

District of Chetwynd, West Moberly First Nations & Sauleau First Nations Extreme Heat Mapping Assessment and Extreme Heat Response Plan

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Prepared For:
District of Chetwynd,
Saulteau First Nations, and
West Moberly First Nations

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Extreme Heat Mapping and Assessment Report

Background and Objectives

Background

In the summer of 2021, communities across British Columbia faced an unprecedented extreme heat event known as a “heat dome”, which had wide-ranging impacts including over 600 heat-related deaths. Many communities experienced temperatures up to 20°C above normal. The Chetwynd area was also impacted by the heat dome, which prompted the District of Chetwynd (the ‘District’) to partner with West Moberly First Nations and Saulneau First Nations to incorporate planning and mitigation of extreme heat events into the District of Chetwynd’s Emergency Plan, West Moberly’s Emergency Plan and Saulneau’s Emergency Plan.

The District of Chetwynd, West Moberly First Nations, and Saulneau First Nations were awarded funding through the Union of BC Municipalities’ 2022 Community Emergency Preparedness Fund to develop an Extreme Heat Risk Mapping, Assessment, and Response Plan (Heat Response Plan). Frontera Forest Solutions, Inc (www.fronterasolutions.ca) was awarded the contract to complete the entire project and this document forms the main deliverable of this contract.

Objectives

The objectives of this document are to:

1. Identify the social impacts of extreme heat in the District of Chetwynd, West Moberly First Nations and Saulneau First Nations, including mapping vulnerable populations and neighbourhoods;
2. Consult and engage with emergency managers, non-profit agencies, other levels of government, First Nations, and community staff members;
3. Develop an Extreme Heat Response Plan that includes recommended response actions to mitigate impacts of extreme heat on vulnerable populations; and
4. Feed into a series of educational materials for the three communities, including social media and web-based messaging.

Community Description

This Plan’s Area of Interest (Figure 1) includes the lands within the District of Chetwynd Boundaries, West Moberly First Nations, and Saulneau First Nations. The District is located on Treaty 8 Territory in northeastern BC.

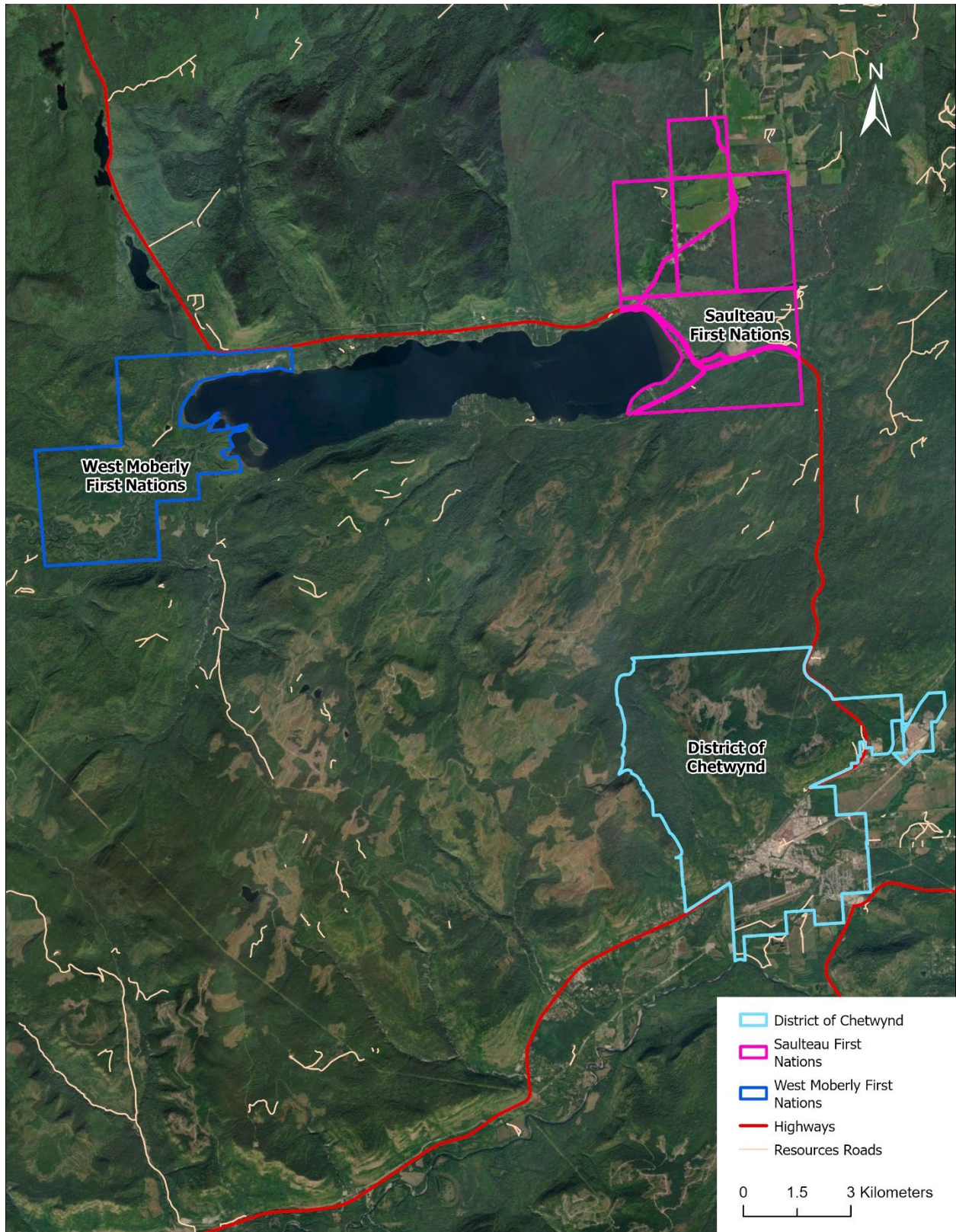


Figure 1: Area of Interest.

Saulteau First Nations

Saulteau First Nations (‘Saulteau’) is located on the eastern shore of Moberly Lake on East Moberly Lake IR 169, which has a land area of 3,025.8 ha. The reserve is approximately 20 km north of Chetwynd. The community consists of housing, infrastructure, community facilities, and an industrial park. The reserve is bisected by the Don Phillips Highway (BC 29) which runs along the shore of Moberly Lake.

Saulteau has a total of 1,218 members, two-thirds of whom (66%) live off-reserve¹. A significant proportion of this membership is young adults, with the largest demographic group in 2020 being between 26-35 years old. In 2020, 31% of the members were over the age of 45.

Table 1: Community demographics from the 2021 Census – IR East Moberly Lake 169.

Total Population (year)	297 (2021)
Population Density (people per km ²)	9.6
Median Age (years)	41.2
Housing Units	130
Median Home Value	Unavailable
Median Household Income	\$50,800
Data Sources	Statistics Canada ²

West Moberly First Nations

West Moberly First Nations (‘West Moberly’) has one reserve located at the west end of Moberly Lake – IR #168A West Moberly Lake. The community is located approximately 33 km northwest of Chetwynd and about 13 km west of Saulteau. As of 2022, there were 341 members, with 122 members living on-reserve and 219 members living off-reserve³, and in 2023 there were 160 residents living on reserve⁴. The 2022 West Moberly Housing Strategic Plan found that there were 48 homes on-reserve, with every unit needing repairs and renovations.

Table 2: Community Demographics from the 2021 Census – IR West Moberly Lake 168A.

Total Population (year)	122 (2022)
Population Density (people per km ²)	5.2
Median Age (years)	40.4
Housing Units	47

¹ <https://www.saulteau.com/component/edocman/saulteau-ccp/viewdocument/133?Itemid=0>

² <https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=East%20Moberly%20Lake%20169&DGUIDlist=2021A00055955801&GENDERlist=1,2,3&STATISTIClist=1&HEADERlist=0>

³ <https://westmo.org/wp-content/uploads/2023/04/WMFN-Housing-Strategic-Plan-2022-April-20-2023.pdf>

⁴ Gil Davis, West Moberly Housing & Capital Projects Manager - Personal communication

Median Home Value	\$202,000
Median Household Income	Unavailable
<i>Data Sources</i>	<i>Statistics Canada</i> ⁵

District of Chetwynd

The District of Chetwynd is a district municipality located in northeastern BC approximately 300 km northeast of Prince George, on the intersection of Highway 97 and Highway 29. The population of Chetwynd is approximately 3,100 according to the District’s website, with official 2021 census numbers being slightly lower at 2,302. The wider region has a significant amount of industrial activity (mining, hydro, oil and gas, forestry, and agriculture), with temporary/seasonal employees that cause local population numbers to fluctuate and strongly influence housing vacancy and rental rates.

The median age in Chetwynd is 36.2, which is comparable to the wider Peace River Regional District, and lower than the provincial median age of 42.8. 21% of Chetwynd’s population identifies as Indigenous. The unemployment rate in 2021 was 7.1%; employment in this region also tends to fluctuate due to fluctuations in the industrial sector, primarily in the oil and gas industry.

As of 2016, there were 1,005 housing units in Chetwynd, of which 55% were single-detached homes. A slight majority (51%) of the housing stock in Chetwynd was built before 1980, which correlates with a relatively high rate (56%) of homes requiring minor or major repairs⁶.

Table 3: Community Demographics from the 2021 Census – District of Chetwynd.

Total Population (year)	2,302 (2021)
Population Density (people per km ²)	36.2
Median Age (years)	36.0
Housing Units	995
Median Home Value	276,000
Median Household Income	104,000
Unemployment Rate	7.1
<i>Data Sources</i>	<i>Statistics Canada</i> ⁷

⁵<https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=West%20Moberly%20Lake%20168A&DGUIDlist=2021A00055955802&GENDERlist=1,2,3&STATISTIClist=1&HEADERlist=0>

⁶<https://www.gochetwynd.com/wp-content/uploads/2021/03/2021-Chetwynd-Housing-Needs-Report.pdf>

⁷<https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=chetwynd&DGUIDlist=2021A00055955010&GENDERlist=1,2,3&STATISTIClist=1,4&HEADERlist=0>

Impacts of Extreme Heat

Health

Extreme heat can have severe impacts on human health, particularly for vulnerable populations. Extreme heat exposure affects health either directly or indirectly. Direct causes include heat illness or cardiovascular complications during heat waves, while indirect causes include increased air pollution, changes in local climate increasing mosquito-borne disease occurrence, or increased pollen in plants such as ragweed⁸.

Heat illnesses are caused by over-exposure to extreme heat and can be compounded by age and physical condition. Heat illnesses include:

- Heat rash,
- Heat stroke,
- Heat fainting,
- Heat exhaustion,
- Heat cramps (muscle cramps), and
- Heat edema (swelling of hands, feet, and ankles)⁹.

During the unprecedented heat dome event from June 25 – July 1, 2021, 619 people in British Columbia died of heat-related causes¹⁰. Most of the deceased were older adults with compromised health due to chronic disease and who lived alone. The BC Coroner's Report identified that vulnerable populations at risk of heat-related health impacts included the elderly, people with chronic diseases (schizophrenia, substance use disorder, epilepsy, chronic obstructive pulmonary disease, depression, asthma, mood and anxiety disorders, and diabetes), people with limited mobility, people with cognitive impairment, and people who live alone¹¹. One study found that people with schizophrenia were particularly at risk, followed by people with chronic kidney disease and ischemic heart disease¹². Other factors that influence the risk of health impacts during extreme heat include lower economic and social status, lower neighbourhood greenness, age, and sex¹³, with women at higher risk because they are more likely to live alone in older age.

Social and Economic

The social impacts of extreme heat are varied; beyond physical health many also report that extreme heat has mental health impacts: in BC after the 2021 heat dome five elderly people and 12 people with disabilities said that the heat dome significantly affected their physical and mental health¹⁴. Fourteen people said that they experienced trauma, anxiety, or depression because of their experience in the heat dome and worry about surviving future heatwaves. People with pre-existing mental health conditions

⁸ Arie Ponce Manangan, Christopher K. Uejio, Shubhayu Saha, Paul J. Schramm, Gino D. Marinucci, Claudia Langford Brown, Jeremy J. Hess, George Luber. *Assessing Health Vulnerability to Climate Change: A Guide for Health Departments*. 2015.

⁹ <https://www.canada.ca/en/health-canada/services/climate-change-health/extreme-heat/who-is-at-risk.html>

¹⁰ *Extreme Heat and Human Mortality: A Review of Heat-Related Deaths in B.C. in Summer 2021. Report to the Chief Coroner of British Columbia. June 7, 2022.*

¹¹ *Ibid.*

¹² Lee, M. J., McLean, K. E., Kuo, M., Richardson, G. R. A., & Henderson, S. B. (2023). Chronic diseases associated with mortality in British Columbia, Canada during the 2021 western North America extreme heat event. *GeoHealth*, 7, e2022GH000729. <https://doi.org/10.1029/2022GH000729>

¹³ Henderson, S.B., McLean, K.E., Lee, M.J., Kosatsky, T. (2022). Analysis of community deaths during the catastrophic 2021 heat dome. *Environmental Epidemiology* (2022) 6:e189

¹⁴ <https://www.hrw.org/news/2021/10/05/canada-disastrous-impact-extreme-heat>

said the heat dome worsened their symptoms, with six saying that they feared for their lives. Increased crime has also been correlated to extreme heat, including street violence, gun crime, road rage, and rioting and unrest¹⁵.

The economic impacts of extreme heat are primarily related to reduced labour productivity. It is estimated that the United States could lose approximately \$100 billion annually from heat-induced lost labour productivity¹⁶. Another study found that from 1992 to 2013, heat waves caused an estimated \$16 trillion in losses¹⁷. The International Labour Organization (ILO) predicts that heat waves could reduce the number of hours worked globally by more than 2% by 2030¹⁸. During the 2021 heat dome, various impacts were reported, from work cancellations or delays to work modifications¹⁹. The losses are highest in sectors where outdoor work is prevalent²⁰ such as agriculture and construction, as well as in the service sector which is vulnerable to heat due to limited air-conditioning. Measures to mitigate the labour impacts of extreme heat include rescheduling tasks, increasing the number of breaks, or switching activities from outdoor to indoor environments if possible²¹.

Environmental

Extreme heat can contribute to other natural disasters like droughts, flooding, and wildfires. Droughts are caused by a combination of low snow accumulation, hot and dry weather, or delayed or low rainfall – extreme heat can increase the severity and duration of droughts²². Warmer and drier conditions also increase wildfire risk²³. During the heat dome in 2021, the town of Lytton set an all-time Canadian temperature record of 49.6°C and shortly thereafter was almost completely destroyed in a wildfire.

Another of the main environmental impacts of extreme heat is worsening air quality; extreme heat can worsen the respiratory effects of both smog and wildfire smoke²⁴. Increased population growth of pests and pathogens during warm weather may impact local natural ecosystems as well as agricultural food crops.

Agricultural

Many key crops such as corn, soy, and wheat, are vulnerable to extreme heat – yield losses for these crops could be up to 11-13% by 2050²⁵. The 2021 heat dome affected the health of livestock and shellfish across BC, with over 600,000 poultry deaths, declines in egg and dairy production, and decreases of 25% in farmed mussel production and up to 70% losses of farmed shellfish in some areas of the province²⁶. Fruit and vegetable production declined in many regions, although those effects are difficult to separate from other extreme weather events that occurred in 2021 such as wildfire and

¹⁵ https://www.researchgate.net/publication/45513548_The_Social_Impacts_Of_Heat_Waves

¹⁶ *Extreme Heat: The Economic and Social Consequences for the United States. (2021).*

¹⁷ <https://home.dartmouth.edu/news/2022/10/heat-waves-have-cost-world-economy-trillions-dollars>

¹⁸ <https://www.weforum.org/agenda/2022/07/heat-waves-economy-climate-crisis/>

¹⁹ <https://www.mdpi.com/2227-9032/11/17/2423>

²⁰ <https://www.nature.com/articles/s41467-021-26050-z>

²¹ *Ibid.*

²² <https://www2.gov.bc.ca/gov/content/safety/emergency-management/preparedbc/know-your-hazards/severe-weather/extreme-heat>

²³ <https://www.c2es.org/content/wildfires-and-climate-change/>

²⁴ <https://climatereadybc.gov.bc.ca/pages/extreme-heat>

²⁵ *Ibid.*

²⁶ <https://climateinstitute.ca/wp-content/uploads/2023/06/The-case-for-adapting-to-extreme-heat-costs-of-the-BC-heat-wave.pdf>

floods. However, one study found that live green vegetation (an indicator of plant health) dropped in six of eight BC agricultural divisions between June 20 – July 3, 2021²⁷.

Agricultural impacts can be further compounded by reduced labour productivity²⁸ as discussed above. As noted above, pests and diseases may also be able to propagate more rapidly in warmer temperatures, potentially affecting food crops as well as animal agriculture.

Indigenous Food Systems

Extreme heat and general warming temperatures over the past few decades, have already affected the timing, availability, and abundance of traditional foods²⁹. Human Rights Watch has reported that climate change has impacted food security by reducing the quantity of resources available as well as increased the difficulty and danger in harvesting: this is attributed to changes in wildlife habitat, wildfires, warming water temperatures, changes in precipitation and water levels, and unpredictable weather³⁰. People who hunt, fish, or harvest traditional foods experienced additional impacts in food availability during the 2021 heat wave³¹. The Canadian Climate Institute notes that the extreme heat in 2021, accompanied by drought, disrupted the development of seeds and plants, which had downstream impacts on animals and trees: “the heat, insects, and the drought severely disrupted food harvesting and preservation initiatives. Berries and fruit shrivelled on bushes and trees. Bears went hungry.”³²

In the longer term, climate change has compounded effects: species that distribute seeds to new locations are no longer doing so, causing the further decline of food crops; birds are not returning to their usual areas and new birds are now appearing, plant communities are shifting in composition and range, and elk, moose, wolves and cougars are changing their habitat ranges, which impacts other species in the area³³.

Approach and Methods

Assumptions and Standards

Heat Warning

In the Northern Provincial Health Authority, a heat warning is defined as a discrete event which lasts two or more consecutive days and follows a high-low-high temperature pattern of more than 29°-14°-29° These thresholds were defined with the goal of facilitating heat emergency response from weather forecasts two days prior to the occurrence of an event. In the study performed to identify these thresholds, mortality was measured over the duration of the full days elapsing the high-low-high pattern.³⁴ As such, heat warnings do not have defined bounds on the scale of hours.

²⁷ *Ibid.*

²⁸ <https://www.atlanticcouncil.org/wp-content/uploads/2021/08/Extreme-Heat-Report-2021.pdf>

²⁹ <https://ncceh.ca/sites/default/files/Indigenous%20Food%20Safety%20and%20Security%20-%20Feb%202019%20-%20EN.pdf>

³⁰ https://www.hrw.org/report/2020/10/21/my-fear-losing-everything/climate-crisis-and-first-nations-right-food-canada#_ftn301

³¹ <https://climateinstitute.ca/wp-content/uploads/2023/06/The-case-for-adapting-to-extreme-heat-costs-of-the-BC-heat-wave.pdf>

³² <https://climateinstitute.ca/publications/community-solution-2021-extreme-heat-emergency-experience-british-columbia-first-nations/>

³³ https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/indigenous/food_security_report_-_2023.pdf

³⁴ McLean, K. E., Stranberg, R., MacDonald, M., Richardson, G. R., Kosatsky, T., & Henderson, S. B. (2018). Establishing heat alert thresholds for the varied climatic regions of British Columbia, Canada. *International journal of environmental research and public health*, 15(9), 2048.

For the purposes of this work, the duration of heat warnings is defined as the full two-day period over which a weather pattern breaking the thresholds of 29°-14°-29° was observed. This two-day period begins at midnight on the day of the first breaking of the 29° threshold and ends at 23:59 on the day of the second breaking of the 29° threshold.

Extreme Heat Emergency

An extreme heat emergency is a new classification defined in the BC Provincial Heat Alert and Response System (BC HARS): 2022.³⁵ The criteria for an extreme heat emergency are that the criteria for a heat warning be met, and that daytime maximum temperatures are expected to rise substantively day-over-day for three or more consecutive days. The term “substantively” is not detailed, as the decision of whether or not to define a given weather event as an extreme heat emergency is the result of a consensus from a committee.

When there is potential for a heat warning to evolve into an extreme heat emergency, Environment and Climate Change Canada (ECCC) will signal to the Provincial Health Duty Officer that members of the BC HEAT Committee should meet. When determining if an extreme heat event is to be categorised as an Extreme Heat Emergency, the BC Heat Committee must meet as only they have the authority to make the declaration. The committee consists of the following participants: a medical health officer from the affected area, a medical officer from the First Nations Health Authority, the medical director from the BC Centre for Disease Control, the provincial health officer, a warning meteorologist from Environment and Climate Change Canada, and an emergency management representative from the Ministry of Health. If consensus cannot be met through discussion, a vote is needed to decide whether to declare an extreme heat emergency.

For the purposes of this work, the duration of extreme heat emergencies is defined as a full three-day period over which the heat warning criteria are met and over which there was any day-over-day rise in temperature for at least three consecutive days. The duration of an extreme heat emergency was extended to include additional days if the criteria for a heat warning continued to be met after all criteria for an extreme heat warning were met, even if there was an observed decrease in the maximum temperature on subsequent days.

Air Temperature vs. Land Surface Temperature

Air temperature refers to temperature in the air at around human eye level (Figure 2). Air temperature is usually measured at meteorological stations.

Land surface temperature (LST) is how hot the surface of the Earth would be to the touch in a particular location (Figure 2). It is measured primarily using satellite remote sensing.

³⁵ <http://www.bccdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Guidelines%20and%20Manuals/Health-Environment/Provincial-Heat-Alerting-Response-System.pdf>

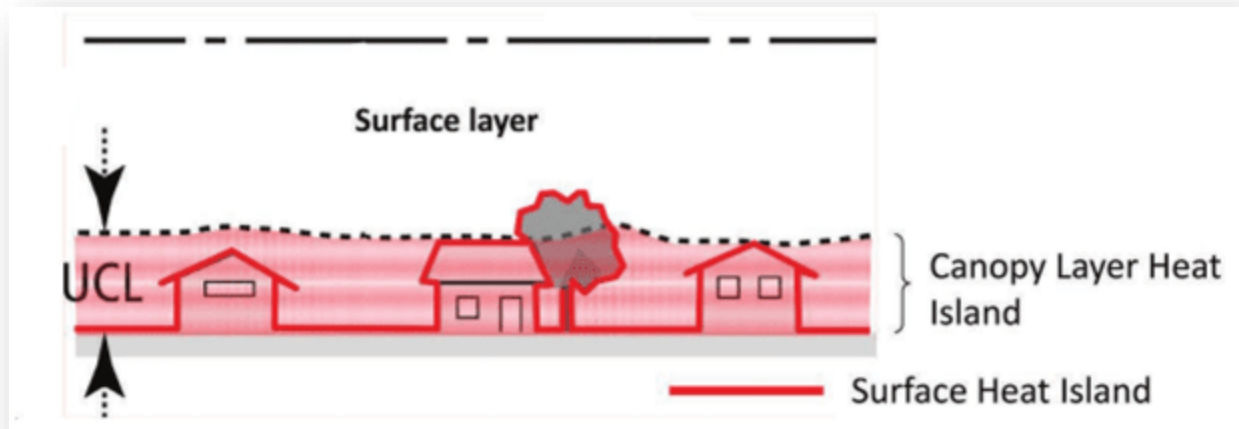


Figure 2: Adapted from Oke (1997).³⁶

Weather Station Data

Weather station data was used to:

1. Characterize and comprehend local weather patterns,
2. Identify the occurrences of heat warnings and extreme heat events, and
3. Identify appropriate dates for satellite imagery acquisition for heatmapping applications.

The Chetwynd Airport weather station operated by Environment Canada was the only available consistent weather station within the vicinity of all three communities. For this reason, the Chetwynd Airport weather station is the primary weather station for this report. Weather data were acquired from a third party, the Pacific Climate Impacts Consortium (PCIC), which allows for data to be downloaded *en masse* within a specified timeframe. Data from the Chetwynd Airport station was acquired for the months of May through September, and between years 2013 and 2023 to match the data availability of Landsat 8 and Landsat 9 images.

Additional Weather Gauges

The nearest and only long-term weather station for all three communities is the Chetwynd Airport weather station operated by Environment Canada. However, this weather station is approximately 18 km away from Saulteau and 21 km away from West Moberly and therefore may not be as accurate for those communities due to differences in local weather patterns. Notably, Saulteau and West Moberly are on Moberly Lake which would generally provide a cooling effect.

In addition to differences in local weather, there are differences in microclimate based on land cover types³⁷. Land cover types include different forest types (conifer or “needleleaf”, deciduous “broadleaf”, and mixed), shrubland, grassland, wetland, cropland (agricultural fields), barren land, urban or paved areas, and water. All of these land cover types will have slightly different microclimates due to differences in shade, humidity, effects of different vegetation on wind speed, etc. Since the Chetwynd

³⁶ Oke, T. R. (1997). *Urban environments. The surface climates of Canada*, 303-327.

³⁷ <https://link.springer.com/article/10.1007/s00704-012-0758-z>

airport weather station is placed in an open paved environment, it is likely to be slightly different than air temperatures in forests or fields.

To account for these local weather and microclimate variations, Frontera put out nine additional temperature gauges (Kestrel Drop D2) in the three communities to better determine local temperatures in different land covers. Three land covers were sought to be represented by the gauges: urban (Figure 3), field (Figure 4), and forest (Figure 5). In the maps below (Figure 6, Figure 7, Figure 8), the temperature gauges are labelled based on the land cover class³⁸ they are placed in.



Figure 3: Kestrel Temperature Gauge - Sauleau, Urban Land Cover Placement.

Figure 4: Kestrel Temperature Gauge - Chetwynd, Field Land Cover Placement.

Figure 5: Kestrel Temperature Gauge - West Moberly, Forest Land Cover Placement.

The temperature gauges were placed in areas that were relatively uniform in terms of land cover. Ideal placement also considered factors such as ease of retrieval, obscurity from the public, avoidance of trespassing, and ability to secure them in-place. Gauges were set up at heights above the ground and distances away from structures following best practices³⁹. Gauge distances from the ground and distances from buildings are shown in Table 4. Setup parameters for the Chetwynd airport weather station operated by Environment Canada were measured during an in-person visit.

Table 4: Temperature gauge identification and setup parameters.

Community	Land Cover	Gauge Height (m)	Gauge Distance from Nearest Tall Object (m)	Description
Sauleau First Nations	Field	1.46	125	In the pasture
Sauleau First Nations	Forest	1.80	< 1	In the forest south of the Muskochees Subdivision

³⁸ <https://open.canada.ca/data/en/dataset/ee1580ab-a23d-4f86-a09b-79763677eb47>

³⁹ <https://www.weather.gov/media/epz/mesonet/CWOP-Siting.pdf>

Community	Land Cover	Gauge Height (m)	Gauge Distance from Nearest Tall Object (m)	Description
Saulteau First Nations	Urban	1.43	14	Near the band office
West Moberly First Nations	Field	1.43	45	In the hay field in the southwest of the reserve
West Moberly First Nations	Forest	1.43	< 1	Between the community and Highway 29
West Moberly First Nations	Urban	1.43	11	Near the administration building
District of Chetwynd	Field	1.40	70	East of the riding arena
District of Chetwynd	Forest	1.52	< 1	Within the urban reserve
District of Chetwynd	Urban	1.46	8	Near the town hall
District of Chetwynd	Urban (Airport)	1.71	15	Chetwynd Airport



Figure 6: Placement of Kestrel Drop temperature gauges around the Saulteau First Nations reserve.

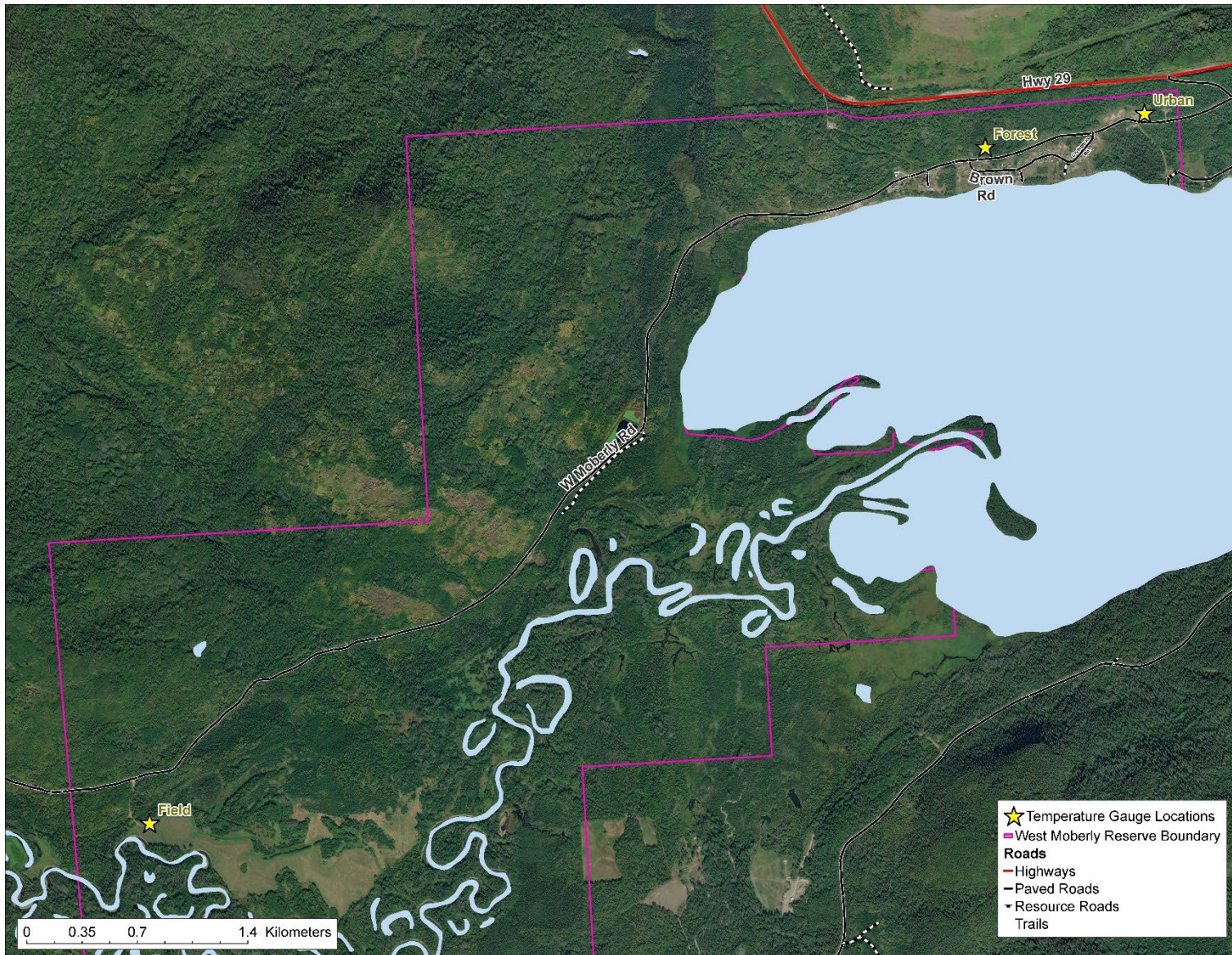


Figure 7: Placement of Kestrel Drop temperature gauges around the West Moberly First Nations reserve.

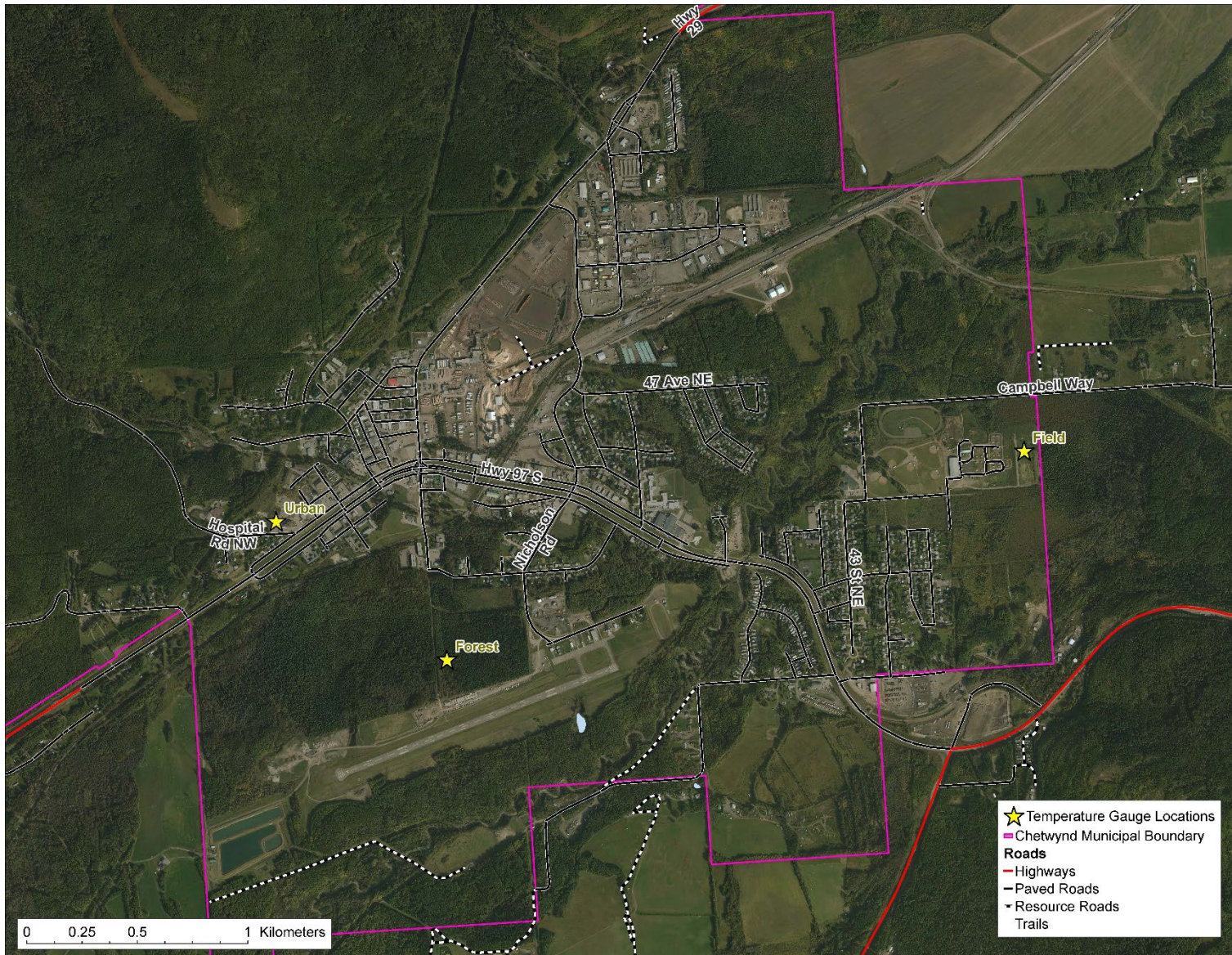


Figure 8: Placement of Kestrel Drop temperature gauges around the District of Chetwynd.

Description of Weather Patterns

To demonstrate regional temperature patterns, hourly temperatures were averaged over the same month, day, and hour in all years for which data was available from the Chetwynd Airport in the time frame of interest. This analysis resulted in five graphs displaying hourly average temperatures for the months of May through September.

In addition, daily maxima (highest temperature) and minima (lowest temperature) from each of the nine installed temperature gauges were determined and graphed.

Identification of Heat Warnings and Extreme Heat Emergencies

The same graphs used for quality control were used to identify the occurrence of heat warnings and extreme heat emergencies. Definitions for these terms in the context of this work can be seen in the Assumptions and Standards section. Each of these graphs was reviewed for the weather patterns specified for each event. For each event found, the dates were verified using the associated tabular data.

Remote Sensing

Satellites for Thermal Remote Sensing

The Landsat series of satellites provide infrared data at a high spatial resolution of ~100 m, and with a time series beginning in 1984 with Landsat 5. This infrared data can be used to calculate LST. The revisit time of Landsat satellites is approximately 16 days. Imagery of the Chetwynd/Moberly Lake area is acquired at this frequency at approximately 12:00 PM local time.

LST mapping for the defined area was carried out using satellite imagery. Imagery from the Landsat 8 Thermal Infrared Sensor (TIRS) and from the Landsat 9 Thermal Infrared Sensor 2 (TIRS-2) was chosen to do temperature mapping for daytime heat mapping. This choice was made to represent temperature patterns that are more recent.

Imagery from Landsat 8 TIRS is available since its launch in 2013, and imagery from Landsat 9 TIRS-2 is available since 2021. These satellites collectively allow us to pull imagery collected over the past 11 years from 2013 to 2023. Imagery from Landsat 7 is affected by the scan line corrector failure, causing striping in the imagery in which data is unavailable. To avoid additional processing associated with handling these errors, Landsat 7 data was not used.⁴⁰

Satellite Image Acquisition

Weather data from the Chetwynd Airport station was used to identify days on which to seek satellite imagery to model extreme heat across the land base of the three communities. To identify potential case-temperatures for the development of an extreme heat product, maximum temperatures were binned in a histogram to assess their distributions. Maximum temperatures were used despite the acquisition times of the satellite imagery over the area surrounding Moberly Lake and the District of Chetwynd (12:00 PM for Landsat satellites 8 and 9) as thresholds for heat events and planning for heat response is based on temperature maxima⁴¹. Availability of satellite imagery was then verified for each maximum in order of decreasing magnitude until an available image meeting required criteria were found. Satellite images were filtered and acquired from the USGS Earth Explorer web application⁴².

⁴⁰ <https://www.usgs.gov/landsat-missions>

⁴¹ <https://www.mdpi.com/1660-4601/15/9/2048>

⁴² <https://earthexplorer.usgs.gov/>

Satellite images chosen were allowed to have a maximum of 30% cloud cover. Each image was inspected to ensure that clouds did not overlap the communities.

A case-temperature of 37°C was chosen. The corresponding image was acquired on June 28, 2021 during the heat dome event. This was informed by a general qualification of an extreme heat event, typically occurring once or twice per decade. All days with daytime highs equal to the case-temperature $\pm 1^\circ\text{C}$ were noted to seek available imagery. No other imagery meeting this daytime temperature criteria was available. Using a single satellite image to accurately represent surface urban heat islands is common within primary sources. Zhou et al., 2018 performed a review of 492 studies analyzing surface urban heat islands and found that approximately 64% of publications used a single time-point. However, they acknowledge that this choice is a limitation as LST values are variable due to changing climate, weather conditions, vegetation, and human activities. They recommend a larger number of images be used when available.⁴³

Satellite imagery was also sought over the acquisition periods of the gauges and the weather stations identified in Table 7. This imagery was acquired to establish relationships between LST and air temperature. No daytime temperature criteria were set for the selection of these images to maximize the availability of data and to better understand the relationship between LST and air temperature across a range of springtime and summertime temperatures. However, acquisitions were restricted to May through September for data to show trends over the hotter months of the year. The same web application and cloud cover threshold was used for the selection of these images.

Land Surface Temperature Algorithms were used to determine actual air temperature from the satellite imagery - please see Appendix A: Technical for a thorough explanation.

Risk Assessment Maps

Two types of risk assessment maps were developed for this Report: simple risk and vulnerability-incorporated risk. These risk maps were developed using a combination of four variables: air temperature, housing unit density, proximity to low-income housing, and proximity to senior’s housing. Each of these factors were developed on a 30 m x 30 m grid within 1 km of the communities’ boundaries. As such, we were able to develop risk maps at this same spatial resolution. Each of these factors were given a score of 0 to 10 (low to high risk; Table 5). Using this scoring system, 0 corresponds to negligible risk, while 10 corresponds to a very high risk.

Table 5: Risk scoring and associated ratings.

Minimum Risk Score	Maximum Risk Score	Risk Rating
0	0	Nil Risk
0.01	3.33	Lower
3.34	6.66	Medium
6.67	10	Higher

⁴³ Zhou, D., Xiao, J., Bonafoni, S., Berger, C., Deilami, K., Zhou, Y., ... & Sobrino, J. A. (2018). Satellite remote sensing of surface urban heat islands: Progress, challenges, and perspectives. *Remote Sensing*, 11(1), 48.

Air Temperature

Please see Appendix A: Technical for a thorough explanation.

Population Density

Structure locations used to measure population density were acquired from the ICI Society for all three communities (Figure 9, Figure 10, Figure 11, Figure 12). Field work conducted in the three communities on July 26th and 27th assisted to refine these data. Multiplexes were identified within the three communities using information provided from the communities themselves. Identification of multiplexes in the District of Chetwynd was done using spatial data for their zoning bylaws. All structures within zones designated for multi-unit housing were visited, and the number of housing units were recorded in each structure⁴⁴.

Population density was measured in terms of housing units within a 100 m radius, or within a 3.14 ha area. The cooling effects of green spaces is highly variable, but a treed area such as a park or a forest approximately 1 ha in size is thought to have a cooling effect up to 100 m⁴⁵. As such, 100 m was chosen to highlight areas where various land management projects affect heat experienced by populations. Furthermore, a resolution of 1 km is too coarse given the size of these communities and fails to identify local areas of higher or lower density.

⁴⁴ Note: The number of housing units in multi-use housing structures was field-verified via "drive-by"; no entry was made into units.

⁴⁵ <https://www.inspq.qc.ca/sites/default/files/publications/3327-urban-heat-island-mitigation.pdf>

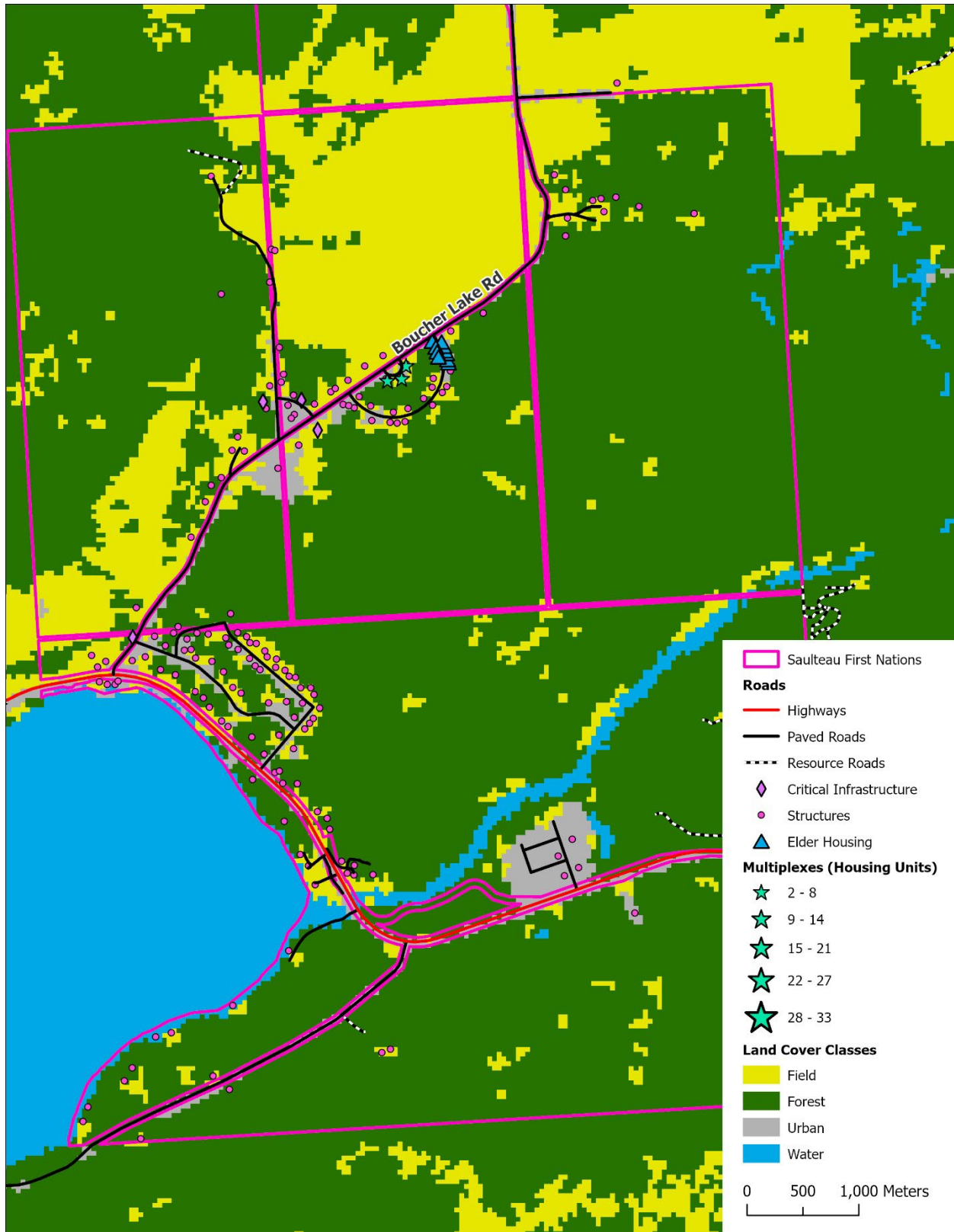


Figure 9: Land cover reclassification applied to the federal land cover product for the Saulteau First Nations.

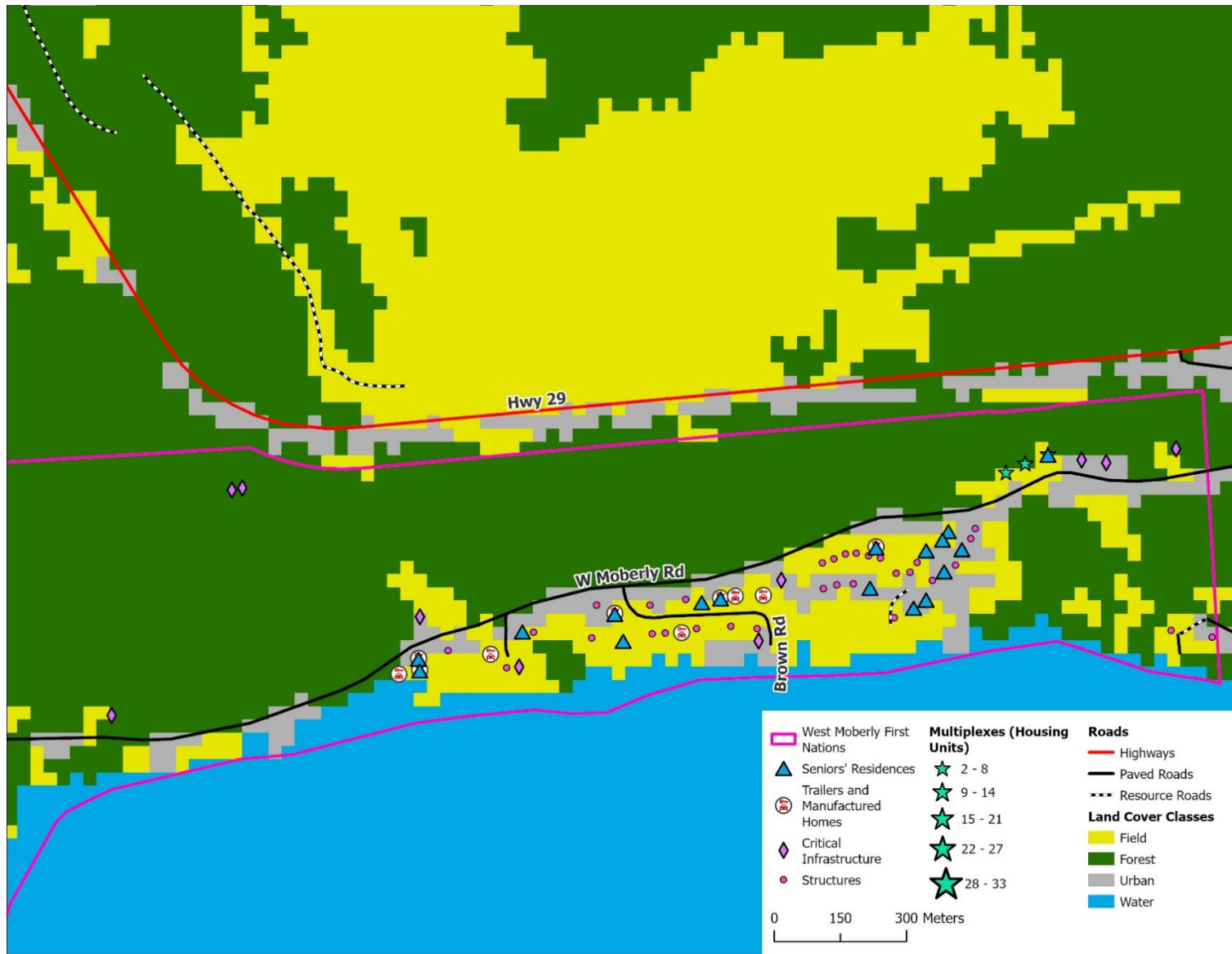


Figure 10: Land cover reclassification applied to the federal land cover product for the West Moberly First Nations. This section is zoomed into the residential area of West Moberly's reserve. Seniors were defined as persons 55+, this information was provided by Darren Robertson.

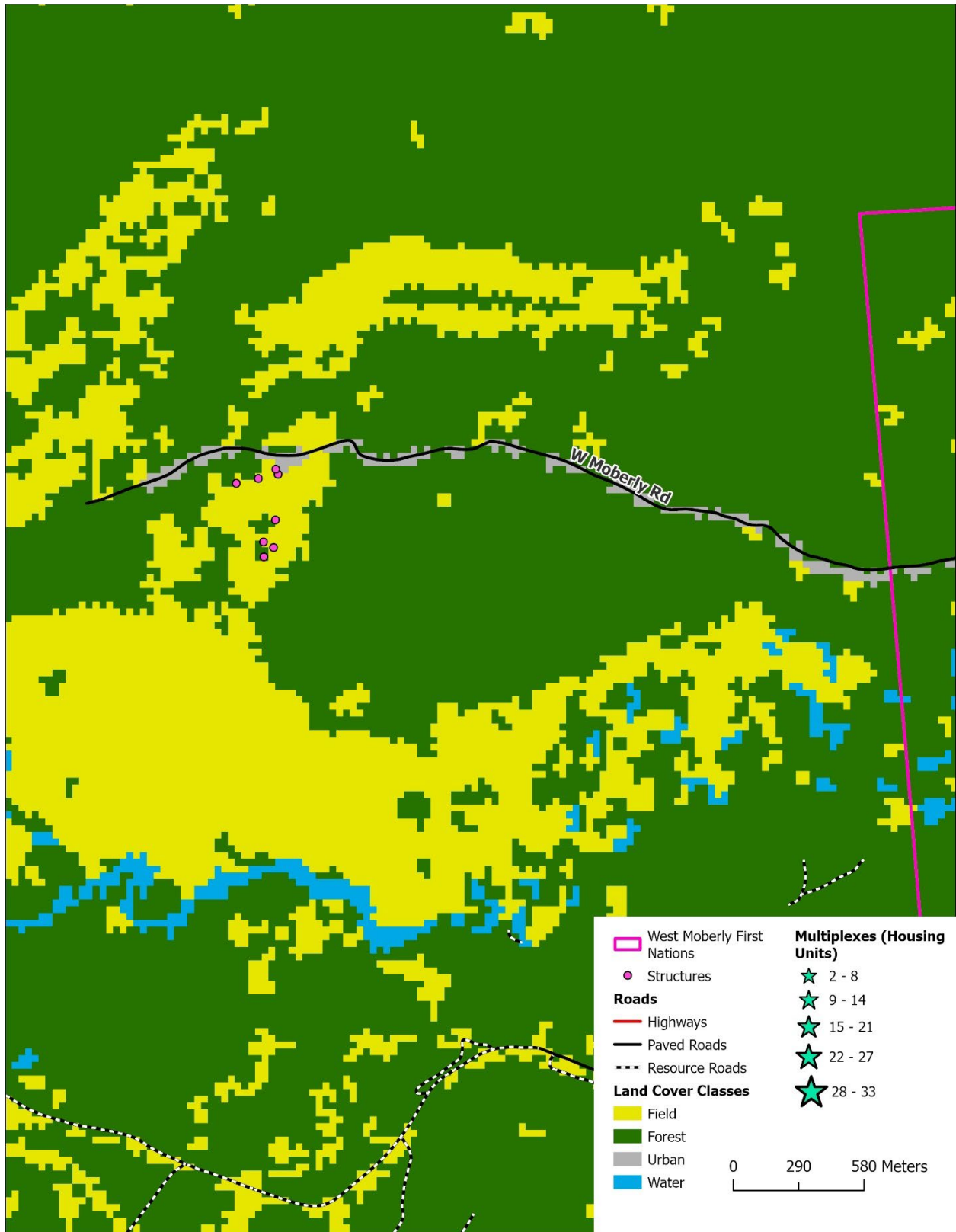


Figure 11: Land cover reclassification applied to the federal land cover product for the West Moberly First Nations. This section is zoomed into an area on reserve west of West Moberly's main residential area.

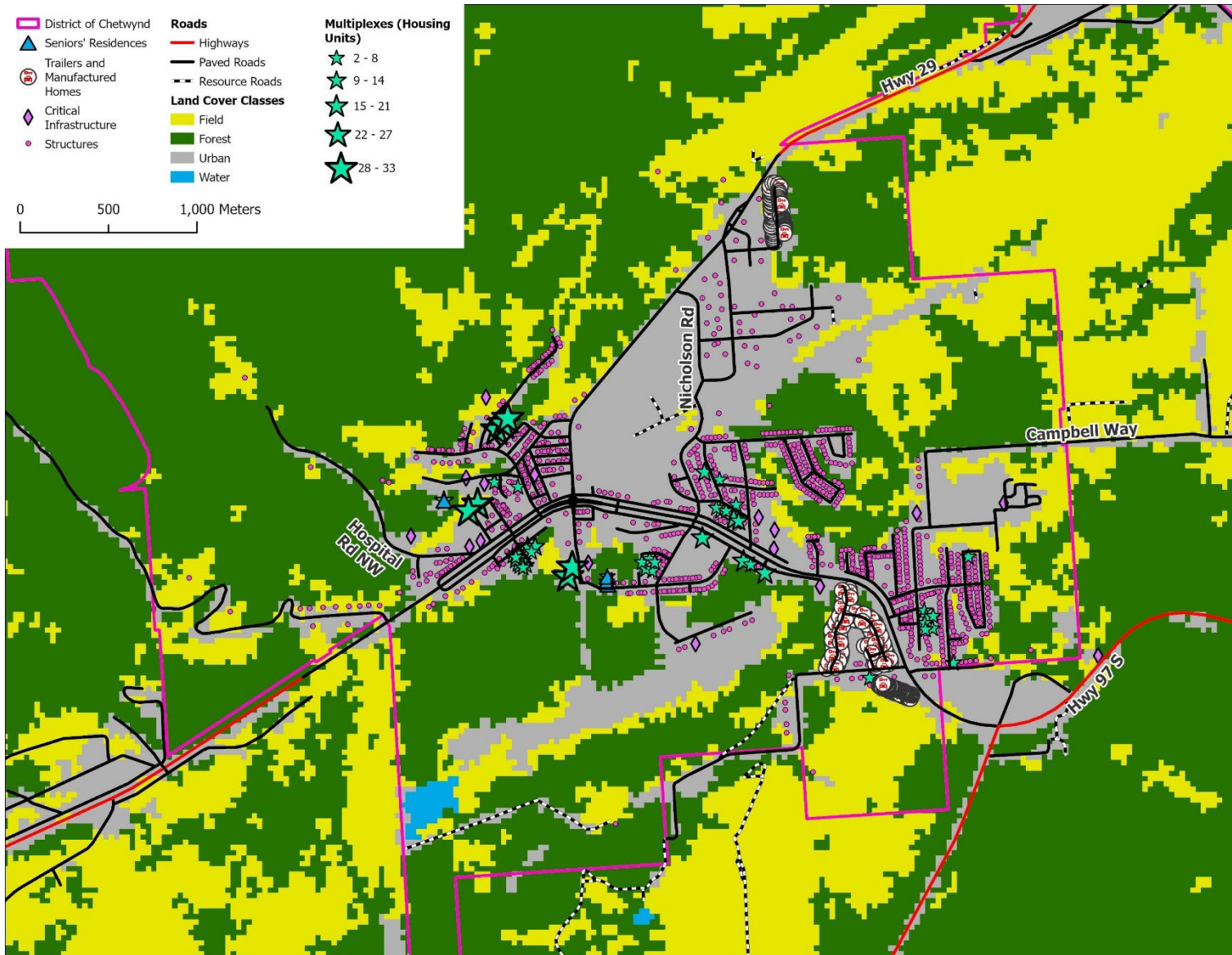


Figure 12: Land cover reclassification applied to the federal land cover product for the District of Chetwynd.

Vulnerability

Two factors were considered to assess vulnerability: low income populations and senior populations. Interviews with all relevant staff members in all communities were conducted to determine how, or whether, to identify vulnerable populations.

Income data were not available on an individual home basis due to both a lack of data at this scale, as well as privacy considerations. As such, proxies were used to infer locations of potential low-income housing. First, information provided by the District of Chetwynd identified certain residential zones and some specific multiplexes designated as low-income housing. Secondly, mobile or manufactured homes were categorized as low-income housing units based on research into social vulnerability indices⁴⁶. Locations of mobile or manufactured homes were verified in the District of Chetwynd during the July, 2023 fieldwork, and were provided on a home-by-home basis for West Moberly. No low income housing data was provided by Sauleau.

In the District of Chetwynd, the presence of seniors was mapped directly from either housing designated for seniors or assisted living facilities. The locations of these seniors' homes were verified during the July 2023 fieldwork. Therefore, the District's seniors' spatial dataset is likely underrepresenting the actual population as it does not include seniors living in other types of residences (their own homes, with family, etc.). West Moberly provided the location of housing units with senior residents on their reserve⁴⁷. Some limited elder housing spatial data was provided by Sauleau, which has been incorporated in this report's maps and risk assessment.

Low-income vulnerability and seniors' vulnerability were mapped separately and incorporated separately into the risk products. A presence-absence approach was used for mapping rather than measuring density due to the uncertainty of the locations of vulnerable populations outside of information provided or identified for this work. There are many different factors and conditions which can render different people vulnerable such as schizophrenia, diabetes, or depression to name a few⁴⁸. As such, the goal incorporating this vulnerability data was to demonstrate known locations of vulnerable populations rather than treating it as complete information which could overshadow other high-risk areas. The presence of a vulnerable housing unit was marked within a 100 m radius from it. The 100 m radius was chosen using the same rationale provided in the Vulnerability section.

For the classification of these products, the presence of a vulnerable housing unit (within 100 m of a vulnerable housing unit) was provided a score 10, while absence thereof was provided a score of 0.

Risk Mapping Approach #1 – Simple

A simple risk product was developed for all three communities. These products were developed using the population density products and the air temperature products. All locations with a population density score of 0 were provided a risk of 0 as risk is negligible in the absence of people. The following equation was applied to develop simple risk:

⁴⁶ https://www.atsdr.cdc.gov/placeandhealth/svi/img/pdf/Flanagan_2011_SVIforDisasterManagement-508.pdf

⁴⁷ West Moberly "senior residents" were defined as persons over 55 years of age, so this includes elders (over 60 years of age) as well as some persons between 55-60 who are not yet considered elders. This distinction was made by West Moberly Emergency Manager Darren Robertson, so as to include potentially vulnerable residents who are not yet considered elders.

⁴⁸ https://www2.gov.bc.ca/assets/gov/birth-adoption-death-marriage-and-divorce/deaths/coroners-service/death-review-panel/extreme_heat_death_review_panel_report.pdf

$$(Air\ Temperature * 0.5) + (Population\ Density * 0.5) = Simple\ Risk\ Formula$$

Risk Mapping Approach #2 – Incorporating Vulnerability

Vulnerability-incorporated risk map products were developed for all three governments. Wherever possible, these products were developed using the population density products, the air temperature products, the seniors presence-absence products, and low-income presence-absence products. All locations with a population density score of 0 were provided a risk of 0 as risk is negligible in the absence of people. The following equation was applied to develop vulnerability risk for the District and West Moberly:

$$(Air\ Temperature * 0.5) + (Population\ Density * 0.5) + (Seniors * 0.2) + (Low\ Income * 0.2) = Vulnerability\ Incorporated\ Risk\ Formula$$

A slight modification was made to Saulteau’s formula due to the fact that only seniors data were available and no low income data. The formula used was:

$$(Air\ Temperature * 0.5) + (Population\ Density * 0.5) + (Seniors * 0.4) = Vulnerability\ Incorporated\ Risk\ Formula$$

Results

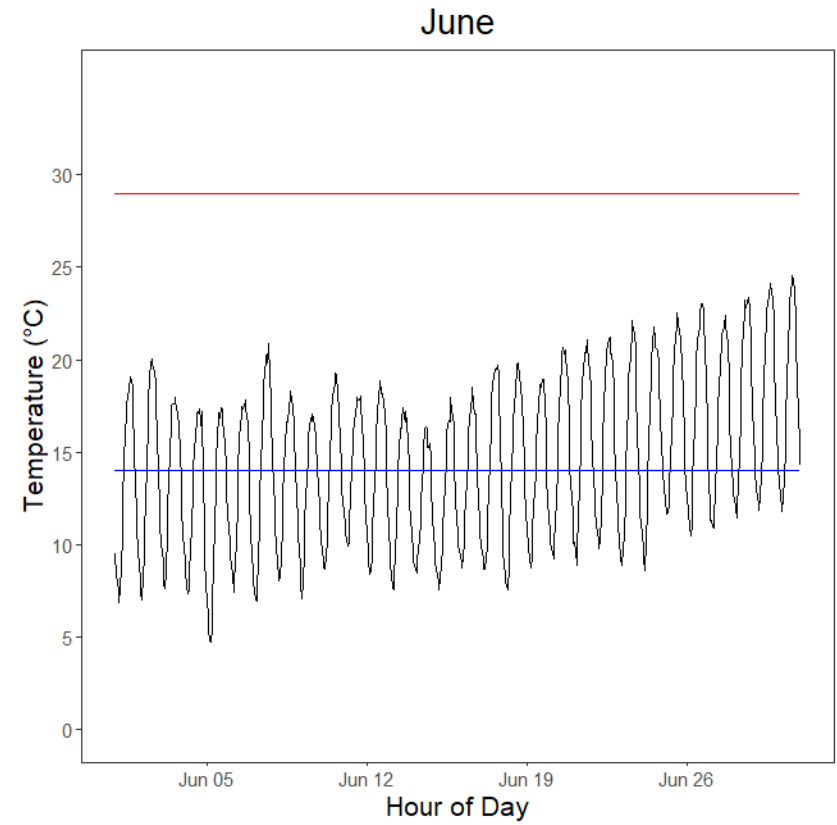
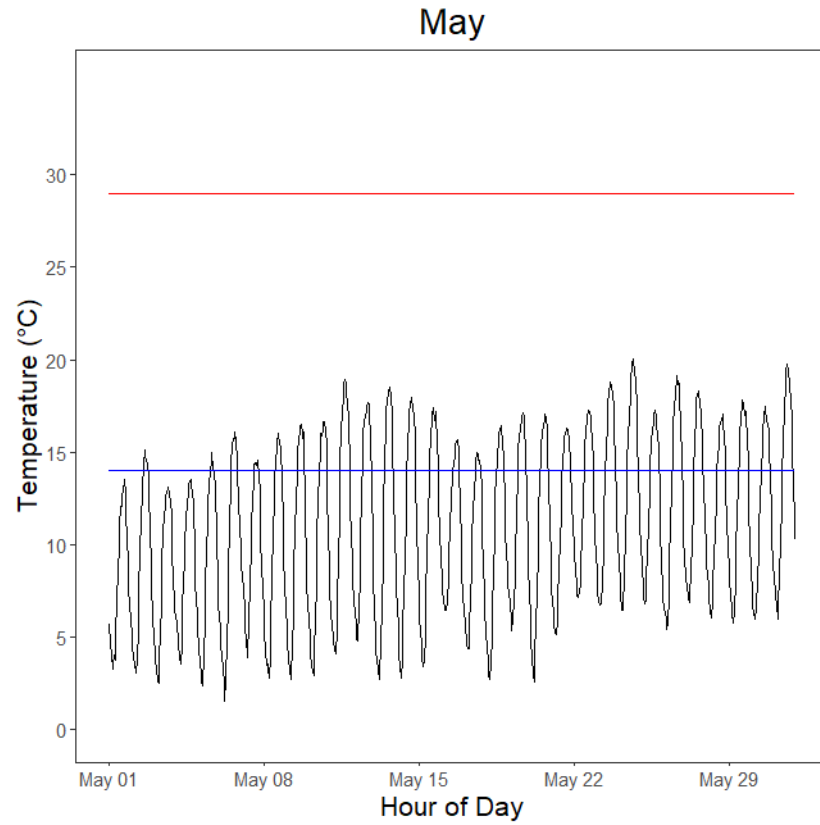
Weather Data Patterns

Description of Weather Patterns

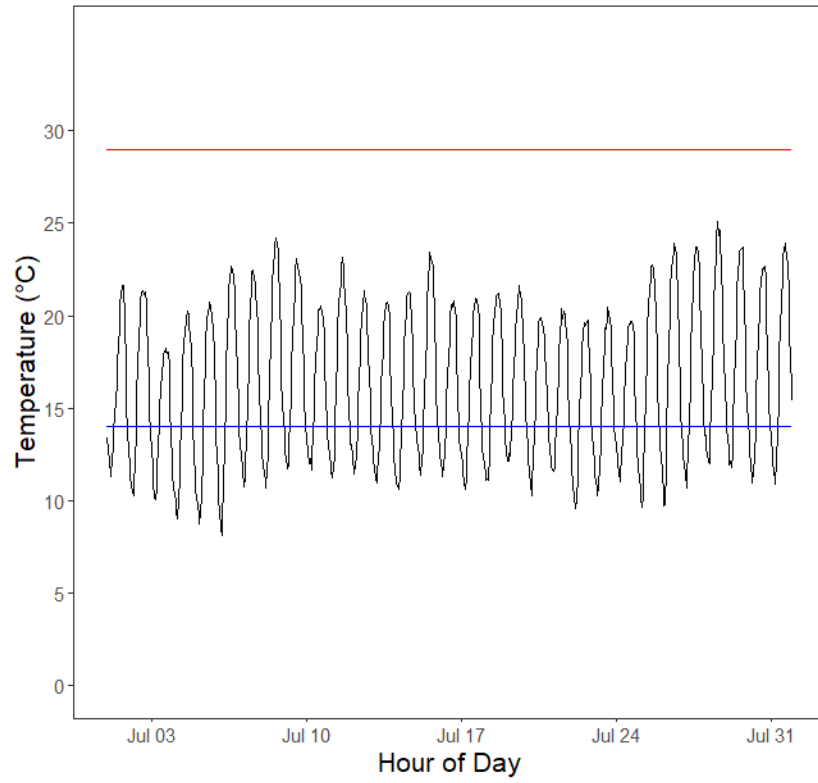
Average hourly weather trends from data at the Chetwynd Airport weather station for the month of May show that daily highs typically remain over 15° C by the second week of the month and rise to 20° C by the end of the month (Figure 13). Daily highs remain between 15-20° C for the first half of June, then rise slowly to reach 25° C by the end of June. In July daily high temperatures fluctuate around 20° C, plus or minus 5° C. In the last week of July and first two weeks of August, daily highs tend to be closer to 25° C, however by mid-August daily high temperatures are below 20° C and continue declining through the end of the month. By September daily highs do not exceed 20° C and more often are around 15° C or lower by late-September.

Daily lows in May hover around 5° C until later in the month when they start to climb. In June, daily lows stay below 10° C until around the last week, when they rise to approximately 12° C. Lows stay around that 12° C mark for most of July. In August there are several days where the daily low is at or just below the 15° C mark, but that is rarer with most daily lows in August at or below 10° C by mid-month. In September once again daily lows are below 10° C and declining toward 5° C by the end of the month.

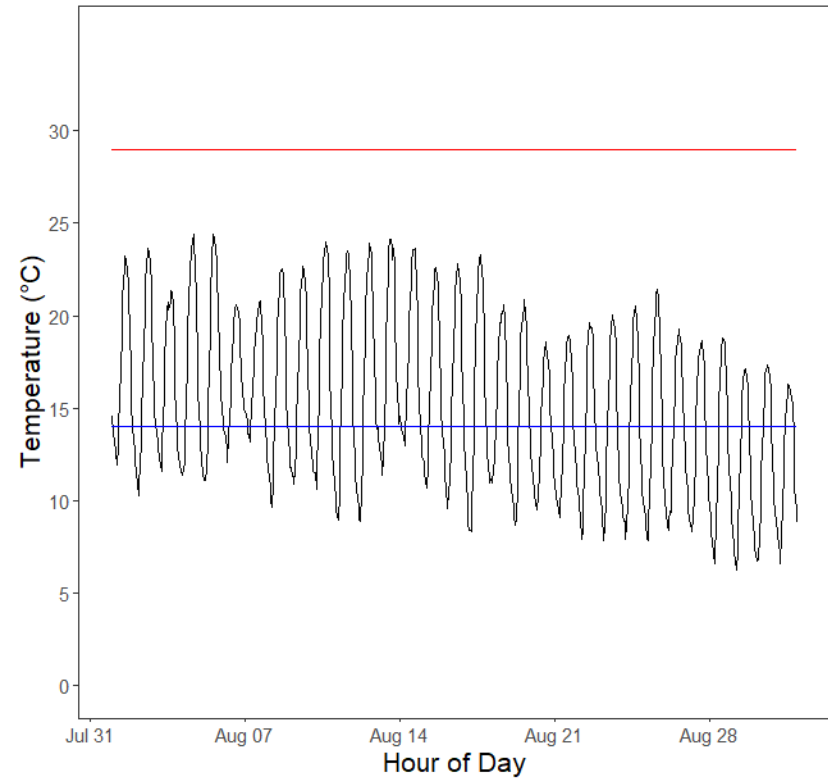
**Average Temperature per Hour for Months May – September and Years 2013 – 2022
at Chetwynd Airport Weather Station**



July



August



September

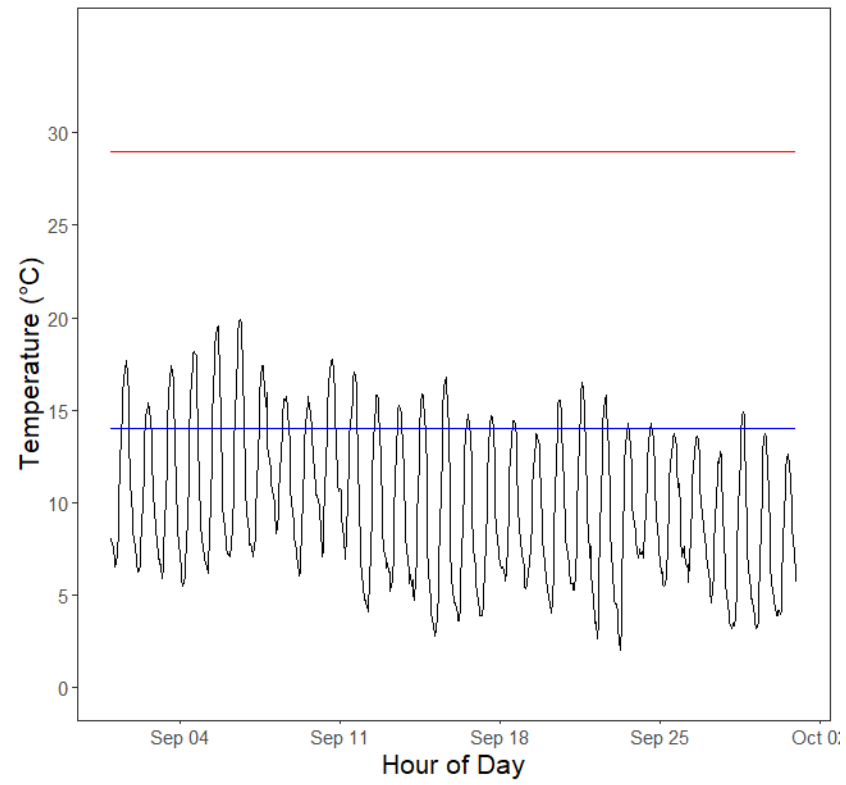


Figure 13: Average temperature per hour in the months of May to September. Hourly temperatures were averaged over years 2013 - 2022. The red line is the the 29°C maximum temperature threshold for heat warnings and extreme heat emergencies. The blue line is the 14°C minimum temperature threshold for these same heat-related events.

Saulteau First Nations

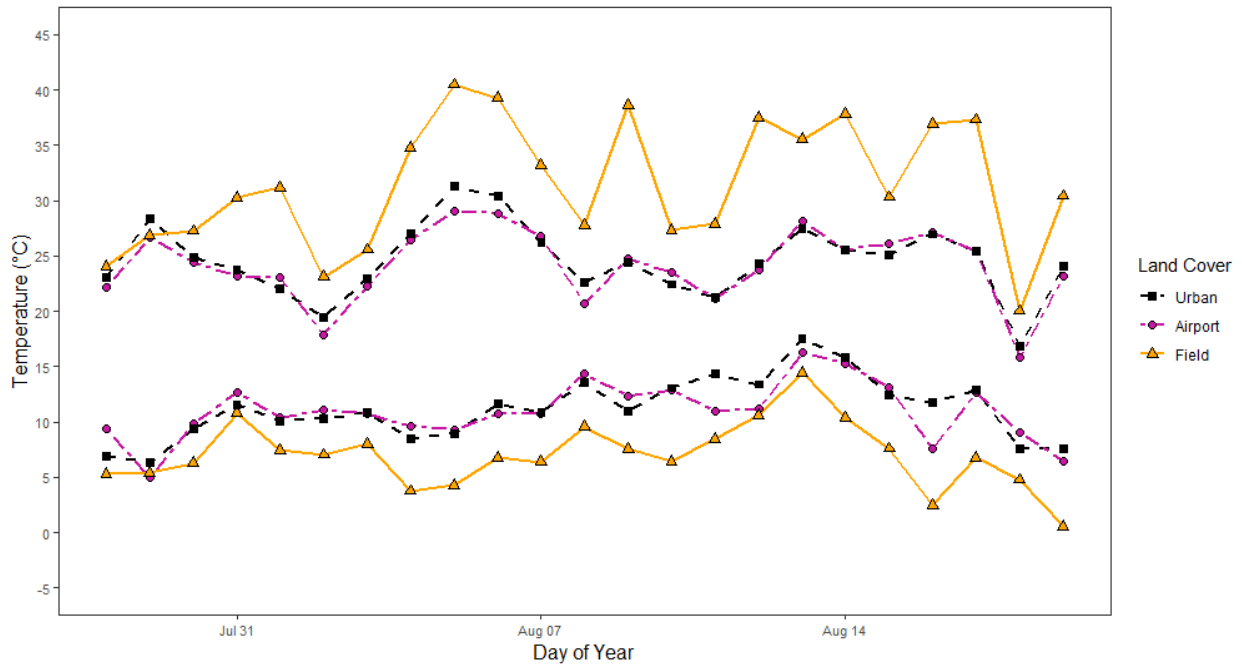
The “forest” gauge installed at the Saulteau First Nations unfortunately failed and no Saulteau forest data could be used in this report’s analysis. However, the District and West Moberly’s forest gauge data were incorporated into the analysis in order to ensure a high level of air surface temperature prediction.

Overall, the highest daytime temperatures were recorded by the “field” gauge (Figure 14). On many days, the “field” gauge read maximums reaching 40° C or close to it. On many days, maximum temperatures over this land cover were as much as 10°C hotter than those measured by the other sensors. Daytime high temperatures measured from the “field” gauge varied more on a day-by-day basis than the other sensors.

The lowest nighttime temperatures were also recorded by the “field” gauge. Comparatively, nighttime low temperatures were generally closer in magnitude among the different land cover types. Typically, the difference in lows between the “field” gauge and the other gauges tended to hover around 4°C.

The “urban” gauge measured maximum and minimum temperatures very close to Chetwynd Airport. There were a few exceptions: towards the end of August the “urban” gauge showed roughly a 3°C difference at night, and in early September the “urban” gauge showed roughly a 5°C discrepancy for a few days.

Saulteau — Daily Temperature Maxima and Minima by Land Cover Type:
Jul 28 - Aug 19, 2023



Saulteau — Daily Temperature Maxima and Minima by Land Cover Type:
Aug 20 - Sep 11, 2023

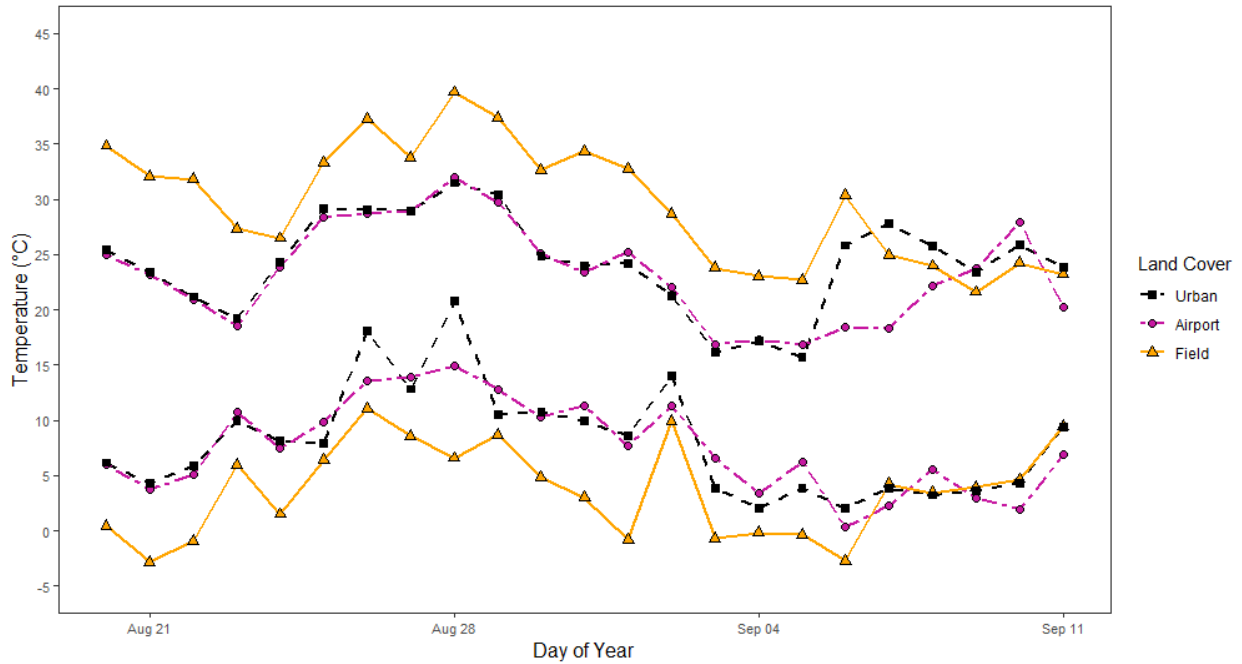


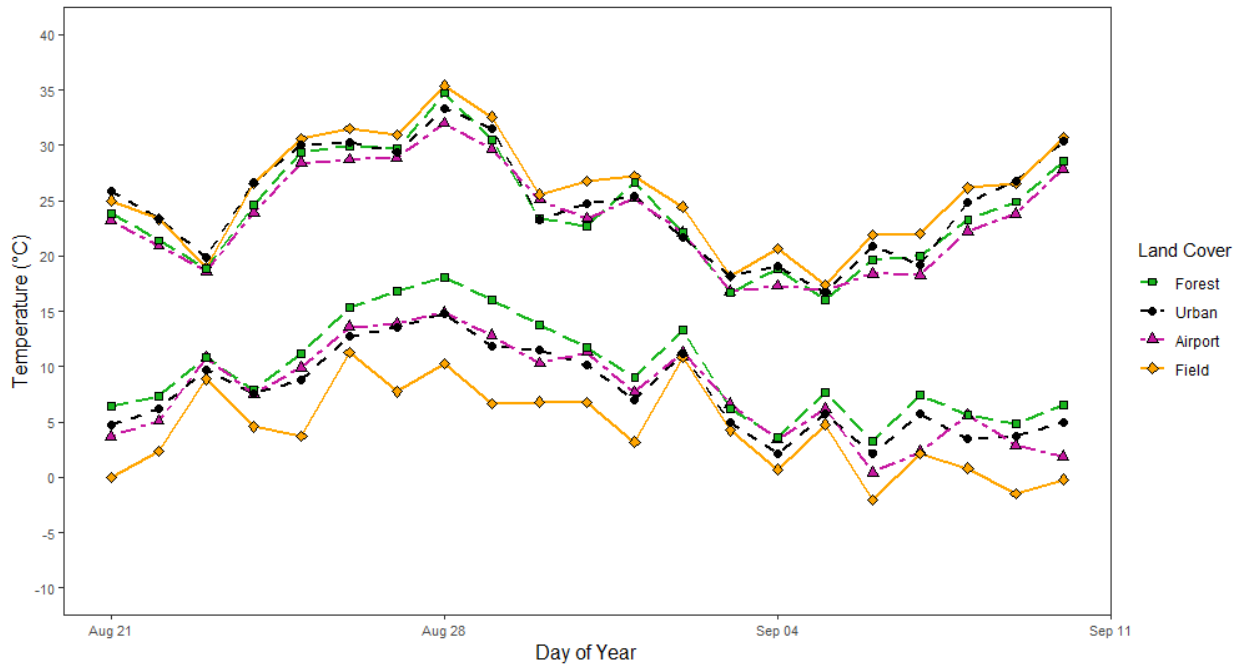
Figure 14: Daily maximum and minimum temperatures measured by the temperature gauges at the Saulteau First Nations reserve between July 28 and September 11, 2023.

West Moberly First Nations

Temperature minima and maxima all matched very closely for each of the gauges installed at West Moberly First Nations (Figure 15). On most days, the “field” gauge typically read the hottest maximum temperatures, but only by a degree or so. One moment of sudden change is shown on September 25th which showed a drop of about 10°C. However, this same pattern occurred in all the temperature gauge readings. The readings of all the gauges matched closely with those of the Chetwynd Airport.

Minimum temperatures read by each of the gauges showed a bit more variance. Overall, the “forest” gauge consistently measured minimum temperatures about 2-3°C warmer at night. The “field” gauge on the other hand consistently read the coolest minimum temperatures at night by about 3°C or so. Nighttime minimum temperatures were quite stable and showed relatively little variation on a day-to-day basis. Minimum temperatures from the Chetwynd Airport matched quite closely to the “urban” temperature gauge at night for the first three or so weeks of acquisition, but then seemed to align more closely with the “field” gauge in the weeks following.

West Moberly — Daily Temperature Maxima and Minima by Land Cover Type:
Aug 21 - Sep 10, 2023



West Moberly — Daily Temperature Maxima and Minima by Land Cover Type:
Sep 11 - Oct 02, 2023

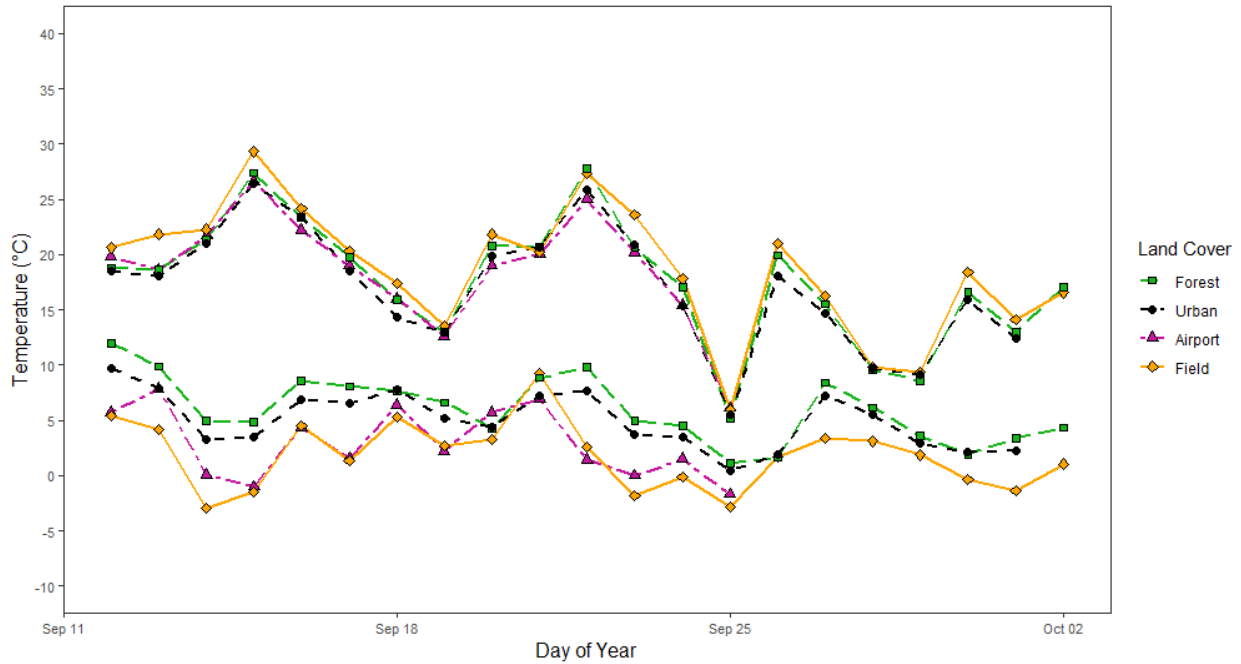


Figure 15: Daily maximum and minimum temperatures measured by the temperature gauges at the West Moberly First Nations reserve between August 21 and October 2, 2023.

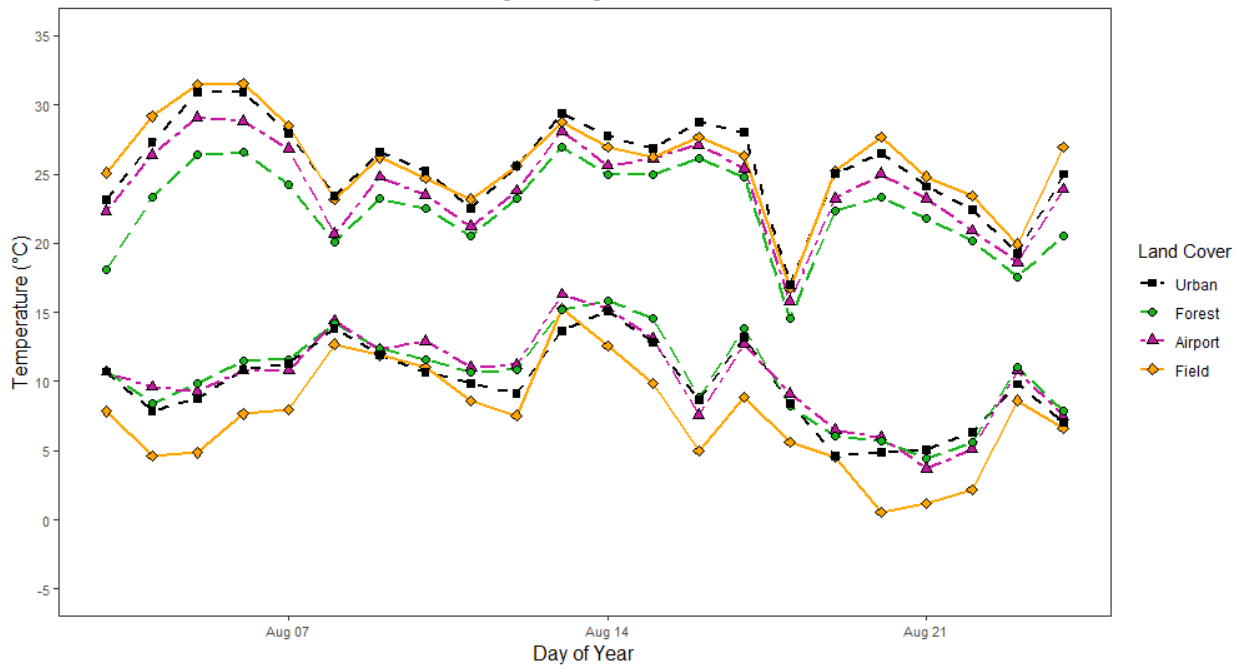
District of Chetwynd

Overall, the highest daytime maximum temperatures were recorded by the “urban” gauge (Figure 16). The “urban” and “field” maximum temperatures were generally quite close in value until early September when the “urban” maximum temperature increased suddenly to about 35°C. The maximum temperatures recorded by this gauge remain elevated and misaligned with the other land covers for a period of about five days, after which a 3-5°C discrepancy higher remains for the rest of the time series. Given that the “urban” data is consistent with the other land covers up until early September and given the gauge’s central location near the Chetwynd Town Hall, it seems as though the sudden increase and generally higher temperatures thereafter could have been caused by human factors or some other anomaly.

The data from the “forest” temperature gauge consistently recorded the lowest daytime maximum temperatures. Generally, maximum temperatures measured by all gauges were consistent with one another and with the Chetwynd Airport over the time series available and varied by at most 5° C except for the “urban” gauge’s data anomaly.

The lowest nighttime temperatures were recorded by the “field” gauge. This gauge recorded minimum temperatures roughly between 1-5° C colder than the other temperatures. The “forest” temperature gauge consistently recorded the highest nighttime lows. For the most part, the “forest” and “urban” nighttime lows aligned well with one another and with the Chetwynd Airport minimums. In early September there was a period of about a week where the “urban” minimum temperatures matched more closely with the “field” temperatures, showing as much as a 5°C difference relative to Chetwynd Airport.

Chetwynd — Daily Temperature Maxima and Minima by Land Cover Type:
Aug 03 - Aug 24, 2023



Chetwynd — Daily Temperature Maxima and Minima by Land Cover Type:
Aug 25 - Sep 18, 2023

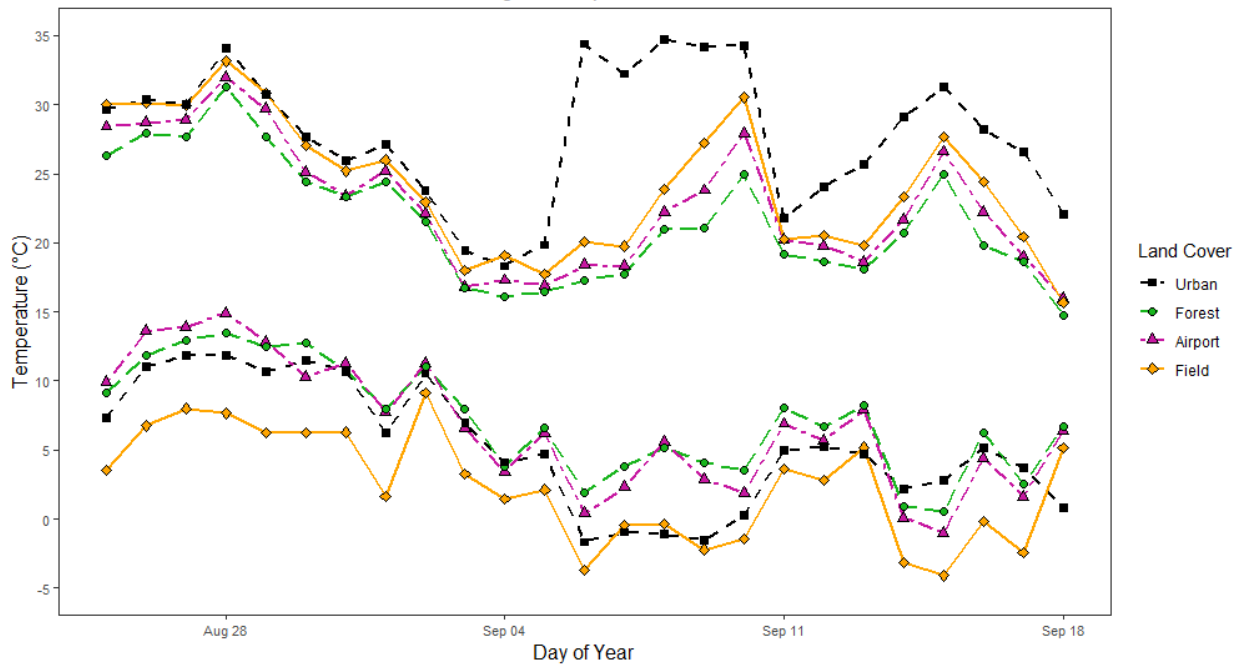


Figure 16: Daily maximum and minimum temperatures measured by the temperature gauges in the District of Chetwynd between August 3 and September 18, 2023.

Identification of Heat Warnings and Extreme Heat Emergencies

The analysis of hourly temperatures for the years 2013-2022 from the Chetwynd Airport weather station indicate the occurrence of six heat warnings and one extreme heat emergency (Table 6). The extreme heat emergency was associated with the 2021 heat dome event, during which the station measured a maximum temperature of 39.3°C on June 29, 2021. The hourly temperature graph for June-July 2021 showing the 2021 heat dome event is shown in Figure 17, while Figure 18 shows a temperature graph for July 2023 which shows the heat event that occurred between July 8-10, 2023.

Table 6: Weather events identified from weather data taken from the Chetwynd Airport weather station operated by Environment Canada. Data was used for years 2013 - 2022.

Event ID	Event Type	Year	Month	Day	Minimum Temperature (°C)	Maximum Temperature (°C)
1	Heat Warning	2014	August	15	9.3	30.1
				16	15.8	29.7
				17	14.1	28.4
2	Heat Warning	2014	July	12	13.7	33.8
				13	14.4	34.7
				14	13.4	35
3	Heat Warning	2021	July	7	11.3	31.1
				8	14.1	29.3
				9	15	31
				10	14.4	22.4
4	Heat Warning	2021	June	24	9.5	24.4
				25	16.2	31.6
				26	15.8	34.1
5	Extreme Heat Emergency	2021	June	27	13	37.2
				28	19.6	37.2
				29	18.8	39.3
				30	16.7	34
			July	1	18.7	23.9
6	Heat Warning	2022	July	28	13.2	33.2
				29	16.2	29.1
				30	16.7	22.7
7	Heat Warning	2023	July	8	9.9	30.9
				9	14.4	32.6
				10	14.9	23

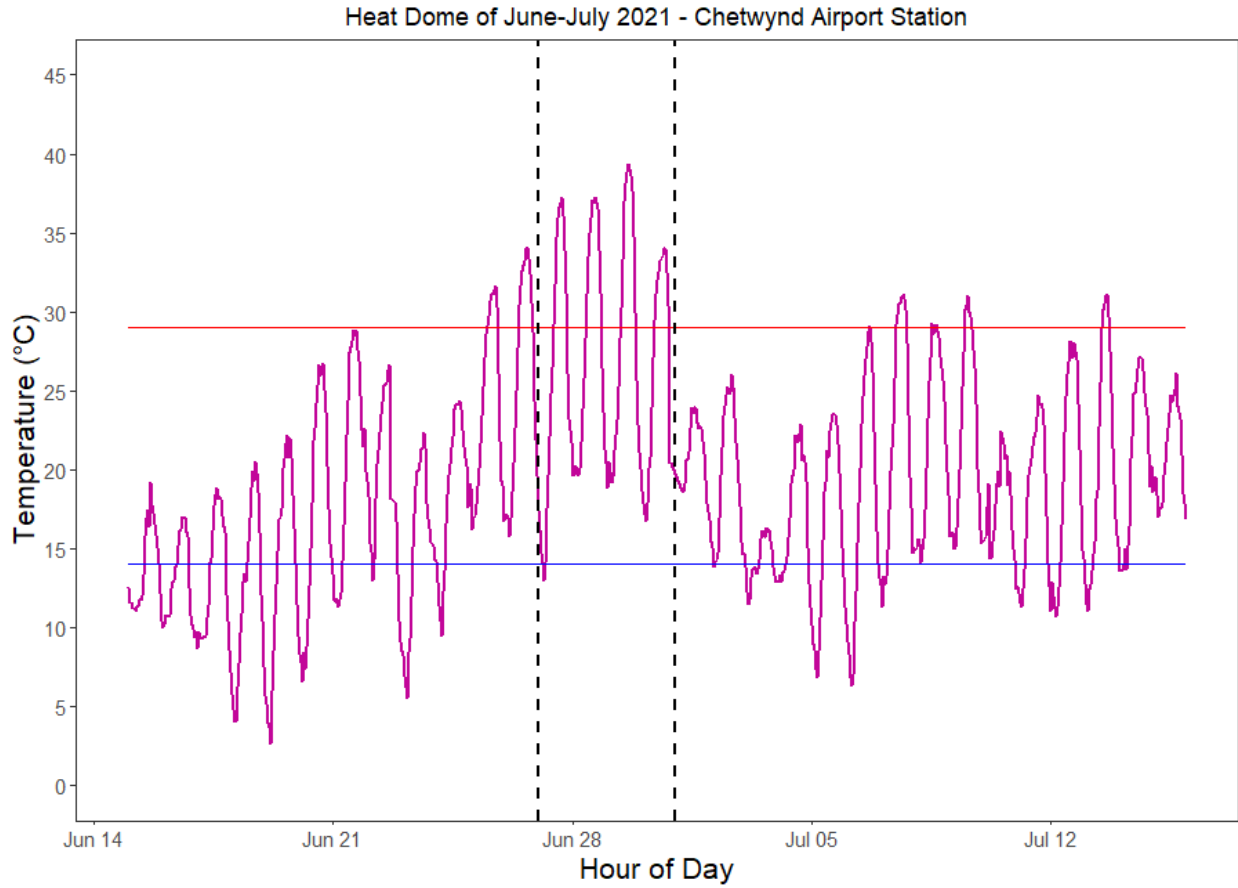


Figure 17: Observed hourly temperatures from June 15th to July 15th, 2021. The red line is the 29°C maximum temperature threshold for heat warnings and extreme heat emergencies. The blue line is the 14°C minimum temperature threshold for these same heat-related events. The black dashed lines delimit the beginning and end of the extreme heat emergency as per the definition used in this work.

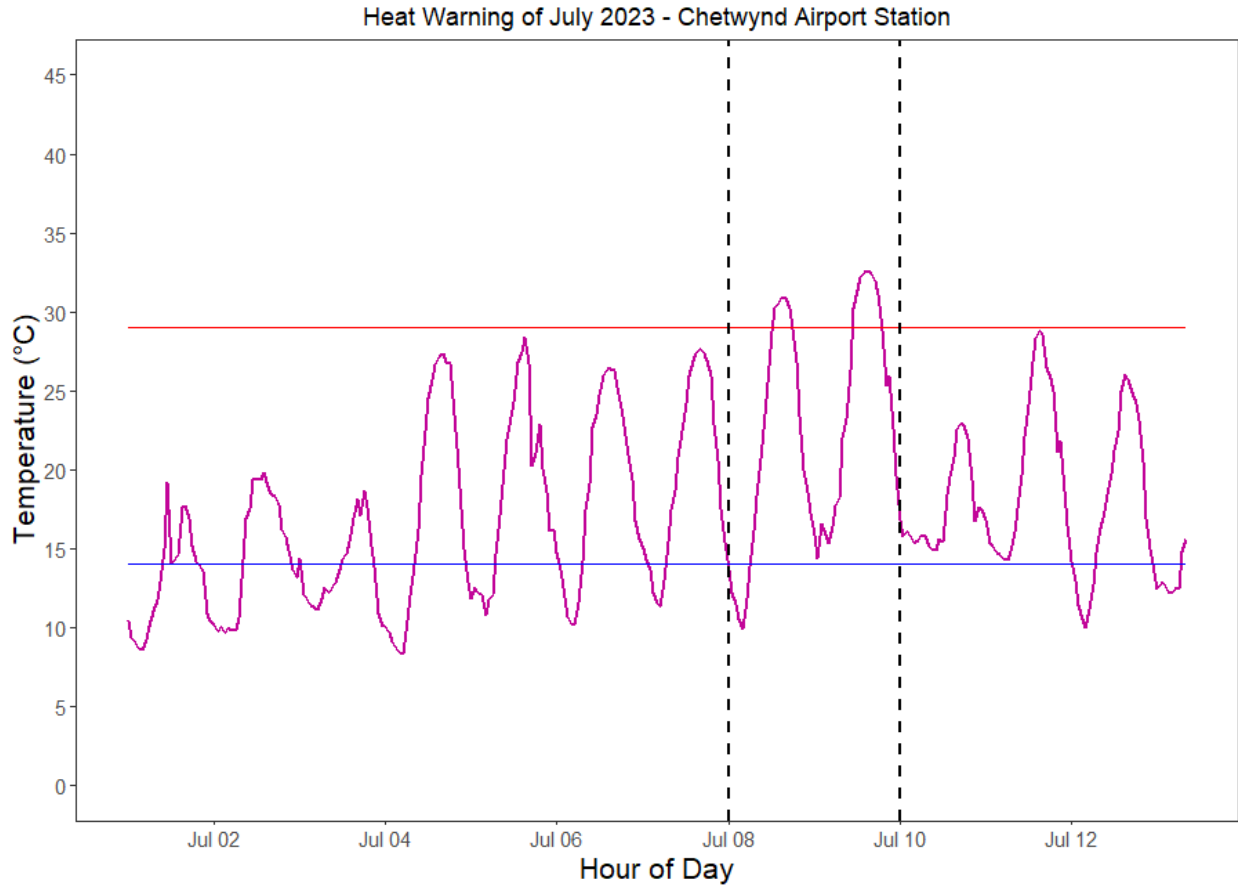


Figure 18: Observed hourly temperatures over the month of July, 2023. The red line is the 29°C maximum temperature threshold for heat warnings and extreme heat emergencies. The blue line is the 14°C minimum temperature threshold for these same heat-related events. The black dashed lines delimit the beginning and end of the heat warning.

Risk Assessment

Air Temperature Mapping

One of the primary objectives of this report was the development of air temperature maps for the three communities. These maps are important to show the spatial variability of temperature within the communities – this will help leadership prioritize many of the recommendations presented in this report. For example, urban trees may be planted in hot spot areas to help reduce urban heat island effects, or residents in hot spot areas may be prioritized for wellness checks during a heat wave.

Saulteau First Nations

Hot spots highlighted on Saulteau’s air temperature product include the industrial park along Highway 29, the quarry, the band office, and some spots and areas around the perimeter of the pasture (Figure 19). These areas reach temperatures around the low-to-mid 40s. Cold spots include Moberly Lake and Moberly River. Areas around the lake are generally a bit cooler than areas further toward the northeast. The Onion Hill subdivision has the highest population density on the reserve, due to the density of the seniors housing project development and the triplexes in its center. Otherwise, the rest of the population is either scattered or within the Lakeview subdivision.

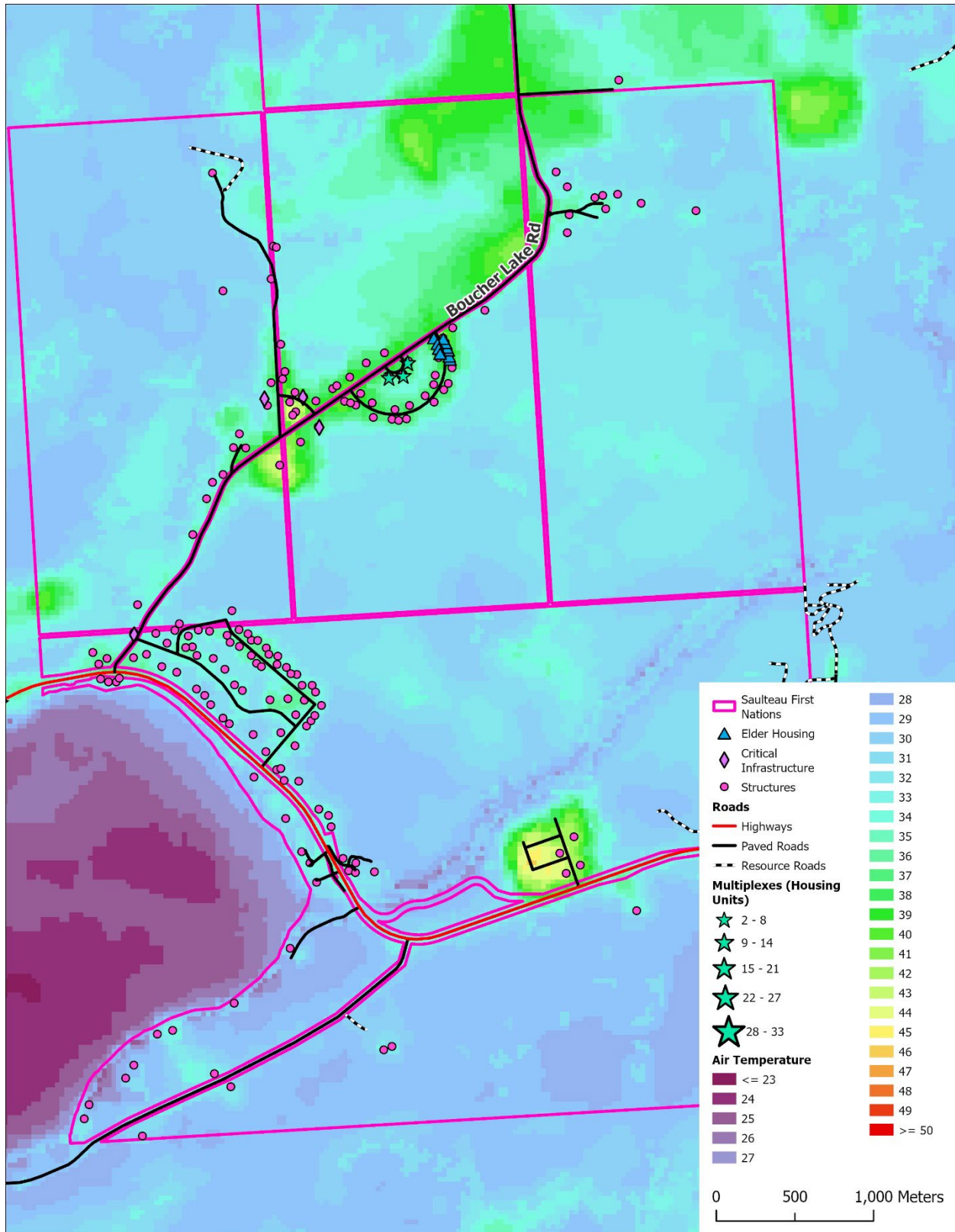


Figure 19: Air temperature product developed for the Saulteau First Nations.

West Moberly First Nations

Hot spots identified on West Moberly's air temperature product include the hay field, the ranch, and the community in general (Figure 20, Figure 21). Cold spots include the lake and Moberly River. The populated area overall shows up as being 5°C – 10°C hotter than the surrounding forest. Notably, a patch in the hay field near the ranch shows up as extremely hot, reaching above 50°C. The ranch itself is also quite hot, reaching the mid-40s. The Cryingman subdivision has a higher concentration of seniors while the Brown subdivision has a higher concentration of mobile homes. As an aggregate, the vulnerable populations are spread out relatively evenly over the community. The population density is highest in the Cryingman subdivision but is also evenly spread.

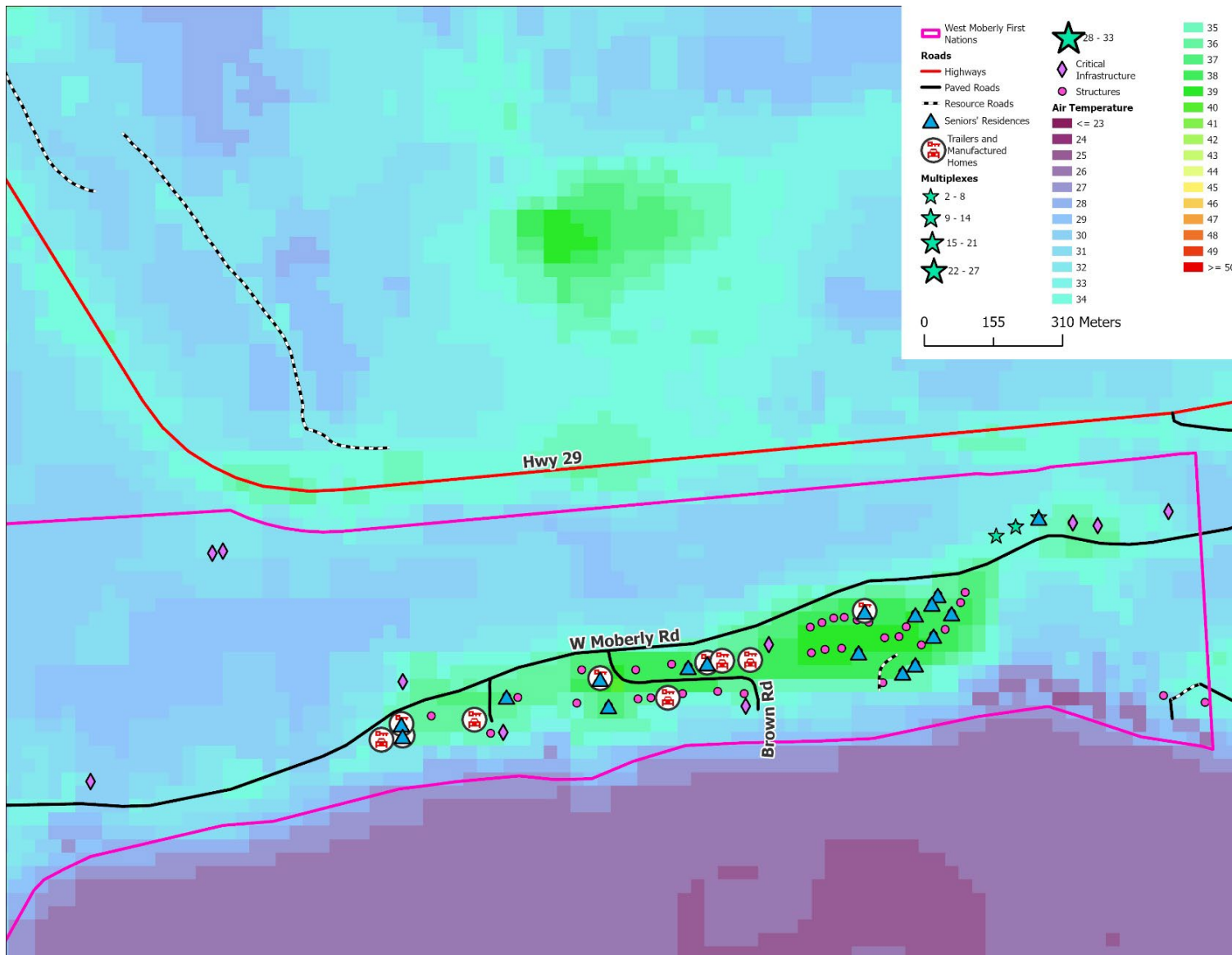


Figure 20: Air temperature product developed for the West Moberly First Nations.

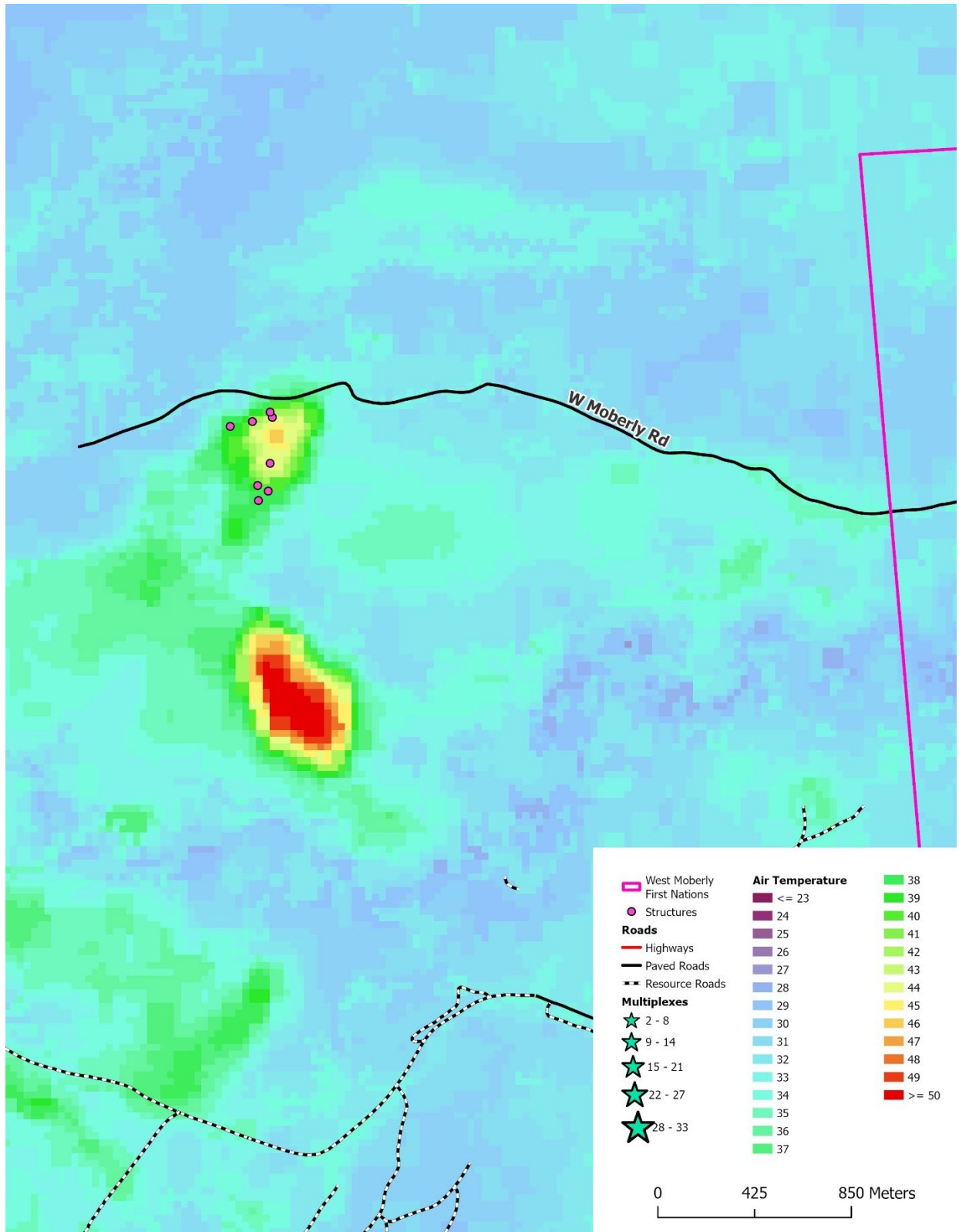


Figure 21: Air temperature product developed for the West Moberly First Nations. This section is zoomed into the Nation-owned, off-reserve ranch.

District of Chetwynd

Hot spots highlighted on the District's air temperature product include the industrial park, the downtown core, Chetwynd Plaza, and the general area covering the high school and the community center (Figure 22). These areas reached about or just below 50° C. Cool spots include the forested urban reserve, and the Little Prairie Community Forest. These forested areas generally remained in the low-30s. Heat patterns within the District of Chetwynd are somewhat variable which generally seem to reflect the variety in urban density. Many less developed urban areas such as the residential suburbs, the riding arena, and the airport all show temperatures ranging from the high-30s to mid-40s. While many residences are located on the periphery where temperatures were comparably cooler, the Windrem apartments and the apartments west of the community centre do fall a bit more cleanly into areas of higher temperatures, generally within the mid-40s.

Population Density in the District of Chetwynd is highest at the locations of its multiplexes. The three apartment complexes across from The Lion's Inn & Suites, the Windrem apartments, the low-income housing across Highway 29 from Chetwynd Plaza, and the Gwillim Gardens apartment complexes all have relatively high density. Other moderately dense areas include the RV parks and the two apartment complexes to the west and to the south of the community centre. Chetwynd's mapped vulnerable populations include the Little Prairie Haven and Surerus Place assisted living facilities, the mobile homes at the Pinewood RV and Trailer Park and at the Westwind RV Park, and manufactured homes within the area zoned for such housing. As this was not an exhaustive mapping of Chetwynd's seniors or vulnerably-housed population, the distribution of these populations within other areas of the District is unknown.

The size and layout of the community generally has most population dense areas located on its periphery where temperatures are cooler than the more commercial or industrial areas. The same is true of the locations of its known vulnerable populations.

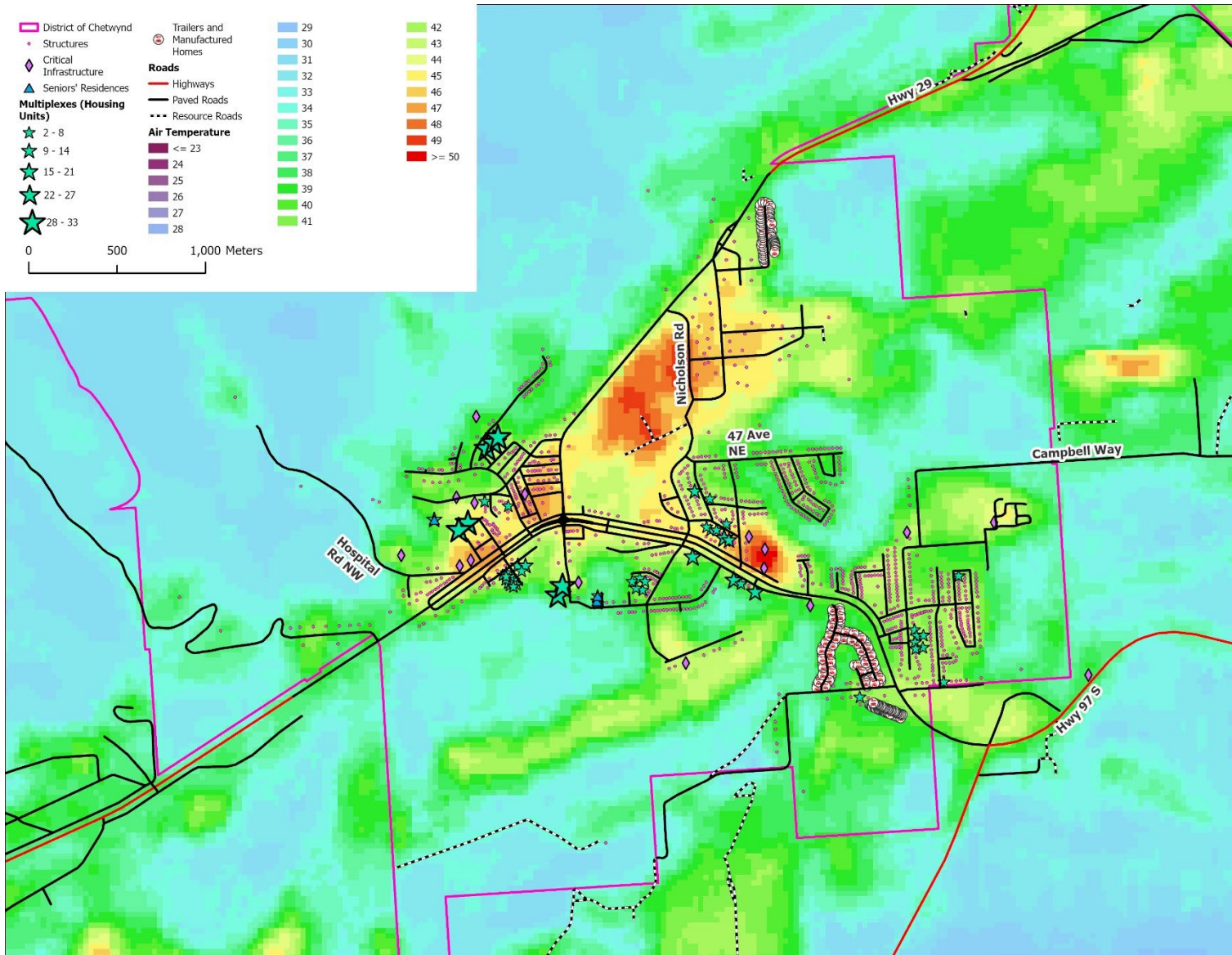


Figure 22: Air temperature product developed for the District of Chetwynd.

Risk Mapping #1 – Simple

Saulteau First Nations

Saulteau's simple risk map indicates overall a generally low risk level for extreme heat impacts (Figure 23). Highlighted areas include the quarry, the area around the school and the band office, the industrial park, and the denser areas of the Onion Hill subdivision. The low overall risk reflects the cooling effects afforded by Moberly Lake to adjacent residents. Despite the low density around the quarry, the band office, and the industrial park, these areas were highlighted due to high temperatures. These areas should be considered in future long-term heat mitigation or adaptation strategies as people still frequent these areas during the day. Aid and relief should also be planned for residents of the seniors' housing project.

The pasture is identified as nil risk due to the lack of structures there. However, the communal pasture is a community value and the heat experienced in this area will certainly impact the livestock pastured here during extreme heat conditions. Care should be taken to mitigate livestock's heat exposure during such heat events.

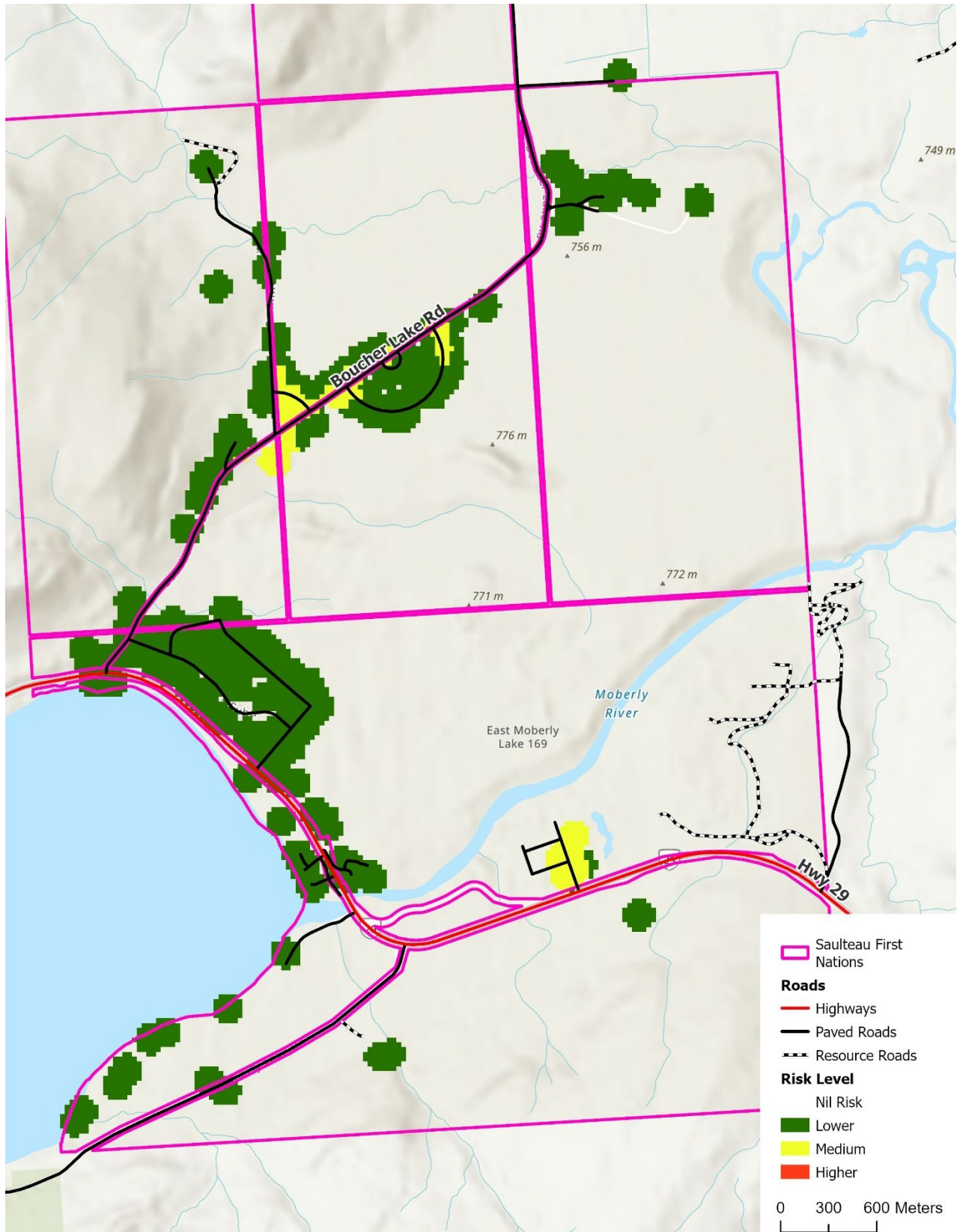


Figure 23: Saulteau First Nations extreme heat risk map.

West Moberly First Nations

West Moberly's simple risk mapping is generally low (Figure 24, Figure 25). Highlighted areas demonstrate where population density was high enough to mark certain areas as medium, as well as the off-reserve ranch which reached higher temperatures compared to the rest of the community. The temperatures in the community were relatively low for exposed areas and the population density was relatively evenly distributed, and this is reflected in the simple risk. Future long-term heat mitigation or adaptation strategies should thus consider different areas of the community with roughly equal concern.

The hay field near the ranch is identified as nil risk due to the lack of structures there – although this area is off-reserve it was identified as an area important to the community. However, extreme heat can have adverse effects on the productivity of crops⁴⁹. Consideration should be given to Nation members who are at the ranch frequently.

⁴⁹ <https://climatereadybc.gov.bc.ca/pages/extreme-heat>

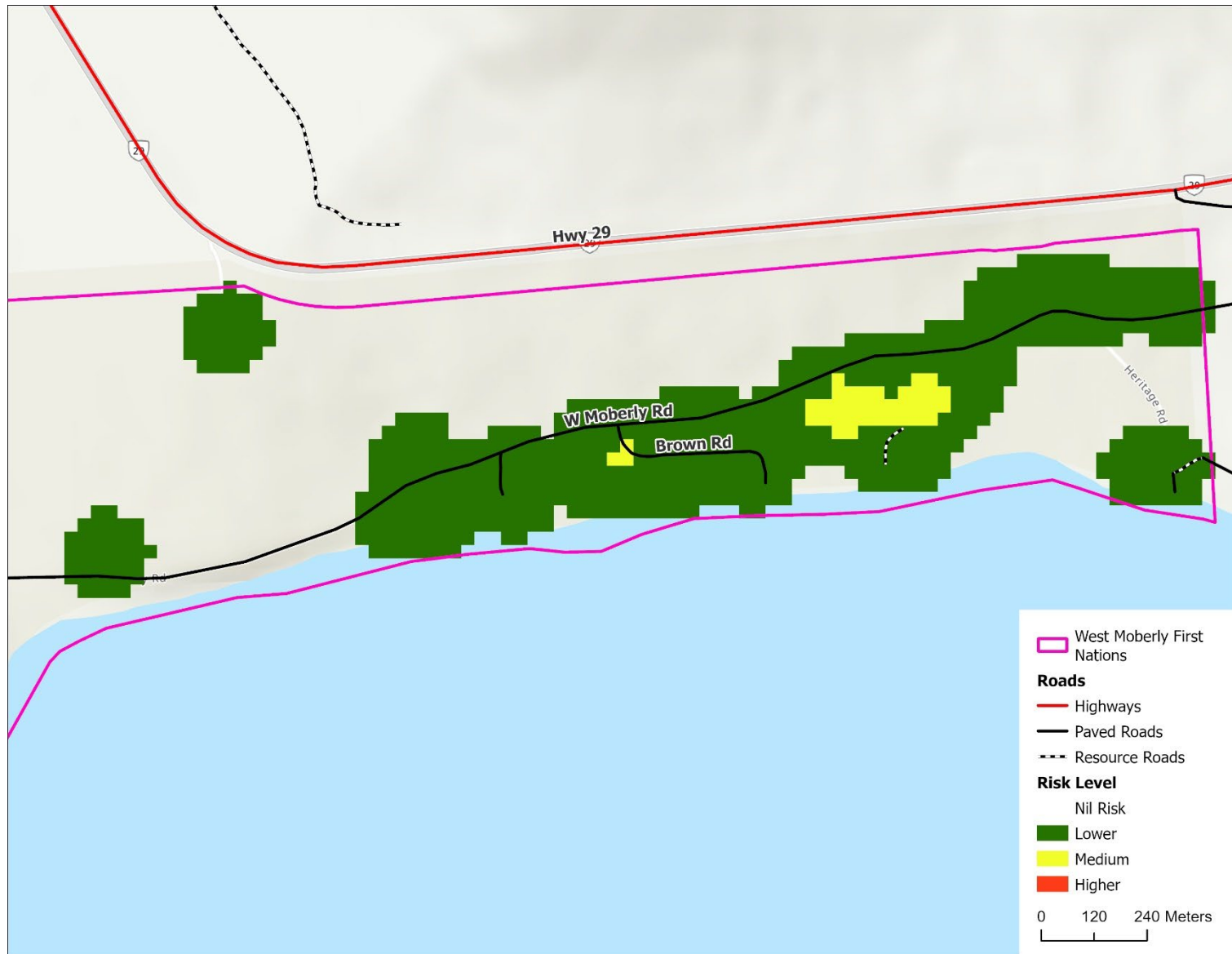


Figure 24: West Moberly First Nations community extreme heat risk map - zoomed into the residential area of the Nation's reserve.

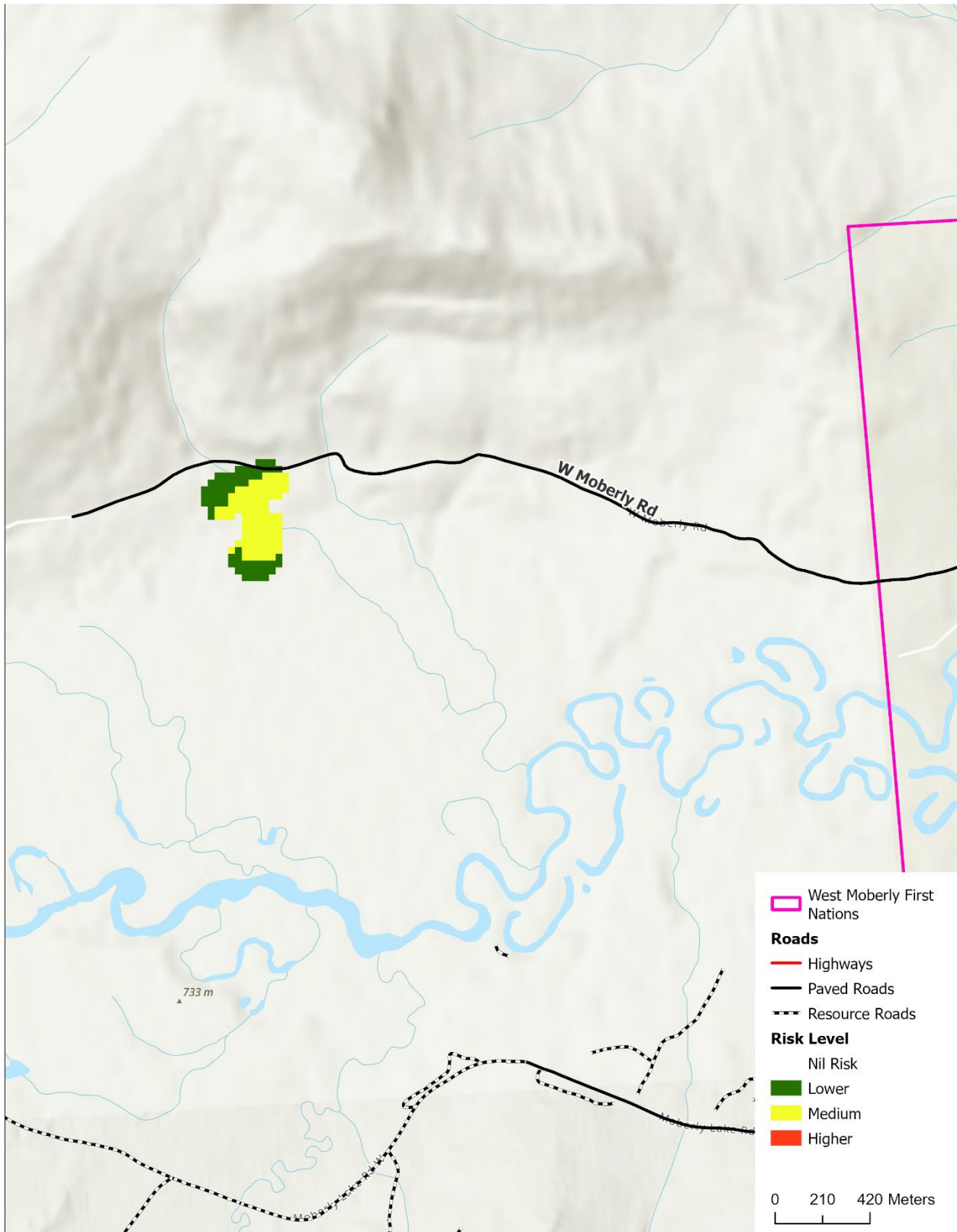


Figure 25: West Moberly First Nations ranch extreme heat risk map - zoomed into the Nation-owned, off-reserve ranch.

District of Chetwynd

The District's simple risk is generally medium (Figure 26). Highlighted areas include the areas of highest population density. These include the apartment complexes across from The Lion's Inn & Suites, the Windrem apartment complexes, the low-income housing across Highway 29 from Chetwynd Plaza, the Gwillim Gardens apartment complexes, and the group of apartments just west of the community centre. Future urban planning should consider the locations of these high-density complexes in more urbanized areas and implement strategies that could offer methods for mitigation or adaptation. The medium overall risk reflects the moderate temperatures that were present throughout the community, with nearly no residential areas falling below temperatures in the high-30s.

Other areas of moderate density were either not sufficiently dense to increase the risk rating to "Higher" or else were not sufficiently hot. These areas include the Westwind RV Park, the Pinewood RV and Trailer Park, and the apartment complexes south across Highway 29 from the community centre.

A large area within the industrial park as well as the riding arena are identified as nil risk due to the lack of structures there. However, the industrial park is certainly a place of work for many community members and would frequent this area daily in the summer. Great care should be taken in extreme heat events to ensure that employees working outdoors or indoors without air conditioning in the industrial park are getting the needed support perform their jobs safely. The downtown core is identified as moderate risk. However, given the relatively hot temperatures modeled in this area, caution should also be taken for residents who frequent this area during the day for extended periods of time.

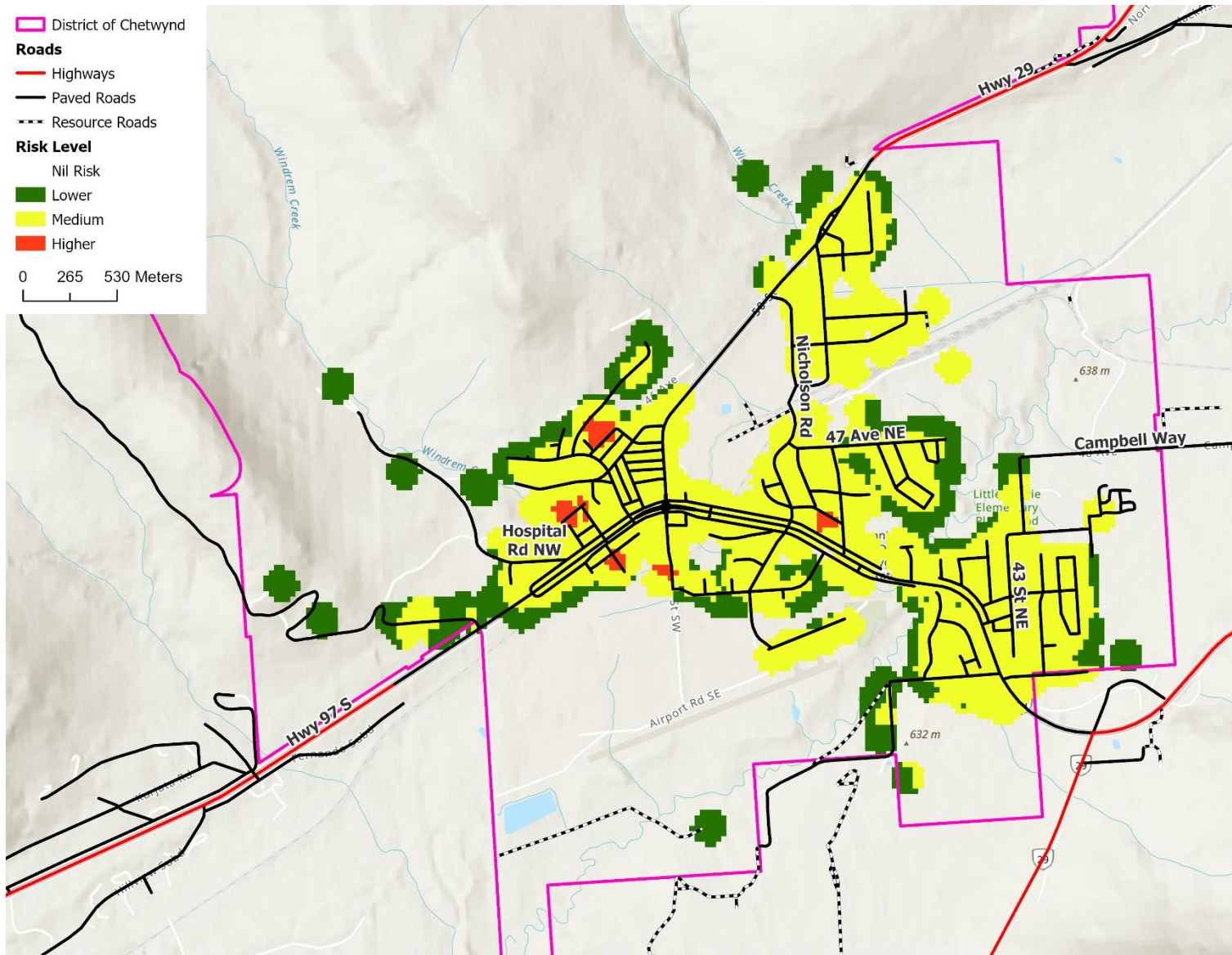


Figure 26: District of Chetwynd extreme heat risk map.

Risk Mapping #2 – Incorporating Vulnerability

Saulteau First Nations

Saulteau’s vulnerability-incorporated risk (Figure 27) is quite similar to its simple risk map (Figure 23). This is because a single vulnerability parameter (Elder Housing, see Figure 9) was summed into Saulteau’s vulnerability risk map (Figure 27). Given that the vulnerability parameters are summed together with the simple risk parameters, areas that previously had a rating of lower or medium and which are not within 100 m of the identified vulnerable populations are still low or medium.

Many other factors not considered here render people vulnerable to extreme heat. As such, community leaders in Saulteau should use this map, as well as knowledge of the conditions of their residents to make critical decisions around mitigation and adaptation planning for extreme heat events. More information regarding the vulnerability of Saulteau’s residents would facilitate extreme heat planning for decision makers.

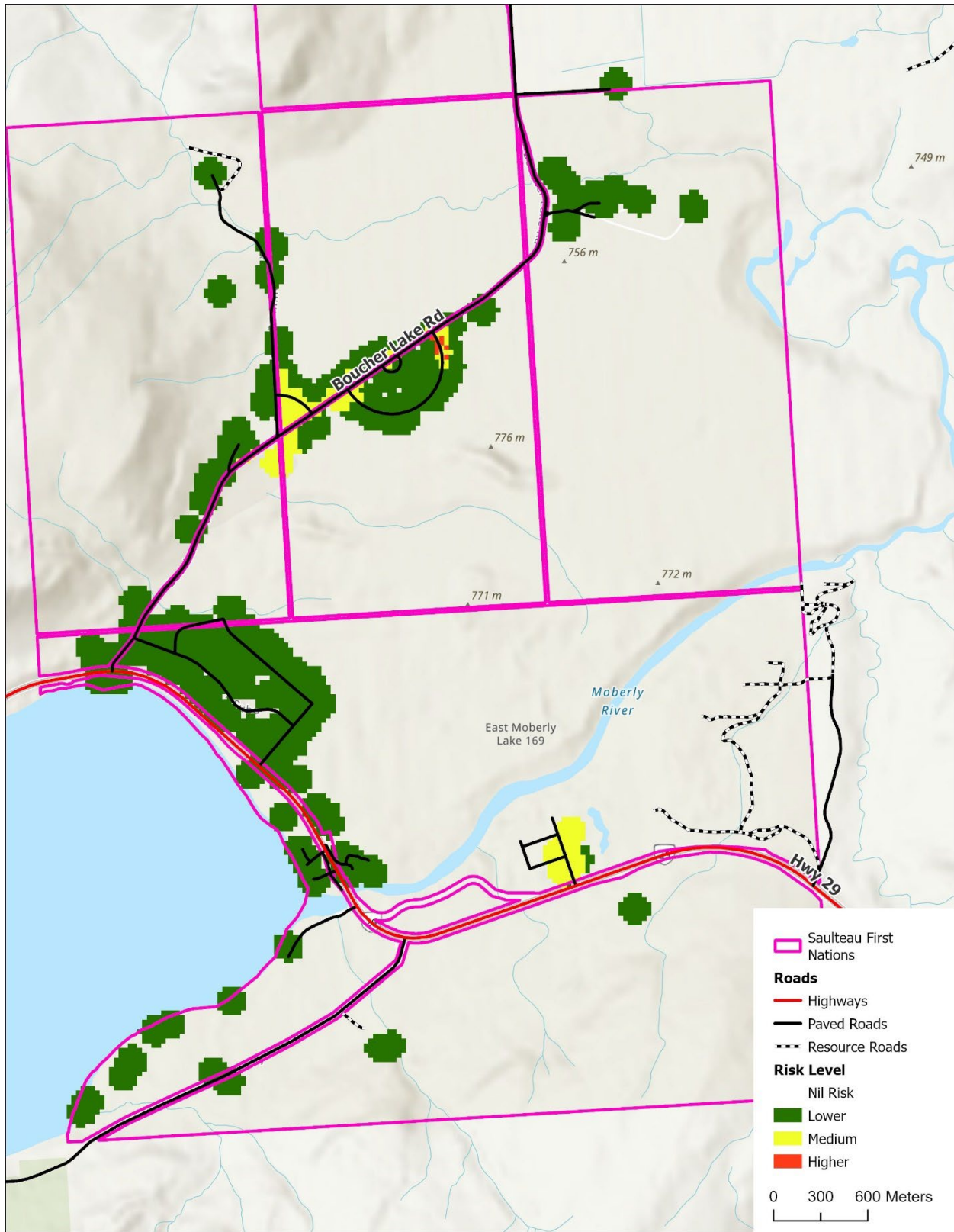


Figure 27. Saulteau extreme heat risk map.

West Moberly First Nations

West Moberly's vulnerability-incorporated risk is quite different from its simple risk. This risk map now demonstrates a large variety of risk ratings over the small area covered by the community (Figure 28). Given that the vulnerability parameters are summed together with the simple risk parameters, areas that previously had a rating of low and which are not within 100 m of the identified vulnerable populations are still low. The Cryingman subdivision had seven seniors' residences and two manufactured homes, the Brown subdivision had six seniors' residences and seven manufactured homes, and the Dokkie Subdivision area of the community had three seniors' residences and three manufactured homes. The West End subdivision has the Senior's triplex (3 units – of which only 1 is currently occupied by a senior tenant), and all 3 buildings (1 triplex and 2 duplexes) are manufactured homes (for a total of 7 residential units). Because vulnerability parameters were mapped as presence-absence data, almost any area within 100 m of these residents had its risk rating heightened. Vulnerable populations were distributed relatively evenly and continuously throughout the community, and so this is reflected in the vulnerability-incorporated risk map as most areas where people live are now given at least a medium risk. The community also has eight seniors who live in manufactured homes. The areas of "Higher" risk in the map demonstrate areas proximal to these residents.

Conversely, the risk around the ranch is identical to that demonstrated by the simple risk product as there are no known vulnerable populations there (Figure 29).

Many other factors not considered here render people vulnerable to extreme heat. For example, it is estimated that 80% of residents have some type of respiratory disorder, and this is also known to increase susceptibility to extreme heat⁵⁰. As such, community leaders at West Moberly should use this map, as well as knowledge of the conditions of their residents to make critical decisions around mitigation and adaptation planning for extreme heat events.

⁵⁰ https://www2.gov.bc.ca/assets/gov/birth-adoption-death-marriage-and-divorce/deaths/coroners-service/death-review-panel/extreme_heat_death_review_panel_report.pdf

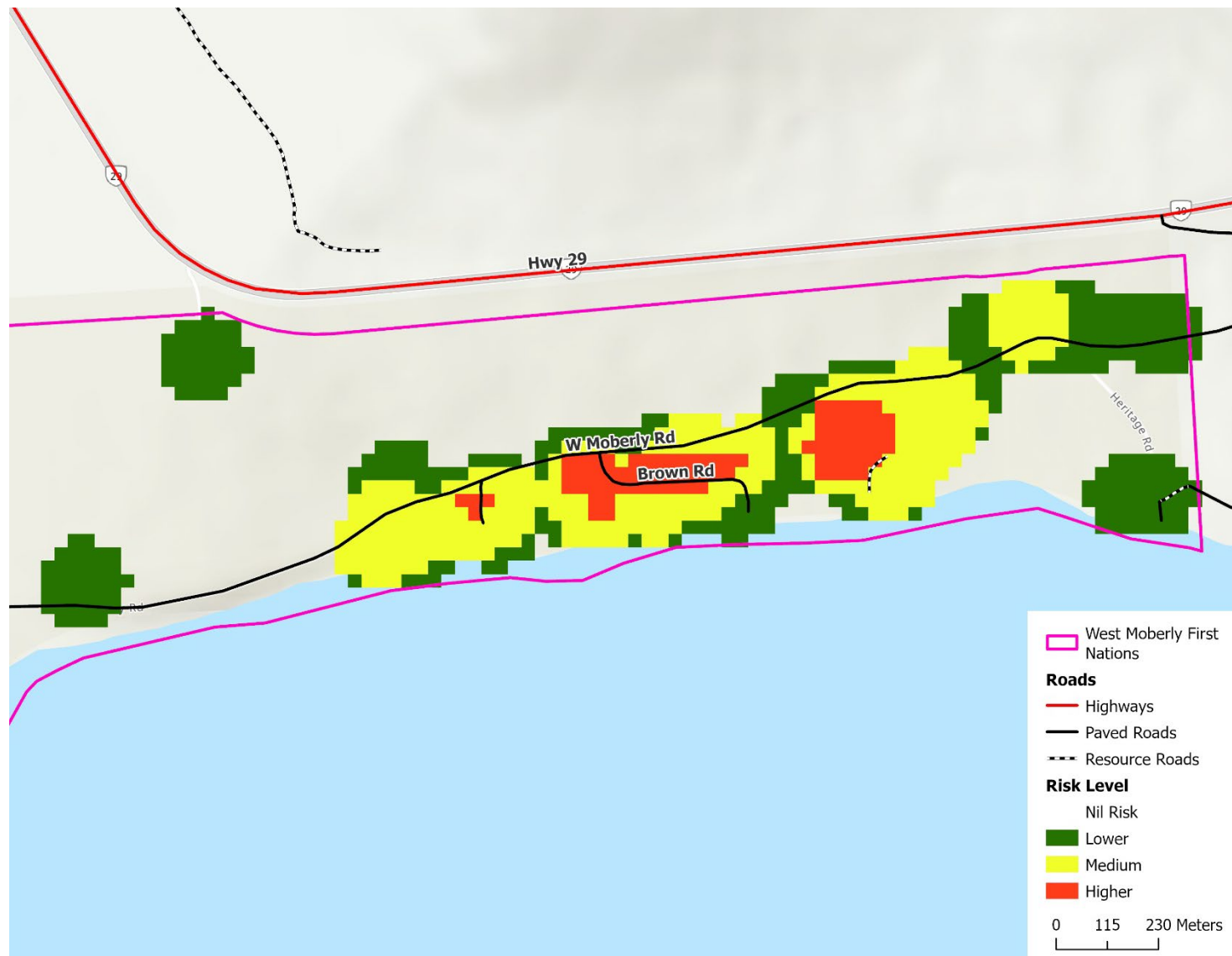


Figure 28: West Moberly First Nations community extreme heat risk map - zoomed into the residential area of the Nation's reserve.

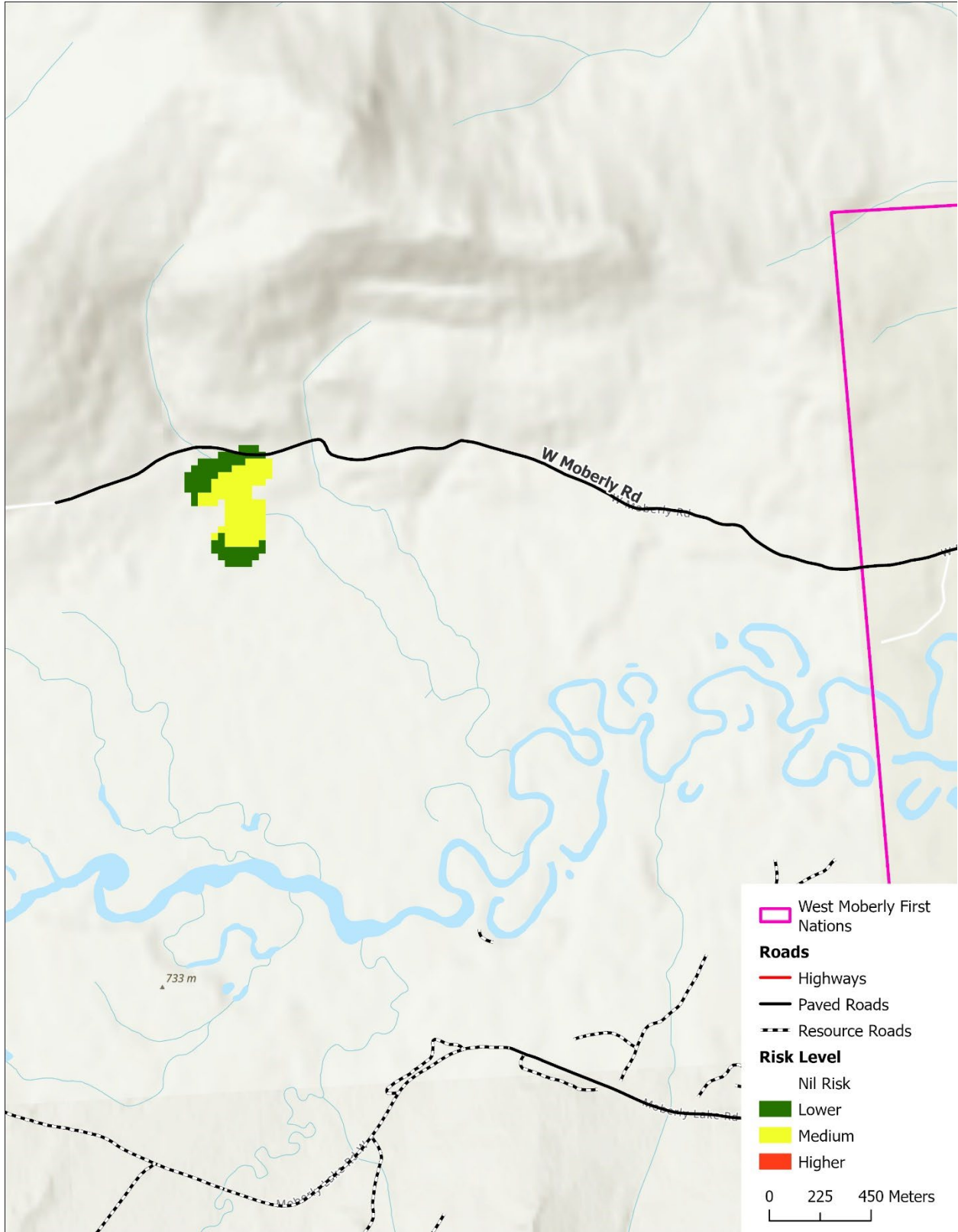


Figure 29: West Moberly First Nations community extreme heat risk map - zoomed into the Nation-owned, off-reserve ranch.

District of Chetwynd

The District of Chetwynd's vulnerability-incorporated risk is quite similar to its simple risk (Figure 30). Given that the vulnerability parameters are summed together with the simple risk parameters, areas that previously had a rating of lower or medium and which are not within 100 m of the identified vulnerable populations are still lower or medium. The most apparent changes are because of the mobile and manufactured home mapping. The map now highlights homes in the Pinewood RV & Trailer Park, in the Westwind RV Park, some parts of the residential area zoned for manufactured homes. Given that all 3 of these locations are designated for this type of housing, population density is moderate in these areas, though these areas were previously obscured in the simple risk product due to their peripheral locations within the District.

The influence of Surerus Place and of Little Prairie Haven is not readily apparent. The area of medium risk near to Little Prairie Haven is expanded slightly. The area of higher risk near the Windrem apartments has expanded slightly to the west due to the added score from Surerus Place. These assisted living facilities are generally areas of lower population density. Temperatures around Little Prairie Haven are some of the lowest in the District outside of forested areas, with temperatures in the mid-30s. These factors would explain the minimal change in risk near these vulnerable populations.

Many other factors not considered here render people vulnerable to extreme heat. As such, community leaders in the District of Chetwynd should use this map, as well as knowledge of the conditions of their residents to make critical decisions around mitigation and adaptation planning for extreme heat events. More information regarding the vulnerability of the District's residents would facilitate extreme heat planning for decision makers.

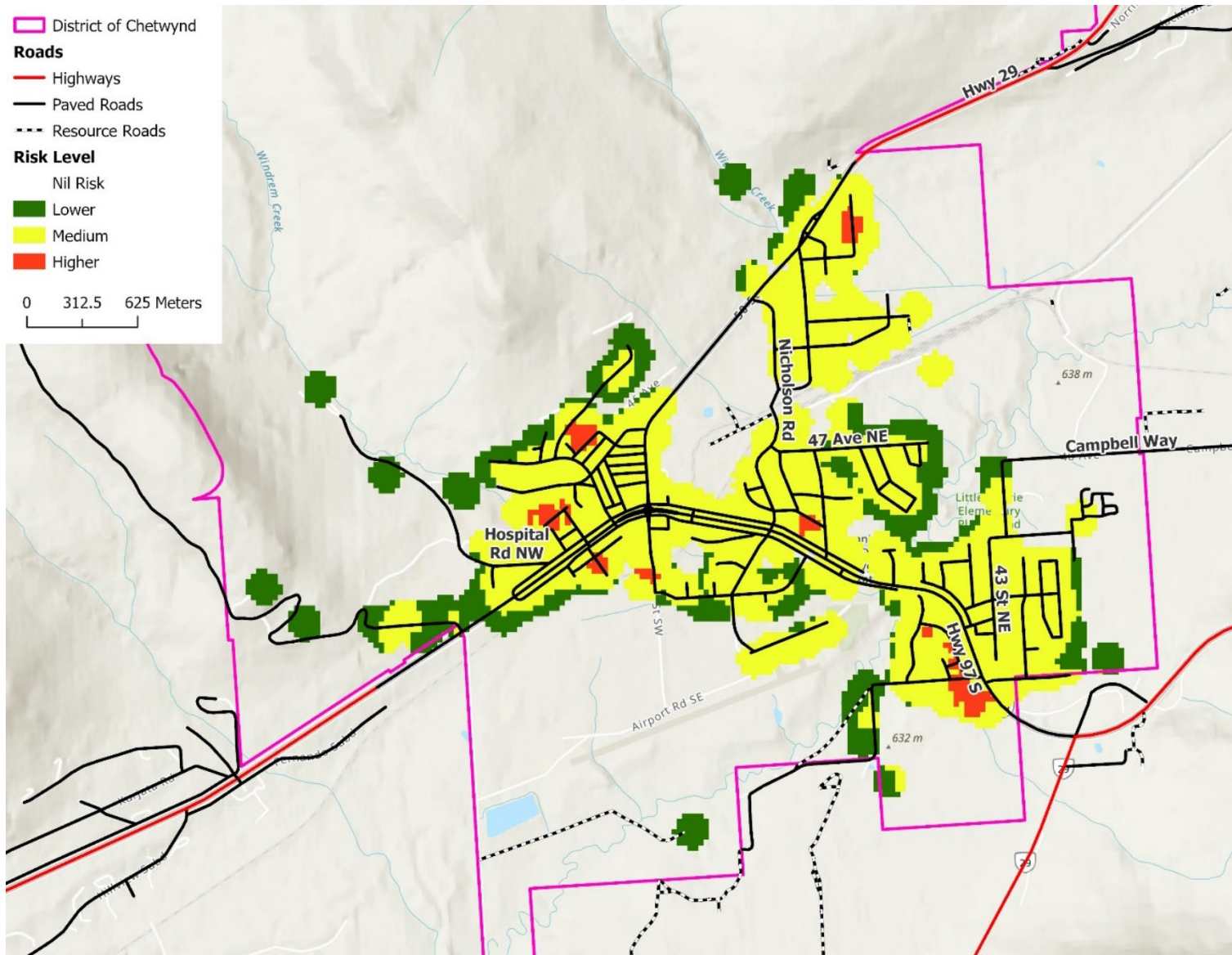


Figure 30: District of Chetwynd extreme heat risk map.

Extreme Heat Response Planning

Risk Identification & Heat Resiliency Actions

The tables provided here outline the overall risks identified for each community. These risks are informed by a combination of field work, community consultation, weather data collected, and land surface temperatures developed from satellite imagery. Following these risks, we've provided a list of heat resiliency actions aimed at helping each of the communities mitigate or adapt to extreme heat events. The organization and framework for these tables and recommendations are derived from California's State Action Plan to Build Community Resilience⁵¹. The state's framework divides actions into four tracks. The first pertains generally to the provision and acquisition of information or knowledge for decision makers as well as for the general public. The second pertains to the development of plans, and services that the community can adapt or provide. The third pertains to methods to upgrade the built environment to mitigate heat. Finally, the fourth section pertains to how vegetation and green spaces can be used either in planning or recreationally to provide relief during extreme heat. From this, we've developed four somewhat analogous categories for our heat resiliency actions:

1. Education
2. Community Services and Response
3. Built Environment
4. Natural Environment

⁵¹ <https://resources.ca.gov/-/media/CNRA-Website/Files/Initiatives/Climate-Resilience/2022-Final-Extreme-Heat-Action-Plan.pdf>

Saulteau First Nations: Risk Identification and Actions

Saulteau First Nations Risk Assessment	
<i>The purpose of a risk assessment is to identify the specific risks to a community. An ongoing review of the risk assessment should occur and an update to this plan should occur before 10 years have elapsed since its completion.</i>	
Read and understand this plan’s identified risks and recommended actions. The risks listed below were identified based on background research, field work data collection, surveys and discussions with staff and community members from the Saulteau First Nation.	
<ul style="list-style-type: none"> I. II. III. IV. V. VI. VII. VIII. 	<p>Saulteau’s Emergency Response Plan is still in its development phase. This makes it more difficult for the community to coordinate its emergency response in a timely and effective manner. However, Saulteau does have an “SFN App” which was brought online in the late fall of 2023, which allows for immediate push notifications in the event of an emergency.</p> <p>The Medical Centre is not intended to accommodate emergency drop-ins. The nearest hospital is located in Chetwynd, roughly a 20 min drive away from Saulteau First Nations. Ambulance response times are often more than 45 min. Furthermore, staff operating these centres are unavailable to respond outside of normal working hours. As such, community members have no access to any form of healthcare locally in the evening when indoor temperatures are highest.</p> <p>Saulteau First Nations lacks a designated cooling centre(s) for members to escape the heat. The two primary reasons for this are limited indoor capacity of the infrastructure and the efficacy of infrastructure air conditioning. The community has a plan for cooling centre designation in the near future upon completion of new infrastructure. Saulteau’s Cultural Centre will be completed within a year.</p> <p>Housing developments designated for seniors and for vulnerable populations lack air conditioning.</p> <p>Extreme heat poses a risk to environmental values by increasing the risk of wildfires on the surrounding landscape.</p> <p>The increasing frequency of extreme heat events due to climate change is also affecting the survivability and growth patterns of traditional plants, likely affecting quantity and seasonality of stream flow, and likely affecting the surface heating of lakes and rivers.</p> <p>Community members have low awareness and urgency around extreme heat safety concerns given the northern and lakeside locations of homes. Community members can therefore find themselves unprepared when these events occur. Furthermore, northeastern British Columbia’s climate has a larger range of annual temperatures as compared to coastal areas of the province or areas further south. Community members are susceptible to extreme heat events and also less acclimated to heat than other communities which experience a higher frequency of hot days.</p> <p>Many critical infrastructures the community lacks any type of backup power in the event of a power outage. Though frequent power outages were not reported to be problematic during periods of extreme heat, power outages are generally considered more likely to occur during such events due to increased electricity demands for air conditioning use. The inability to power water treatment plants in these communities during a power outage could lead to water shortages and exacerbate extreme heat risks.</p>

Saulteau First Nations Risk Assessment	
IX.	Saulteau First Nations should seek to further integrate their internal data related to community comorbidities during an extreme heat event into their emergency planning - further liaison work between their emergency planning staff, housing staff, and health care staff will lead to a more effective heat management plan that respects the bounds of confidentiality for all those involved.

Based on the identified risks outlined above, we have identified 20 Action Items which can be implemented to mitigate the effects of extreme heat on the Saulteau First Nations community. The Action Items have identified certain people or position(s) in the community who are recommended to lead the actions, priority level (very high, high, moderate, and low), suggested time frame, resources required (e.g. staff time or funding), a metric or result by which to identify if the action is successfully completed, and any additional notes.

Saulteau First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Education						
Read and understand this Report’s identified risks and recommended actions.	Chief & Council, Emergency Manager	Very High	Immediate	Staff time from the Emergency Manager	Clear understanding of actions required to help the community mitigate and adapt to extreme heat	

Saulteau First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Encourage residents to either download the WeatherCAN app on their phones. The app can send alerts issued by the ECCC directly. Residents can also register for an email-based alert system from the ECCC by following this guide: https://ecalertme.weather.gc.ca/guides/quickstart_en.php	Emergency Manager	Very High	Immediate, then ongoing	Website and social media posts, and discussion with local residents regarding availability of the app	N/A	
Encourage participation in the BC government’s Energy Conservation Assistance Program (ECAP). This program allows eligible applicants to acquire portable air conditioners and air purifiers for relief from extreme heat events. The program also offers other energy-efficient appliances which can reduce electricity costs and reduce power demands at times when power grids risk overload.	Housing Manager	High	Within 2 years (by spring 2025), then ongoing	Distribution of resources to make community members aware of this opportunity.	N/A	More information is available at the ECAP website ⁵²

⁵² <https://communityclimatefunding.gov.bc.ca/funding/57721a76-07c1-ec11-983f-000d3a09e59c/#:~:text=Description,energy%2Dsaving%20products%20and%20advice>

Saulteau First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Community Services and Response						
Incorporate the Emergency Response Plan component of this work into the Nation's Emergency Plan.	Emergency Manager	Very High	Immediate	Staff time from the Emergency Manager to edit the Emergency Plan	Emergency Response from this plan is incorporated into the community's Emergency Plan	
Designate cooling centres in the community. These cooling centres can change as new constructions are completed that would more effectively meet this need, such as the Cultural Centre.	Emergency Manager	Very High	Immediate	Bottled water, chairs and blankets, website and social media posts, discussion with local residents regarding the new cooling centre location, allocation of staff time to be present at a cooling centre.	Designation of a cooling centre and community is made aware of designation	Funding is available from FNHA for resources distributed within cooling centres and to compensate staff and volunteers ⁵³ .
Form a volunteer group designated to assist in emergency operations. These volunteers can: 1. Transport vulnerable populations either to cooling centres or to a hospital/health centre,	Emergency Manager	Very High	Immediate	Website and social media posts, and discussion with local residents regarding need for volunteers	Recruitment of at least 3 volunteers for emergency operations	

⁵³ <https://www.fnha.ca/about/news-and-events/news/fnhas-heat-response-supports>

Saulteau First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
2. Assist in the distribution of fans and A/C units for those unable to collect them themselves, 3. Perform wellness checks for vulnerable populations.						
Perform wellness checks on known vulnerable populations during extreme heat events. Volunteers can be designated to either call them or go directly to their homes. Volunteers should also have water bottles and extreme-heat-related educational materials available to distribute.	Emergency Manager, Health Manager	High	Ongoing	Formation of a volunteer group designated to assist in emergency operations	Wellness checks performed for vulnerable populations during extreme heat events	
Develop a Climate Change Vulnerability Assessment to identify adaptation strategies for: <ul style="list-style-type: none"> - Water systems, - Traditional plants and wildlife, - Infrastructure, - Social systems. 	Emergency Manager, Lands Manager	Very High	Within 1.5 years	Development of a funding application, hiring a qualified consultant to complete the CCVA	Completion of a Climate Change Vulnerability Assessment for the community	Funding for the development of a Climate Change Vulnerability Assessment is available through the Indigenous Climate Hub ⁵⁴ . Blueberry River First Nation developed a

⁵⁴ <https://www.ubcm.ca/cri/firesmart-community-funding-supports>

Saulteau First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
						Framework for Community-Based Landscape Restoration. ⁵⁵ This framework is general enough that it can be implemented for Saulteau First Nation.
Promote the Tansi Friendship Centre (TFC) within First Nations communities and encourage residents to register on their emergency calling list.	Emergency Manager	High	Ongoing	Website and social media posts, and discussion with local residents regarding use of the system	N/A	The Tansi Friendship Centre is also an air-conditioned shelter with accommodation for ~140 people. Residents seeking refuge during extreme heat overnight could potentially come here.
Have a back up of A/C units and/or fans that can be lent out to vulnerable community members when extreme heat is expected.	Emergency Manager	Medium	Within 1 year	~\$2,000 for new portable A/C units	Purchase of 5 new A/C units.	

⁵⁵ <https://david Suzuki.wpenginepowered.com/wp-content/uploads/2021/05/DSF-BRFN-Report-May-2021.pdf>

Saulteau First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Promote a “cool-buddy” system in which participants choose a person who they contact to check on during an extreme heat event. Emergency notifications developed for extreme heat should include reminders for community members to check in on their cool buddies when public alerts are issued.	Emergency Manager, Health Manager	Medium	Ongoing	Website and social media posts, and discussion with local residents regarding use of the system	Registration of at least 10 residents on a self-identified list	
Mandate schools to adjust timing of outdoor extracurricular activities and recreation for recess and lunch periods according to levels referenced in the Emergency Heat Response. Extracurricular activities should be moved to early-morning before classes begin. Students should remain indoors during recess and lunch.	Education Manager	Low	Within 1 year	Staff time from the Education Manager to develop mandate	Completed development of mandate and incorporation into Emergency Plan	
Built Environment						
Seal doors and windows on homes, and seal doors on	Emergency Coordinator, Public Works Manager,	High	Within 3 years	See Notes	Doors and windows sealed on 50 homes	Funding for infrastructure upgrades is available through

Saulteau First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
critical infrastructure to improve insulation.	Housing Manager					<p>UBCM's CRI fund by using the FireSmart rebate program⁵⁶.</p> <p>Funding can only be available upon completion of FireSmart home and critical infrastructure assessments.</p> <p>Funding is available to replace windows with tempered glass or fire-resistant windows. Window gaps on homes could be sealed when these replacements occur.</p>
Install backup generators at the following critical infrastructure: <ul style="list-style-type: none"> - Water Treatment Plant, - Sewer Lift Station, 	Public Works Manager	High	Within 2 years	Backup generators	Backup generators installed at listed critical infrastructures	

⁵⁶ <https://www.ubcm.ca/cri/firesmart-community-funding-supports>

Saulteau First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
- Cultural Centre, - Health Centre.						
Natural Environment						
Continue to expand community food production initiatives to cultivate traditional plants that are in decline in the natural environment. This can include the development of: <ul style="list-style-type: none"> - Community gardens, - Greenhouses, - Residential backyard gardens. 	Lands Manager	High	Within 2 years, then ongoing	Gardening equipment, development of a garden or establishment of a greenhouse, website and social media posts, and discussion with local residents promoting the need for gardeners	Establishment of a community garden or a greenhouse, and use by 5 gardeners.	
Implement prescribed burns identified from the current in-draft CWRP to promote the regeneration of culturally significant berries including: <ul style="list-style-type: none"> - Huckleberries, - Lowbush blueberries. 	Emergency Manager, Treat Rights & Environmental Protection Manager	High	Within 3 years	Development of a funding application, hiring a qualified consultant to complete a prescribed burn plan	Prescribed burn is completed	Funding for the development of a prescribed burn is available through UBCM's CRI fund ⁵⁷ . Funding can only be provided following the completion of a CWRP and assuming that a

⁵⁷ <https://www.ubcm.ca/cri/firesmart-community-funding-supports>

Saulteau First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
						prescribed burn is proposed.
Promote planning and development of green space installation and/or tree planting near and around Saulteau populations	Lands Manager	Medium	Within 5 years	Development of a funding application to begin planning process	A reduction in urban and treeless areas and an increase in tree cover on-reserve	
Further develop trail networks in forested and riparian areas to offer community members options to escape heat. Specifically, areas with potential for further development include: <ul style="list-style-type: none"> - Little Prairie Community Forest, - Near/Along Moberly Lake and/or Moberly River. 	Lands Manager	Medium	Within 5 years	Costs of contracting of foresters, forest operators, and environmental engineers for trail development	At least 2 additional recreation trails developed	The Little Prairie Community Forest is jointly managed by the Saulteau First Nations, the West Moberly First Nations, and the District of Chetwynd. Trail development can benefit all of these communities and should be carried out as a joint effort.

West Moberly First Nations: Risk Identification and Actions

West Moberly First Nations Risk Assessment
<p><i>The purpose of a risk assessment is to identify the specific risks to a community. An ongoing review of the risk assessment should occur and an update to this plan should occur before 10 years have elapsed since its completion.</i></p>
<p>Read and understand this plan’s identified risks and recommended actions. The risks listed below were identified based on background research, field work data collection, surveys and discussions with staff and community members from the West Moberly First Nations.</p> <ol style="list-style-type: none"> I. West Moberly’s Emergency Plan is currently under review and revision to eliminate the various gaps in the 12-year-old document. West Moberly’s Emergency Plan is in print and digital format and is not readily accessible to all West Moberly’s staff and leadership. This makes it more difficult for the community to coordinate its emergency response in a timely and effective manner. Additionally, an official community emergency alert system has not been designed or implemented. <ol style="list-style-type: none"> i. West Moberly does have an Emergency Operations Centre (EOC) Team undergoing training and has some experience in activating and carrying out EOC duties and responsibilities (COVID-19 and Freshet-20). West Moberly has established a communications system for providing emergency alerts to the community (Door-to-door written and online communications via West Moberly’s website, App, and Facebook page), and also has a Communications Officer who services the Nation on a daily administrative operational basis as well as during EOC operational activities that may be up to 24 hrs per day. II. West Moberly’s Health Centre can receive and evaluate persons with heat related medical conditions. However, the Health Centre does not staff nurses or doctors and therefore cannot treat patients with heat related illnesses. The nearest full service medical centre is the Chetwynd Hospital & Health Centre which is located 36 kms from the West Moberly community. III. The community lacks designated cooling centre(s) for members to escape the heat. The two primary reasons for this are limited indoor capacity of the infrastructure and the efficacy of infrastructure air conditioning. The community may plan for cooling centre designation in the future upon completion of new infrastructure. IV. The filtration system at the Water Treatment Plant is not functioning and cannot provide clean drinking water for the community. The community is experiencing a water shortage as a result and must haul water from Chetwynd. This can potentially limit water available to community members during a heat event. However, West Moberly has now received funding from Indigenous Services Canada (ISC) for water systems improvement and the completion of a new Water Treatment Plant design, with project completion anticipated for early 2026. V. Community members are often employed in resource sectors which require a significant amount of their work to be outdoors. This increases their exposure to extreme temperatures when they occur. While West Moberly has some guidelines for outdoor work in extreme heat, the community has no such guidelines formalized in any regulation or plan. Therefore, this is currently a WCB issue for the employers/industrial proponents.

West Moberly First Nations Risk Assessment	
VI.	Extreme heat poses a risk to environmental values by increasing the risk of wildfires on the surrounding landscape. The increasing frequency of extreme heat events due to climate change is also affecting the survivability and growth patterns of traditional plants, likely affecting quantity and seasonality of stream flow, and likely affecting the surface heating of lakes and rivers.
VII.	Community members may lack general awareness or direct experience with extreme heat safety concerns given the northern and lakeside locations of their communities. They can therefore find themselves unprepared when these events occur. Furthermore, northeastern British Columbia’s climate has a larger range of annual temperatures as compared to coastal areas of the province or areas further south. The community is susceptible to extreme heat events and also less acclimated to heat than other communities which experience a higher frequency of hot days.
VIII.	Power outages are generally considered more likely to occur during heat events due to increased electricity demands such as A/C use. All West Moberly critical infrastructure and community buildings have or will have backup generators installed. West Moberly completed a recent feasibility study which recommends the installation of a community microgrid that would power all buildings during a power outage.
IX.	West Moberly has identified the locations of their seniors and the locations of community members living in manufactured homes. Furthermore, West Moberly has studied and determined that 80% of their community members are known to have respiratory disorders. People who are elderly, lower economic standing and/or have existing health conditions are all known to be vulnerable during heat events.

Based on the identified risks outlined above, we have identified 24 Action Items which can be implemented to mitigate the effects of extreme heat on the West Moberly First Nations community. The Action Items have identified certain people or position(s) in the community who are recommended to lead the actions, priority level (very high, high, moderate, and low), suggested time frame, resources required (e.g., staff time or funding), a metric or result by which to identify if the action is successfully completed, and any additional notes.

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Education						
Read and understand this plan’s identified risks and recommended actions.	Chief & Council, Emergency Manager	Very High	Immediate	Staff time from the Emergency Manager	Clear understanding of actions required to help the	

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
					community mitigate and adapt to extreme heat	
Encourage residents to either download the WeatherCAN app on their phones. The app can send alerts issued by the ECCC directly. Residents can also register for an email-based alert system from the ECCC by following this guide: https://ecalertme.weather.gc.ca/guides/quickstart_en.php	Emergency Manager	Very High	Immediate, then ongoing	Website and social media posts, and discussion with local residents regarding availability of the app	N/A	
Install local weather stations in more developed areas of the community (likely adjacent to band offices) to inform local weather patterns and to identify the frequency and magnitude of weather anomalies.	Public Works Manager	Medium	Within 1 year	\$450 for an economy-option weather station purchase	Local weather station is installed and maintained.	
Community Services and Response						
Incorporate the Emergency Response Plan component of this work into the Nation's Emergency Plan	Emergency Manager	Very High	In Progress	Staff time from the Emergency Manager to edit the Emergency Plan	Emergency Response from this plan is incorporated into the	

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
					community's Emergency Plan	
Develop a digital copy of the Emergency Response Plan and distribute to all Nation staff involved in emergency response	Emergency Manager	Very High	In Progress	Staff time from the Emergency Manager to digitize the Emergency Plan	Completion of a digital copy of the Emergency Plan	
Designate cooling centres in the community. These cooling centres can change as new constructions are completed that would more effectively meet this need. <ul style="list-style-type: none"> - Culture/Community Centre (now) - Administration Building (once complete) 	Emergency Manager	Very High	Immediate	Bottled water, chairs and blankets, website and social media posts, discussion with local residents regarding the new cooling centre location, allocation of staff time to be present at a cooling centre.	Designation of a cooling centre and community is made aware of designation	Funding is available from FNHA for resources distributed within cooling centres and to compensate staff and volunteers ⁵⁸ .
Develop use of the Voyent Alert! mass notification system and implement it into emergency response for extreme heat events.	Emergency Manager	Very High	Ongoing	Website and social media posts, and discussion with local residents	Participation and passing of emergency response tests/exercises	

⁵⁸ <https://www.fnha.ca/about/news-and-events/news/fnhas-heat-response-supports>

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
				regarding use of the system	by at least 10 residents	
Form a volunteer (ESS) group designated to assist in emergency operations. These volunteers can: <ol style="list-style-type: none"> 1. Transport vulnerable populations either to cooling centres or to a hospital/health centre, 2. Assist in the distribution of fans and A/C units for those unable to collect them themselves, 3. Perform wellness checks for vulnerable populations. 	Emergency Manager	Very High	<i>Some parts of this are in progress (see notes)</i>	Website and social media posts, and discussion with local residents regarding need for volunteers	Recruitment of at least 3 volunteers for emergency operations	In Progress under EOC/ESS, plus Health Centre's Community Health Rep also available to perform these tasks as needed
Ensure the availability of multi-passenger vehicles that can transport a small group of people during extreme heat events.	Emergency Manager	Very High	Immediate, then ongoing	Collaboration amongst management staff to ensure availability of emergency transportation	Designation of an available vehicle to be available for emergency transportation during extreme heat events	West Moberly has two buses that can be used for this purpose.
Continue performing wellness checks on known vulnerable populations during extreme heat events.	Emergency Manager, Health Manager	High	Ongoing	Formation of a volunteer group designated to assist in	Wellness checks performed for vulnerable	West Moberly's Health Centre staff performs Wellness Checks on

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Volunteers can be designated to either call them or go directly to their homes. Volunteers should also have water bottles and extreme-heat-related educational materials available to distribute.				emergency operations	populations during extreme heat events	vulnerable populations within the Community during any time of duress
West Moberly is in the process of developing a Community Wildfire Resiliency Plan (CWRP) to identify areas of high risk to wildfire within and adjacent to the reserve boundaries.	Emergency Manager	Very High	Within 1.5 years	Development of a funding application, hiring a qualified consultant to complete the CWRP	Completion of a CWRP for the community	West Moberly CWRP to be completed by January 2024.

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Develop a Climate Change Vulnerability Assessment to identify adaptation strategies for: <ul style="list-style-type: none"> - Water systems, - Traditional plants and wildlife, - Infrastructure, - Social systems. 	Emergency Manager, Lands Manager	Very High	Within 1.5 years	Development of a funding application, hiring a qualified consultant to complete the CWRP	Completion of a Climate Change Vulnerability Assessment for the community	Funding for the development of a Climate Change Vulnerability Assessment is available through the Indigenous Climate Hub ⁵⁹ . Blueberry River First Nation developed a Framework for Community-Based Landscape Restoration. ⁶⁰ This framework is general enough that it can be adapted by Saluteau First Nations and West Moberly First Nations for their lands.

⁵⁹ <https://www.ubcm.ca/cri/firesmart-community-funding-supports>

⁶⁰ <https://david Suzuki.wpenginepowered.com/wp-content/uploads/2021/05/DSF-BRFN-Report-May-2021.pdf>

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Develop work-safe guidelines for employers and employees for extreme heat conditions. Guidelines available from WorkSafeBC can be used as guidance. Regulations relating to extreme heat fall under Part 7 – Division 4 of the Occupational Health & Safety Guidelines.	Health Manager	High	<i>In Progress (see notes)</i>	Staff time from the Health Manager to develop work-safe guidelines	Completed development of work-safe guidelines and incorporation into Emergency Plan	In Progress – Extreme Heat Standard Operating Procedure going to JOH&SC for review and recommendation for adoption
Promote the Tansi Friendship Centre (TFC) within First Nations communities and encourage residents to register on their emergency calling list.	Emergency Manager	High	Ongoing	Website and social media posts, and discussion with local residents regarding use of the system	N/A	The Tansi Friendship Centre is also an air-conditioned shelter with accommodation for ~140 people. Residents seeking refuge during extreme heat overnight could potentially come here.
Mandate schools to adjust timing of outdoor extracurricular activities and recreation for recess and lunch periods according to levels referenced in the Emergency Heat Response.	Education Manager	High	Within 1 year	Staff time from the Education Manager to develop mandate	Completed development of mandate and incorporation into	Currently, West Moberly students are bussed to schools in Moberly Lake and Chetwynd. Implementing this recommendation

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Extracurricular activities should be moved to early morning before classes begin. Students should remain indoors during recess and lunch.					Emergency Plan	would require extra coordination with School District, bussing providers, and all school staff.
Have a back up of A/C units and/or fans that can be lent out to vulnerable community members when extreme heat is expected.	Emergency Manager	Medium	Within 1 year	~\$2,000 for new portable A/C units	Purchase of 5 new A/C units.	
Promote a “cool-buddy” system in which participants choose a person who they contact to check on during an extreme heat event. Emergency notifications developed for extreme heat should include reminders for community members to check in on their cool buddies when public alerts are issued.	Emergency Manager, Health Manager	Medium	Ongoing	Website and social media posts, and discussion with local residents regarding use of the system	Registration of at least 10 residents on a self-identified list	
Built Environment						
Complete repairs of West Moberly’s water treatment plant	Public Works Manager	High	<i>In Progress (see notes)</i>	Replacement of filters	Water treatment plant is repaired and hauling water	Currently in progress, will not be fully completed until Jan 2026. Additional funding

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
					is no longer necessary	is available through ISC ⁶¹
Seal doors and windows on homes, and seal doors on critical infrastructure to improve insulation	Emergency Coordinator, Director of Engineering and Public Works	High	<i>In Progress (see notes)</i>	See Notes	Doors and windows sealed on 50 homes	<p>In Progress - Completed majority of this using various funding programs over past 4 years – final funding and work to be completed in 2024.</p> <p>Funding for infrastructure upgrades is available through UBCM’s CRI fund by using the FireSmart rebate program⁶².</p> <p>Funding can only be available upon completion of FireSmart home and critical infrastructure assessments.</p>

⁶¹ <https://www.sac-isc.gc.ca/eng/1646154366434/1646154391314>

⁶² <https://www.ubcm.ca/cri/firesmart-community-funding-supports>

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Install backup generators at the following critical infrastructure: <ul style="list-style-type: none"> - Water Intake Building - Water Treatment Plant - Sewer Lift Station - Health Centre 	Public Works Manager	High	Within 2 years	Backup generators	Backup generators installed at listed critical infrastructures	Water Intake and Water Treatment Plant installations are a part of the current Systems Improvement Project. Sewer Lift Station installation to be completed as part of the Wastewater Systems Improvement Project slated for after Water Systems Improvement Project is completed. Health Centre has had a back up generator since its completion in 2019. All other Community Buildings have had back up generators installed in 2022 and 2023, except the Lands Building which waiting expansion and move – upgraded generator sourced and awaiting approval.
Natural Environment						
Continue to expand community food production initiatives to cultivate traditional plants that are in decline in the natural environment. This can include the development of: <ul style="list-style-type: none"> - Community gardens, - Greenhouses, 	Lands Manager	High	<i>In Progress (see notes)</i>	Gardening equipment, development of a garden or establishment of a greenhouse, website and social media posts, and discussion with local residents promoting the	Establishment of a community garden or a greenhouse, and use by 5 gardeners.	Community greenhouse moved to ranch and will need to be erected and put back into service. All West Moberly residential units received 2 large garden boxes in

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
- Residential backyard gardens				need for gardeners		2020 and are in use.
Implement prescribed burns identified from a CWRP to promote the regeneration of culturally significant berries including: <ul style="list-style-type: none"> - Huckleberries, - Lowbush blueberries. 	Lands Manager	High	Within 3 years	Development of a funding application, hiring a qualified consultant to complete a prescribed burn plan	Prescribed burn is completed	Funding for the development of a prescribed burn is available through UBCM's CRI fund ⁶³ . Funding can only be provided following the completion of a CWRP and assuming that a prescribed burn is proposed.
Further develop trail networks in forested and riparian areas to offer community members options to escape heat. Specifically, areas with potential for further development include: <ul style="list-style-type: none"> - Little Prairie Community Forest, 	Lands Manager	Medium	Within 5 years	Costs of contracting of foresters, forest operators, and environmental engineers for trail development	At least 2 additional recreation trails developed	The Little Prairie Community Forest is jointly managed by the Saulteau First Nations, the West Moberly First Nations, and the District of Chetwynd. Trail development can benefit all of these communities and

⁶³ <https://www.ubcm.ca/cri/firesmart-community-funding-supports>

West Moberly First Nations Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
- Near/Along Moberly Lake and/or Moberly River.						<p>should be carried out as a joint effort.</p> <p>West Moberly has Cultural Trails identified in its Comprehensive Community Plan throughout its traditional territory. The Dunne-Za Lodge located within the community has trails through the protected area for use.</p>

District of Chetwynd: Risk Identification and Actions

District of Chetwynd Risk Assessment
<p><i>The purpose of a risk assessment is to identify the specific risks to a community. An ongoing review of the risk assessment should occur and an update to this plan should occur before 10 years have elapsed since its completion.</i></p>
<p>Read and understand this plan’s identified risks and recommended actions. The risks listed below were identified based on background research, field work data collection, surveys and discussions with staff and community members from the District of Chetwynd. The risks are in no particular order of importance:</p> <ol style="list-style-type: none"> I. Medical centres and housing developments designated for seniors lack air conditioning. II. Community members are often employed in resource sectors which require a significant amount of their work to be outdoors. This increases their exposure to extreme temperatures when they occur. III. Community members have low awareness and urgency around extreme heat safety concerns given the northern and lakeside locations of their communities. They can therefore find themselves unprepared when these events occur. Furthermore,

District of Chetwynd Risk Assessment	
	northeastern British Columbia’s climate has a larger range of annual temperatures as compared to coastal areas of the province or areas further south. The community is susceptible to extreme heat events and also less acclimated to heat than other communities which experience a higher frequency of hot days.
IV.	Extreme heat poses a risk to environmental values by increasing the risk of wildfires on the surrounding landscape.
V.	The District does not have direct jurisdiction over many organizations which can have a significant impact on mitigation for and adaptation to extreme heat. Schools, medical centres, WorkBC, and WorkSafeBC are provincially operated. Other non-governmental organizations which do extensive outreach to vulnerable populations such as the Tansi Friendship Centre are also not operated by the municipality. Finally, assisted living facilities in the District that house known vulnerable populations are privately owned, as are centrally-located retail and industrial properties which are shown to be relatively hot and have high amounts of traffic passing through. This limits the reach that the District can have to impact the well being of its residents.
VI.	Data is currently unavailable from the District hospital and from the medical centre pertaining to patient demographics, and frequency and timing of emergency room intakes. This prevents the municipality from inferring who is seeking medical services during extreme heat events, and from quantifying any change in demand for these services.
VII.	There is limited data on the spatial distribution of vulnerable populations and the prevalence of extreme heat comorbidities that afflict them. Assisted living facilities and the locations of mobile and manufactured homes in RV parks and other areas zoned for such housing were identified during fieldwork of July, 2023. This limits the District’s ability to implement mitigating or adaptive strategies where they are most needed. 11.5% of the District’s population is aged over 65.

Based on the identified risks outlined above, we have identified 16 Action Items which can be implemented to mitigate the effects of extreme heat to the District. The Action Items have identified certain people or position(s) in the community who are recommended to lead the actions, priority level (very high, high, moderate, and low), suggested time frame, resources required (e.g. staff time or funding), a metric or result by which to identify if the action is successfully completed, and any additional notes.

District of Chetwynd Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Education						
Read and understand this plan’s identified risks and recommended actions.	Emergency Coordinator	Very High	Immediate	Staff time from the Emergency Manager	Clear understanding of actions required to help the community	

District of Chetwynd Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
					mitigate and adapt to extreme heat	
Encourage residents to either download the WeatherCAN app on their phones. The app can send alerts issued by the ECCC directly. Residents can also register for an email-based alert system from the ECCC by following this guide: https://ecalertme.weather.gc.ca/guides/quickstart_en.php	Emergency Coordinator	Very High	Immediate, then ongoing	Website and social media posts, and discussion with local residents regarding availability of the app	N/A	
Encourage participation in BC Hydro's free product installation and energy coaching. This program allows eligible applicants to acquire portable air conditioners and air purifiers for relief from extreme heat events. The program also offers other energy-	Economic Development Officer	High	Within 2 years (by spring 2025)	Distribution of resources to make community members aware of this opportunity.	N/A	More information is available at BC Hydro ⁶⁴

⁶⁴ <https://www.bchydro.com/powersmart/residential/rebates-programs/savings-based-on-income/free-product-install-and-advice.html>

District of Chetwynd Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
efficient appliances which can reduce electricity costs, and reduce power demands at times when power grids risk overload.						
Heat response plans should reflect both extreme heat information and current vulnerabilities. They should be seen as living documents and regularly updated. This plan should be reviewed every 2-5 years with leadership and stakeholders and updated when necessary.	Emergency Manager, Public Works, District Staff	Medium	Every 2-5 years	Staff time to schedule and conduct a formal review	Regular reviews of this document are conducted to ensure that action items are being completed and to determine when the plan needs to be updated.	
Make a plan to develop and keep generic records of medical and demographic data. This will facilitate the assessment of vulnerable populations and rates of increased demand during emergencies. Within plan, decide how to perform analysis of medical and	Emergency Coordinator	Medium	0-2 years, then ongoing	Staff time from the Emergency Coordinator to plan and have a conversation	Acquisition of medical and demographic data regarding mortality and emergency room intakes.	The District of Chetwynd's Emergency Coordinator should collaborate with the Health Services Administrator employed through the Northern Health Authority at Chetwynd's Hospital and Health Centre.

District of Chetwynd Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
demographic data for hospital and medical centre emergency room intakes, and of mortality.						
Collaborate with WorkBC office to promote WorkSafeBC guidelines for both employers and employees. Regulations relating to extreme heat fall under Part 7 – Division 4 of the Occupational Health & Safety Guidelines.	OH&S Committee	Medium	Within 1 year	Staff time from the Emergency Coordinator to plan and have a conversation	Conversation occurs with WorkBC to provide informational resources in their office during periods of hot weather	WorksafeBC guidelines are available at: https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-guidelines/guidelines-part-07#97F6CEA89EF842C38445FAAAD7139927
Work with Peace FM community broadcast station to develop a public service announcement targeting populations vulnerable to heat events. This is especially relevant for outdoor workers who've been anecdotally reported to listen to radio often during work and while commuting.	Economic Development Officer	Medium	Within 2 years	Staff time from the Emergency Coordinator to work with Peace FM, costs for a contractor to develop a script for a public service announcement	Development of a public service announcement targeting vulnerable populations of heat events	
Community Services and Response						

District of Chetwynd Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
Incorporate the Emergency Response Plan component of this work into your governmental Emergency Plan	Emergency Coordinator	Very High	Immediate	Staff time from the Emergency Coordinator to edit the Emergency Plan	Emergency Response from this plan is incorporated into the community's Emergency Plan	
<p>EC to oversee and coordinate the Emergency Social Services (ESS) team to coordinate registered community volunteers during extreme heat events. These volunteers can:</p> <ol style="list-style-type: none"> 1. Transport vulnerable populations either to cooling centres or to a hospital/health centre. 2. Perform wellness checks for vulnerable populations 	Emergency Coordinator	Very High	Immediate	Staff time from the Emergency Coordinator to meet with the head of Chetwynd ESS	An agreement formed between the ESS and District	
District to have a discussion with a local transportation company to secure an agreement	Emergency Coordinator	Very High	Immediate, then ongoing	N/A	Secure an agreement with a transportation company	The District of Chetwynd's Emergency Coordinator should collaborate with the Health Services Administrator employed through the Northern

District of Chetwynd Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
to assist during extreme heat events.						Health Authority at Chetwynd's Hospital and Health Centre.
Promote a "cool-buddy" system in which participants choose a person who they contact to check on during an extreme heat event. Emergency notifications developed for extreme heat should include reminders for community members to check in on their cool buddies when public alerts are issued.	Emergency Coordinator	Medium	Ongoing	Website and social media posts, and discussion with local residents regarding use of the system	Registration of at least 30 residents on a self-identified list	The District of Chetwynd's Emergency Coordinator should collaborate with the Executive Director at the TFC. The TFC holds a list of hundreds of self-identified vulnerable individuals who could participate in this system.
Built Environment						
District to assist and lead the distribution of extreme heat response education materials and action items. One recommendation is to educate citizens on the importance of sealing doors and windows on homes and critical infrastructure to improve insulation.	Emergency Coordinator, Director of Engineering and Public Works	High	Within 3 years	See Notes	Doors and windows sealed on 50 homes	Funding for infrastructure upgrades can be made available through FireSmart Community Funding and Supports upon completion of home and critical infrastructure assessments. Funding for the completion of home and critical infrastructure assessments is available

District of Chetwynd Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
						through the same funding source and can help increase community resilience to wildfire. Funding is available to replace windows with tempered glass or fire-resistant windows. Window gaps on homes could be sealed when these replacements occur.
Revise “Highway Commercial” and “Town Center” development permit area guidelines to promote the development of vegetation islands inside and on the edges of parking lots.	Director of Engineering and Public Works, Parks Manager	Medium	Within 5 years	Variable depending on agreement reached with commercial property owners.	N/A	Ideal trees for planting are native hardwood trees with large canopy cover. Areas with the lowest density of stems should be prioritized for planting. Urban trees provide relief to pedestrians as well as reduced the effects of urban heat islands by cooling paved surfaces.
Install water fountains and shade structures in municipal parks including: - Spirit Park - Crown Park - Kin Park	Director of Engineering and Public Works	Medium	Within 5 years	Materials required to construct water fountains and shade structures, contractor time required for assessing	Fountains and shade structures installed in parks listed	

District of Chetwynd Action Items						
Action	Lead(s)	Priority	Time frame	Resources Required	Metric for Success	Notes
<ul style="list-style-type: none"> - 52 Avenue Park - Wabi Crescent Park 				feasibility, water table access, and construction		
Natural Environment						
Plant boulevard trees along streets in the downtown commercially zoned area of Chetwynd, and adjacent to Chetwynd Secondary School and the recreation centre. Ideal streets for these trees include 46 St. NE, 51 St. NW, 52 St. NW, 53 St. NW, 54 St. NW, and N. Access Rd.	Director of Engineering and Public Works, Parks Manager	Medium	Within 5 years	Costs for trees and work required for planting and maintenance	Trees planted along at least 2 of the roads listed	<p>Ideal trees for planting are native hardwood trees with large canopy cover.</p> <p>Areas with the lowest density of stems should be prioritized for planting. Urban trees provide relief to pedestrians as well as reducing the effects of urban heat islands by cooling paved surfaces.</p>
<p>Further develop trail networks in forested and riparian areas to offer community members options to escape heat. Specifically, areas with potential for further development include:</p> <ul style="list-style-type: none"> - Little Prairie Community Forest - Near or along the Pine River 	Parks Manager	Medium	Within 5 years	Costs of contracting of foresters, forest operators, and environmental engineers for trail development	At least 2 additional recreation trails developed	The Little Prairie Community Forest is jointly managed by the Saulteau First Nations, the West Moberly First Nations, and the District of Chetwynd. Trail development can benefit all of these communities and should be carried out as a joint effort.

Heat Preparedness Action Steps

Heat preparedness action steps were developed for each of the communities to provide specific steps each community can take during a heat event or emergency. Consideration should be given to the incorporation of the information provided here into each of the communities’ Emergency Management Plans, it is up to each community to incorporate these action steps into their existing Emergency Management Plans as they see best.

Action Steps are based on the BC ECCC criteria for the Northeast heat warning region (Northern Health Authority)⁶⁵ and are divided into three emergency levels – 1, 2 and 3 (see tables below). The levels correspond to different weather conditions. The first level is a pre-warning and is associated with forecasted temperatures of 25°C for two days or more as reported by the ECCC. This level can be understood as a pre-warning for extreme heat and should be activated as soon as the criteria are seen to be met in the community’s weather forecast. The second level is associated with the criteria for a heat warning. This level should be activated as soon as notification is received by the ECCC that a heat warning has been issued. The third level is associated with the criteria for an extreme heat emergency. There is ambiguity around the criteria for extreme heat emergencies as the decision to announce one is made by committee consensus on a case-by-case basis. During extreme weather events, communities should be prepared for the possibility that an extreme heat emergency alert could be issued suddenly. This level should be activated as soon as notification is received by the ECCC that an extreme heat emergency has been issued.

Saulteau First Nations Action Steps

Emergency Level	Condition of Activation	Activating Party	Action Steps
Level 1	Forecasted temperatures of 25°C for 2 days or more as reported by the ECCC	The Communities Themselves	<ul style="list-style-type: none"> • Send level 1 email notifications to the following departments and stakeholders who can post notices within their premises and/or those providing services to vulnerable populations: <ul style="list-style-type: none"> ○ Education Department ○ Health Department ○ Housing and Capital Projects Department • Send pre-developed level 1 mail-outs to residents • Notify residents via SFN App push notifications • Update community website and social media • Contact staff at designated cooling centres to notify that the community is starting to experience hot weather • Have cooling centres checked to ensure they are ready to be opened • Verify maintenance needs for designated emergency transport vehicle and fix as needed • Place order for bottled water

⁶⁵ <http://www.bccdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Guidelines%20and%20Manuals/Health-Environment/Provincial-Heat-Alerting-Response-System.pdf>

Emergency Level	Condition of Activation	Activating Party	Action Steps
			<ul style="list-style-type: none"> • Place order for extreme heat brochures • Post notices where the public can see them to inform on heat-related illness and ways to stay cool, especially at outdoor facilities • Post call for emergency heat relief volunteers • Provide a training session for volunteers to identify signs of heat exhaustion and heat stroke
Level 2	Forecasted temperatures are above 29°C two days in a row with a nighttime low above 14°C	ECCC	<ul style="list-style-type: none"> • Send level 2 email notifications to the following departments and stakeholders who can post notices within their premises and/or those providing services to vulnerable populations: <ul style="list-style-type: none"> ○ Education Department ○ Health Department ○ Housing and Capital Projects Department ○ Fire Department • Send pre-developed level 2 mail-outs to residents. • Update community website and social media • Contact designated cooling centres to notify that they should be activated, and to set up as needed • Post notices where the public can see them to inform on heat-related illness and ways to stay cool, especially at outdoor facilities • Review supply of extreme heat brochures and re-order if necessary • Review supply of bottled water for each cooling centre and re-order if necessary • Send out push notification • Assign volunteers to perform wellness checks for the elderly, the unstably housed, and people suffering from mental illness.
Level 3	Sustained Level 2 Heat Warning for 3 or more consecutive days	ECCC	<ul style="list-style-type: none"> • Send level 3 email notifications to the following departments and stakeholders who can post notices within their premises and/or those providing services to vulnerable populations: <ul style="list-style-type: none"> ○ Education Department ○ Health Department ○ Housing and Capital Projects Department ○ Fire Department ○ Schools ○ RCMP ○ Tansi Friendship Centre ○ Daycares ○ Hospitals ○ Medical Clinics ○ Chetwynd Senior Citizens Housing Society

Emergency Level	Condition of Activation	Activating Party	Action Steps
			<ul style="list-style-type: none"> • Send pre-developed level 3 mail-outs to residents. • Update community website and social media • Contact designated cooling centres to activate extended operating hours • Post notices where the public can see them to inform on heat-related illness and ways to stay cool, especially at outdoor facilities • Review supply of extreme heat brochures and re-order if necessary • Review supply of bottled water for each cooling centre and re-order if necessary • Send out push notification • Assign volunteers to perform wellness checks for the elderly, the unstably housed, and people suffering from mental illness.

West Moberly First Nations Action Steps

Emergency Level	Condition of Activation	Activating Party	Action Steps
Level 1	Forecasted temperatures of 25°C for 2 days or more as reported by the ECCC	The Communities Themselves	<ul style="list-style-type: none"> • Send level 1 email notifications to the following departments and stakeholders who can post notices within their premises and/or those providing services to vulnerable populations: <ul style="list-style-type: none"> ○ Education Department ○ Health Department ○ Housing and Capital Projects Department • Send pre-developed level 1 mail-outs to residents. • Notify residents to either download the WeatherCAN app on their phones or register for an email-based alert system from the ECCC by following this guide: https://ecalertme.weather.gc.ca/guides/quickstart_en.php • Update community website and social media • Contact staff at designated cooling centres to notify that the community is starting to experience hot weather • Have cooling centres checked to ensure they are ready to be opened • Verify maintenance needs for designated emergency transport vehicle and fix as needed • Place order for bottled water • Place order for extreme heat brochures • Post notices where the public can see them to inform on heat-related illness and ways to stay cool, especially at outdoor facilities • Post call for emergency heat relief volunteers

			<ul style="list-style-type: none"> • Provide a training session for volunteers to identify signs of heat exhaustion and heat stroke
Level 2	Forecasted temperatures are above 29°C two days in a row with a nighttime low above 14°C	ECCC	<ul style="list-style-type: none"> • Send level 2 email notifications to the following departments and stakeholders who can post notices within their premises and/or those providing services to vulnerable populations: <ul style="list-style-type: none"> ○ Education Department ○ Health Department ○ Housing and Capital Projects Department ○ Fire Department • Send pre-developed level 2 mail-outs to residents. • Update community website and social media • Contact designated cooling centres to notify that they should be activated, and to set up as needed • Post notices where the public can see them to inform on heat-related illness and ways to stay cool, especially at outdoor facilities • Review supply of extreme heat brochures and re-order if necessary • Review supply of bottled water for each cooling centre and re-order if necessary • Send out Voyent Alert • Assign volunteers to perform wellness checks for the elderly, the unstably housed, and people suffering from mental illness.
Level 3	Sustained Level 2 Heat Warning for 3 or more consecutive days	ECCC	<ul style="list-style-type: none"> • Send level 3 email notifications to the following departments and stakeholders who can post notices within their premises and/or those providing services to vulnerable populations: <ul style="list-style-type: none"> ○ Education Department ○ Health Department ○ Housing and Capital Projects Department ○ Fire Department ○ Schools ○ RCMP ○ Tansi Friendship Centre ○ Daycares ○ Hospitals ○ Medical Clinics ○ Chetwynd Senior Citizens Housing Society • Send pre-developed level 3 mail-outs to residents. • Update community website and social media • Contact designated cooling centres to activate extended operating hours • Post notices where the public can see them to inform on heat-related illness and ways to stay cool, especially at outdoor facilities

			<ul style="list-style-type: none"> • Review supply of extreme heat brochures and re-order if necessary • Review supply of bottled water for each cooling centre and re-order if necessary • Send out Voyent Alert • Assign volunteers to perform wellness checks for the elderly, the unstably housed, and people suffering from mental illness.
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District of Chetwynd Action Steps

Emergency Level	Condition of Activation	Activating Party	Action Steps
Level 1	Forecasted temperatures of 25°C for 2 days or more as reported by the ECCC	The Communities Themselves	<ul style="list-style-type: none"> • Send level 1 email notifications to the following departments and stakeholders who can post notices within their premises and/or those providing services to vulnerable populations: <ul style="list-style-type: none"> ○ Fire Department ○ Schools ○ RCMP ○ Tansi Friendship Centre ○ Daycares ○ Hospitals ○ Medical Clinics ○ Chetwynd Senior Citizens Housing Society • Send pre-developed level 1 mail-outs to residents. • Notify residents to either download the WeatherCAN app on their phones or register for an email-based alert system from the ECCC by following this guide: https://ecalertme.weather.gc.ca/guides/quickstart_en.php • Update community website and social media • Contact designated cooling centres to notify that the community is starting to experience hot weather • Have cooling centres checked to ensure they are ready to be opened • Verify maintenance needs for designated emergency transport vehicle and fix as needed • Place order for bottled water • Place order for extreme heat brochures • Post notices where the public can see them to inform on heat-related illness and ways to stay cool, especially at outdoor facilities
Level 2	Forecasted temperatures are above 29°C two days in a row with a nighttime	ECCC	<ul style="list-style-type: none"> • Send level 2 email notifications to the following departments and stakeholders who can post notices within their premises and/or those providing services to vulnerable populations: <ul style="list-style-type: none"> ○ Fire Department ○ Schools ○ RCMP

	low above 14°C		<ul style="list-style-type: none"> ○ Tansi Friendship Centre ○ Daycares ○ Hospitals ○ Medical Clinics ○ Chetwynd Senior Citizens Housing Society ● Send pre-developed level 2 mail-outs to residents. ● Update community website and social media ● Contact designated cooling centres to notify that they should be activated, and to set up as needed ● Post notices where the public can see them to inform on heat-related illness and ways to stay cool, especially at outdoor facilities ● Review supply of extreme heat brochures and re-order if necessary ● Review supply of bottled water for each cooling centre and re-order if necessary ● Send out Voyent Alert
Level 3	Sustained Level 2 Heat Warning for 3 or more consecutive days	ECCC	<ul style="list-style-type: none"> ● Send level 3 email notifications to the following departments and stakeholders who can post notices within their premises and/or those providing services to vulnerable populations: <ul style="list-style-type: none"> ○ Fire Department ○ Schools ○ RCMP ○ Tansi Friendship Centre ○ Daycares ○ Hospitals ○ Medical Clinics ○ Chetwynd Senior Citizens Housing Society ● Send pre-developed level 3 mail-outs to residents. ● Update community website and social media ● Contact designated cooling centres to activate extended operating hours ● Post notices where the public can see them to inform on heat-related illness and ways to stay cool, especially at outdoor facilities ● Review supply of extreme heat brochures and re-order if necessary ● Review supply of bottled water for each cooling centre and re-order if necessary ● Send out Voyent Alert

Appendix A: Technical Information

Approach and Methods

Application of LST vs. Air Temperature

Due to limited resources to set up and monitor weather stations, measured air temperatures fail to provide sufficient spatial details for urban land use and climate change mitigation planning. By contrast, satellite remote sensing offers consistent and repeatable observations of the Earth’s surface, at a high spatial resolution. For largely this reason, satellite remote sensing is the default means of measuring urban heat for both research and land use planning applications.⁶⁶

Relating LST derived from satellite remote sensing and air temperature as measured at weather stations is challenging. First, the different modes of measuring temperature are influenced by different factors. Thermometer measurement of air temperature is influenced by turbulent source areas upwind of the measurement site. The exact shape of these areas is influenced by the placement of the thermometer itself and characteristics of atmospheric turbulence and stability. The measurement of surface temperature through thermal remote sensing is affected by what the satellite “observes”. The effective source area for a remote thermal measurement is the instantaneous field of view (IFOV) of the sensor projected onto the surface. A comparison of the two source areas can be seen in Figure 31. The satellite can also only receive radiation from surfaces that are apparent within the IFOV. A complete urban surface may not be visible to a satellite if it’s obscured by the viewing angle or other obstacles.⁶⁷ Both of these modes of measurement will also be affected differently by surface characteristics and conditions including moisture, aerodynamic roughness, albedo, emissivity, and thermal admittance, as well as geography and prevailing weather conditions.

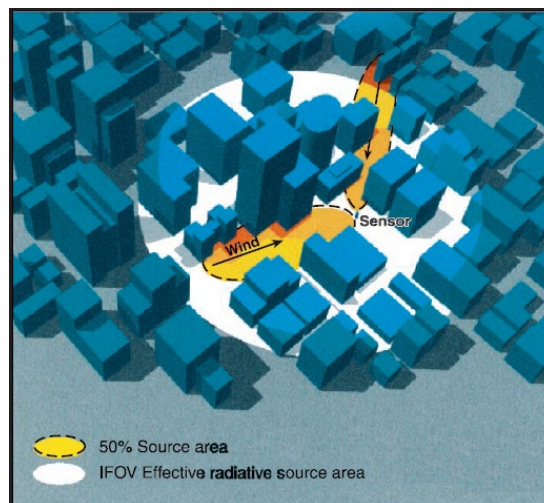


Figure 31: Conceptual source areas. Adapted from Voogt and Oke (2003)⁶⁸.

Second, emitted radiation from a target as registered by a satellite sensor will be influenced by atmospheric effects. More water vapour in the atmosphere significantly affects the precision of land

⁶⁶ Zhou, D., Xiao, J., Bonafoni, S., Berger, C., Deilami, K., Zhou, Y., ... & Sobrino, J. A. (2018). Satellite remote sensing of surface urban heat islands: Progress, challenges, and perspectives. *Remote Sensing*, 11(1), 48.

⁶⁷ Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. *Remote sensing of environment*, 86(3), 370-384.

⁶⁸ *Ibid.*

surface temperature estimates. However, atmospheric water vapour concentrations are typically low on clear days outside of the tropics.⁶⁹ The satellite sensor may also receive atmospheric radiation not emitted from the Earth’s surface.

Third, the radiation registered by a satellite sensor must be normalized based on the emissive properties of the source on Earth’s surface. Accurate quantification of these properties requires accurate identification of the emitting body, and accurate knowledge of the emitting properties of the body.

Weather Stations

For comparison and to supplement the outcomes of this work, additional weather data were acquired from Steven Hvenegaard from FPInnovations. Steven operates a weather station near the Whistler Cemetery in the Resort Municipality of Whistler. More supplementary data were acquired from the Cheakamus weather station near Whistler operated by the BC Wildfire Service (BCWS).

Frontera’s gauges were initially put out on July 27th, 2023. Due to storage capacity limitations and variation on gauge retrieval, the window of data available varied by community. The days of available data and their logging frequency for all gauges and stations considered are shown in Table 7. The forested weather station in Whistler Cemetery has a more formal setup and has a greater logging capacity, and so has a longer availability of data.

Table 7: Data availability from the temperature gauges for each of the communities, and from the established weather stations at the Chetwynd Airport and in Whistler. The data ranges apply to all three of each community’s respective gauges.

Temperature Sensors	Operating Organization	Logging Frequency	Start Date	End Date
Saulteau First Nations gauges	Frontera	10 min	July 28, 2023	September 11, 2023
West Moberly First Nations gauges	Frontera	10 min	August 21, 2023	October 01, 2023
District of Chetwynd gauges	Frontera	10 min	August 03, 2023	September 18, 2023
Chetwynd Airport	Environment Canada	Hourly	May 01, 2013	September 25, 2023
Cheakamus Station	BCWS	Hourly	May 01, 2017	September 25, 2023
Whistler Cemetery Fuel Treatment	FPInnovations	5 min	June 27, 2022	October 05, 2022

Quality Control

Quality control involved graphing the hourly temperatures acquired from each weather station for each month and for each year within our time range of interest to evaluate whether temperatures were reasonable. The hourly median was taken from the 10-minute temperature readings to eliminate noise that arises from natural and unnatural fluctuations. To verify diurnal temperature patterns, hourly

⁶⁹ Ermida, S. L., Soares, P., Mantas, V., Göttsche, F. M., & Trigo, I. F. (2020). Google earth engine open-source code for land surface temperature estimation from the landsat series. *Remote Sensing*, 12(9), 1471.

temperatures were averaged over all days in a month to demonstrate an average 24-hour temperature cycle. This was done for the months of May through October for all years for which data was available from each weather station. Hourly temperature trends were also graphed over the duration of the windows of data available from each gauge from each community Table 7. These graphs are not shown in this report. However, time-stamps on data acquired from the Chetwynd Airport station from the PCIC were adjusted to be consistent with those available from Environment Canada's Historical Data archive.

Land Surface Temperature Algorithms

LST derived from Landsat imagery was calculated using Google Earth Engine with a package developed by Ermida et al., 2021.⁷⁰ There are many ways to calculate LST from Landsat satellite imagery. While many are relatively simple, they must be parameterized using calibration coefficients which are not readily available. The LST algorithm implemented in their package was developed by the Climate Monitoring Satellite Application Facility.⁷¹ Google Earth Engine offers a platform which can easily store and process large datasets without imposing heavy storage and processing requirements on the user. Use of the package was also recommended for use in NASA's training in the use of satellite remote sensing for the detection of urban heat islands.⁷²

The LST algorithm implemented in the package is based on the ASTER temperature emissivity separation algorithm.⁷³ The model Ermida et al., 2020 used to estimate emissivity in urban and vegetated areas is heavily influenced by the estimated vegetation cover within a pixel. Vegetation cover is estimated based on the normalized-difference vegetation index (NDVI) using Landsat 8 and 9 bands within the visible spectrum. Emissivity typically falls within a range of 0.95 (no vegetation) to 0.99 (fully vegetated). The final product is available at a 30 m resolution because the bands used to develop NDVI are available at this resolution. Use of the package was also recommended for use in NASA's training in the use of satellite remote sensing for the detection of urban heat islands.⁷⁴

Air Temperature

Air temperature was developed by adjusting LST according to measurements acquired from gauges and weather stations. Gauges and weather stations were categorized into three classes according to their surrounding land cover: field, forest, and urban. Temperature data from each of the gauges and weather stations logged at 12:00 PM were matched to the LST developed at the locations of the gauges and stations for corresponding dates. Then, linear regression models relating LST to air temperature were developed for each of the land cover classes. To apply these models for the adjustment of the 37°C

⁷⁰ Ermida, S. L., Soares, P., Mantas, V., Göttsche, F. M., & Trigo, I. F. (2020). Google earth engine open-source code for land surface temperature estimation from the landsat series. *Remote Sensing*, 12(9), 1471.

⁷¹ Duguay-Tetzlaff, A., Bento, V. A., Göttsche, F. M., Stöckli, R., Martins, J. P., Trigo, I., ... & Kunz, H. (2015). Meteosat land surface temperature climate data record: Achievable accuracy and potential uncertainties. *Remote Sensing*, 7(10), 13139-13156.

⁷² McCartney, S.; Mehta, A.; Shandas, V.; Gallo, K.; Paris, G.; Nix, S.; Quintero, T.; Tomlinson, A.; Xian, G. (2020). *Satellite Remote Sensing for Urban Heat Islands*. NASA Applied Remote Sensing Training Program (ARSET). <https://appliedsciences.nasa.gov/join-mission/training/english/arset-satellite-remote-sensing-urban-heat-islands>

⁷³ Gillespie, A., Rokugawa, S., Matsunaga, T., Cothorn, J. S., Hook, S., & Kahle, A. B. (1998). A temperature and emissivity separation algorithm for Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) images. *IEEE transactions on geoscience and remote sensing*, 36(4), 1113-1126.

⁷⁴ (2022). ARSET - Satellite Remote Sensing for Measuring Urban Heat Islands and Constructing Heat Vulnerability Indices. NASA Applied Remote Sensing Training Program (ARSET). <http://appliedsciences.nasa.gov/join-mission/training/english/arset-satellite-remote-sensing-measuring-urban-heat-islands-and>

extreme heat product, the federal land cover product was reclassified to generalize each of the classes to either field, forest, or urban (Table 8).

Table 8: Land Cover reclassification schema used to inform where to apply different transformations of LST into air temperature. The three different simplified classes represent three different models intended to be applied.

Original Classification	Simplified Reclassification
Temperate or sub-polar conifer forest	Forest
Temperate or sub-polar broadleaf forest	Forest
Mixed Forest	Forest
Temperate or sub-polar shrubland	Field
Temperate or sub-polar grassland	Field
Wetland	Forest
Cropland	Field
Barren Lands	Urban
Urban Area	Urban
Water	Water

Only land cover classes occurring within 1 km of the boundaries of each of the communities was reclassified. Different forest types were reclassified as forest, urban areas remained urban, and land covers dominated by grasses and other non-tree species were reclassified as field. Lands within the “Temperate or sub-polar shrubland” class seemed like forests sometimes, and fields other times based on visual assessments from satellite imagery and from the District of Chetwynd’s 2020 orthophotography. This was ultimately classified as field as the more ambiguous locations were generally further away from human populations, and areas within the three communities visited in person would be more accurately described as fields, such as West Moberly’s hay field (Figure 7). Wetlands were classified as forests as those pixels generally seemed to occur within or adjacent to forests. The coverage of wetlands was relatively small and generally located away from human populations. Barren lands were classified as urban. Though they possess fewer radiating objects they intensify the urban heat island as compared to urban areas, they are generally impervious surfaces with limited water retention⁷⁵. Finally, the only class which was not reclassified was water. While water temperatures are available from the LST products, these were not adjusted, and so they retained their original value in the air temperature product.

Following the reclassification, the land cover product was then smoothed using the “sieve” function in QGIS. This was done in order to eliminate single pixels and to generalize areas with mixed land covers (such as within the urban-wildland interface) to determine the dominant land cover in order to apply a

⁷⁵ <https://link.springer.com/article/10.1007/s00704-012-0758-z>

representative model. The final results of the land cover reclassification and smoothing are shown in Figure 9, Figure 10, Figure 11, and Figure 12.

Risk Assessment

Approach #1 – Simple Approach

Within this formula, risk consists of two components: a threat, and the presence of values which can succumb to said threat. Here, air temperature is the threat component of the risk while population density is the values component of the risk. The equation above does not assign a disproportionate weight of importance to either the threat component or values component, and thus the overall risk due to extreme heat is the sum of the threat and the density of values in equal part. The classification of simple risk into different ratings is shown in Table 9.

Table 9: Simple risk rating classification from calculated ordinal values. Lower and upper bounds of each class are included within the class itself. Classifications are based on exponentially increasing scores because the simple risk score is developed from the multiplication of its parameters.

Minimum Risk Score	Maximum Risk Score	Risk Rating
0	0	Nil Risk
0.01	3.33	Lower
3.34	6.66	Medium
6.67	10	Higher

Approach #2 – Vulnerability Risk Approach

This equation was developed by adding vulnerability factors onto the simple risk formula explained above. The logic behind the additive approach of the parameters and the choice of the weights was informed and adapted by an extreme heat vulnerability proposed by NASA⁷⁶. This framework posits vulnerability to consist of three components: exposure, sensitivity, and adaptive capacity. Exposure is analogous to threat; it is the intensity of heat. Sensitivity measures the different conditions and qualities people have that can either lessen or intensify the impacts of extreme heat. Adaptive capacity measures the resources available to people to cope with extreme temperatures such as installing air conditioning or leaving to go somewhere else.

Within this framework, status as a senior can be understood as a vulnerability while status as low-income can be understood as affecting one’s ability to adapt to extreme heat. Within this framework, NASA categorized population density within the category of exposure. Furthermore, retaining the simple risk component within this vulnerability-incorporated risk renders them more readily comparable, as the two products for a community are the same where vulnerable populations are absent. The classification of vulnerability-incorporated risk into different ratings is shown in Table 10; this is the same classification as is used for simple risk in order to render the two products easily comparable.

⁷⁶ https://appliedsciences.nasa.gov/sites/default/files/2022-08/UHI_Part2_Final.pdf

Table 10: Complex risk rating classification from calculated ordinal values. Lower and upper bounds of each class are included within the class itself. Classifications are based on exponentially increasing scores because the complex risk score is developed from the addition of its parameters.

Minimum Risk Score	Maximum Risk Score	Risk Rating
0	0	Nil Risk
0.01	3.33	Lower
3.34	6.66	Medium
6.67	10	Higher

Population Density

This work aimed to demonstrate risk to the population at their place of residence because we cannot know where different residents go out during the day or for how long. As such, the number of housing units associated with any non-residential structures was given a value of 1. This was done in order to include them, but not emphasize them within the risk mapping analysis.

Measures of density were reclassified into equal classes to provide a score out of 10 (Table 11). Given that population density in the District of Chetwynd is significantly higher than the Saulteau and West Moberly reserves, this classification inflates the general risk apparent in Chetwynd and reduces the risk apparent on the Nations’ reserves. This choice was made given that both Nations have a significant number of members living in Chetwynd whom they would like represented.

Table 11: Population density ordinal reclassification schema used for the development of risk products. Density was measured based on housing units such as a house or one unit within an apartment, for example. Density was measured within a radius of 100 m, or within a 3.14 ha area. A value of 0 is thus associated with no risk and a value of 10 is associated with a very high risk.

Minimum Units within 100 m	Maximum Units within 100 m	Ordinal Reclassification
0	0	0
1	9	1
10	19	2
20	29	3
30	39	4
40	49	5
50	59	6
60	69	7
70	79	8
80	89	9
90	105	10

All locations with a population density score of 0 were provided a risk of 0 as risk is negligible in the absence of people. Otherwise, the following equation was applied to develop simple risk:

$$(Air\ Temperature * 0.5) + (Population\ Density * 0.5) = Simple\ Risk$$

This risk framework has been implemented in other works applied to wildfire risk assessment, but can be applied here intuitively^{77, 78}. Within this framework, risk consists of two components: a threat, and the presence of values which can succumb to said threat. Here, air temperature is the threat component of the risk while population density is the values component of the risk. The equation above does not assign a disproportionate weight of importance to either the threat component or values component, and thus the overall risk due to extreme heat is the sum of the threat and the density of values in equal part. The classification of simple risk into different ratings is shown in Table 9.

All data points available are shown in Figure 32. Note that while the Chetwynd Airport data points are differentiated from the other land covers to distinguish them, it was deemed to represent the “Urban” land cover. Overall, the data points from each of the land covers tend to parallel the one-to-one line for nearly a 30°C range of LSTs. This suggests that a simple linear regression can likely be applied to relate LST and air temperature across the full range of LSTs for each land cover.

Regression

To develop a regression, guidance was taken from do Nascimento et al., 2022⁷⁹. Due to the radiative properties of different Earth surfaces, it should be expected that differences between LST and air temperature should be within 3°C in the absence of other confounding factors. As such, general descriptive statistics were calculated for these temperature differences for each land cover class including the mean, standard deviation, the upper and lower bounds of the 95% confidence interval of the distributions. Based on these statistics, outliers were eliminated if they fell outside of the 95% confidence interval⁸⁰. As well, the means of the distributions were assessed to see if they fell within the bounds of $-3^{\circ}\text{C} \leq x \leq 3^{\circ}\text{C}$.

Following this, models were developed relating LST to air temperature for each of the land covers using simple linear regression. To assess the rigor of these models, we calculated the coefficient of determination (R^2) and the overall p-values of the regressions. Finally, models with sufficient rigor were applied to the 37°C LST product by land cover reclassification to develop the air temperature product.

To incorporate air temperature into the risk products, air temperature was reclassified according to Table 12 to provide a score out of 10. Classes were generated by parsing the data into nine equal intervals between 29°C and the maximum value. 29°C was chosen given that it's the threshold maximum temperature for heat warnings. 29°C is associated with an approximate 5% increase in mortality in the northeast⁸¹. Because this increased risk is non-zero, two additional classes were added below 29°C to provide risk scores of 1 and 0.

77

https://www.researchgate.net/publication/343955737_Wildfire_Risk_Assessment_Based_on_Geospatial_Open_Data_Applicati_on_on_Chios_Greece

78 <https://www.mapleridge.ca/DocumentCenter/View/1050/Wildfire-Risk-Management-System-PDF?bidId=>

79 <https://www.mdpi.com/2073-4433/13/3/491>

80 https://www.sfei.org/sites/default/files/biblio_files/Stevens_ThresholdCalculationReport_May2011.pdf

81 <https://www.mdpi.com/1660-4601/15/9/2048>

Table 12: Air temperature ordinal reclassification schema used for the development of risk products. A value of 0 is thus associated with no risk and a value of 10 is associated with a very high risk.

Minimum Temperature	Maximum Temperature	Ordinal Reclassification
23.0	26.5	0
26.6	28.9	1
29.0	31.3	2
31.4	33.7	3
33.8	36.1	4
36.2	38.5	5
38.6	40.9	6
41.0	43.3	7
43.4	45.7	8
45.8	48.1	9
48.2	52.0	10

Correspondence of Land Surface Temperature and 12:00 PM Air Temperature by Land Cover

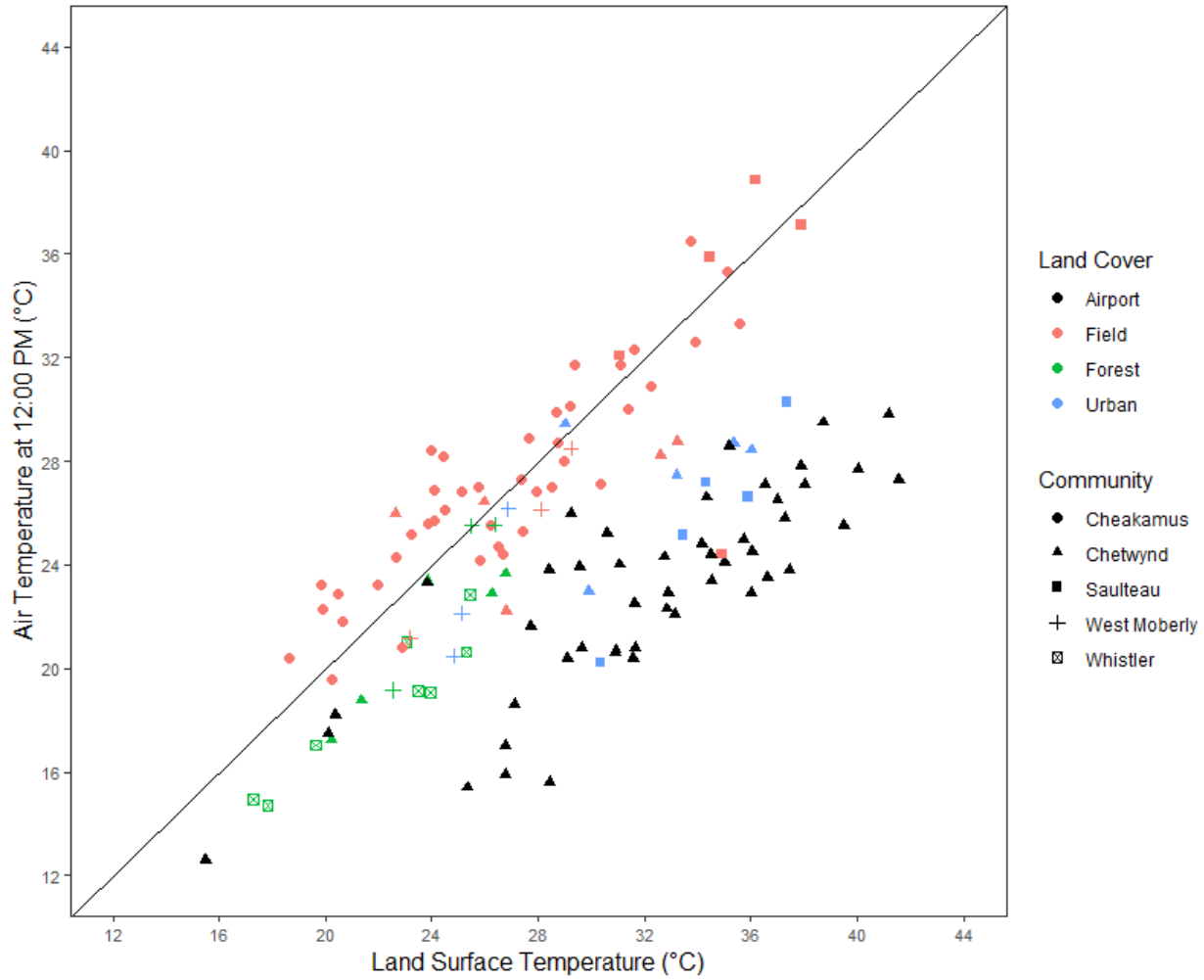


Figure 32: Correspondence of all air temperature and land surface temperature pairs within each land cover reclassification.

The scatter among the “Field” points is generally low with a correlation coefficient of $r = 0.85$. Of the 54 total “Field” points, 41 of them were obtained from the Cheakamus Station and the remaining 13 were obtained from the three communities collectively. The points from the Cheakamus Station align well with those from the communities. Data acquired from the Sauteau First Nations in this class showed some temperatures that were remarkably hot, nearly reaching 40°C , except for one data point strongly misaligned with all other “Field” points collectively. Points from the West Moberly First Nations and the District of Chetwynd were roughly towards the middle of the range of LST with generally less scatter. Points from the communities appear slightly more scattered on their own as compared to those from the Cheakamus station, though this can be due to the relatively small sample. The points follow the one-to-one line very closely, suggesting that LST matches air temperature quite well in this land cover prior to any adjustments.

The scatter among the “Forest” points is even lower than those of the field with a correlation coefficient of $r = 0.91$. Of the 16 total “Forest” points, 8 of them were obtained from the Whistler Cemetery weather station and the remaining 8 were obtained from the West Moberly First Nations and the District of Chetwynd. Unfortunately, the “Forest” gauge installed on-reserve at the Sauteau First Nations failed and any data collected from it could not be retrieved. Overall, this failure had little to no impact on this analysis outputs. The points from the Whistler Cemetery station align well with those from the communities. The points fall a bit below the one-to-one line with a mean difference of about 2.7°C between LST and air temperature measurements. This suggests that transfer of heat from the ground is either less efficient in the assessed forests as compared to the assessed fields or that there are other factors causing these discrepancies.

The scatter among the “Urban” points is the highest of the three land covers considered with a correlation coefficient of $r = 0.78$. Of the 61 total “Urban” points, 48 of them were obtained from the Cheakamus Airport and the remaining 13 were obtained from the three communities. Different patterns are apparent from each of these sensors. Data from the Cheakamus Airport shows more scatter as compared to the other “Urban” sensors. Data from Chetwynd’s sensor near the town hall and from the sensor near Sauteau’s band office fall relatively close to one another. These points are generally a bit closer to the one-to-one line than most of the points from the Chetwynd Airport. Points from West Moberly were more closely aligned with the other “Forest” points than they were with the “Urban” points. Collectively, the “Urban” points fall far below the one-to-one line with a mean difference of about 8.5°C between LST and air temperature measurements.

The Application of LST vs. Air Temperature section near the top of this plan discusses three factors that can cause discrepancies between LST and air temperature in a general sense. Otherwise, two other factors specific to these communities are identified here. Mixed-land use tends to be more prevalent in smaller remote communities as the ratio of the perimeter of the community to the total area of the community is much larger as compared to larger cities. As a result, a much larger areal proportion of smaller communities lies within rural, wildland, or forested interfaces with a mix of land covers⁸². Indeed, many of the “Urban” gauges installed were on the community perimeters. These interface areas could demonstrate discrepancy for LST and air temperature for a few reasons. Given that Landsat 8 and 9 thermal satellite imagery has a spatial resolution of 100 m, the discrepancy could be caused by the algorithm for LST overestimating the influence of the impervious surfaces or not sufficiently accounting

⁸² <http://www.igsnrr.ac.cn/xwzx/jxltwj/200711/W020090715580901287379.pdf>

for the influence of other vegetated areas. Another potential cause could be the influence of nearby forests. The forests near to many of these communities are not parks but rather are often large swaths of land on the scale of square kilometers. There is a lot of uncertainty around the magnitude and the extent of the cooling effect provided by forests. One review found that the cooling distance of urban forests could range from around 150 m at the end of the day and up to 860 m in the morning⁸³. Another study stated that cooling effects could extend as far as about 450 m away from borders of large urban parks (~500 ha)⁸⁴. The effects of cooling gains from green spaces reported variations in cooling magnitudes ranging from 1°C up to around 6°C⁸⁵. In all, wind, atmospheric effects, land cover mixes, and vegetative cooling can all be potential causes for discrepancies between LST and air temperature.

Following the removal of one outlier from the “Field” data points using the method outlined in the Air Temperature section of the Approach and Methods, linear models were developed to model air temperature. Two models are shown: one for forested land and one for non-forested land. The model for forested land was developed from the “Forest” data points in Figure 32. The model for non-forested land was developed from the “Field” data points. While the “Urban” weather data was good and its relationship to LST seemed acceptable, applying this model would significantly reduce the magnitude of temperatures in the most heavily urbanized areas such as in the District of Chetwynd’s industrial park. As such, the non-forested land regression was applied to all non-forested land cover types, including urban areas to retain the well-documented effect of the urban heat island⁸⁶.

⁸³ <https://www.sciencedirect.com/science/article/pii/S1618866719302572?via%3Dihub>

⁸⁴ <https://www.mdpi.com/2220-9964/5/2/12>

⁸⁵ <https://www.inspq.qc.ca/sites/default/files/publications/3327-urban-heat-island-mitigation.pdf>

⁸⁶ <http://www.regionalclimateperspectives.com/uploads/4/4/2/5/44250401/post6oke1973uhiscaling.pdf>

Relationships between Land Surface Temperature and 12:00 PM Air Temperature by Land Cover

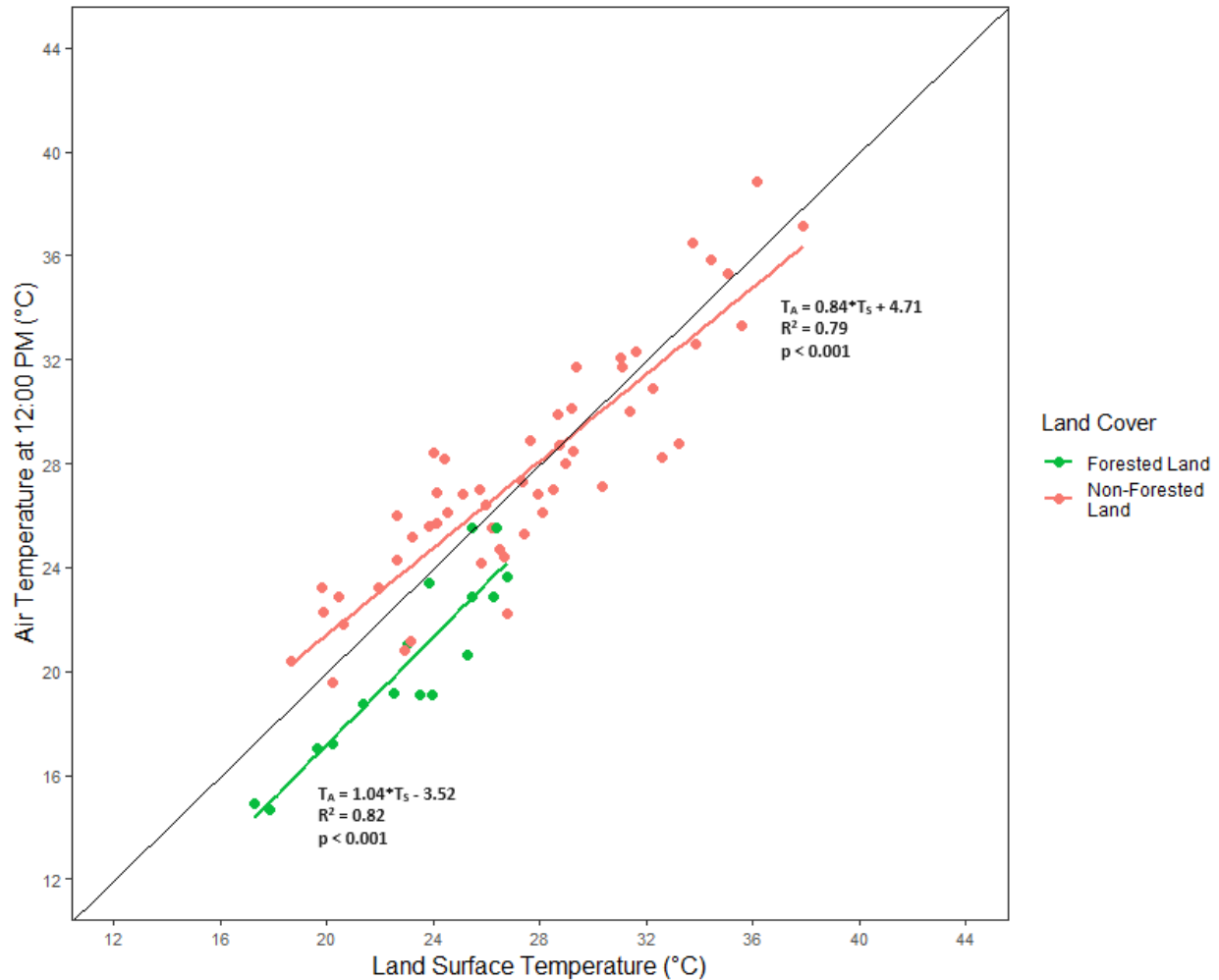


Figure 33: Regressions used in the development of air temperature products. Text boxes next to each of the regressions show from top to bottom: the equation for the best-fit line, the coefficient of determination, and the p-value of the regression.

Results

Air Temperature Mapping

Descriptive statistics for the differences between observations of air temperature and temporally corresponding measures of LST are available in Table 13. Based on the criteria set by for the mean difference to be between within the bounds of $-3^{\circ}\text{C} \leq x \leq 3^{\circ}\text{C}$, the “field” and “forest” data points were found to have acceptable outcomes while the urban outcome was not acceptable⁸⁷.

⁸⁷ <https://www.mdpi.com/2073-4433/13/3/491>

Table 13: Descriptive statistics for the differences between observations of air temperature and land surface temperature measurements developed from Landsat 8 and 9 satellite imagery. Statistics were developed for all air temperature and land surface temperature pairs within each land cover reclassification.

Land Cover Reclassification	Descriptive Statistic of Air-Surface Temperature Differences	Value
Field	Mean Difference	0.00
	Mean Absolute Difference	1.89
	Standard Deviation	2.59
	Upper Limit	5.18
	Lower Limit	-5.18
Forest	Mean	-2.71
	Mean Absolute Difference	2.71
	Standard Deviation	1.40
	Upper Limit	0.10
	Lower Limit	-5.51
Urban	Mean	-8.51
	Mean Absolute Difference	8.52
	Standard Deviation	3.47
	Upper Limit	-1.58
	Lower Limit	-15.44

Table 14: Land cover types and proportion and area across all communities.

Land Cover Classification	Saulteau First Nations		West Moberly First Nations		District of Chetwynd	
	Count of Pixels	Proportion of Total Area (%)	Count of Pixels	Proportion of Total Area (%)	Count of Pixels	Proportion of Total Area (%)
Temperate or sub-polar conifer forest	8520	12.9	9793	13.4	16294	18.5
Sub-polar taiga conifer forest	0	0.0	0	0.0	0	0.0
Temperate or sub-polar broadleaf forest	2	0.0	0	0.0	4	0.0
Mixed Forest	36770	55.8	40485	55.4	42650	48.4
Temperate or sub-polar shrubland	6411	9.7	11890	16.3	9220	10.5
Temperate or sub-polar grassland	1348	2.0	1077	1.5	4104	4.7
Subpolar or polar shrubland-lichen-moss	0	0.0	0	0.0	0	0.0
Sub-polar or polar grassland-lichen-moss	0	0.0	0	0.0	0	0.0
Sub-polar or polar barren-lichen-moss	0	0.0	0	0.0	0	0.0
Wetland	459	0.7	186	0.3	428	0.5
Cropland	5239	8.0	0	0.0	7013	8.0
Barren Lands	255	0.4	184	0.3	553	0.6
Urban Area	1453	2.2	901	1.2	7497	8.5
	5436	8.2	8610	11.8	283	0.3
Snow and Ice	0	0.0	0	0.0	0	0.0
TOTAL	65893	100.0	73126	100.0	88046	100.0