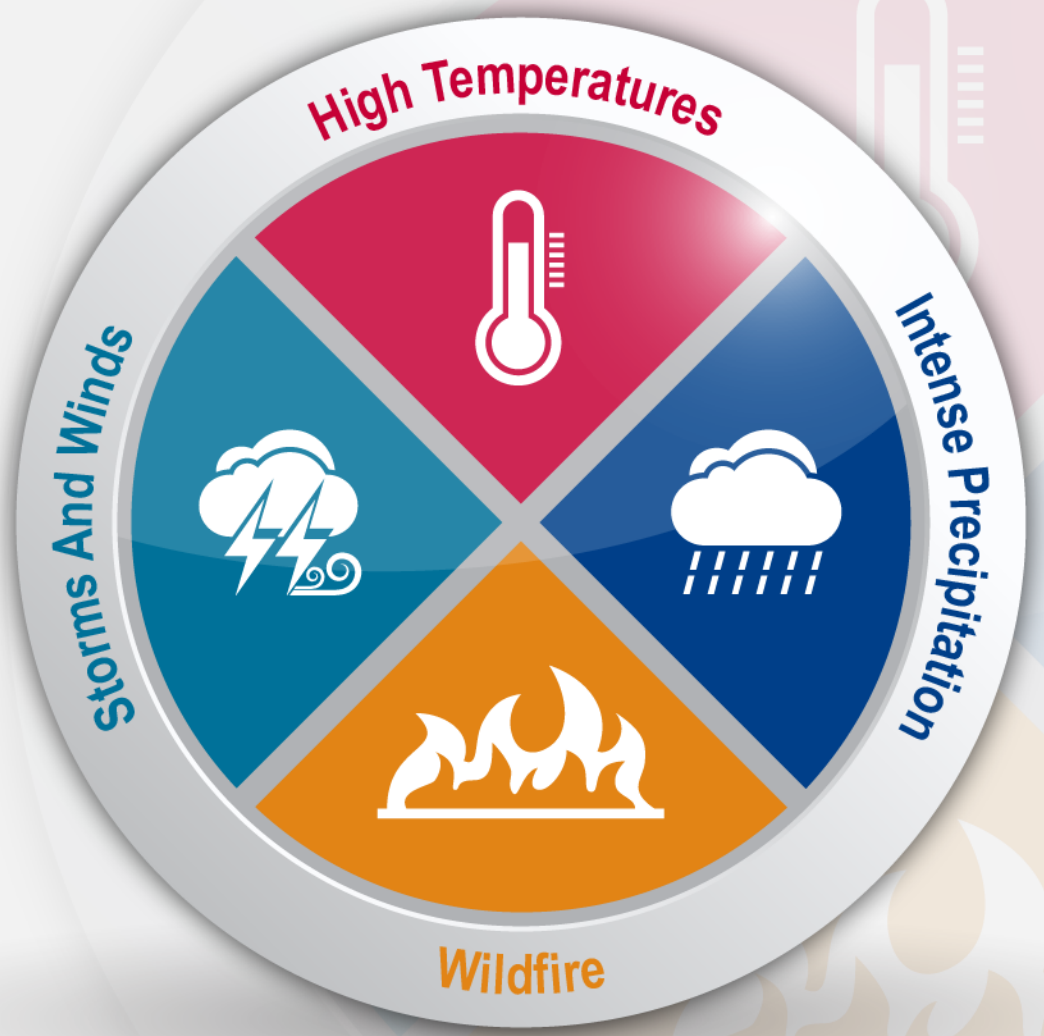
Current Measures/Plans

- ✓ Most stormwater currently infiltrates the surface, enabled by swells

New Measures

- ✓ Revisit current floodplain in code relative to flood scenarios
- ✓ Model how changes in river water height could affect water table
- ✓ Identify remaining stormwater connections to municipal sewer and redirect to ground (e.g., BRSW loading dock)
- ✓ Expand swell size to increase infiltration

Core System: Transportation



Transportation – Lower Priority

High temperatures

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Potential Vulnerabilities

- Increased degradation rate of roads, sidewalk surfaces and parking lots

Current Measures/Plans

- ✓ Repair as needed

New Measures

- ✓ None noted

Transportation – Lower Priority

Intense precipitation

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Potential Vulnerabilities

- Increased degradation or damage to campus roads, parking lots and sidewalks

Current Measures/Plans

- ✓ Repair as needed

New Measures

- ✓ None noted

Transportation – Lower Priority

Wildfire

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Potential Vulnerabilities

- Structural damage to roads

Current Measures/Plans

- ✓ Plowed firebreaks along major road ways
- ✓ City/County keeps fuel away from roads

New Measures

- ✓ Manage landscaping to reduce combustible loads near campus roads

Transportation – Lower Priority

Storms and winds

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Potential Vulnerabilities

- Obstructions on the roads inside and outside the campus

Current Measures/Plans

- ✓ Plans to reduce hard-paved areas by implementing pervious materials or paving design (CMP)
- ✓ Plans for use of landscape elements (e.g. berms, swales, filtration strategies) to treat storm water for reuse (CMP)

New Measures

- ✓ None noted

Future Plans and Lessons Learned

Next Steps

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- Host meetings with key external stakeholders to share findings
  - Hanford Site Sustainability Program contractor (MSA), RL site office, Office of River Protection, and Pacific Northwest Site Office
  - BPA and City of Richland utilities
- Internal stakeholder team will conduct annual review of climate resilience plan to coincide with SSP development
  - Have we implemented the new measures we committed to?
  - Have there been changes in climate exposures and systems that require us to revisit our vulnerability assessment and resilience plans?
- Select metrics will be documented into the Sustainability Operations & Management Program plan and reviewed annually (see next slides)

Metrics to Track and Review as Part of Annual Vulnerability Assessment

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- High temperature risk
  - Number of consecutive days over 100 per year
    - Source: Hanford weather station
    - POC: Marc Berman
  - Premature HVAC equipment failure rates for envelope degradation rate
    - Source: Use 5-yr condition assessments to compare planned life of unit vs. estimated remaining life
    - POC: Tom Davis
  - Change in cooling season utility costs, sustained year-over-year
    - Source: EnergyCap utility management system
    - POC: Marc Berman
  - Rate of water use for cooling
    - Source: Building Operations Control Center
    - POC: Marc Berman

Metrics to Track and Review as Part of Annual Vulnerability Assessment

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- Wildfire risk
  - Change in number of fire events per year in region
    - Source: Hanford Off-Normal Occurrence Center
    - POC: Alisa Haller
  - Change in filter loading rate
    - Source: BOCC (real time)
    - POC: Shan Belew
  - Cost of responding to wildfire events
    - Source: Facility Reliability Index
    - POC: Reed Sharp

Metrics to Track and Review as Part of Annual Vulnerability Assessment

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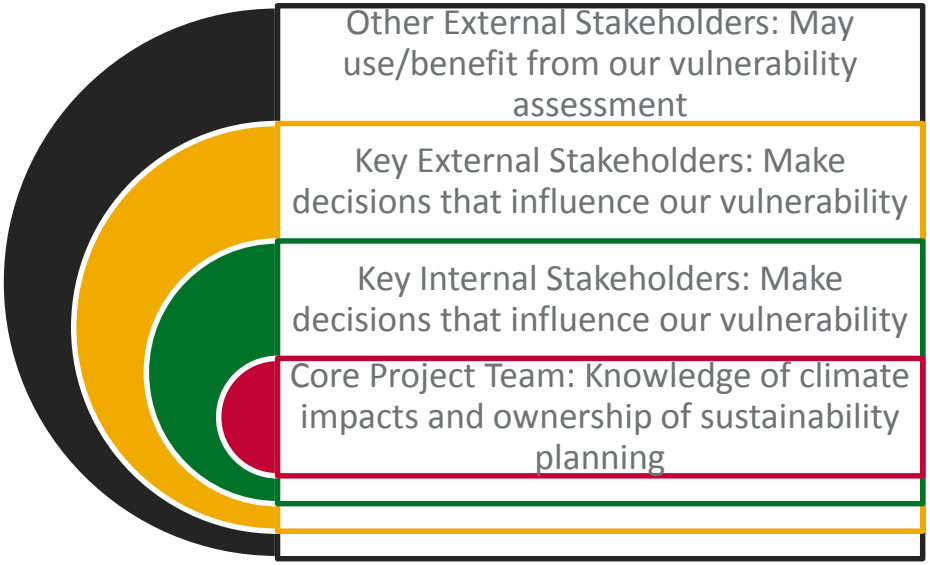
- Intense precipitation risk
  - Number of rainfall events per year that exceed 1” in 24 hours (design standard for our drainage systems)
    - Source: Hanford weather station
    - POC: Marc Berman
  - Number of flood incidents per year that affect facilities and infrastructure (e.g. vaults)
    - Source: Facilities Engineering records and service requests
    - POC : Dave Brown
  - Cost of response to flood events
    - Source: Facility Reliability Index
    - POC : Reed Sharp
  - Number of times catch-basins are clogged per year and requiring maintenance (beyond annual PM)
    - Source: Service request system
    - POC: Reed Sharp

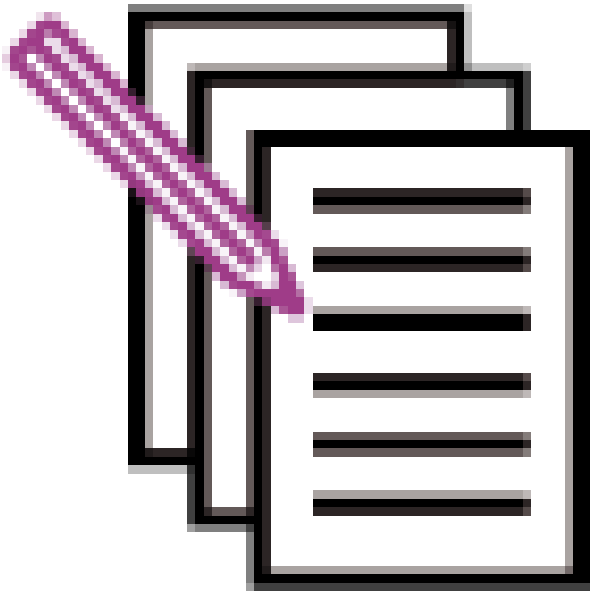
Lessons Learned about Resilience Planning

- **Establish stakeholder engagement needs for the site and engage strategically**
  - Stakeholder engagement can make or break a process with cross-cutting dependencies like climate resilience planning, but all stakeholders may not need to be at the table at the outset
  - Need for engagement will vary based on knowledge of climate change impacts and decision-making influence over core systems with potential vulnerabilities
  - The circle of stakeholders can expand as required for future planning efforts



Lessons Learned about Resilience Planning

- **Upfront data collection and analysis took significant effort but was essential to productive engagements with senior-level stakeholders**
  - Climate impacts research, brief introductory meetings, one-on-one meetings with select personal, and a review of all relevant plans by internal and external stakeholders occurred prior to the first workshop
  - Workshops focused on validating initial assessments of vulnerabilities and current adaptation measures, and brainstorming new measures
  - Quality input captured from senior management in a relatively short time while securing support for the process



Lessons Learned about Resilience Planning

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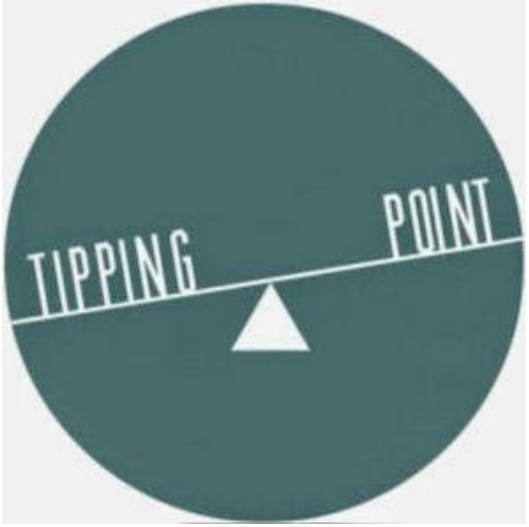
- **There is no "right way" to structure the dialogue and solicit feedback**
  - Some liked seeing the entire vulnerability assessment framework and complex web of core systems, climate impacts, current adaptation measures and stakeholders in an Excel-based spreadsheet
  - Others found it onerous and difficult to work through and preferred focusing on a single aspect of the problem
  - Providing detailed systems-level views and simplified views of the process will help to reach different audiences

Example Excel spreadsheet format

External Stakeholders			Core Issue		Internal Stakeholders					
Existing and planned adaptation measures	Prior or ongoing assessments by external stakeholders	External stakeholders	Systems	Climate exposure	Potential vulnerability	Thresholds	Past impacts	Existing or planned coping measures	Potential future adaptation measures to increase resilience	Stakeholders
None identified	None identified	Electrical Power Suppliers and Gov't Agencies that may ration power (BPA, COR, State of Washington)	Buildings	High temperatures	Increased degradation rate of building exterior and HVAC Increased costs for energy use and facility maintenance Setbacks and evaporative cooling will be less effective Higher initial cost of building (envelope; HVAC) Utility could limit power distribution if taxed by higher demand/lower supply			PM plans reviewed annually Cool roofs are the design default Maximize use of light-colored materials for roofs & hard-paved areas (CMP) Shade trees (CRGP) Building orientation (Design Guide) Considering a mobile chiller to boost systems stressed by heat	Integrate these vulnerabilities into preventative maintenance plans Add a check for remaining life expectancy in the 5 yr condition assessment Track equipment life relative to life expectancy assumptions and adjust in LCC analyses if needed Use Metasys to alternate operating schedules to reduce power load if needed Model temp increases in new designs	F&O Director F&O Engineering Chief Facilities Engineer F&O Strategic Projects F&O Strategic Planning Campus Master Planning Facility Sustainability Energy Operations

Lessons Learned about Resilience Planning

- **Start with metrics, and work toward thresholds**
  - Vulnerability “thresholds” can help sites to know when to take action, but can be difficult to establish up front
    - E.g. how many days >100F would cause overstress on your HVAC system?
  - Agreeing on metrics to track and review periodically may be a good first step



Observations from Stakeholders on the Process

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- *The process was helpful. It introduced some new lines of thought about our vulnerabilities that we weren't aware of.*
- *It was difficult at the start to work through all the elements of the vulnerability framework (a bit "unruly"), but we ended up in right place.*
- *I like the outcome. We are challenged to affect decisions proactively when you have a 5-yr contract cycle. And when we have operating conditions that pressure us to [for example] reduce the inventory of HEPA filters. This type of planning can help justify some of those decisions.*
- *I saw the vulnerability assessment framework as value added. It was nice to see the input I provided show up in the work product.*
- *The process brought out good nuggets of "tribal knowledge".*
- *The approach was logical and organized. I think the metrics to assess vulnerabilities over time are key because that tribal knowledge will leave the Lab someday.*