

# MEMORANDUM

**Date:** May 8, 2015  
**To:** **Craig Saxton and Water Right File 29-7869**  
**From:** Michele Edl  
**Re:** Heating water use

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## Introduction

I have been asked to evaluate the water use by a spa-pool which was developed under permit 29-7869. This memo summarizes my calculations and recommendations for the use.

## Project Description

The subject spa-pool is located within Lava Hot Springs Inn property. It is sited on the north side of the inn, between the inn and the Portneuf River. The pool utilizes low-temperature geothermal water for heating use. The warm water is put to direct use in the pool rather than through a heat exchanger system. The source of the geothermal water is at least one well also located within the inn's property. The 113-122 deg F geothermal water is pumped continuously and after some residence time in the spa-pool, is discharged into the river.

Contemporary photos of the pool show it as a concrete, in-ground pool screened on one side and sheltered by trees on another side. It is not an enclosed pool. Wood decking is attached to the pool and borders it on all four sides. Dimensions given in the decking plans show that the pool has two chambers and in total, has 12 feet by 34 feet of exposed surface.

## Method

An unenclosed body of water exchanges heat with the atmosphere through four mechanisms. In order of magnitude from greatest to smallest they are: evaporation, convection, radiation, and conduction. Each of the mechanisms is influenced by several parameters so the equations are complex.<sup>1</sup> However, I have found that the Geo-Heat Center (GHC) at the Oregon Institute of Technology has developed software which does the calculation work for several direct uses of geothermal water, including the heating use for this type of pool. My recommendations are based on calculations implemented by that software.

Seven parameters are required by the GHC's Direct Use Software HEATOOLS to model heat loss in an uncovered pool. The parameters are:

1. Resource temp
2. Length
3. Width
4. Water temp
5. Cover thickness
6. Cover "k" (a property of the cover material)
7. Wind velocity
8. Air temp
9. Relative humidity

Values for parameters 1 through 6 were provided by the permit holder or were part of the water right file. Those four values are assumed constant for this spa-pool. In contrast, parameters 7 through 9 are variable and required research into local weather and the collection of weather data from an acceptable source.

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<sup>1</sup> The methodology is described in detail by Kevin D. Rafferty, P.E., in Aquiculture, Geothermal Direct-Use Engineering and Design Guidebook, Chapter 15, published by Geo-Heat Center, Klamath Falls, OR, 1998.

I found that the closest NWS station was more than 10 miles away in McCammon, Idaho. However, I also found that the City of Lava Hot Springs has a young weather station with data from 2010 to present. The data from KIDLAVAH2 is available as instantaneous, real-time data which is available from query of the internet.<sup>2</sup> Although this real-time data is not vetted by a national weather service office, I found it sufficiently credible for use in the model and preferable to data from more distant weather stations.

#### Use of Heating Degree Days (HDD)

Degree Days are a simplified form of historical weather data. They were developed and are intended for use in estimating the energy loss or gain from buildings. There are two main types of degree days: Heating Degree Days (HDD) and Cooling Degree Days (CDD). Degree Days are readily available for most weather stations and are easy to work with. I used HDD in my evaluation of the annual volume of water required for this water right. Because this pool is not enclosed inside a building, application of precise HDD numbers in any calculation would be misleading. However, in situations such as this one, HDD can be used as an indicator of weather severity without gross error.

#### **Results**

I modeled two scenarios through the HEATOOLS software. The first modeling run mimics a mild summer day. The daily average outside temperature is 64 °F. This is a HDD = 1 day. For that scenario, a pump delivering 90 gpm of geothermal water to the spa-pool would more than sufficient to maintain the desired temperature of 103 deg F. (See results page labeled One Degree Day Scenario.)

The second modeling run is a scenario which mimics a colder, windier day. The daily average outside temperature is 10 deg F (HDD = 65). See results page labeled High Heating Demand Scenario. For that scenario, the same 90 gpm pump delivering the same geothermal water to the same spa-pool would be insufficient to maintain the desired temperature. A higher pumping rate or warmer water would be required.

#### **Conclusions**

Two weather scenarios and their HDD values were used to calculate a reasonable volume for the license.

A HDD1 requires approximately 52.1 gpm to maintain the temperature of the pool at 103 ° F. The City of Lava Hot Springs likely experiences HDD of 7000 or more each year.

The volume of water pumped by a 90 gpm pump in continuous operation is less than the volume calculated to meet the heating need at a site with 7000 HDD.

#### **Recommendations**

A pump capable of delivering 90 gpm of 113 °F water to this spa-pool would be more than sufficient for most days in typical year. It would not be sufficient for a small percentage of days where the air temperature is low and the wind is high.

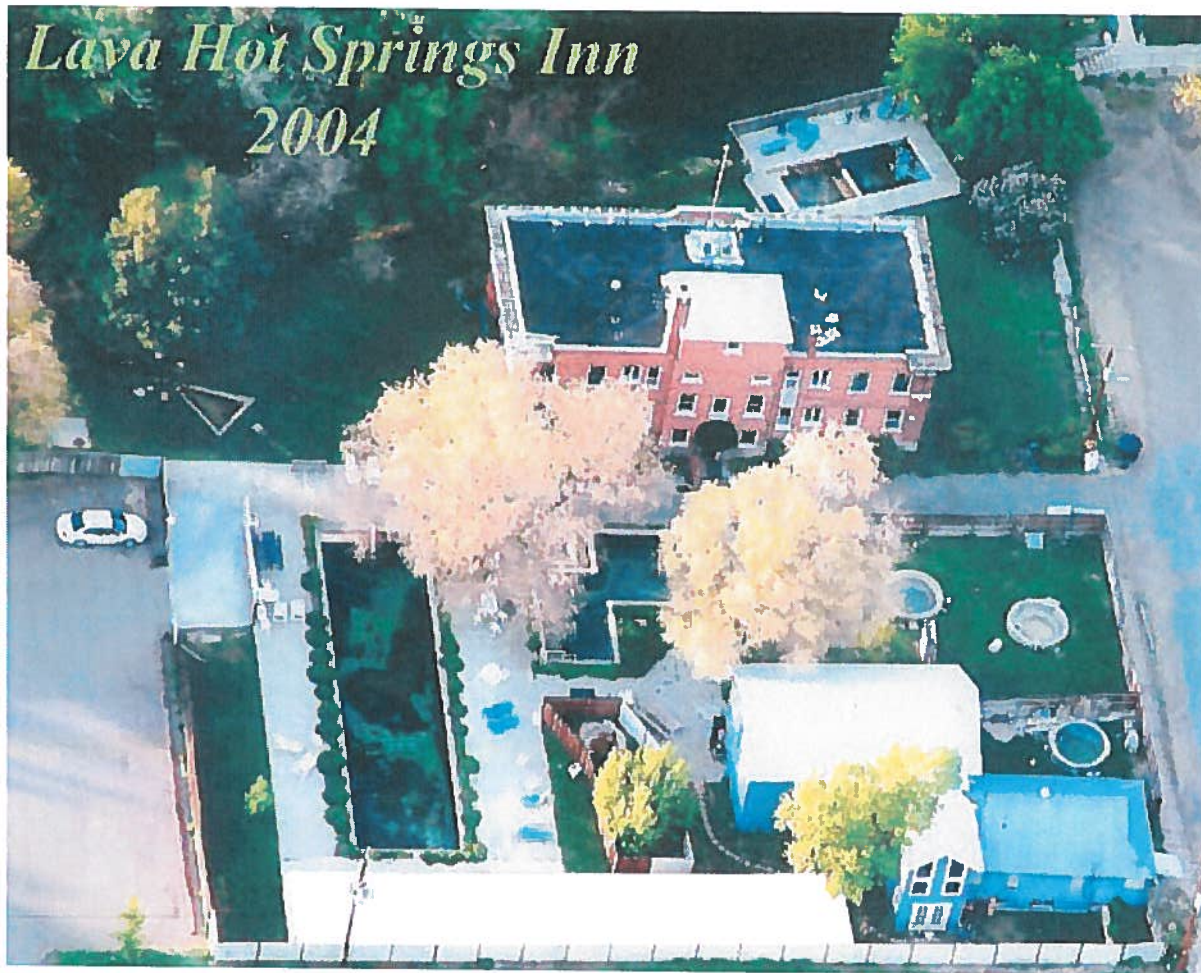
Two weather scenarios were modeled after two days in 2011. They do not represent extreme weather days but are weather data obtained from a local station for 2011. It may be possible to correlate Lava Hot Springs weather to more extreme weather years (higher HDD) which is available from the two long-term stations in the vicinity. A more intensive comparison should be done for determination of the additional volume required.

I recommend that a license be issued for 0.2 cfs and 144.8 AF, the rate and maximum volume diverted by that rate.

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<sup>2</sup> <http://www.wunderground.com/personal-weather-station/dashboard?ID=KIDLAVAH2> or <http://www.intellicast.com/Local/History.aspx?>





Created by Michele Edl for 29-7869

### HEAT LOSS FROM PONDS

#### OPEN PONDS - One Degree Day Scenario

|                               |                       |
|-------------------------------|-----------------------|
| 1. Resource temp              | 113 F                 |
| 2. Length                     | 34 ft                 |
| 3. Width                      | 12 ft                 |
| 4. Water temp                 | 103 F                 |
| 5. Wind velocity              | 5 mph                 |
| 6. Air temp                   | 64 F                  |
| 7. Cover thickness            | 0.00 in               |
| 8. Cover "k"                  | 0.40 btu in/hr sqft F |
| 9. Relative humidity          | 50 %                  |
| 10. Calculated water vap pres | 1.087 psia            |

#### COMMENT

resource temperature  
based on the decking plans  
based on the decking plans  
desired spa-pool temperature  
average wind velocity for a mild summer day; the calculation is sensitive to wind speed and direction  
daily average temp for a HDD =1 (base 65 F). Refer to 6/21/2011 for a specific reference day  
NA; no cover  
NA; no cover  
varies with temp; 50% is reasonable for a 1HDD; the calc is not very sensitive to RH

|                       |               |                   |
|-----------------------|---------------|-------------------|
| 1. Evaporative Loss   | 193226 btu/hr | 473.6 btu/hr sqft |
| 2. Convective Loss    | 48194 btu/hr  | 118.1 btu/hr sqft |
| 3. Radiant Loss       | 16557 btu/hr  | 40.6 btu/hr sqft  |
| 4. Conductive Loss    | 2404 btu/hr   | 5.9 btu/hr sqft   |
| 5. Total Loss         | 260381 btu/hr | 638.2 btu/hr sqft |
| 6. Required flow rate | 52.1 gpm      |                   |

#### CONCLUSION

If every day were 1HDD, then a 90 gpm pump would be more than sufficient for the beneficial heating use.

|           |        |
|-----------|--------|
| ha        | 3.03   |
| x/k       | 0.00   |
| p. press  | 0.144  |
| area      | 408.00 |
| surf temp | 103.00 |
| U         | 3.03   |

**HEAT LOSS FROM PONDS****OPEN PONDS - High Heating Demand Day**

|                               |                       |
|-------------------------------|-----------------------|
| 1. Resource temp              | 113 F                 |
| 2. Length                     | 34 ft                 |
| 3. Width                      | 12 ft                 |
| 4. Water temp                 | 103 F                 |
| 5. Wind velocity              | 13.2 mph              |
| 6. Air temp                   | 10 F                  |
| 7. Cover thickness            | 0.00 in               |
| 8. Cover "k"                  | 0.40 btu in/hr sqft F |
| 9. Relative humidity          | 49 %                  |
| 10. Calculated water vap pres | 1.087 psia            |

**COMMENT**

resource temperature  
 based on the decking plans; reversing the length and width will yield a smaller resulting flow rate (gpm)  
 based on the decking plans  
 desired spa-pool temperature; consistent with industry standard for this type of pool  
 average wind velocity for a breezy winter day; the calculation is sensitive to wind speed and direction.  
 temp for a HDD = 55 (for HDD base 65 deg F); refer to 2/1/2011 for the specific reference day  
 NA uncovered  
 NA uncovered; calculates only when a value is entered in parameter 7. Cover thickness  
 varies with temp; the calculation is not very sensitive to RH  
 refer to 2/1/2011 for a specific reference day

|                       |               |                    |
|-----------------------|---------------|--------------------|
| 1. Evaporative Loss   | 272363 btu/hr | 667.6 btu/hr sqft  |
| 2. Convective Loss    | 143507 btu/hr | 351.7 btu/hr sqft  |
| 3. Radiant Loss       | 34116 btu/hr  | 83.6 btu/hr sqft   |
| 4. Conductive Loss    | 7812 btu/hr   | 19.1 btu/hr sqft   |
| 5. Total Loss         | 457798 btu/hr | 1122.1 btu/hr sqft |
| 6. Required flow rate | 91.6 gpm      |                    |

**CONCLUSION**

Pumping at 90 gpm would not maintain the desired temperature of the pool during most of the reference day.

|                |        |
|----------------|--------|
| h <sub>a</sub> | 3.78   |
| w/k            | 0.00   |
| p. press       | 0.022  |
| area           | 408.00 |
| surf temp      | 103.00 |
| U              | 3.78   |

**HDD1 compared to realistic HDD**

|                             |             |                     |
|-----------------------------|-------------|---------------------|
| Recommended flow rate       | 0.201 cfs   | = 90 gpm/448.83     |
| Available volume            | 144.80 AFA  | =0.2*365*1.9835     |
| Flow rate for a HDD =1      | 0.12 cfs    | = calc 6 gpm/448.83 |
| Volume for a HDD=1 day; AF1 | 0.23 AF     | =cfs x1HDDx1.9835   |
| HDDest                      | 7,000       |                     |
| Volume for HDDest           | 1611.71 AFA | =AF1*HDDest         |
| Available volume            | 144.80 AFA  |                     |
| Deficit volume              | 1,466.91    |                     |

**COMMENT**

maximum annual volume possible for 90 gpm pump  
 52.1 gpm from 1 HDD scenario  
 volume required to maintain pool temperature for a HDD=1 day  
 estimated annual HDD; refer to HDD data tables from 2 weather stations in the vicinity of Lava Hot Springs

**CONCLUSION**

Continuous flow at 90 gpm would not maintain the desired temperature of the pool during a realistic HDD year

# SODA SPRINGS AP, IDAHO

## Period of Record General Climate Summary - Heating Degree Days

| Station:(108535) SODA SPRINGS AIRPORT                 |      |      |      |      |     |      |      |      |      |      |      |      |        |
|-------------------------------------------------------|------|------|------|------|-----|------|------|------|------|------|------|------|--------|
| From Year=1978 To Year=2012                           |      |      |      |      |     |      |      |      |      |      |      |      |        |
| Heating Degree Days for Selected Base Temperature (F) |      |      |      |      |     |      |      |      |      |      |      |      |        |
| Base                                                  | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Annual |
| 65                                                    | 1411 | 1230 | 1071 | 739  | 506 | 255  | 70   | 93   | 332  | 690  | 1039 | 1381 | 8816   |
| 60                                                    | 1256 | 1089 | 916  | 589  | 358 | 140  | 23   | 31   | 200  | 535  | 889  | 1226 | 7252   |
| 57                                                    | 1163 | 1004 | 823  | 501  | 277 | 90   | 11   | 15   | 135  | 444  | 799  | 1133 | 6394   |
| 55                                                    | 1101 | 947  | 761  | 442  | 228 | 64   | 7    | 9    | 100  | 384  | 739  | 1071 | 5854   |
| 50                                                    | 946  | 806  | 606  | 304  | 126 | 23   | 3    | 2    | 43   | 247  | 589  | 916  | 4611   |

Heating Degree Day units are computed as the difference between the base temperature and the daily average temperature. (Base Temp. - Daily Ave. Temp.) One unit is accumulated for each degree Fahrenheit the average temperature is below the base temperature. Negative numbers are discarded. Example: If the days high temperature was 65 and the low temperature was 31, the base 50 heating degree day units is  $50 - ((65 + 31) / 2) = 2$ . This is done for each day of the month and summed.

Table updated on Oct 31, 2012

Months with 5 or more missing days are not considered

Years with 1 or more missing months are not considered

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Western Regional Climate Center, [wrcc@dri.edu](mailto:wrcc@dri.edu)

# MCCAMMON, IDAHO

## Period of Record General Climate Summary - Heating Degree Days

| Station:(105716) MCCAMMON                             |      |      |      |      |     |      |      |      |      |      |      |      |        |
|-------------------------------------------------------|------|------|------|------|-----|------|------|------|------|------|------|------|--------|
| From Year=1949 To Year=2012                           |      |      |      |      |     |      |      |      |      |      |      |      |        |
| Heating Degree Days for Selected Base Temperature (F) |      |      |      |      |     |      |      |      |      |      |      |      |        |
| Base                                                  | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Annual |
| 65                                                    | 1289 | 1054 | 888  | 590  | 366 | 149  | 19   | 32   | 201  | 547  | 917  | 1224 | 7277   |
| 60                                                    | 1134 | 913  | 733  | 440  | 228 | 66   | 4    | 9    | 96   | 394  | 767  | 1069 | 5855   |
| 57                                                    | 1041 | 828  | 640  | 353  | 159 | 36   | 1    | 4    | 56   | 307  | 677  | 976  | 5078   |
| 55                                                    | 979  | 772  | 578  | 297  | 119 | 23   | 0    | 2    | 37   | 253  | 617  | 914  | 4591   |
| 50                                                    | 824  | 630  | 424  | 172  | 49  | 5    | 0    | 0    | 12   | 139  | 468  | 759  | 3483   |

Heating Degree Day units are computed as the difference between the base temperature and the daily average temperature. (Base Temp. - Daily Ave. Temp.) One unit is accumulated for each degree Fahrenheit the average temperature is below the base temperature. Negative numbers are discarded. Example: If the days high temperature was 65 and the low temperature was 31, the base 50 heating degree day units is  $50 - ((65 + 31) / 2) = 2$ . This is done for each day of the month and summed.

Table updated on Oct 31, 2012

Months with 5 or more missing days are not considered

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Western Regional Climate Center, [wrcc@dri.edu](mailto:wrcc@dri.edu)

Leaf Wetness:

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6:16 AM

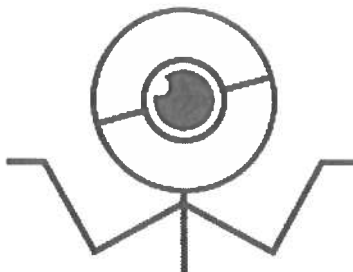
8:33 PM

Waning Gibbous | 92% Illuminated

Radar

**Webcam**

⚙ Compare



**Missing webcam**

[View webcams on WunderMap](#)

[Add Webcam](#)

Weather History for Lava Hot Springs, ID [KIDLAVAH2]

Daily Mode

February

1

2011

**View**

[Previous](#)

[Next](#)

**Summary**

**February 1, 2011**

|               | High  | Low    | Average |
|---------------|-------|--------|---------|
| Temperature   | 22 °F | -8 °F  | 8 °F    |
| Dew Point     | 4 °F  | -24 °F | -8 °F   |
| Humidity      | 49%   | 43%    | 46%     |
| Precipitation | 0 in  | --     | --      |

|                | High     | Low      | Average |
|----------------|----------|----------|---------|
| Wind Speed     | 20 mph   | --       | 10 mph  |
| Wind Gust      | 25 mph   | --       | --      |
| Wind Direction | --       | --       | NNW     |
| Pressure       | 30.27 in | 30.06 in | --      |

Graphs

Table



Download

## Weather History Table

February 1, 2011

| Time     | Temperature | Dew Point | Humidity | Wind  | Speed    | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
|----------|-------------|-----------|----------|-------|----------|----------|----------|---------------|----------------|
| 12:09 AM | 11.8 °F     | -3.6 °F   | 49 %     | North | 10.5 mph | 13.2 mph | 30.06 in | 0 in          | 0 in           |
| 12:20 AM | 11.7 °F     | -3.8 °F   | 49 %     | North | 15.4 mph | 15.4 mph | 30.06 in | 0 in          | 0 in           |
| 12:30 AM | 11.5 °F     | -4 °F     | 49 %     | North | 12.8 mph | 15.9 mph | 30.06 in | 0 in          | 0 in           |
| 12:39 AM | 11.3 °F     | -4.1 °F   | 49 %     | North | 13.2 mph | 13.2 mph | 30.06 in | 0 in          | 0 in           |
| 12:49 AM | 11.3 °F     | -4.1 °F   | 49 %     | NNW   | 15 mph   | 15.4 mph | 30.09 in | 0 in          | 0 in           |
| 12:59 AM | 10.9 °F     | -4.5 °F   | 49 %     | North | 10.5 mph | 16.8 mph | 30.09 in | 0 in          | 0 in           |
| 1:09 AM  | 10.8 °F     | -4.6 °F   | 49 %     | NNW   | 14.1 mph | 14.1 mph | 30.09 in | 0 in          | 0 in           |
| 1:19 AM  | 10.2 °F     | -5.1 °F   | 49 %     | North | 11.9 mph | 15 mph   | 30.09 in | 0 in          | 0 in           |
| 1:29 AM  | 10 °F       | -5.3 °F   | 49 %     | North | 15.4 mph | 15.4 mph | 30.09 in | 0 in          | 0 in           |
| 1:40 AM  | 9.7 °F      | -5.6 °F   | 49 %     | NNW   | 11 mph   | 15.4 mph | 30.09 in | 0 in          | 0 in           |
| 1:50 AM  | 9.5 °F      | -5.8 °F   | 49 %     | NNW   | 10.5 mph | 11 mph   | 30.09 in | 0 in          | 0 in           |

| Time    | Temperature | Dew Point | Humidity | Wind  | Speed    | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
|---------|-------------|-----------|----------|-------|----------|----------|----------|---------------|----------------|
| 1:59 AM | 9.5 °F      | -5.8 °F   | 49 %     | NNW   | 13.2 mph | 13.2 mph | 30.09 in | 0 in          | 0 in           |
| 2:09 AM | 8.2 °F      | -7 °F     | 49 %     | NNW   | 10.1 mph | 13.2 mph | 30.09 in | 0 in          | 0 in           |
| 2:19 AM | 7.9 °F      | -7.3 °F   | 49 %     | NW    | 12.8 mph | 13.2 mph | 30.09 in | 0 in          | 0 in           |
| 2:30 AM | 7.5 °F      | -7.6 °F   | 49 %     | NNW   | 15 mph   | 15 mph   | 30.09 in | 0 in          | 0 in           |
| 2:39 AM | 7.5 °F      | -7.6 °F   | 49 %     | North | 15 mph   | 15 mph   | 30.09 in | 0 in          | 0 in           |
| 2:50 AM | 7.5 °F      | -7.6 °F   | 49 %     | North | 20.1 mph | 20.1 mph | 30.09 in | 0 in          | 0 in           |
| 2:59 AM | 6.3 °F      | -8.8 °F   | 49 %     | NNW   | 13.2 mph | 20.1 mph | 30.09 in | 0 in          | 0 in           |
| 3:09 AM | 6.1 °F      | -9 °F     | 49 %     | NW    | 13.6 mph | 15.4 mph | 30.12 in | 0 in          | 0 in           |
| 3:19 AM | 6.1 °F      | -9 °F     | 49 %     | NW    | 11 mph   | 13.6 mph | 30.12 in | 0 in          | 0 in           |
| 3:29 AM | 5.5 °F      | -9.5 °F   | 49 %     | NNW   | 13.2 mph | 13.2 mph | 30.12 in | 0 in          | 0 in           |
| 3:40 AM | 5.5 °F      | -9.5 °F   | 49 %     | NNW   | 13.2 mph | 13.2 mph | 30.12 in | 0 in          | 0 in           |
| 3:49 AM | 4.5 °F      | -10.5 °F  | 49 %     | NW    | 16.8 mph | 16.8 mph | 30.12 in | 0 in          | 0 in           |
| 4:00 AM | 4.1 °F      | -10.8 °F  | 49 %     | NNW   | 16.8 mph | 16.8 mph | 30.12 in | 0 in          | 0 in           |
| 4:10 AM | 4.1 °F      | -10.8 °F  | 49 %     | NNW   | 15.9 mph | 24.6 mph | 30.09 in | 0 in          | 0 in           |
| 4:19 AM | 4.1 °F      | -10.8 °F  | 49 %     | NW    | 17 mph   | 19.7 mph | 30.12 in | 0 in          | 0 in           |
| 4:39 AM | 2.5 °F      | -12.3 °F  | 49 %     | NW    | 15.4 mph | 15.4 mph | 30.12 in | 0 in          | 0 in           |
| 4:49 AM | 2.1 °F      | -12.6 °F  | 49 %     | NNW   | 13.2 mph | 15.4 mph | 30.12 in | 0 in          | 0 in           |

| Time    | Temperature | Dew Point | Humidity | Wind | Speed    | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
|---------|-------------|-----------|----------|------|----------|----------|----------|---------------|----------------|
| 4:59 AM | 1.8 °F      | -13 °F    | 49 %     | NW   | 11 mph   | 13.2 mph | 30.12 in | 0 in          | 0 in           |
| 5:10 AM | 1.8 °F      | -13 °F    | 49 %     | NW   | 15.4 mph | 15.4 mph | 30.12 in | 0 in          | 0 in           |
| Time    | Temperature | Dew Point | Humidity | Wind | Speed    | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
| 5:19 AM | 1.8 °F      | -13 °F    | 49 %     | NW   | 15 mph   | 15.4 mph | 30.12 in | 0 in          | 0 in           |
| 5:29 AM | 1.8 °F      | -13 °F    | 49 %     | NW   | 13.6 mph | 16.3 mph | 30.12 in | 0 in          | 0 in           |
| 5:39 AM | 1.8 °F      | -13 °F    | 49 %     | NW   | 13.2 mph | 13.6 mph | 30.12 in | 0 in          | 0 in           |
| 5:49 AM | 1.8 °F      | -13 °F    | 49 %     | WNW  | 12.3 mph | 15.4 mph | 30.12 in | 0 in          | 0 in           |
| 5:59 AM | 1.9 °F      | -12.8 °F  | 49 %     | WNW  | 13.2 mph | 15 mph   | 30.15 in | 0 in          | 0 in           |
| 6:10 AM | 1.9 °F      | -12.8 °F  | 49 %     | NW   | 14.1 mph | 14.1 mph | 30.15 in | 0 in          | 0 in           |
| 6:20 AM | 1.9 °F      | -12.8 °F  | 49 %     | NW   | 12.8 mph | 15.4 mph | 30.15 in | 0 in          | 0 in           |
| 6:30 AM | 1.6 °F      | -13.1 °F  | 49 %     | NW   | 11 mph   | 13.2 mph | 30.15 in | 0 in          | 0 in           |
| 6:40 AM | 1.6 °F      | -13.1 °F  | 49 %     | NNW  | 15 mph   | 15 mph   | 30.15 in | 0 in          | 0 in           |
| 6:49 AM | 1.6 °F      | -13.1 °F  | 49 %     | NW   | 15 mph   | 15 mph   | 30.15 in | 0 in          | 0 in           |
| 6:59 AM | 0.7 °F      | -14 °F    | 49 %     | NW   | 13.2 mph | 15.4 mph | 30.15 in | 0 in          | 0 in           |
| 7:10 AM | 0.5 °F      | -14.1 °F  | 49 %     | NW   | 15 mph   | 15 mph   | 30.18 in | 0 in          | 0 in           |
| 7:20 AM | 0.5 °F      | -14.1 °F  | 49 %     | NW   | 15 mph   | 15 mph   | 30.18 in | 0 in          | 0 in           |
| 7:29 AM | 0.3 °F      | -14.3 °F  | 49 %     | NW   | 15 mph   | 15 mph   | 30.18 in | 0 in          | 0 in           |

| Time     | Temperature | Dew Point | Humidity | Wind | Speed    | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
|----------|-------------|-----------|----------|------|----------|----------|----------|---------------|----------------|
| 7:40 AM  | 0.3 °F      | -14.3 °F  | 49 %     | NNW  | 14.5 mph | 15 mph   | 30.18 in | 0 in          | 0 in           |
| 7:49 AM  | 0.3 °F      | -14.3 °F  | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.18 in | 0 in          | 0 in           |
| 8:00 AM  | 0.1 °F      | -14.5 °F  | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.18 in | 0 in          | 0 in           |
| 8:10 AM  | 0 °F        | -14.6 °F  | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.18 in | 0 in          | 0 in           |
| 8:19 AM  | 0 °F        | -14.6 °F  | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.18 in | 0 in          | 0 in           |
| 8:39 AM  | 2.1 °F      | -12.6 °F  | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.21 in | 0 in          | 0 in           |
| 8:49 AM  | 3.6 °F      | -11.3 °F  | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.21 in | 0 in          | 0 in           |
| 8:59 AM  | 5.4 °F      | -9.6 °F   | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.21 in | 0 in          | 0 in           |
| 9:09 AM  | 5.9 °F      | -9.1 °F   | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.21 in | 0 in          | 0 in           |
| 9:19 AM  | 7.2 °F      | -8 °F     | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.21 in | 0 in          | 0 in           |
| 9:30 AM  | 7.9 °F      | -7.3 °F   | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.21 in | 0 in          | 0 in           |
| 9:40 AM  | 8.6 °F      | -6.6 °F   | 49 %     | NNW  | 14.5 mph | 14.5 mph | 30.24 in | 0 in          | 0 in           |
| 9:49 AM  | 9.1 °F      | -6.1 °F   | 49 %     | NNW  | 13.2 mph | 14.5 mph | 30.24 in | 0 in          | 0 in           |
| 9:59 AM  | 10 °F       | -5.3 °F   | 49 %     | NNW  | 13.2 mph | 13.2 mph | 30.24 in | 0 in          | 0 in           |
| 10:09 AM | 10.4 °F     | -5 °F     | 49 %     | NNW  | 11 mph   | 13.2 mph | 30.24 in | 0 in          | 0 in           |
| 10:19 AM | 11.3 °F     | -4.1 °F   | 49 %     | NNW  | 10.5 mph | 11 mph   | 30.24 in | 0 in          | 0 in           |
| Time     | Temperature | Dew Point | Humidity | Wind | Speed    | Gust     | Pressure | Precip. Rate. | Precip. Accum. |

| Time     | Temperature | Dew Point | Humidity | Wind  | Speed    | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
|----------|-------------|-----------|----------|-------|----------|----------|----------|---------------|----------------|
| 10:29 AM | 13.3 °F     | -2.3 °F   | 49 %     | NNW   | 10.1 mph | 10.5 mph | 30.24 in | 0 in          | 0 in           |
| 10:39 AM | 14 °F       | -2.1 °F   | 48 %     | NNW   | 10.1 mph | 10.1 mph | 30.24 in | 0 in          | 0 in           |
| 10:50 AM | 14.5 °F     | -2 °F     | 47 %     | North | 8.1 mph  | 10.1 mph | 30.24 in | 0 in          | 0 in           |
| 10:59 AM | 15.6 °F     | -1 °F     | 47 %     | NNW   | 11 mph   | 11 mph   | 30.24 in | 0 in          | 0 in           |
| 11:09 AM | 17.1 °F     | 0.3 °F    | 47 %     | North | 11 mph   | 11 mph   | 30.24 in | 0 in          | 0 in           |
| 11:19 AM | 17.2 °F     | 0.5 °F    | 47 %     | NNW   | 15 mph   | 15 mph   | 30.24 in | 0 in          | 0 in           |
| 11:29 AM | 18.5 °F     | 1.2 °F    | 46 %     | NNW   | 10.5 mph | 15 mph   | 30.24 in | 0 in          | 0 in           |
| 11:40 AM | 19 °F       | 1.7 °F    | 46 %     | NNW   | 13.2 mph | 17 mph   | 30.24 in | 0 in          | 0 in           |
| 11:49 AM | 19.6 °F     | 2.2 °F    | 46 %     | NNW   | 13.2 mph | 13.2 mph | 30.24 in | 0 in          | 0 in           |
| 11:59 AM | 19.9 °F     | 2.5 °F    | 46 %     | NNW   | 15.4 mph | 15.4 mph | 30.24 in | 0 in          | 0 in           |
| 12:09 PM | 20.3 °F     | 2.8 °F    | 46 %     | North | 12.8 mph | 15.4 mph | 30.24 in | 0 in          | 0 in           |
| 12:19 PM | 20.5 °F     | 2.5 °F    | 45 %     | NNW   | 15.4 mph | 15.4 mph | 30.24 in | 0 in          | 0 in           |
| 12:29 PM | 20.5 °F     | 2.5 °F    | 45 %     | NNW   | 15.4 mph | 15.4 mph | 30.24 in | 0 in          | 0 in           |
| 12:39 PM | 20.5 °F     | 2.5 °F    | 45 %     | North | 10.5 mph | 15.4 mph | 30.24 in | 0 in          | 0 in           |
| 12:50 PM | 20.5 °F     | 2.5 °F    | 45 %     | NNW   | 12.8 mph | 13.6 mph | 30.24 in | 0 in          | 0 in           |
| 12:59 PM | 20.7 °F     | 2.7 °F    | 45 %     | NNW   | 11 mph   | 12.8 mph | 30.24 in | 0 in          | 0 in           |
| 1:10 PM  | 21.2 °F     | 3.2 °F    | 45 %     | North | 13.2 mph | 13.2 mph | 30.24 in | 0 in          | 0 in           |

| Time    | Temperature | Dew Point | Humidity | Wind  | Speed    | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
|---------|-------------|-----------|----------|-------|----------|----------|----------|---------------|----------------|
| 1:19 PM | 21.2 °F     | 3.2 °F    | 45 %     | NNW   | 11 mph   | 13.2 mph | 30.24 in | 0 in          | 0 in           |
| 1:29 PM | 21.6 °F     | 3.5 °F    | 45 %     | North | 13.2 mph | 13.2 mph | 30.24 in | 0 in          | 0 in           |
| 1:39 PM | 22.5 °F     | 4.3 °F    | 45 %     | NNW   | 14.1 mph | 15 mph   | 30.24 in | 0 in          | 0 in           |
| 1:49 PM | 22.5 °F     | 3.9 °F    | 44 %     | NNW   | 13.2 mph | 14.1 mph | 30.24 in | 0 in          | 0 in           |
| 2:00 PM | 22.1 °F     | 3.5 °F    | 44 %     | NNW   | 8.7 mph  | 13.2 mph | 30.24 in | 0 in          | 0 in           |
| 2:09 PM | 21.7 °F     | 3.2 °F    | 44 %     | NNW   | 13.2 mph | 13.2 mph | 30.21 in | 0 in          | 0 in           |
| 2:19 PM | 21.9 °F     | 3.4 °F    | 44 %     | NNW   | 12.8 mph | 13.2 mph | 30.21 in | 0 in          | 0 in           |
| 2:29 PM | 22.1 °F     | 3.5 °F    | 44 %     | NNW   | 10.5 mph | 13.2 mph | 30.21 in | 0 in          | 0 in           |
| 2:39 PM | 22.5 °F     | 3.9 °F    | 44 %     | North | 13.2 mph | 13.2 mph | 30.24 in | 0 in          | 0 in           |
| 2:49 PM | 21.6 °F     | 2.5 °F    | 43 %     | North | 12.8 mph | 15.4 mph | 30.24 in | 0 in          | 0 in           |
| 2:59 PM | 21.2 °F     | 2.7 °F    | 44 %     | NW    | 12.8 mph | 12.8 mph | 30.24 in | 0 in          | 0 in           |
| 3:10 PM | 21.7 °F     | 3.2 °F    | 44 %     | NNW   | 8.3 mph  | 13.2 mph | 30.24 in | 0 in          | 0 in           |
| 3:19 PM | 21.6 °F     | 2.5 °F    | 43 %     | NNW   | 10.5 mph | 11 mph   | 30.24 in | 0 in          | 0 in           |
| Time    | Temperature | Dew Point | Humidity | Wind  | Speed    | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
| 3:30 PM | 21.2 °F     | 2.7 °F    | 44 %     | NNW   | 12.8 mph | 13.2 mph | 30.24 in | 0 in          | 0 in           |
| 3:39 PM | 20.8 °F     | 1.9 °F    | 43 %     | NW    | 11 mph   | 12.8 mph | 30.24 in | 0 in          | 0 in           |
| 3:49 PM | 20.5 °F     | 1.5 °F    | 43 %     | NNW   | 10.1 mph | 12.8 mph | 30.24 in | 0 in          | 0 in           |

| Time    | Temperature | Dew Point | Humidity | Wind | Speed    | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
|---------|-------------|-----------|----------|------|----------|----------|----------|---------------|----------------|
| 3:59 PM | 20.3 °F     | 1.4 °F    | 43 %     | NW   | 12.3 mph | 13.2 mph | 30.24 in | 0 in          | 0 in           |
| 4:09 PM | 19.4 °F     | 0.6 °F    | 43 %     | NW   | 9.6 mph  | 12.3 mph | 30.24 in | 0 in          | 0 in           |
| 4:20 PM | 18.7 °F     | -0.1 °F   | 43 %     | NW   | 11 mph   | 11 mph   | 30.24 in | 0 in          | 0 in           |
| 4:29 PM | 18 °F       | -0.8 °F   | 43 %     | NW   | 12.3 mph | 12.3 mph | 30.24 in | 0 in          | 0 in           |
| 4:40 PM | 17.1 °F     | -1.6 °F   | 43 %     | NW   | 15 mph   | 15 mph   | 30.24 in | 0 in          | 0 in           |
| 4:49 PM | 16 °F       | -2.6 °F   | 43 %     | NW   | 12.3 mph | 15 mph   | 30.24 in | 0 in          | 0 in           |
| 4:59 PM | 14.9 °F     | -3.1 °F   | 44 %     | NW   | 10.5 mph | 12.8 mph | 30.24 in | 0 in          | 0 in           |
| 5:09 PM | 14.5 °F     | -3.4 °F   | 44 %     | NW   | 10.1 mph | 11 mph   | 30.24 in | 0 in          | 0 in           |
| 5:19 PM | 13.3 °F     | -4.6 °F   | 44 %     | NNW  | 10.5 mph | 10.5 mph | 30.24 in | 0 in          | 0 in           |
| 5:30 PM | 12.6 °F     | -5.2 °F   | 44 %     | NW   | 11 mph   | 11 mph   | 30.24 in | 0 in          | 0 in           |
| 5:39 PM | 11.7 °F     | -6 °F     | 44 %     | NNW  | 11 mph   | 11 mph   | 30.24 in | 0 in          | 0 in           |
| 5:50 PM | 10.9 °F     | -6.7 °F   | 44 %     | NW   | 8.7 mph  | 11 mph   | 30.24 in | 0 in          | 0 in           |
| 5:59 PM | 10.2 °F     | -7.3 °F   | 44 %     | NNW  | 10.1 mph | 10.1 mph | 30.24 in | 0 in          | 0 in           |
| 6:09 PM | 9.3 °F      | -8.2 °F   | 44 %     | NNW  | 10.5 mph | 11 mph   | 30.27 in | 0 in          | 0 in           |
| 6:20 PM | 9.1 °F      | -8.3 °F   | 44 %     | NNW  | 10.1 mph | 11 mph   | 30.24 in | 0 in          | 0 in           |
| 6:39 PM | 8.1 °F      | -9.3 °F   | 44 %     | NW   | 10.1 mph | 11 mph   | 30.24 in | 0 in          | 0 in           |
| 6:49 PM | 7.9 °F      | -9.5 °F   | 44 %     | NW   | 10.1 mph | 11 mph   | 30.27 in | 0 in          | 0 in           |

| Time    | Temperature | Dew Point | Humidity | Wind  | Speed   | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
|---------|-------------|-----------|----------|-------|---------|----------|----------|---------------|----------------|
| 6:59 PM | 7.3 °F      | -10 °F    | 44 %     | NW    | 5.8 mph | 10.1 mph | 30.27 in | 0 in          | 0 in           |
| 7:09 PM | 7 °F        | -10.3 °F  | 44 %     | SE    | 3.6 mph | 6.7 mph  | 30.27 in | 0 in          | 0 in           |
| 7:19 PM | 5.9 °F      | -11.3 °F  | 44 %     | SSE   | 3.1 mph | 3.6 mph  | 30.27 in | 0 in          | 0 in           |
| 7:30 PM | 4.8 °F      | -12.3 °F  | 44 %     | South | 0 mph   | 6.3 mph  | 30.27 in | 0 in          | 0 in           |
| 7:39 PM | 3.2 °F      | -13.8 °F  | 44 %     | South | 3.1 mph | 5.8 mph  | 30.27 in | 0 in          | 0 in           |
| 7:50 PM | 2.5 °F      | -14.4 °F  | 44 %     | South | 0 mph   | 3.6 mph  | 30.27 in | 0 in          | 0 in           |
| 7:59 PM | 1.9 °F      | -14.9 °F  | 44 %     | SW    | 0 mph   | 3.1 mph  | 30.27 in | 0 in          | 0 in           |
| 8:09 PM | 1.6 °F      | -15.3 °F  | 44 %     | West  | 4 mph   | 4 mph    | 30.27 in | 0 in          | 0 in           |
| 8:19 PM | 1.2 °F      | -15.6 °F  | 44 %     | WNW   | 0 mph   | 4 mph    | 30.27 in | 0 in          | 0 in           |
| 8:29 PM | 0.3 °F      | -16.4 °F  | 44 %     | WNW   | 0 mph   | 4 mph    | 30.27 in | 0 in          | 0 in           |
| Time    | Temperature | Dew Point | Humidity | Wind  | Speed   | Gust     | Pressure | Precip. Rate. | Precip. Accum. |
| 8:39 PM | 0 °F        | -16.8 °F  | 44 %     | SSW   | 4 mph   | 6.3 mph  | 30.27 in | 0 in          | 0 in           |
| 8:50 PM | -0.9 °F     | -17.6 °F  | 44 %     | SW    | 4 mph   | 4 mph    | 30.27 in | 0 in          | 0 in           |
| 9:00 PM | -1.5 °F     | -18.1 °F  | 44 %     | SW    | 0 mph   | 4 mph    | 30.27 in | 0 in          | 0 in           |
| 9:09 PM | -1.7 °F     | -18.2 °F  | 44 %     | SW    | 0 mph   | 0 mph    | 30.27 in | 0 in          | 0 in           |
| 9:19 PM | -1.8 °F     | -18.4 °F  | 44 %     | SW    | 0 mph   | 0 mph    | 30.27 in | 0 in          | 0 in           |
| 9:39 PM | -3.1 °F     | -19.6 °F  | 44 %     | SW    | 0 mph   | 0 mph    | 30.27 in | 0 in          | 0 in           |

| Time     | Temperature | Dew Point | Humidity | Wind  | Speed   | Gust    | Pressure | Precip. Rate. | Precip. Accum. |
|----------|-------------|-----------|----------|-------|---------|---------|----------|---------------|----------------|
| 9:50 PM  | -3.5 °F     | -19.9 °F  | 44 %     | SW    | 2.7 mph | 2.7 mph | 30.27 in | 0 in          | 0 in           |
| 9:59 PM  | -4 °F       | -20.4 °F  | 44 %     | SW    | 0 mph   | 2.7 mph | 30.27 in | 0 in          | 0 in           |
| 10:10 PM | -4.4 °F     | -20.7 °F  | 44 %     | SW    | 2.7 mph | 2.7 mph | 30.27 in | 0 in          | 0 in           |
| 10:19 PM | -4.5 °F     | -20.9 °F  | 44 %     | SW    | 0 mph   | 2.7 mph | 30.27 in | 0 in          | 0 in           |
| 10:29 PM | -4.7 °F     | -21.1 °F  | 44 %     | SW    | 0 mph   | 0 mph   | 30.27 in | 0 in          | 0 in           |
| 10:39 PM | -5.1 °F     | -21.4 °F  | 44 %     | SW    | 0 mph   | 0 mph   | 30.27 in | 0 in          | 0 in           |
| 10:49 PM | -5.6 °F     | -21.9 °F  | 44 %     | SW    | 0 mph   | 0 mph   | 30.27 in | 0 in          | 0 in           |
| 11:00 PM | -6 °F       | -22.2 °F  | 44 %     | SW    | 0 mph   | 0 mph   | 30.27 in | 0 in          | 0 in           |
| 11:10 PM | -6.3 °F     | -22.5 °F  | 44 %     | SW    | 0 mph   | 3.1 mph | 30.27 in | 0 in          | 0 in           |
| 11:20 PM | -7.2 °F     | -23.4 °F  | 44 %     | SW    | 2.7 mph | 2.7 mph | 30.27 in | 0 in          | 0 in           |
| 11:29 PM | -7.8 °F     | -23.9 °F  | 44 %     | SW    | 0 mph   | 2.7 mph | 30.27 in | 0 in          | 0 in           |
| 11:39 PM | -8 °F       | -24 °F    | 44 %     | NNW   | 6.3 mph | 6.3 mph | 30.27 in | 0 in          | 0 in           |
| 11:49 PM | -7.8 °F     | -23.9 °F  | 44 %     | NNW   | 4 mph   | 8.7 mph | 30.27 in | 0 in          | 0 in           |
| 11:59 PM | -8 °F       | -24 °F    | 44 %     | North | 3.1 mph | 4 mph   | 30.27 in | 0 in          | 0 in           |