Heat Impacts on Infrastructure & Personnel:
A DW Case Study

Final Report

Resilient Analytics

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Executive Summary

Denver Water (DW) will experience several vulnerabilities due to future increases in extreme heat events as a result of projected changes in climate. Resilient Analytics (RA) is using a climate stressor methodology to analyze the impact of such extreme temperature events on critical DW physical infrastructure assets and personnel. The methodology focuses on examining the effects of extreme temperatures on personnel and facilities in the years 2030, 2050 and 2070, compared to a 1990 to 2009 baseline. Projected costs presented in this study do not account for inflation.

Climate Summary: The climate data used to project future climate conditions in the analysis are the Localized Constructed Analogs (LOCA) climate projections for North America[1]. In total 32 models and two representative concentration pathways (RCPs) were used in this analysis (RCP 4.5 and RCP 8.5 represent intermediate and high future greenhouse gas emissions scenarios, respectively).

The historic data used in this analysis is the Livneh et al. (2015) data set[2]. This was chosen to remain consistent with the observed dataset used in the downscaling process. The historic period used is 1990 to 2009. The projection data used is set over the period 2021 to 2080. For brevity, results are presented for three future time periods averaged over 20-year time span for each RCP. The time frames used are 2030 which averages 2021-2040, 2050 (averages 2041 to 2060), and 2070 (averages 2061 to 2080). The average temperature increase corresponding to the time frame and mean RCP scenario can be seen in Table *2*. The climate summary data represents a spatial average of the DW service area.

	Change in Average Temperature (°F)		
	2030	2050	2070
Mean RCP 4.5	3.3	4.6	5.5
Mean RCP 8.5	3.6	5.6	8.1

Table 1: Change in average annual temperature relative to the historic period

For simplicity, the climate analysis was limited to the service area, which is where the majority of DW assets and personnel are located. The data in Table 1 does not reflect locations outside of the service area. The majority of the locations outside of the service area are west of the foothills and at elevation.

Personnel Summary: According to data compiled from the Bureau of Labor Statistics (BLS), exposure to excessive environmental heat stress killed 783 U.S. workers and seriously injured 69,374 workers from 1992 through 2016 across all industries[3]. Increases in daily heat index and daily maximum temperatures will put additional stress on outdoor workers. This could lead to additional workplace accidents resulting in additional costs for DW; however, adaptation measures can be put in place that would both reduce costs and reduce heat-related injuries. The following bullets summarize average heat-related projections, impacts to personnel, and example solutions and associated costs.

- By 2030, it is projected that the DW service area will see an additional three weeks of temperatures over 90°F, and two days of temperatures over 100°F each year.
- By 2070, it is projected that the DW service area will see an additional six weeks of temperatures over 90°F, and twelve days of temperatures over 100°F each year.
- If DW does nothing, the risk of workplace accidents and injuries is estimated to increase by 1% by 2030 for RCP 4.5 and by as much as 5% by 2070 for RCP 8.5.

- The number of Moderate Heat Index days per year is estimated to increase from 13 days to 22 days by 2030, and to 42 days by 2070. Historically almost zero High Heat Index days occur. By 2070 the RCP 8.5 models are projecting one to two High Heat Index days annually. These days will present high risk to outdoor worker safety.
- A national heat stress standard could be put into place, which would require DW to follow a regulated work/rest cycle. Implementing a standard work/rest cycle will help to avoid additional worker accidents and fatalities from increased heat.
- To offset losses in productivity associated with increases in work/rest cycles, DW should consider scheduling related adaptation strategies to reduce exposure to mid-day heat. One example would be to flex outdoor worker schedules to earlier in the morning. Under this scenario, DW would see savings from increased productivity. Annual savings range from $13,000 to $99,000 in 2030 and $36,000 to $395,000 in 2070 depending on the heat standard.

In a series of meetings and conference calls, a list of adaptation strategies currently utilized by the participating case study organizations was constructed. This master list includes all adaptation strategies currently being implemented by one or more organizations. Other potential adaptation strategies do exist and can be explored further by DW. A list of ideas shared during the DW meetings in February of 2020 is included in Appendix B. Additionally, meeting notes are included in Appendix C.

- Heat training and classes related to heat stress for all staff
- Safety campaigns via employee-wide emails and safety briefing sheets posted at visible locations are deployed at the beginning of summer to raise awareness during times when temperatures start rising. These safety campaigns remind staff of heat stress symptoms and encourage field crews to hydrate appropriately.
- Provide ice machines and water coolers at buildings where vehicles deploy
- Incorporate heat-related illness training and heat awareness into other training sessions such as confined space and fall prevention
- Establish cooling stations for field crews. This is in addition to common areas under HVAC at plants and other facilities
- Establish an Employee Injury and Illness Reporting Reference Guide
- Keep records of heat-related illnesses
- Schedule more evening and early morning working hours
- Design electrical rooms, and other areas that need to be serviced by electricians using protective equipment, with appropriate HVAC
- Provide covered, ventilated areas for vehicle maintenance work
- Vehicles are equipped with water coolers and the warehouse stocks electrolyte replenishment drink packs
- Employees with the greatest exposure are provided with mobile shade devices (Awnings, umbrellas); all employees have access to oversized hats, tinted safety glasses, neck shade, and cooling devices.
- Use NIOSH/OSHA Heat App to monitor exposure and manage schedule
- Each work center employs an appropriate work-rest/cycle.

Infrastructure Assets Summary: The facilities and assets owned and operated by DW will also experience additional stress due to increases in temperature. Cooling operating costs are projected to increase and the increase in outdoor temperature is projected to reduce the lifespan of critical assets.

The following bullets summarize average heat-related projections, impacts to assets, and example solutions.

- Cooling costs are projected to increase by 13% to 17% by 2030, 28% to 40% by 2050 and 37% to 71% by 2070.
- From 2021 to 2080, the average increase in total cooling cost for the facilities included in this study is projected to be between $3.5 million and $4.7 million.
- To prepare for heat impacts, Denver Water should consider:
    - Including the above additional costs in near- and long-term budget planning.
    - Upgrading outdated cooling equipment including chillers and air handling units, which will help to offset additional cost of cooling.
    - Prioritizing the Recycling Plant Facility cooling system. The facility has a large cooling demand, so a replacement will yield higher savings.
    - Upgrading parking lot binder grade to limit damage and repair costs caused by increased temperatures.
    - Investigating the cost/benefit of installing, or upgrading in the case of an undersized system, a cooling system to control the indoor temperature and limit equipment lifespan degradation due to high temperature operation. Equipment that operates in spaces with high ambient operating temperature (ventilated spaces, spaces with an undersized cooling system, spaces without any means of temperature control, etc.) will have shorter lifespans.
    - Monitoring indoor temperatures to determine whether the cooling system is providing the necessary and expected cooling effect. If elevated temperatures are seen, or temperatures show a trend of increasing, consider investigating the cost/benefit of installation of additional cooling capacity as mentioned above. Additionally, the installation of extra cooling capacity can be evaluated now in anticipation of increasing outdoor air temperatures.
    - Evaluating the cost/benefit of retrofitting existing facilities with such features to minimize the heat load inside of any given facility due to outdoor air temperature. The susceptibility of an indoor facility's temperature to change in response to changing outdoor air temperature can be reduced using various building improvements. These include increased envelope insulation, tighter air sealing to prevent infiltration of outdoor air, and pre-conditioning ventilation air that is brought into the space.
    - Revising engineering specifications for new construction with the intent of minimizing heat gain from the outdoors in new facilities.
    - Rewinding existing motors, or purchasing new motors, with a higher temperature rating. In the case of existing motors, DW can consider the cost/benefit of rewinding the motor with a higher insulation temperature rating, which will increase the winding lifespan. DW can also investigate the installation of new motors with higher insulation temperature ratings, which can tolerate higher operating temperatures. However, it is important to note that a motor's rated operating temperature is made up of three components: ambient temperature, internal temperature rise, and hotspot allowance. It is possible that a motor with a higher insulation temperature rating may operate at a higher internal temperature, leaving no increase in allowable ambient temperature[4]. Therefore, when specifying new motors with higher insulation temperature ratings it is

essential to first determine, with the manufacturer and specifying engineer, the allowable *ambient* operating temperature of the motor. A cost/benefit analysis can then be undertaken weighing the additional upfront cost versus the cost savings from any extension in the motor lifespan due to the increased allowable ambient operating temperature.

- Closely monitoring the operation and maintenance schedules of each motor to optimize the motor lifespan. Besides ambient operating temperature, motors overheat and prematurely fail due to several other factors that should be mitigated. These factors include dirt, improper and/or imbalanced voltage, frequent start/stop cycles, and others[4].
- At times when the space temperature setpoint (temperature for which the cooling system is sized and set to maintain) is higher than the outdoor air temperature, an airside economizer can be used to circulate untreated outdoor air to cool the space. This strategy is commonly used to save energy in a comfort cooling application where the space would be maintained at the cooling setpoint during airside economizer operation. However, in spaces where comfort is not a priority (mechanical spaces, pump rooms, etc.), an airside economizer may be able to be used to achieve indoor space temperatures lower than the cooling setpoint during periods where the outdoor air temperature is between some temperature below the cooling setpoint (depending on fan capacity) and the heating threshold. However, the system's fan airflow capacity may need to be increased to achieve this effect. Theoretically, according to the 10-degree rule, this would extend motor lifespan and possibly save on cooling costs if an airside economizer is not currently used. However, motor lifespan is also affected by humidity, temperature fluctuation, and other factors as noted above. For this reason, investigation with the motor manufacturer, building engineers, and local code authorities should be undertaken along with a cost/benefit analysis prior to initiating the airside economizer operation.
- Taking further steps to evaluate the vulnerability of assets not included in this study under increased temperature. These assets include dams, water storage tanks and the water distribution system.