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Final Report for ALDOT Project 931-065

# Determining the Average Available Workdays for ALDOT Construction Projects

Submitted to

The Alabama Department of Transportation

Prepared by

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Highway construction projects are susceptible to impacts from weather as it can directly affect the duration of projects by causing delays to construction activities. ALDOT uses pre-determined monthly Average Available Workdays (AAWDs) to determine schedule deviations for highway construction projects. AAWDs exclude weekends, legal holidays, rainy days, and days with cold air temperatures. This research developed a statewide weather-based guidance and determined monthly AAWDs for highway construction projects across the five ALDOT Regions. The study is based on the analysis of weather data from 88 climate stations with at least 10 years of valid data. The project selected and tested several rainfall and air temperature thresholds to determine variations of the monthly AAWDs with these limits. The monthly AAWDs for rainfall >0.2 in. and daily mean air temperature < 40 °F as adverse weather thresholds were then determined for five ALDOT Regions. Annual AAWDs were determined to be 185, 193, and 200 days for three climate zones (North, Central, and South Regions) in Alabama, but monthly available workdays vary year by year and should be considered for project planning. The determined AAWDs will serve as a guide to assist ALDOT and contractors in creating a more accurate project schedule.

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Research Report

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## ABSTRACT

Highway construction projects are susceptible to impacts from weather as it can directly affect the duration of projects by causing delays to construction activities. ALDOT uses pre-determined monthly Average Available Workdays (AAWDs) to determine schedule deviations for highway construction projects. AAWDs exclude weekends, legal holidays, rainy days, and days with cold air temperatures. This research developed a statewide weather-based guidance and determined monthly AAWDs for highway construction projects across the five ALDOT Regions. The study is based on the analysis of weather data from 88 climate stations with at least 10 years of valid data. The project selected and tested several rainfall and air temperature thresholds to determine variations of the monthly AAWDs with these limits. The monthly AAWDs for rainfall >0.2 in. and daily mean air temperature < $40^{o}$ F as adverse weather thresholds were then determined for five ALDOT Regions. Annual AAWDs were determined to be 185, 193, and 200 days for three climate zones (North, Central, and South Regions) in Alabama, but monthly available workdays vary year by year and should be considered for project planning. The determined AAWDs will serve as a guide to assist ALDOT and contractors in creating a more accurate project schedule.

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# CHAPTER 1 INTRODUCTION

Given the dynamic nature of the process, construction planning is a complex and time-consuming task. Contractors frequently face project delays and cost overruns, making accurate estimation and construction timeline adherence critical. Weather, planning, technical issues, and procurement decisions can cause deviations from the planned schedule (Le 2014).

Highway construction project durations are specified on contracts, which explicitly define the timeline for the completion of all work described on contract documents (Jeong et al. 2009; Taylor et al. 2012). Adequate procedures on how to determine contract durations for highway construction projects should be written by the state transportation agencies (e.g., project owner). These procedures should account for geography and climate difference throughout the State and the fact that some type of work can or cannot be undertaken during certain times of the year or may experience a reduction of the labor productivity (FHWA 2002). Contracts should clearly indicate how delays of all magnitude will be handled and include threshold values for predictable and unpredictable severe weather impacts (Nguyen et al. 2010).

Inaccurate estimation of contract time on highway projects can lead to major loses (Abdel-Raheem and Reyes 2020), as deviations from planned project durations can have an economic burden for transportation agencies, contractors, and a social impact on the lifestyle of the dwellers of the area. Establishing reasonable and accurate contract time for highway projects is imperative for transportation agencies, as if time is insufficient bid prices will increase along with contractor claims (FHWA 2002). Project schedulers need to consider, when determining contract duration, time-sensitive factors, such as material and equipment readability and logistics, labor, traffic conditions and locations constraints, including weather characterization (Herbsman and Ellis 1995). As Ballesteros-Pérez et al. (2017) stated, project durations can increase 5%–20% if weather-related delays are not considered during planning.

Construction activities are highly susceptible to adverse weather (Moselhi et al. 1997; Nguyen et al. 2010) as it impacts productivity which lead to an increase in unforeseen delays and costs (Ballesteros-Pérez et al. 2017) for contractors and project owners (Ballesteros-Pérez et al. 2018). Most construction projects are composed of multiple weather-sensitive activities which interact through a precedence sequences (Ballesteros-Pérez et al. 2018). Seasonal and daily weather changes by climate regions in the United States affect grading, surfacing and structural construction projects (Kenner et al. 1998). Moselhi et al. (1997) conducted a study in which they classified the productivity impact of adverse conditions on highway projects into two categories: (1) partial loss and (2) complete loss. A partial loss occurs when adverse weather causes a decrease in labor productivity on specific construction tasks or activities. In other words, while certain parts of the project may experience reduced efficiency or slower progress because of the weather, overall project work continues. On the other hand, a complete loss occurs when adverse weather conditions are severe enough to halt or completely halt all project activities. In this case, the weather conditions are so bad that work on the entire project is halted.

Environmental factors such as rainfall, tropical storms, and cold weather conditions can all have an impact on construction operations. Adverse weather during construction projects reduces productivity, causing significant project delays, and is a common source of time extension requests from contractors (Ballesteros-Pérez et al. 2017; Nguyen et al. 2010). Excessive rainfall can cause significant delays in grading operations, and cold weather below 40° F can prevent adequate compaction of bituminous paving (National Academies of Sciences 2017). In colder regions, numerous State Departments of Transportation (DOTs) implement seasonal restrictions, either complete or partial, which stop highway construction projects from occurring during the winter season. This typically spans from November 15th to April 1st.

This project aimed to develop statewide weather-based guidance to determine the monthly average available workdays (AAWDs) for highway construction projects in the state of Alabama. The study is based on the analysis of weather data from eighty-one (81) climate stations dispersed throughout the five ALDOT Regions, and border states, Georgia (2 stations) and Mississippi (4 stations), for an overall total of eighty-seven (87) climate station regions with at least 10 years of valid data. The climate data utilized in this study was sourced from the National Oceanic and Atmospheric Administration (NOAA) and involved the use of two specific databases: (1) the Global Historical Climatology Network (GHCN) and (2) the Global Summary of the Day (GSD), both obtained from the National Centers for Environmental Information (NCEI-NOAA).The project chose and tested several rainfall thresholds (e.g., >0, 0.1, 0.2, and 0.3 in.) and air temperature limits (e.g., 30, 35, and 40°F) to see how monthly AAWDs varied with these limits. Appropriate monthly AAWDs for highway construction projects are then determined based on project geographic locations (ALDOT regions).

The AAWDs developed can function as a valuable resource to aid ALDOT and contractors in several ways, including:

- Enhancing the precision of project schedules.
- Restructuring project planning processes.
- Minimizing contractual disputes between ALDOT and contractors.
- Refining contract duration specifications.
- Clearly define non-workdays and workdays.
- Ultimately leading to cost savings for taxpayers.

## 1.1 PROJECT OBJECTIVES

The objective of this project was to develop a robust method for determining monthly Adverse Weather Workdays (AAWDs) for highway construction projects across the five ALDOT Regions using current long-term (ten years or more) local climate data. The resulting tool aims to improve the accuracy of previous methods used by ALDOT engineers for AAWD estimation, and it can be easily updated by incorporating current weather data, ensuring its continued relevance. The project identified and selected appropriate rainfall and air temperature databases, as well as monthly AAWDs for highway construction projects, based on construction project geographic locations and tasks. To achieve the objective of this project six tasks were established:

1. **Literature Review & Survey:**
   Conduct a comprehensive literature review including journal and conference papers, state DOT manuals and polices, and studies relevant to the project's focus and a state-of-practice survey to evaluate the usual practices and guidelines employed by transportation agencies in the US concerning the management of adverse weather effects on the duration of highway construction project contracts.
2. **Identify & Assess Weather-Related Factors Affecting Construction Operations to Define Weather Condition Thresholds for Analysis:**
   Utilize insights gathered from the literature review and the state-of-practice survey to determine the threshold values of weather conditions for determining non-workdays of construction projects in this project. After consulting with the ALDOT project advisory committee, define/select the threshold values for determining non-workdays due to adverse weather conditions for ALDOT construction projects, and establish criteria for selecting data for further analysis.
3. **Develop Guidance for Determining Monthly Available Workdays (AWDs) and Average Available Workdays (AAWDs) for Weather Stations:**
   Outline the workflow for processing the collected data. Classify days as non-workdays due to adverse weather and identify available workdays throughout the records of weather stations. This process leads to determining monthly available workdays (AWDs) in each year and then monthly average AWDs (i.e., AAWDs) over many years (e.g., >10 years) for each climate station based on the criteria defined in this project.
4. **Determine AAWDs for Construction Projects in Each of the Five ALDOT Regions:**
   Distribute climate stations spatially among the five ALDOT Regions. Process the data to determine average AAWDs from all weather stations in each Region based on information from the corresponding climate stations.
5. **Use Recent Construction Projects to Verify AAWDs:**
   Realize a verification process using contractor’s daily projects records or logs from five completed highway projects. Compare the results obtained from the developed tool for

determining AAWDs and AWDs with information from climate stations near each project to assess the tool's validity and determine if calibration is required.

6. **Guidelines for Future Updates and Use of the Tools to Determine AWDs and AAWDs:**
   Provide the necessary materials and resources to ALDOT engineers and future users. This should include guidance on effectively managing and utilizing the developed tools to determine AAWDs and AWDs, as well as instructions on obtaining accurate data to ensure the tool delivers precise results.

## 1.2 REPORT ORGANIZATION

This report is divided into six chapters that address the objective of improving highway contract planning by considering adverse weather conditions and variability that can affect project duration. The first chapter serves as an introduction, providing an overview of the project objective and outlining the report's organization. The second chapter is a literature review that delves into various aspects, such as the impact of weather on construction activities, available literature on contract time determination systems, and the importance of accounting for non-workdays due to adverse weather. It also contains a detailed examination of the "Development of Working Day Weather Charts for Transportation Construction in South Dakota" study, which is closely related to the research conducted in this report. The third chapter presents the findings of a state-of-practice survey conducted among 50 DOT agencies. The survey sought information on current practices and guidance used by DOT construction engineers in determining non-workdays due to inclement weather. The fourth chapter focuses on the project framework, outlining the project goal and detailing the methodology used in this research. It also discusses the sources and tools used to create charts and guidelines that will allow ALDOT engineers to calculate the AAWDs for highway projects in each of the five ALDOT Regions. The results of the developed charts and guidelines are showcased in Chapter 5, which are intended to assist ALDOT engineers in determining AAWDs for highway projects in the five ALDOT Regions. This chapter ends by providing guidance and final recommendations for future uses of the tool and it also highlights future recommendations for improving the current schedule review practice. The fifth chapter focuses on validating the AAWD tool developed through recently finished projects by the Alabama Department of Transportation (ALDOT). In this chapter, we delve into the outcomes of a thorough examination, comparing the daily project logs. This comparison involves assessing the contractor's claims regarding non-workdays and workdays against the established workdays determined through the utilization of our developed tool, which sources data from the nearest climate stations data obtained from NOAA databases. Finally, based on the research findings, Chapter 6 provides the summary and conclusions of the study guidance and final recommendations.

## 1.3 Executive Summary

Spreadsheet-based tools were developed to determine monthly AAWDs from long-term climate data (10–121 years) in 88 weather stations (cities) including 83 stations in Alabama, two stations in Georgia, and three stations in Mississippi. The maximum number of years of weather data used was 121 at Talladega (East Central Region). There were 45, 28, 17 stations with more than 30, 50, and 70 years of weather data to determine AAWDs, respectively. Long-term weather data were from NOAA's two databases: (1) Global Summary of the Day (GSOD) and (2) Global Historical Climatology Network (GHCN). There are 23, 19, 14, 8, and 24 stations used to determine AAWDs for ALDOT North Region, West Central Region, East Central Region, Southwest Region, and Southeast Region, respectively.

Non-workdays for construction projects include weekends, Alabama legal holidays (12 or 13 days/year), and adverse weather days. Adverse weather conditions were determined from thresholds of daily rainfall greater than 0.2 in. and daily mean air temperature less than 40 $^{o}$F. Monthly available workdays (AWDs) were first determined in each month in each year for each station, and then AAWDs were determined for each station over years with valid data then each ALDOT Region using all stations within a Region. It was further found that AAWDs can be grouped into three climate zones in Alabama: ALDOT North Region, Central Regions (East Central and West Central Regions), and South Regions (Southeast and Southwest Regions) with annual AWWDs of 185, 193, and 200 days as shown in Table 1.1. These annual AWWDs are eight (Divisions 1 and 2), five or seven (Divisions 3 to 5), and two to five (Divisions 6 to 9) more days when comparing with ALDOT 1998 and 2003 studies (Table 2-1).

The standard deviations of average AAWDs (Table 1.1) from all stations in a Region or zone were low and ranged from zero to three days. Most warmer months (April to October) had almost the same AAWDs because of zero or one day for standard deviation, but winter months had large variations. The minimum and maximum AAWDs only differed by one or two days in April to October, but up to seven days in January and December. This means that the AAWDs in summer/fall months can be determined from one station (e.g., with long data record and little missing data) in the Region, which is what ALDOT did in two previous studies (one representative station for each Region). For winter months, it is necessary to use local weather data to determine AAWDs.

The maximum difference of AWDs over available years in summer is 13 days (2.5 weeks) and 20 days (4 weeks) in winter months. Therefore, monthly AWDs can vary significantly from one year to another, depending on precipitation and air temperature. Therefore, it is recommended using Excel-based tools developed for this project to determine monthly AWDs during the project period, especially for winter months, using long-term climate data from a nearby weather station. Guidance, electronic data files, and training videos are provided to ALDOT for future applications.

**Table 1-1. Monthly Average Available Workdays in three Alabama climate zones.**

| Month | North Region | Central Regions | South Regions |
|---|---|---|---|
| Jan | 9 | 11 | 13 |
| Feb | 10 | 12 | 14 |
| March | 16 | 17 | 18 |
| April | 17 | 17 | 17 |
| May | 18 | 18 | 18 |
| June | 17 | 17 | 17 |
| July | 18 | 17 | 17 |
| Aug | 19 | 19 | 18 |
| Sept | 18 | 18 | 18 |
| Oct | 18 | 19 | 19 |
| Nov | 14 | 15 | 16 |
| Dec | 11 | 13 | 15 |
| Annual AAWDs | 185 | 193 | 200 |
| % of 365 days | 51% | 53% | 55% |

# CHAPTER 2. LITERATURE REVIEW

## 2.1 BACKGROUND

Highway construction project durations are specified on contracts, which explicitly define the timeline for the completion of all work described on the project's contractual documents (Jeong et al. 2009; Taylor et al. 2012). Adequate procedures on how to determine contract time for highway projects should be established by the transportation state agencies. These procedures should account for geography and climate difference throughout the State and the fact that some type of work can or cannot be undertaken during certain times of the year or may experience a reduction of the labor productivity (FHWA 2002). Contracts should clearly indicate how delays of all magnitude will be handled and include threshold values for predictable and unpredictable severe weather impacts (Nguyen et al. 2010).

According to the Federal Highway Administration (FHWA) policy, each state must establish necessary documented processes for determining project contract durations (FHWA 2002). As a result, state DOTs have developed various contract time determination systems (CTDSs) or procedures, such as Texas DOT CTDS, Louisiana CTDS, Kentucky CTDS (Taylor et al. 2012) and Oklahoma CTDS (Abdel-Raheem and Reyes 2020; Jeong et al. 2009). Approximately 15 DOTs have developed and use CTDSs, while 17 DOTs currently rely on engineering experience to determine contract time, and other DOTs use a variety of similar methods (Abdel-Raheem and Reyes 2020). The effect of weather on production rates was taken into account in the CTDSs developed by the DOTs of Indiana, Oklahoma, and Wisconsin (Abdel-Raheem and Reyes 2020). Before reporting production rates, these CTDSs either provide an adjustment factor or solicit user input on adjustment factors applicable to different work items. There is an increase in the number of DOTs who recognize weather as a major factor affecting construction project productivity rates (Abdel-Raheem and Reyes 2020).

## 2.2 IMPACT OF ADVERSE WEATHER IN CONSTRUCTION ACTIVITIES

The construction activity itself, the workers performing the activity, and the environment in which the activity is performed are three sources of variability in task completion time (Le 2014). Accurate forecast of highway project contract time including the effect of adverse weather is crucial for contractors, as it allows to predict more realistic duration and costs and helps to aim litigation process between transportation agencies and subcontractors by clearly stating and defining time extensions due to weather day beyond the normal conditions (Jeong et al. 2009; Moselhi et al. 1997). The weather parameters (rainfall, temperature, wind, etc.) and the magnitude of its effect on the project duration depend on the geophysical conditions of the project and the type of construction developed (Kenner et al. 1998). Rainfall is one of the major uncertainty factors that has adverse impact on productivity and duration of highway construction activities (Pan 2005). By determining the weather impact, the complications of assessing time-extension dispute and unpredictable cost can be reduced (Smith and Hancher 1989). Contract managers should define in the contracts how time extensions due to adverse weather are granted and differentiate them from other delay-causer factors (Nguyen et al. 2010). However, adverse weather and a normal weather delay must be defined by the project scheduler as they might have a different impact on the project duration (Smith and Hancher 1989).

The impact of adverse weather conditions, such as rain, is a common cause of construction project delays, legal claims, and economic losses (Ballesteros-Pérez et al. 2018). Engineers managing highway construction projects should take into account the amount, frequency, intensity, and duration of precipitation on various construction operation tasks. However, there is little or no guidance on how to quantify the impact of the rain and other adverse weather conditions. Several studies have been conducted to develop progress schedules and the critical path method for calculating contract time (FHWA 2002; Herbsman and Ellis 1995). The impact of weather on the duration of construction activities and created an automated decision support system (dubbed WEATHER) was determined by Moselhi et al. (1997) to calculate the combined effect of reduced labor productivity and work stoppage caused by adverse weather conditions on construction sites. Their system is portable and can be used in any city in Canada where weather data is available, but it cannot be used for construction projects in the United States.

Nguyen et al. (2010) list seven factors that need to be considering when accounting the effect of weather-related delay on highway projects: 1) definition of normal weather, 2) weather thresholds, 3) type of construction activity, 4) lingering days, 5) criteria for lost day, 6) lost days equivalent due to loss of productivity and 7) workdays lost versus calendar days lost. Nagata and Haydt (2018) suggested the following approaches to account for lost day due to weather when developing the contract schedule: a) Include non-workdays in the schedule calendars to represent the workdays that might be lost to adverse weather. b) Increasing the durations of weather-sensitive work activities to represent the workdays that might be lost to adverse weather. c) Adding an “adverse weather” activity at the end of project with a duration that equals the number of workdays that might be lost to adverse weather.

## 2.3 Contract Time Determination System

Working days are the most used method of defining contract time (Hinze and Couey 1989). In a 1989 survey, 34% of DOTs allocated construction time using working days, 12% using calendar days, and 14% using completion dates (Hinze and Couey 1989). Weather has a significant impact on construction productivity; 60% of state DOTs surveyed included expected weather delays in contract time estimates (Hinze and Couey 1989). "How should a project schedule incorporate workdays that might be lost due to adverse weather?" is a frequently debated question (Nagata and Haydt 2018). The critical path method is frequently used to calculate project completion time and is supported by a variety of scheduling software packages such as Microsoft Project, CPM Scheduling Primavera, and others.

Engineers should consider several factors, such as weather, location, soils, traffic, and equipment technology, when determining construction contract time and productivity rates (Abdel-Raheem and Reyes 2020). However, there is currently no guidance on how to consider adverse weather conditions on construction operations. The creation of project-specific contract time or production rates frequently relies on "rules of thumb" or engineering judgment. The contract time could be over- or underestimated if weather data is not properly analyzed. Overestimation may cause the project to be completed later than expected. Underestimation might result in a contractor bidding higher unit prices in order to accelerate the work.

The WEATHER program (Moselhi et al. 1997) performs a statistical analysis on 10 years of historical hourly weather data from the city where the construction project is located in order to determine productivity factors for construction activities in Canda.

Another method for considering weather impacts on construction planning is to analyze historic weather data to determine the AAWDs in each calendar month that construction operations can continue. ALDOT's Construction Bureau, for example, developed AAWDs using 3-5 years of rainfall data from major cities or airports in Alabama (Huntsville, Birmingham, Tuscaloosa, Montgomery, and Mobile), shown in Figure 2-1. The number of AWDs in each month was manually counted, excluding weekends, legal holidays, rainy days, and days with cold air temperatures.


**Figure 2-1. ALDOT Divisions, Alabama counties, and five major cities and/or airport used to determine AAWDs in 1989 and 2003 studies.**

ALDOT engineers conducted two analyses, one in 1989 and one in 2003. In the 1989 analysis, the state was divided into three zones, each with two to four ALDOT Division, presented in Figure 2-1, whereas the state was divided into four zones in the 2003 study. Each month, AAWDs ranged from 8 to 19 days. Because of the effects of colder weather on paving operations during the winter and spring months, two Divisions (Divisions 1 and 2) in northern Alabama had fewer AAWDs. Despite having a higher number of rainfall events, four Divisions (Divisions 6-9) in southern Alabama have slightly higher AAWDs due to warmer temperatures. Between the two studies, AAWDs differ by no more than two days. The results obtained in these studies are presented in Table 2-1.

**Table 2-1. AAWDs determined in the 1989 and 2003 ALDOT studies.**

| Month | 1989 Study | | | 2003 Study | | | |
|---|---|---|---|---|---|---|---|
| | Divisions 1-2 | Divisions 3–5 | Divisions 6–9 | Divisions 1-2 | Divisions 3–5 | Divisions 6-7 | Divisions 8-9 |
| **Jan** | 9 | 11 | 14 | 11 | 12 | 15 | 16 |
| **Feb** | 9 | 11 | 14 | 10 | 12 | 15 | 15 |
| **March** | 16 | 17 | 17 | 15 | 16 | 16 | 16 |
| **April** | 16 | 17 | 17 | 16 | 17 | 17 | 18 |
| **May** | 17 | 18 | 18 | 16 | 17 | 18 | 19 |
| **June** | 17 | 17 | 16 | 15 | 15 | 15 | 15 |
| **July** | 16 | 15 | 14 | 16 | 16 | 15 | 16 |
| **Aug** | 18 | 17 | 18 | 18 | 17 | 18 | 17 |
| **Sept** | 16 | 17 | 17 | 16 | 16 | 16 | 17 |
| **Oct** | 19 | 19 | 19 | 18 | 19 | 19 | 19 |
| **Nov** | 16 | 17 | 17 | 16 | 16 | 16 | 16 |
| **Dec** | 8 | 12 | 15 | 10 | 13 | 15 | 14 |
| **Total** | **177** | **188** | **196** | **177** | **186** | **195** | **198** |
| **% of 365 days** | **48%** | **52%** | **54%** | **48%** | **51%** | **53%** | **54%** |

### ***Liquidated damages & time extensions in construction projects***

The topic of liquidated damages and extensions of time is complicated. They often lead to contract claims in construction project contracts (Eggleston 2009). In examining the treatment of liquidated damages within the construction industry, it is evident that practices vary among different entities. According to Hinze and Couey (1989), the Forest Service offices typically exclude liquidated damages from their contracts, while the Corps of Engineers employ calendar days for assessing such damages. Meanwhile, departments of transportation (DOTs) lack a consistent approach to evaluating liquidated damages.

There are misconceptions about the purpose of liquidated damages and extensions of time. Contrary to common beliefs, liquidated damages actually help contractors by limiting their liability for completing work late and showing them the risks involved when submitting a bid. This challenges the idea that these provisions only benefit employers. While liquidated damages provide relief for employers and the right to deduct damages from payments to the contractor, relying solely on them might put employers at a disadvantage if actual losses are greater than the agreed level. This understanding emphasizes the complexity of contractual provisions in construction projects and highlights the importance of accurately determining contractual time durations, especially considering the impact of adverse weather conditions (Eggleston 2009).

## 2.4 State Agency AAWDs Guidance and Reference

Most DOTs agencies in the U.S. have developed tools and methods that allow planners to assess the weather-related delays and more accurately build project schedules and contracts (Smith and Hancher 1989; Taylor et al. 2012). The accuracy of the tools requires an understanding of the effect of the weather on different types of construction and geographical and climate characteristics of the projects' location (Kenner et al. 1998).

For the Texas Department of Transportation (TxDOT), Woods et al. (2006) proposed a simple regression equation that contractors can use to estimate the number of non-workdays that will occur during any month of a construction project. Monthly precipitation, monthly temperature, number of weekend days, and number of holidays are all input variables in the equation. The necessary input data for calculating non-workdays are easily accessible on the web. The study emphasized the importance of accurately estimating non-workdays to reduce the impact of severe weather on project schedules. To avoid disputes over weather-related non-workdays, the Texas Department of Transportation has increasingly required contractors to bid on fixed contract periods. This method shifts risk to contractors, making it critical for them to have a dependable tool for calculating and forecasting the number of workdays lost due to inclement weather.

A step-by-step methodology for predicting rain delays and an analysis of rainfall event probabilities in the Asheville, North Carolina area was developed to demonstrate how construction project managers can calculate statistical probabilities of significant rainfall events to forecast delays; Ford et al. (2009) suggests that during the proposal stage, project managers can use daily rainfall datasets to estimate potential delays and assess the feasibility of the customer's provided timeline.

### 2.4.1 Study SD97-07 by the South Dakota Department of Transportation

After the recognition that resolving disputes between contractors and the South Dakota Department of Transportation (SDDOT) contract duration and time extension due to weather consumes a significant amount of time and effort during the contracting period; the SDDOT realized the need of including more innovating contracting methods that will help to speed up highway construction projects, such as incentive-disincentive contracts, A+B bidding, and lane rental. However, before the implementation of these contract procedures, the SDDOT's engineers and contractors need guidance on the appropriate number of constructions working days for grading, surfacing, and structural projects in different climate regions of South Dakota. Therefore, the study SD97-07 prepared for the South Dakota Department of Transportation (SDDOT) and titled as "Development of Working Day Weather Charts for Transportation Construction in South Dakota", was developed to provide the amount of working-days that will be available for each of the South Dakota climate zone and for each type of construction project, i.e., grading, surfacing, and structural projects.

The primary goals of this project were to: 1) reduce the risks that contractors face when bidding on innovative contracting, calendar-day, working-day, and completion-date projects; 2) reduce the frequency and severity of disputes, claims, time extension requests, and costs associated with weather-related delays; and 3) provide the Department of Transportation with tools to determine contract completion requirements more accurately (Kenner et al. 1998).

The EarthInfo summary of the day CD-ROM which had completed historical climate records for up to 1995, for both active and inactive weather stations in South Dakota was the primary source used to create the weather database used in this study. The database collected weather records such as daily precipitation, snowfall, maximum and minimum temperatures, and the spatial information related to each station such as latitude, longitude, and period of data record coverage. A total of 293 climate stations were downloaded for analysis, however just 103 stations were used to develop the weather charts after applying the following selection criteria:

1. Only active stations were used.
2. Stations with at least 30 years of record were used.
3. The percentage coverage of the records must be at least 90%.
4. Climate stations must have valid precipitation and temperature data.

To spatially distribute the climate stations in this study, the Inverse Distance Weighted (IDW) interpolation method was used. IDW assumes that the influence of each climate station decreases with distance, so closer points are given more weight. The number of nearest neighbors, which was set to 12 for this study, and the power exponent, which controls the significance of surrounding points on the interpolated value, were both specified for IDW.

The criteria used to classify non-working days were based on the values analyzed from literature reviews, interviews with contractors and field engineer and field notes from 54 projects. To compare the weather-related diary comments with the climate station data, the project data tables were created. The construction projects were geolocated and overlaid with climate stations, with the closest stations (usually within ten miles) chosen to validate the weather comments from the project records. The created project data tables included project coordinates, corresponding climate station information, climate data (such as maximum and minimum temperature, precipitation, and snowfall), bio-weekly progress report weather comments, and field engineer diary weather-related comments. Based on the information gathered in the project data table, threshold for precipitation was determined, however, due to the lack of data it was impossible to determine temperature thresholds (Kenner et al. 1998).

From the evaluation of all the projects (54), it was noted that precipitation amounts typically ranged between 0.25 in. and 0.50 in. for all construction types resulted in non-working days, with the notable exception that extreme precipitation exceeding 0.75 in. for grading projects but not for surfacing or structural projects. Table 2-2 shows the statistics of the estimated threshold for precipitation based on the construction type determined from the project data tables.

**Table 2-2. Statistic of Estimated Threshold Based on Construction Type (Table 4.3) from the SD97-07 study (Kenner et al. 1998).**

| Construction Type | Surfacing | | Grading | | Structural | | Multi-task | |
|---|---|---|---|---|---|---|---|---|
| Statistics/Units | (mm) | (in.) | (mm) | (in.) | (mm) | (in.) | (mm) | (in.) |
| Max | 11.43 | 0.45 | 11.43 | 0.45 | 12.7 | 0.5 | 10.16 | 0.4 |
| Min | 7.62 | 0.3 | 6.35 | 0.3 | 7.62 | 0.3 | 7.62 | 0.3 |
| Median | 10.16 | 0.4 | 8.89 | 0.35 | 8.89 | 0.35 | 10.16 | 0.4 |
| Mean | 9.65 | 0.38 | 8.64 | 0.34 | 9.4 | 0.37 | 9.65 | 0.38 |

One of the tasks held in this study that helped the researchers determine weather related factors and their influence on construction project durations was the interview of construction contractors and SDDOT engineers. A total of 33 contractors from the 54 projects, which daily records were used to compare and create project data tables, were interviewed, which according to the author, represents an even distribution among the project types studied.

The interview process and evaluation of project data tables revealed that grading project were affected by precipitation events that occur in previous days causing to add an additional non-working day; this led the research to make a division resulting in grading and surfacing/structural projects.

For temperature, thresholds could not be determined from the WPRs or diaries due to a lack of data and documentation, so a temperature threshold of 32°F was chosen based on existing literature and its use by various DOTs. The estimation of the expected weather day for each month is determined by implementing a statistical approach using as precipitation threshold of greater than 0.30 in., a maximum daily temperature threshold of less than 32 °F and 40 °F, and sensitivity analysis on the precipitation threshold's impact.

The 80$^{th}$ percentile (not average or median) was a statical approach used to determine the adverse weather days for all the scenarios. The percentile is the cumulative frequency (number of years over the thirty-year period) of occurrences, i.e., the number of days that exceeded the 0.30 in. precipitation threshold in June. An example presented in the study shows the analysis for the Pierre Municipal AP station, which had data records from 1965–1994; the analysis results (Figure 2-2) show that over a thirty-year period, the occurrence of days with more than 0.30 in. of precipitation in June is five days based on 80 percentile, which means 20% of the 30 years have more than five days in June with precipitation greater than 0.3 in. Kenner et al. (1998) also presented the results (Figure 2-3) of the sensitivity analysis performed for the Pierre Municipal Airport station using precipitation thresholds of 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 in.

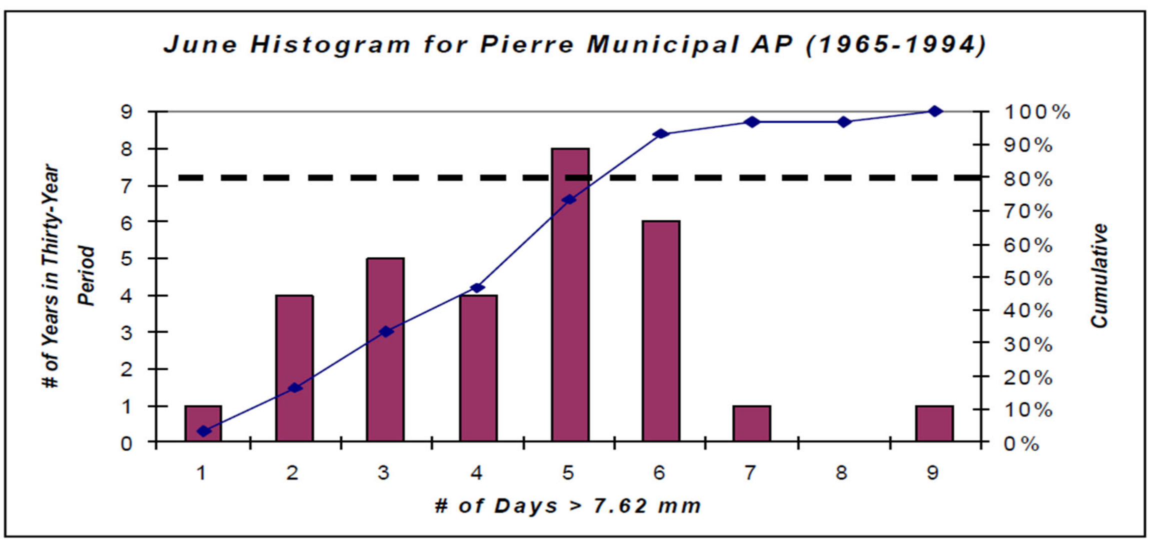


**Figure 2-2. Histogram of Adverse Weather days for June at Pierre Municipal Airport, Figure 5.1 from the SD97-07 study (Kenner et al. 1998).**

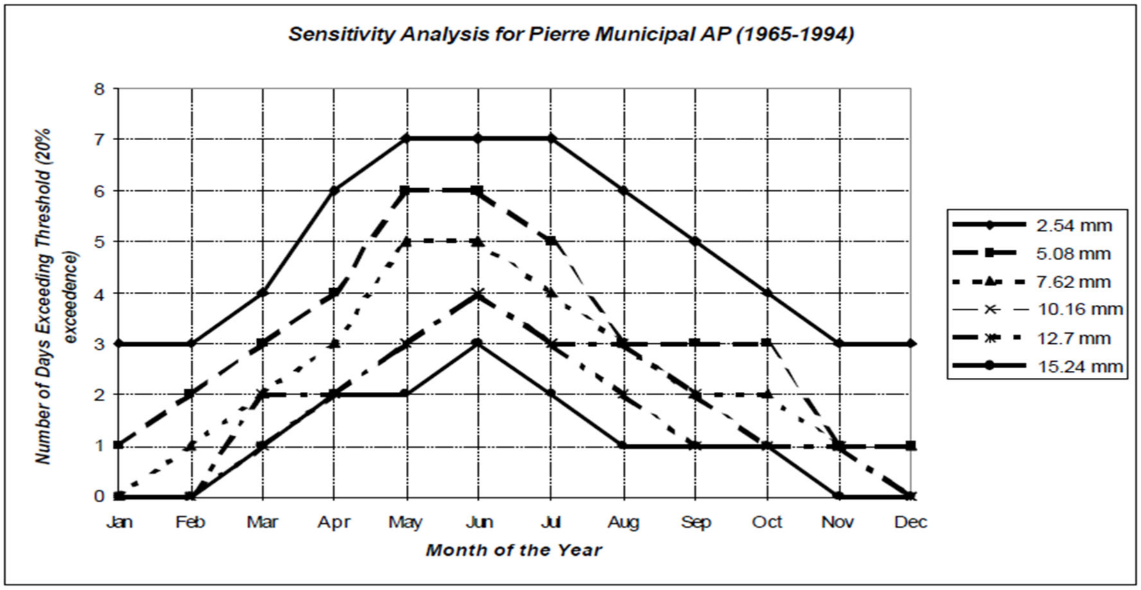


**Figure 2-3. Monthly number of exceedances for six rainfall thresholds, Figure 5.3 from the SD97-07 study (Kenner et al. 1998).**

In summary, the following criteria were used for the 80$^{th}$ percentile to classify non-working days were based on the values analyzed from literature reviews, interviews with contractors and field engineer and field notes from 54 projects, and sensitivity analysis:

1. To determine adverse weather days for all construction types across the state, a uniform precipitation threshold of 0.30 in. was used.
2. Two temperature thresholds, 32°F and 40°F, were uniformly applied across the state, with the results comparing them.
3. For grading projects only, a precipitation threshold of 0.75 in. was used to identify additional adverse weather days.
4. To avoid double counting, a joint probability of temperature below 32°F and precipitation greater than 0.3 in. was calculated. The same method was used for temperatures less than 40°F and precipitation greater than 0.3 in., but only for surfacing and structural projects.

### 2.4.2 RESULTS OF SDOT PROJECT

The number of adverse weather days determined was incorporated into the spatial representation of climate stations. Using these data, spatial distributions of expected adverse weather days were generated for the construction season (April 1 to November 30) and the off-season (December 1 to March 31). The construction season spatial distribution was utilized to establish climate zones (zone one to six in Figure 2-4) since working days are only counted during this period. The zones were modified to follow county lines to make it easy to distinguish which zone a project was in. The climate stations were then assigned to their respective zones, and summary data including the maximum, minimum, mean, and standard deviation of expected adverse weather days were calculated for each zone and construction category. In each zone, the standard deviation of expected adverse weather days during construction season from climate stations was small (ranging from 0-2 days with a large majority having a standard deviation of one day).

The regional weather charts created could be used by construction contractors to request time extensions for their projects, one day for 0.30 in. of rain, two days for 0.75 in. of rain, and one day for maximum daily temperatures of 32°F or less. Three charts were developed by Kenner et al. (1989) provide information such as:

- **Chart 1:** Cumulative count of day available for construction in a month (including weekends and holidays, and excluding the estimated number of adverse weather days)
- **Chart 2:** The estimated percentage of expected calendar days available per month for each zone and construction type (including weekends and holidays, and excluding the estimated number of adverse weather days)
- **Chart 3:** The expected number of adverse days remaining in a month in calendar day and the expected number of calendar days remaining in any month for each zone and construction type.

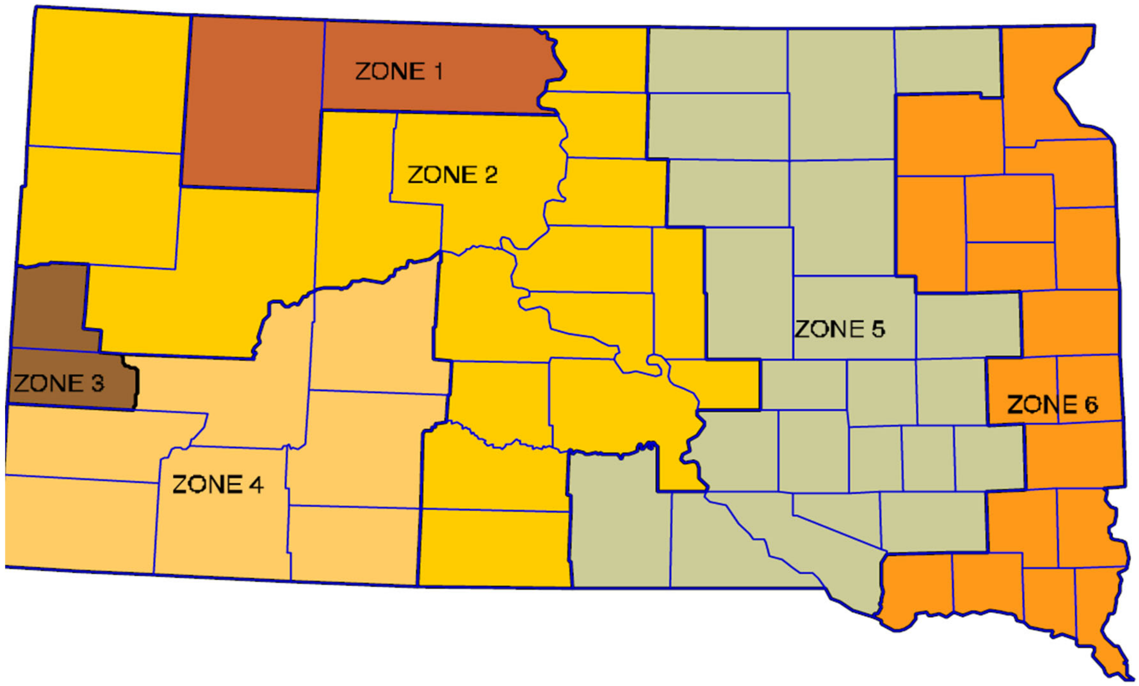


**Figure 2-4. Spatial distribution of the zones used to determine the adverse weather days for South Dakota SD97-07 study (Kenner et al. 1998).**

# CHAPTER 3. SURVEY OF STATE PRACTICES FOR AAWDS DETERMINATION AND USE

A state-of-practice survey was conducted to assess the current practices employed by state Departments of Transportation (DOTs) in considering the impact of adverse weather on the planning and duration determination of highway projects. The survey was distributed to the Directors of the construction division or similar positions at 50 state DOTs, as well as the District of Columbia DOT.

Out of the 51 DOTs contacted, a total of 30 DOTs responded, resulting in a survey response rate of 51%, depicted in Figure 3-1 . The respondents provided valuable information regarding the current practices and guidelines utilized to evaluate the effects of weather-related parameters. Additionally, the survey explored the methods employed to determine adverse weather conditions or non-workdays for highway construction projects. The survey questions and a summary of the raw survey results are given elsewhere by Mejia (2023) in Appendix A and Appendix B for her Master thesis**.**

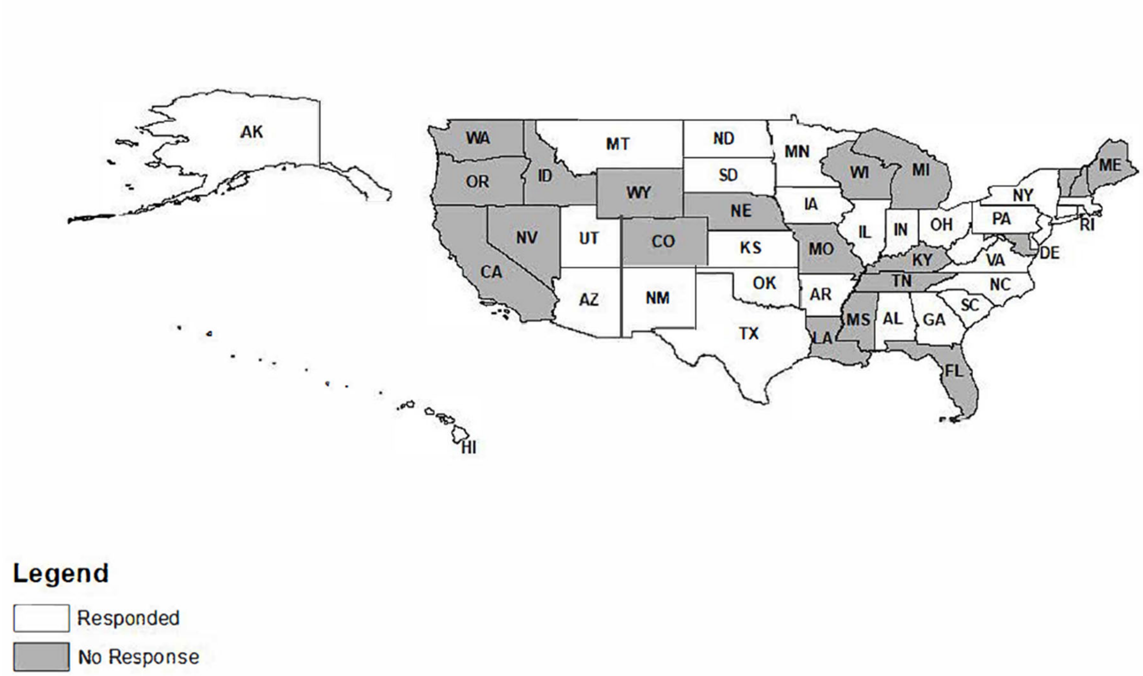


**Figure 3-1. State-of-practice survey's DOTs response status.**

This chapter is organized into seven sections: (1) description of the survey questionnaire logic, (2) what contract type and delayer factors have DOTs agencies identified for highway projects, (3) current status of existing guidance to determine non-workdays due to adverse weather conditions by state DOTs, (4) which criteria values are being used by DOTs to define non-workdays due adverse weather conditions, (5) others criterion and tools implemented to evaluate non-workdays due to weather, (6) how states DOTs perceive the weather impact on construction activities in roadway projects, and (7) the track of the cost impact due to adverse weather in highway construction by DOTs agencies.

## 3.1 Questionnaire Logic

The survey questions were thoroughly discussed with representatives from ALDOT prior to distribution. The questionnaire targeted construction professionals from state DOTs and sought concise yet precise information as input.

Questions Q0 (a & b) through Q4 were applicable to all participants. The fourth question was deliberately formulated to differentiate DOTs agencies that utilize guidance and/or manuals to determine the impact of adverse weather on highway projects from those DOTs that do not. Respondents who answered negatively to Q4 proceeded to questions Q4.1–Q4.2 and concluded with the final survey questions, Q15–Q16. Conversely, participants who answered affirmatively to Q4 advanced to questions Q5–Q7.

The seventh question served as an additional pivotal point, where respondents were queried regarding the categorization of the guidance used to determine non-workdays due to adverse weather conditions. Affirmative responses to Q7 led to Q8.a, requiring respondents to provide specific weather parameter values for each project type, i.e., grading, surfacing (asphalt/concrete), structural, and multitasking projects. Conversely, a negative response led to Q8.b, where general criteria values were requested as input. The subsequent questions inquired about Q9-Q12.

Based on the recorded responses in Q7, participants who answered "Yes" were then prompted with Q13.a, where specific project-type information, like Q8.a, was requested. On the other hand, respondents who answered "No" were directed to Q13.b, which sought more general criteria as input. Following this, respondents were presented with Q14–17.

## 3.2 Contract Type and Delayer Factors in Highway Construction

Question Q1 asked about the contract time administration used by DOTs for roadway construction projects. It allows DOTs to select all that apply from four options: calendar-day, working-day, completion-date, and innovative contract. Out of 30 responded DOTs, 25 (83%) DOTs agencies indicated that they use completion-date contracts, whereas 20 (67%) DOTs use calendar-day contracts, being these are the most common contract time used by the DOTs, as shown in Figure 3-2. Some DOTs also stated the use of other contract types and methods (Table 3-1) for time administration.

**Table 3-1. Other contract time administration used by DOTs for roadway construction projects.**

| Other answers to Question Q1 |
|---|
| Contractor bids the working days. |
| Use of Primavera P6 CPM to determine contract time. |
| A combination of completion date and day count. Also, A+B, lane rental, and block rental, which utilize lane mile days. |

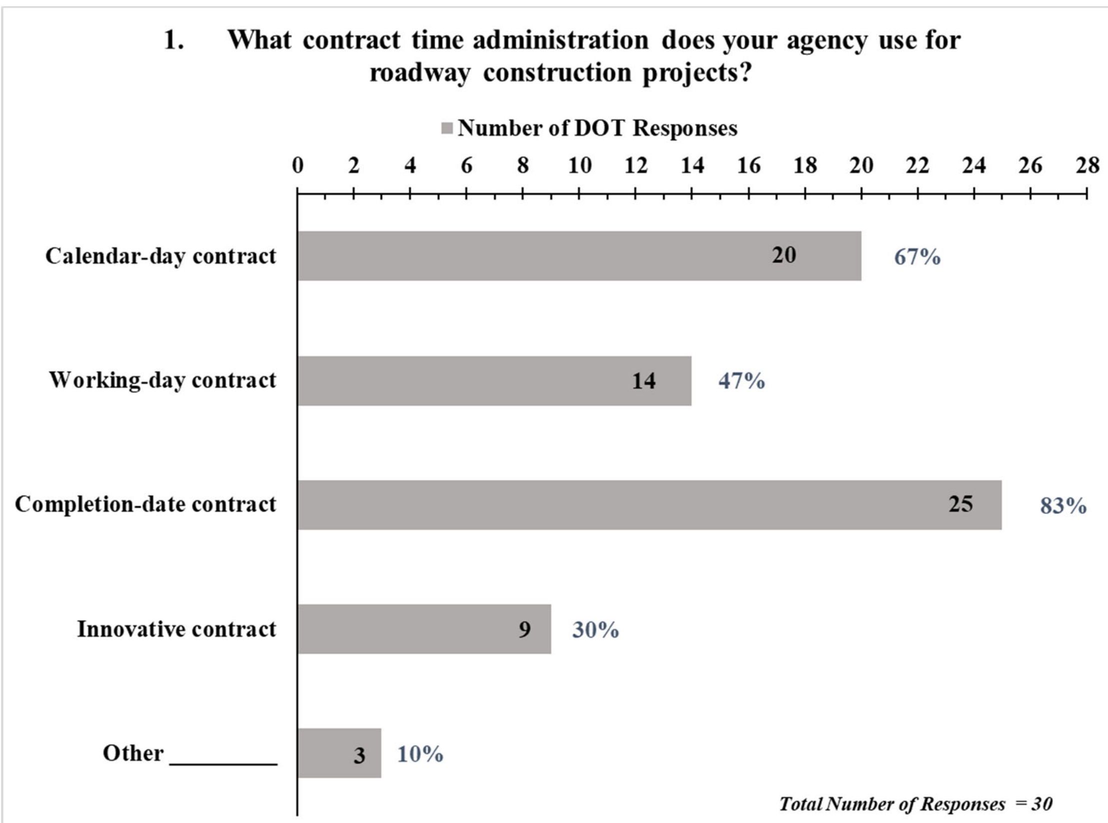


**Figure 3-2. Contract time administration use by DOTs for roadway construction projects. Survey respondents were allowed to select multiple choices.**

The second survey question (Q2) sought to identify from construction factors such as workforce shortage, poor project management, contractor inexperience, material shortage, adverse weather conditions and tight schedule, which of those contribute the most to construction project delays. The participants were given a set of options representing various contributors to construction delays, and they were asked to rank these factors on a scale of one (Highest) to six (Lowest), indicating which factors they believed caused the most delays in highway construction activities. Figure 3-3 and Figure 3-4 illustrate average ranks and the ranking distributions for each factor as perceived by the respondents. It is evident from the data that material shortage, with an average ranking of 2.6, and poor project management, with an average ranking of 3.0, are among the primary contributors to delays in DOTs projects. Adverse weather conditions are ranked as the third primary contributor to project delays. One quarter or more (≥ 25%) of respondents ranked these three factors as the highest contributor (Figure 3-4).

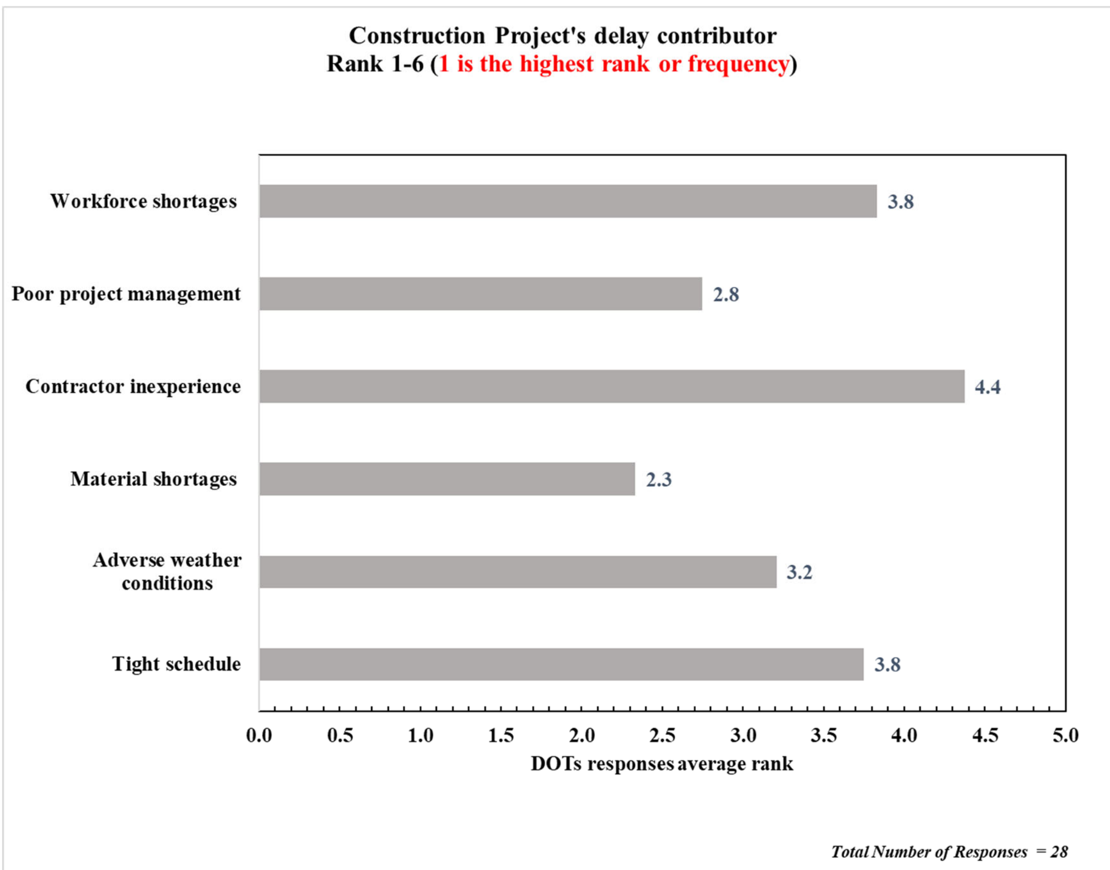


**Figure 3-3. Construction project's delay contributor frequency average ranks. Survey respondents were indicated to rank factor in a scale of 1 (highest) to 6 (lowest).**

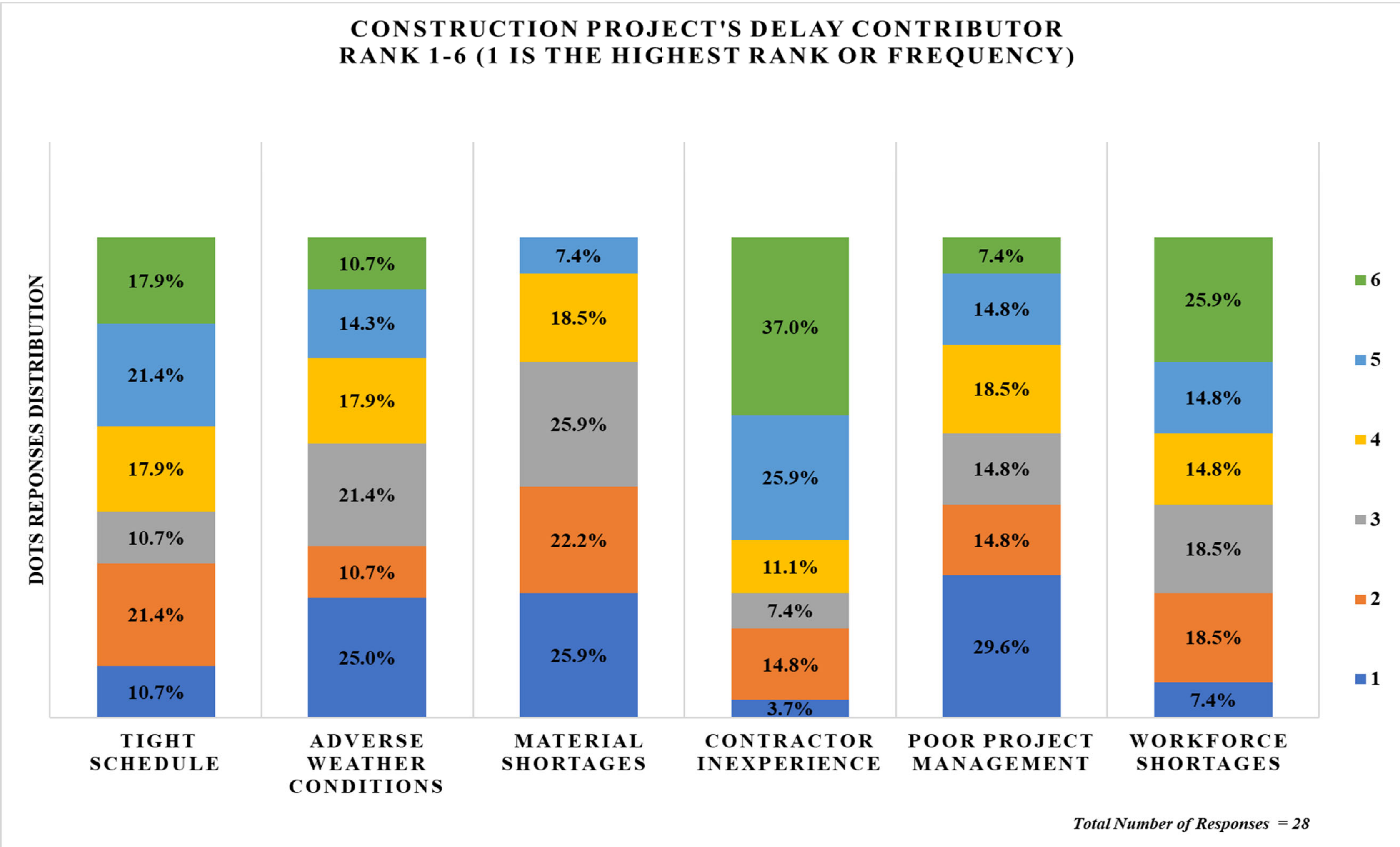


**Figure 3-4. Construction project's delay contributor frequency distributions. Survey respondents were indicated to rank factor in a scale of 1 (highest) to 6 (lowest).**

The DOT representatives emphasized that from the eight given factors/variable that can affect projects' duration, the type of construction is one of the most crucial when estimating the duration of highway project contracts. DOTs agencies engage in various types of construction, including surfacing, paving, structural work, or a combination of these activities, each presenting its own unique expertise and challenges. Additionally, factors such as project size and workforce production rate were identified as significant considerations when assessing the duration of roadway projects, as depicted in Figure 3-5. The participants also highlighted utility-related issues as additional factors considered when determining the contract duration for highway construction projects. Table 3-2 provides an overview of other pertinent factors and variables.

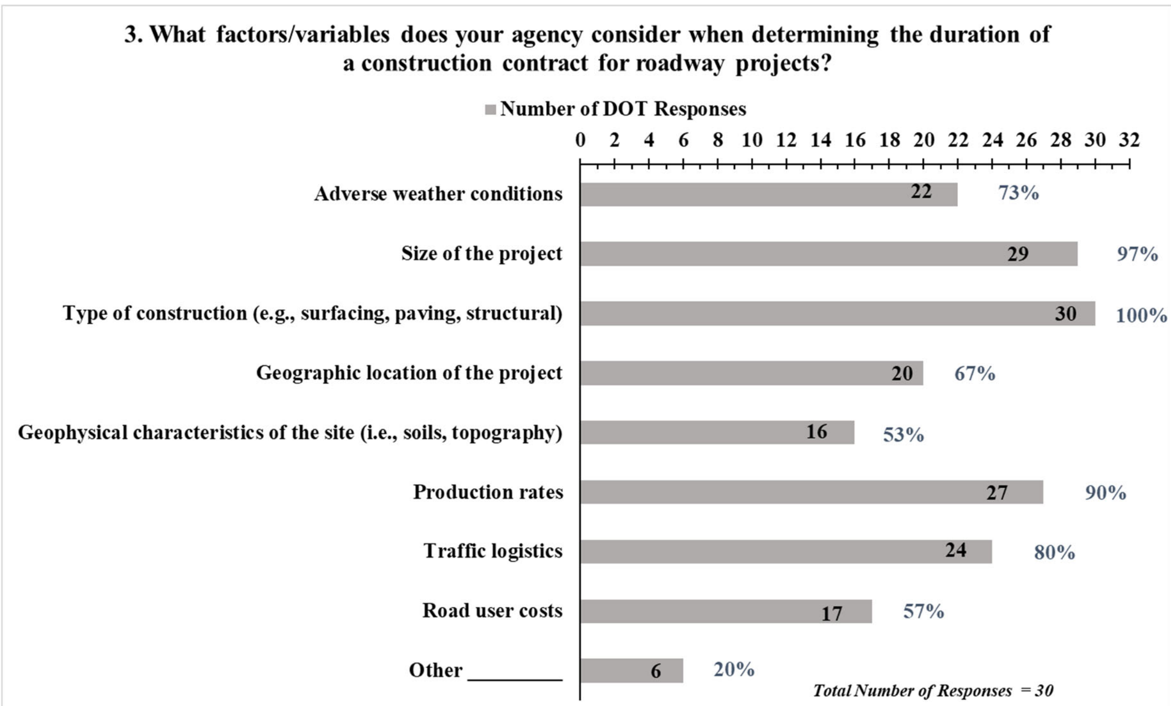


**Figure 3-5. Factors and variables considered by DOTs agencies to determine the duration of a construction contract for roadway projects. Survey respondents were allowed to select multiple choices.**

**Table 3-2. Other factors and variables indicated by the DOTs are considered when determining the duration of a construction contract for roadway projects.**

| Other answers to Question Q3 | Count | Percent[1] |
|---|---|---|
| Utility complications (relocations). | 3 | 60% |
| Winter conditions are factored into both production rates and calendars that exclude work from Dec 1 thru March 15. | 1 | 20% |
| Design Directive (DD) - 803 outlines criteria for determining the project completion date. | 1 | 20% |

## 3.3 Current Status of Existing Guidance to Determine Non-workdays due to Adverse Weather for Roadway Project Duration Estimation

Based on the 30 recorded responses, 18 states (60% of the total responses) have established guidelines, such as contract language, tools, charts, and furthermore, for determining the number of non-workdays attributed to adverse weather when estimating the duration of highway projects. In contrast, the remaining 12 states (40%) do not have any such guides available (Figure 3-6).

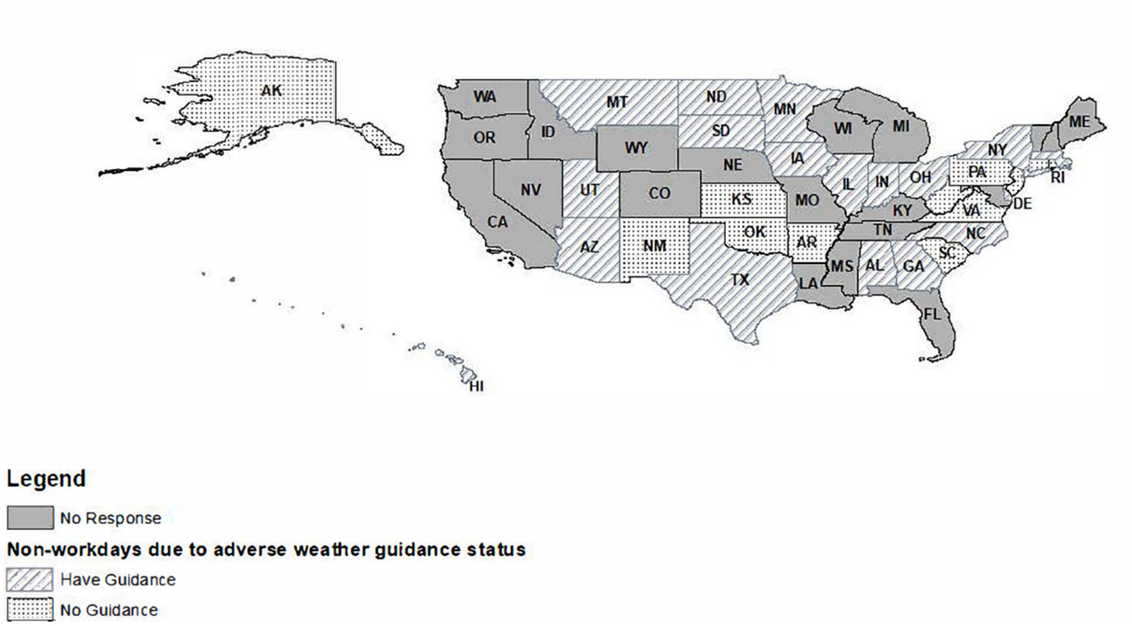


**Figure 3-6. Status of DOTs agencies use of guidance to determine non-workdays due to adverse weather conditions for highway project contract.**

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[1] Percent based on total counts provided other answers.

### 3.4 STATUS OF DOTS WITH NO GUIDANCE TO DETERMINE NON-WORKDAYS DUE TO WEATHER CONDITIONS FOR HIGHWAY CONSTRUCTION CONTRACT

When asked if the agency has any plans to develop any type of guidance to estimate non-workday due to adverse weather for roadway project contracts, 11 of the 12 respondents said "No," while only one state said "Yes," corresponding to 92% vs. 8%.

As depicted in Figure 3-7 (percentages are based on total responses for the question), most DOTs representatives from states without guidance to determine the impact of adverse weather on the duration of highway project contracts believe that the existing methodologies for estimating contract durations are satisfactory. Consequently, they do not perceive the need for adverse weather guidance, charts, or tools. Other reasons limiting the implementation of this guidance are related to the lack of personnel for the management and development of these tools. Additional reasons provided by respondents are presented in Table 3-3.

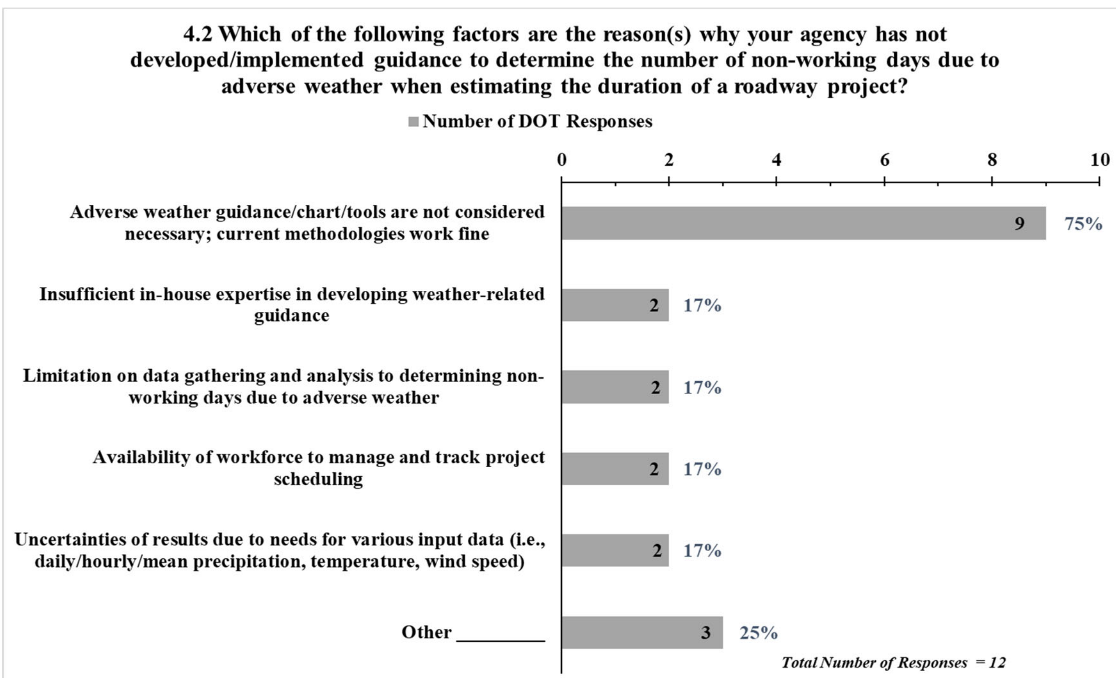



**Figure 3-7. DOTs' reason(s) of why they have not developed/implemented guidance to determine the non-workdays due to adverse weather for the estimation of roadway project duration. Survey respondents were allowed to select multiple choices.**

**Table 3-3. Other reason(s) of why DOTs have not developed/implemented guidance to determine the non-workdays due to adverse weather for the estimation of roadway project duration.**

| Other answers to Question Q4.2 |
|---|
| Many of our projects contain a Special Provision where the contractor bids the contract time (working days and calendar days). Jobs with road user costs utilize the bid time as part of the determination of the award, but jobs with no road user cost do not include the bid time as part of the award consideration. |
| Weather days are not significant. |
| The agency has winter shut down period. |

## 3.5 Status of DOTs with Guidance to Determine Non-workdays due to Weather Conditions for Highway Construction Contract

The subsequent questions aim to determine the practices, guidance, and tools currently applied by DOTs to determine non-workdays due to adverse weather and how they are being used when estimating contract duration for highway projects. Among the 18 states that have guidance to determine non-workday due to inclement weather, 12 (67%) indicated that state working-day weather charts/tools are the guidance used in their agencies, which is complemented by the project manager knowledge/experience as seven (39%) stated when asked which guidance is used in their agencies to account for non-working days due to adverse weather when developing the roadway project contract (Figure 3-8). Other guidance and methods used by DOTs are shown in Table 3-4.

**Table 3-4. Other guidance used by DOTs agencies to account for non-workdays due to adverse weather when developing roadway project contracts.**

| Other answers to Question Q5 |
|---|
| For working day projects which are Monday through Friday and only charged from May 1st to November 30th, contractors will charge a day for bad weather. |
| We have standardized calendars for groups of activities that are weather dependent. We either exclude winter work or have it work on an inefficiency calendar, i.e., three days a week, assuming two days will be lost during winter conditions. |
| Recommendation from our CPM (Critical Path Method) Scheduling Pay Item Specification. |

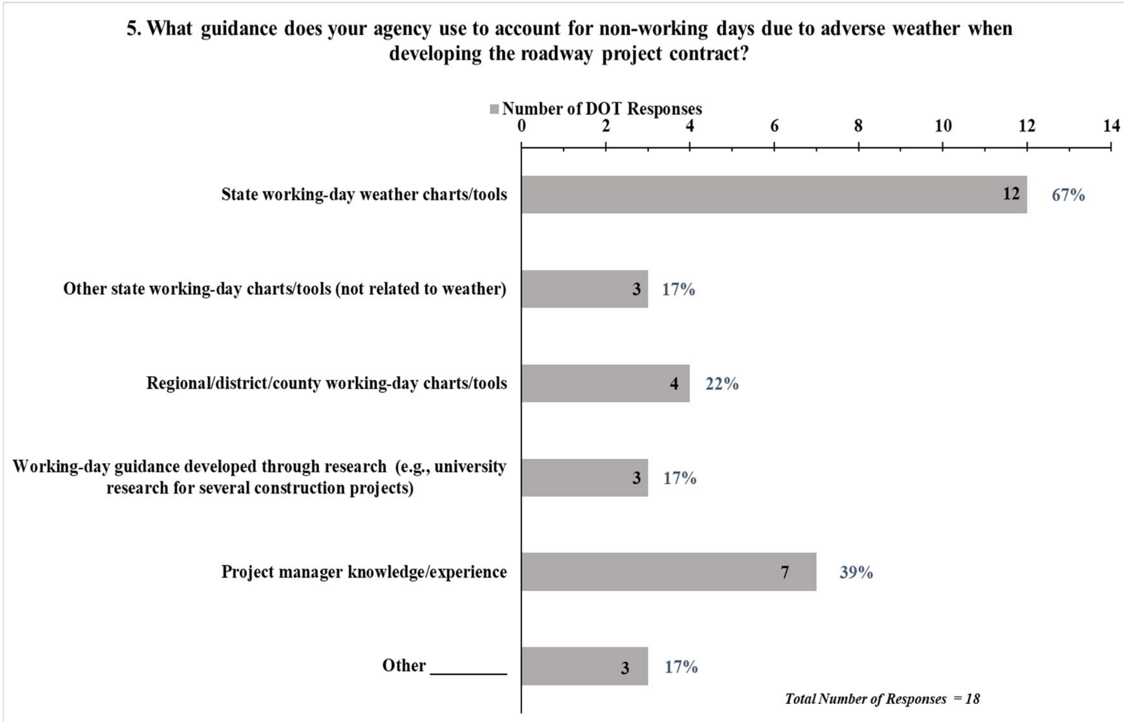



**Figure 3-8. Guidance used by DOTs agencies to account for non-workdays due to adverse weather when developing roadway project contract. Survey respondents were allowed to select multiple choices.**

Climate variability can have a significant impact on the effectiveness of guidance and tools used to assess the impact of adverse weather on daily construction project productivity, especially when there is no one-size-fits-all solution due to weather variations. To achieve more precise estimations of contract durations while considering inclement weather, six agencies (33%) relied on guidance that considers the climate characteristics of the specific geographic zone. Similarly, six agencies (33%) based their guidance on the administrative district/region/area offices of the DOTs, as illustrated in Figure 3-9. Table 3-5 lists additional references used for spatial distribution considerations during the development of guidance.

**Table 3-5. Other division references used by DOTs when developing adverse weather guidance/chart/tools to determine non-workdays for roadway projects.**

| Other answers to Question Q6 |
| --- |
| State as a whole. |
| Six districts mostly follow the same restrictions. Or southern District, which includes Cape Cod, also has significant summer restrictions on impacted roadways due to traffic constraints on the Cape. |

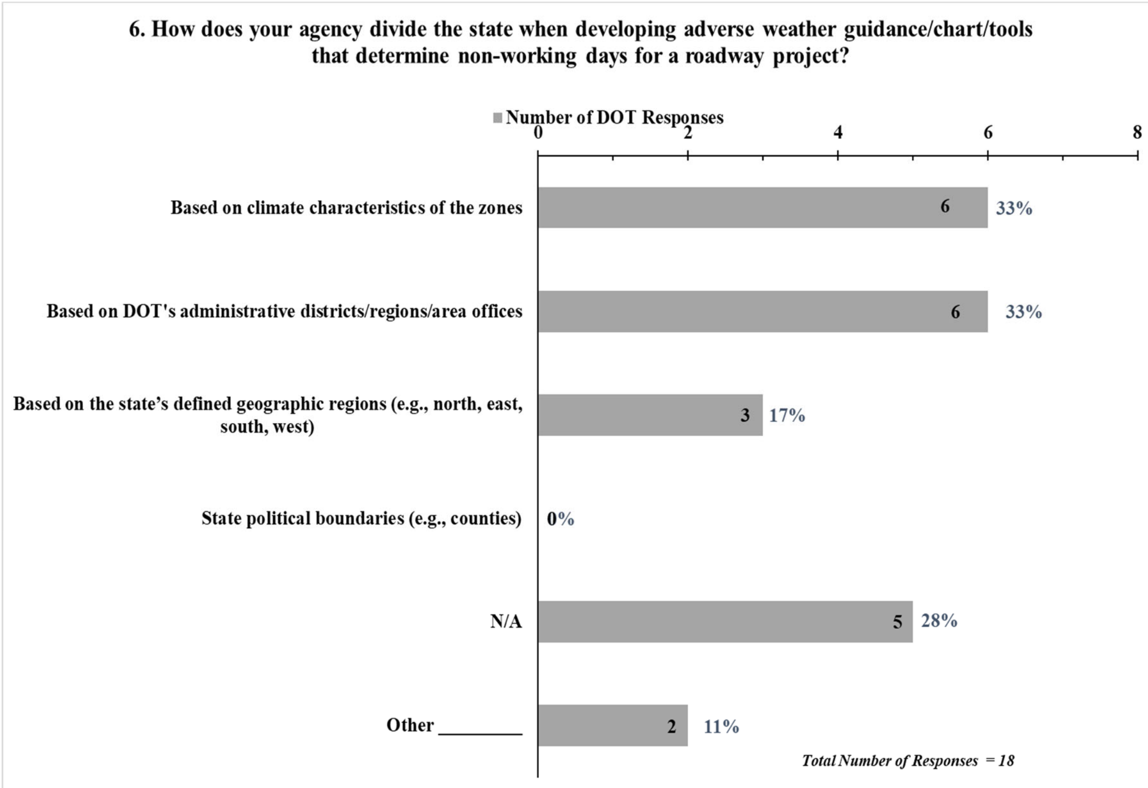



**Figure 3-9. Division references used by DOTs when developing adverse weather guidance/chart/tools to determine non-workdays for roadway projects. Survey respondents were allowed to select multiple choices.**

Adverse weather conditions can have varying levels of impact depending on the specific construction activity, particularly in the case of highway projects that encompass surfacing, grading, structural work, and a combination of all. When respondents were asked about the categorization of the developed guidance based on construction type, 11 states (61%) indicated that the guidance used to determine non-workdays due to inclement weather does not consider the specific construction project type. In contrast, seven states (39%) stated that they do consider the construction type when determining non-workdays (Figure 3-10.

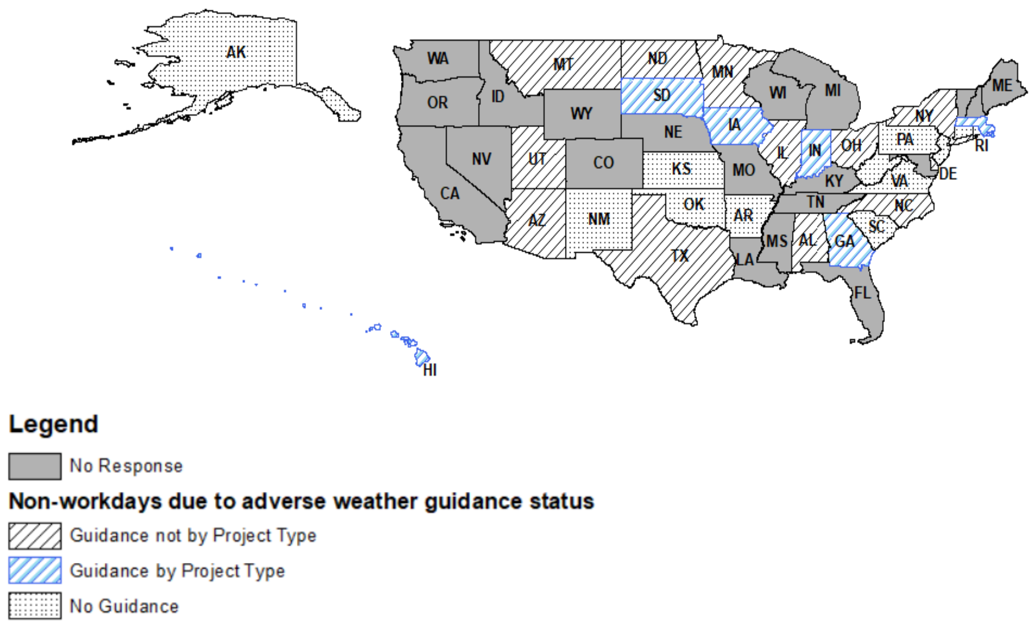



**Figure 3-10. Status of DOTs with guidance categorized by construction project type to determine non-workdays due to adverse weather.**

## 3.6 Criteria Used by DOTs to Consider Non-workdays due to Weather

Participants were asked to provide the parameter values, criteria, and/or threshold values outlined in their respective guidance documents, allowing them to classify days affected by inclement weather as non-workdays. The sections that follow present the input values of the criteria used by state agencies that are classified by construction project type (seven states) and those that do not classify their guidance (11 states).

### 3.6.1 Agencies with Non-workdays Guidance Categorized by Project Type

The criteria values used by DOTs to classify non-workdays due to inclement weather are shown in Table 3-6. The data presented is based on responses from three (43%) of the seven states, with guidance categorized by construction type (grading, surfacing, structural, and multitask projects). Based on limited information from three DOTs, daily rainfall greater than zero (any amount of rainfall) or 0.5 in. and temperature less than 32° F were used for adverse weather thresholds for grading projects.

**Table 3-6. Criteria values used to determine non-workdays by DOTs which guidance are categorized by project type.**

| Grading projects - Non-workdays consideration criteria | | | |
|---|---|---|---|
| Weather parameter | State 1 | State 2 | State 3 |
| Daily Precipitation (in.) | ≥ 0.5 | N/A | ≥ 0 |
| Min. Temperature (°F) | N/A[2] | N/A | ≤ 32 |

| Surfacing Project (Asphalt) - Non-workdays consideration criteria | | | |
|---|---|---|---|
| Weather parameter | State 1 | State 2 | State 3 |
| Min. Precipitation (in.) | 0 | N/A | 0 |
| Min. Temperature (°F) | 32 | 45 | 45 |
| Daily mean temperature (°F) | N/A | N/A | 45 |

| Surfacing Project (Concrete) - Non-workdays consideration criteria | | | |
|---|---|---|---|
| Weather parameter | State 1 | State 2 | State 3 |
| Min. Precipitation (in.) | 0 | N/A | 0 |
| Min. Temperature (°F) | 32 | 32 | 40 |

| Structural Projects - Non-workdays consideration criteria | | | |
|---|---|---|---|
| Weather parameter | State 1 | State 2 | State 3 |
| Min. Precipitation (in.) | N/A | N/A | 0 |

| Multitask Projects - Non-workdays consideration criteria | | | |
|---|---|---|---|
| Weather parameter | State 1 | State 2 | State 3 |
| Min. Precipitation (in.) | 0.5 | N/A | 0 |
| Min. Temperature (°F) | N/A | N/A | 45 |

Note: “Min. Precipitation” means threshold value for precipitation, “Min. Temperature” means daily minimum temperature in comparison to “Daily Mean Temperature” as another option.

[2] N/A means the agency did not report a specific criteria value for that weather parameter.

### 3.6.2 AGENCIES WITH NON-WORKDAYS GUIDANCE NOT CATEGORIZED BY PROJECT TYPE

States whose guidance is not classified by construction type were asked for general input values. The criteria values reported by five (~45.5%) of the 11 states are presented in Table 3-7.

**Table 3-7. General criteria values used to determine non-workdays by DOTs which guidance are not categorized by project type.**

| General Criteria for Non-working days - Non guidance DOTs | | | | | |
|---|---|---|---|---|---|
| Weather parameter | State 1 | State 2 | State 3 | State 4 | State 5 |
| Min. Precipitation (in.) | 0.1 | N/A[3] | N/A | 0.1 | N/A |
| Min. Temperature (°F) | 32 | N/A | 32-45 | N/A | N/A |
| Daily mean temperature (°F) | N/A | N/A | N/A | N/A | N/A |
| Daily mean precipitation (in.) | 0.25 | 0.1 | N/A | N/A | 0.5 |
| Wind speed (mph) | N/A | N/A | 25 | N/A | N/A |

## 3.7 OTHER CRITERION AND TOOLS USED TO EVALUATE NON-WORKDAYS DUE TO ADVERSE WEATHER CONDITIONS

When participants were asked whether their agency's guidance includes a criterion to differentiate between non-workdays and partial non-workdays, 53% (nine states out of 17 responses) indicated that they do not have such a criterion, while 47% (eight states) stated that they do. Establishing defined criteria threshold values can assist in generating more precise estimates for contract durations. Consequently, Table 3-8 presents some of the criteria employed by DOTs to distinguish between partial non-workdays and full lost days attributable to adverse weather.

One of the advantages of having guidance that determines non-workdays due to adverse weather conditions and aids in preparing more accurate contract durations is the reduction of conflicts and legal disputes with contractors and subcontractors regarding time extensions or delays caused by the climate. There are 15 states (88% out of 17 responses) indicated that they conduct

[3] N/A means the agency did not report a specific criteria value for that weather parameter.

meetings with contractors to discuss delays and exceptional circumstances resulting from adverse weather, and mutually agree upon solutions in advance.

**Table 3-8. Criteria used by the DOTs to differentiate a partial non-workday and a full non-workday due to adverse weather.**

| Question Q9 - Criterion used to differentiate a full non-working and a partial non-working day due to adverse weather conditions |
|---|
| Increment of 0.25 days. |
| We only give full non-working days based on whether the controlling operation is delayed by rain or other inclement weather. |
| The Contractor will be charged 1/2 working day when weather or other conditions beyond the control of the Contractor permit work for at least 1/2 but less than 3/4 of a working day. The Contractor will not be charged a working day when weather or other conditions beyond the control of the Contractor work for less than 1/2 of a working day. In the event of adverse weather when work on a project is ready to be started or resumed and the Contractor is not on the project, working days will not be charged during the inclement weather period provided the Contractor starts work as soon as weather and ground conditions permit work to be started or resumed. |
| Amount of work can be completed on the Critical path activity currently governing the project along with the efficiency of that operation. |
| 1/2 day or more of inclement weather is a non-working day. |
| Less than 50% productive. |
| A 1/2 working day will be counted for any day described as a working day (per agency's specs) on which conditions are such that the Contractor would be expected to or does at least 2 hours but not more than 6 hours work on the controlling item. |

Participants mentioned using various tools and documentation to verify the non-workdays claimed by contractors. The field engineer diary is the most relied-upon resource, with 16 DOTs (94% out of 17 responses) indicating its usage. Additionally, 12 DOTs (71%) employ weekly progress reports to verify the reported non-workdays due to adverse weather, as depicted in Figure 3-11. Other tools and documentation used by DOTs to corroborate non-workdays reported by contractors are shown in Table 3-9.

**Table 3-9. Others tool and documents used by DOTs to corroborate claimed non-workday due to adverse weather reported by contractors.**

| Other answers to Question Q11 |
|---|
| Monthly Reconciliation |
| CPM Schedule |

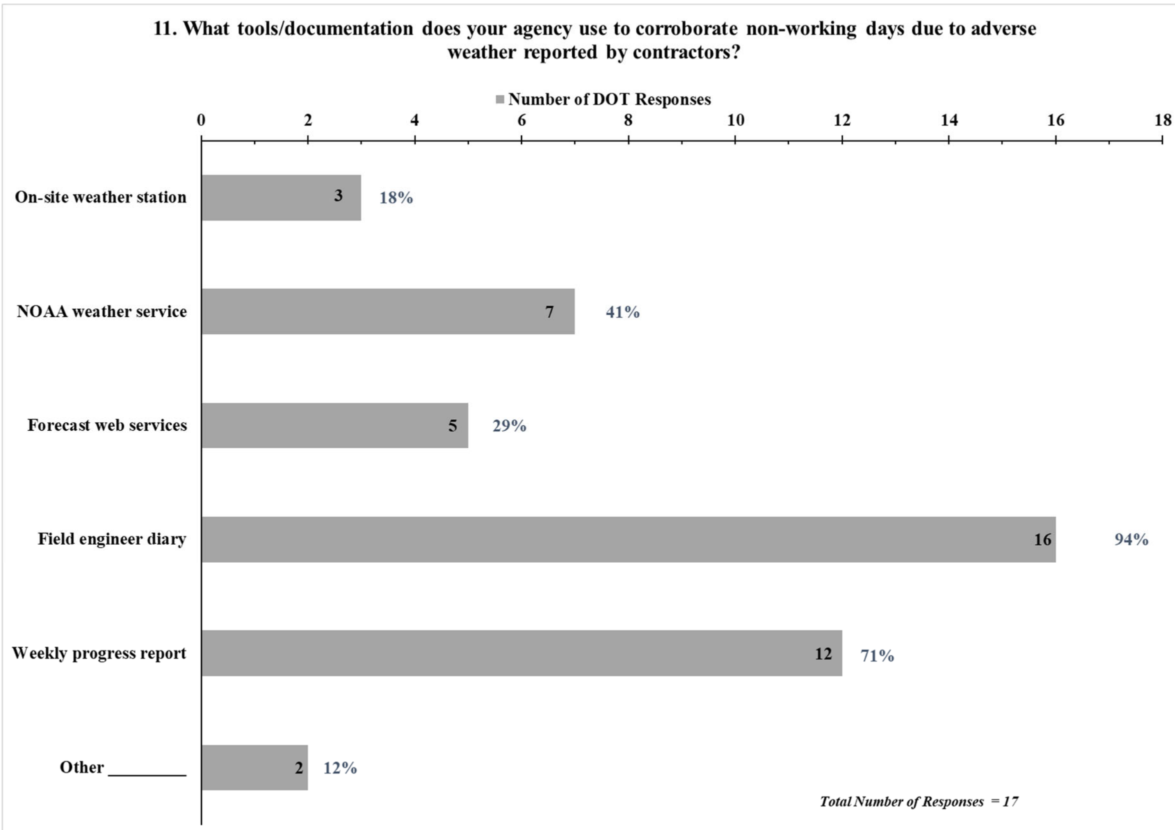



**Figure 3-11. Tool and documents used by DOTs to corroborate claimed non-workday due to adverse weather reported by contractors. Survey respondents were allowed to select multiple choices.**

Seven (41%) states indicated that they held weekly meetings with contractors to reconcile and review non-workdays due to inclement weather, whereas five (29%) participants indicated that their state holds this meeting at other frequencies, as shown in Figure 3-12. Table 3-10 shows additional frequencies indicated by DOTs.

**Table 3-10. Other frequency of meetings between DOTs and contractors to review and reconcile non-workdays due to adverse weather reported by contractors.**

| Other answers to Question Q12 |
|---|
| Varies by project. |
| Contract duration factors in adverse weather conditions and no time extension are given for ordinary weather conditions. If there were significant flooding events, or "acts of god" we allow a contractor to submit a contract time determination schedule for consideration. Reviewed and approved on a case-by-case basis. |
| Usually at the time when deciding on an official Project Time Extension date. |
| The agency determines nonworking days. |

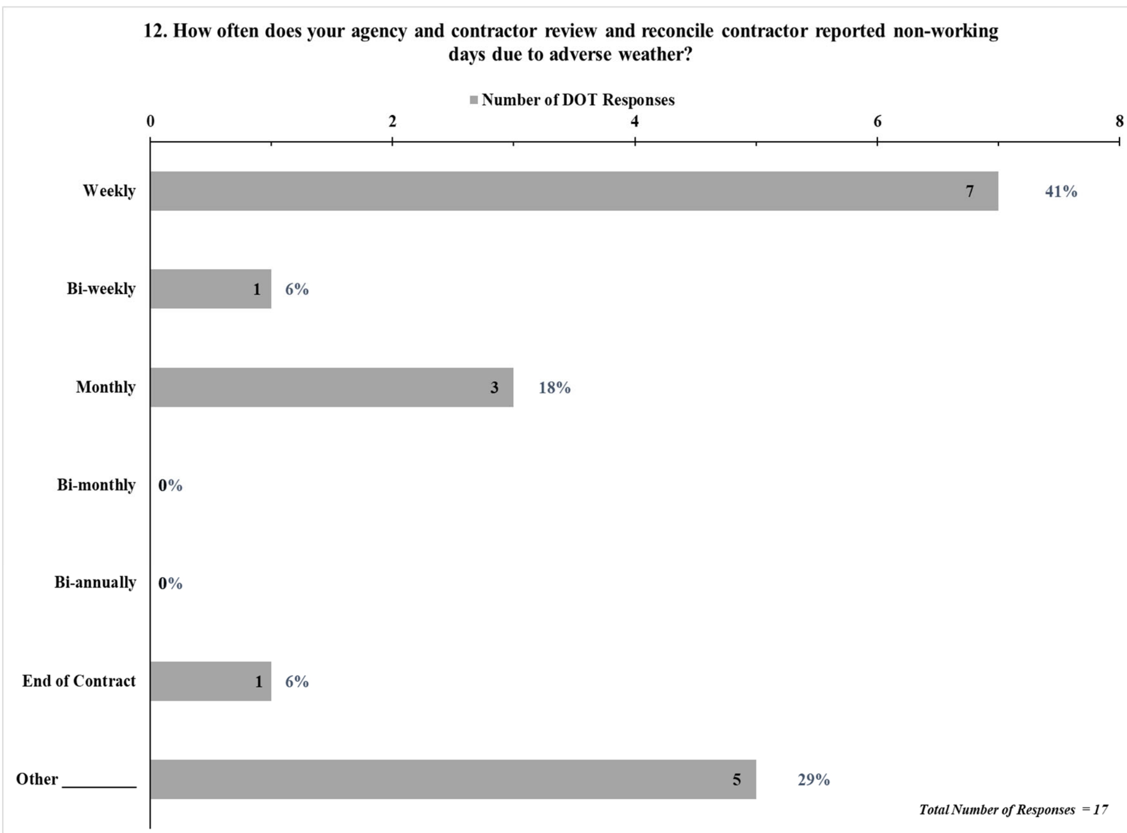



**Figure 3-12. Frequency of meetings between DOTs and contractors to review and reconcile non-workdays due to adverse weather reported by contractors.**

## 3.8 IMPACT OF WEATHER IN CONSTRUCTION ACTIVITIES FOR HIGHWAY PROJECT

Survey participants were asked to rank the most common weather delay factors for construction on a scale of one (highest rank) to six (lowest rank) based on their perceived impact on roadway project construction performance. The responses were recorded for two groups: states with project-specific guidance (five out of seven states) and states with general-criteria guidance (10 out of 11 states). The findings are organized into sections 0 and 3.8.2. of this report.

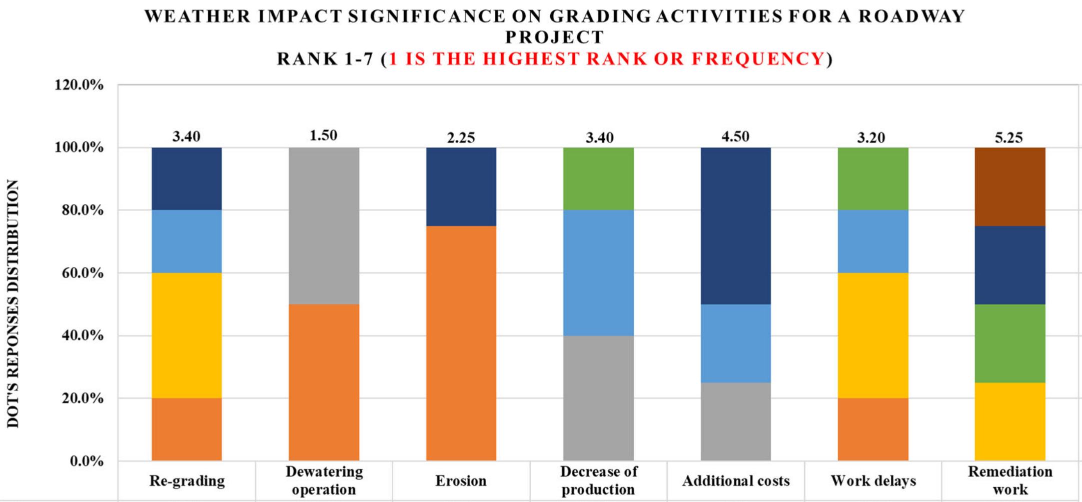
### 3.8.1 AGENCIES WITH NON-WORKDAYS GUIDANCE CATEGORIZED BY PROJECT TYPE

For grading project, participants ranked dewatering operations for grading projects as one of the weather impacts with a significant effect on delaying roadway projects. Erosion, caused by the effects of precipitated water on open-graded areas, was also identified as a noteworthy factor in grading projects. The DOT's average rankings for these two factors were 1.5 and 2.25 (showing on top of each bar), respectively, as depicted in Figure 3-13. In contrast, remediation work was ranked with 5.25, indicating that participants perceived it to be the weather factor with the least significance for grading projects.

For surfacing project (asphalt), similarly, as in grading project, dewatering operation and erosion has been indicated to be one of the weather impacts with higher significance in surfacing project with asphalt, has been ranked with a value of 2; whereas, additional cost produced and remediation work ranked as 4.75 and 4.50 have the lowest significance for asphalt surfacing project (Figure 3-14). For surfacing project (Concrete), when working on surfacing projects with concrete, DOTs indicated that re-grading (2.5) is an additional weather impact with high significance, along with the effects of dewatering operation (2.25) and erosion (2.50), and that similarly the additional cost is the least detrimental weather impact (5), as depicted in Figure 3-15.

For structural projects, with an average rank of 1.5, erosion is considered by the participant as one of the weather factors with the higher significance for structural projects, followed by re-grading with a rank of 2. As in previous project types, additional cost due to weather impact is considered the factor with the lowest effect on this type of project, ranked as 4.25, as depicted in Figure 3-16.

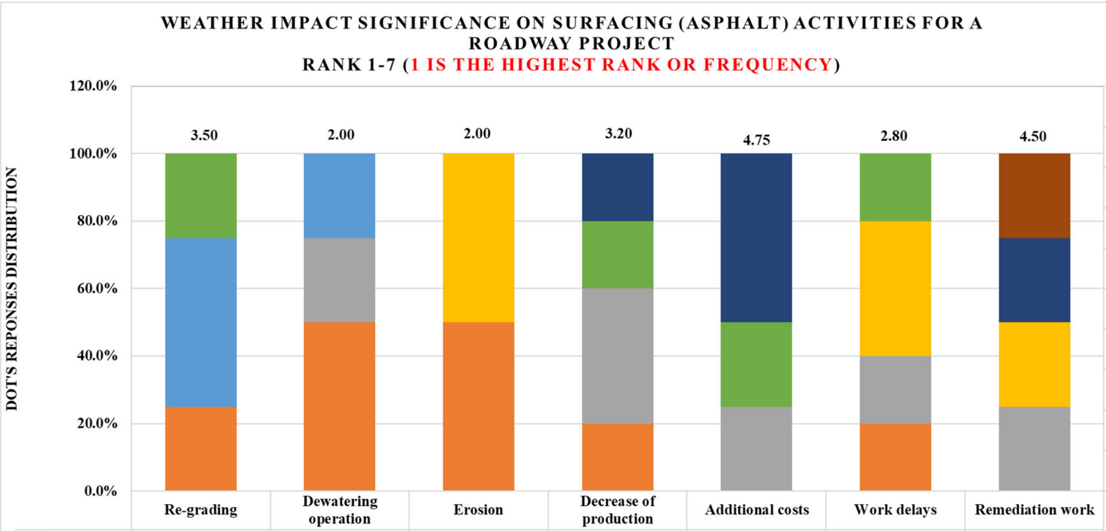
For multitask projects, erosion, dewatering operation and re-grading were considered by the participant as the most detrimental weather impact for multitasking project, ranked between 1.25 and 2, as Figure 3-17 presents; additional costs with a rank of 5, was considered by the participant of having the lowest impact on this type of construction activities.




| | Re-grading | Dewatering operation | Erosion | Decrease of production | Additional costs | Work delays | Remediation work |
|---|---|---|---|---|---|---|---|
| 7 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 25.0% |
| 6 | 20.0% | 0.0% | 25.0% | 0.0% | 50.0% | 0.0% | 25.0% |
| 5 | 0.0% | 0.0% | 0.0% | 20.0% | 0.0% | 20.0% | 25.0% |
| 4 | 20.0% | 0.0% | 0.0% | 40.0% | 25.0% | 20.0% | 0.0% |
| 3 | 40.0% | 0.0% | 0.0% | 0.0% | 0.0% | 40.0% | 25.0% |
| 2 | 0.0% | 50.0% | 0.0% | 40.0% | 25.0% | 0.0% | 0.0% |
| 1 | 20.0% | 50.0% | 75.0% | 0.0% | 0.0% | 20.0% | 0.0% |
| Average Rank | 3.40 | 1.50 | 2.25 | 3.40 | 4.50 | 3.20 | 5.25 |

*Total Number of Responses = 5*

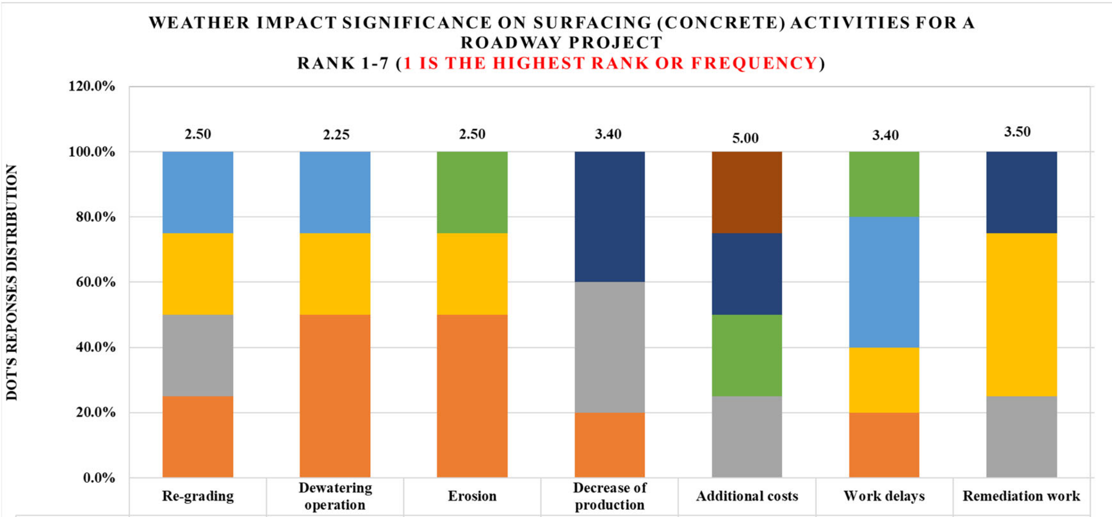
**Figure 3-13. Weather impact factors ranked by DOTs with categorized guidance for grading activities for roadway project.**




| | Re-grading | Dewatering operation | Erosion | Decrease of production | Additional costs | Work delays | Remediation work |
|---|---|---|---|---|---|---|---|
| 7 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 25.0% |
| 6 | 0.0% | 0.0% | 0.0% | 20.0% | 50.0% | 0.0% | 25.0% |
| 5 | 25.0% | 0.0% | 0.0% | 20.0% | 25.0% | 20.0% | 0.0% |
| 4 | 50.0% | 25.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3 | 0.0% | 0.0% | 50.0% | 0.0% | 0.0% | 40.0% | 25.0% |
| 2 | 0.0% | 25.0% | 0.0% | 40.0% | 25.0% | 20.0% | 25.0% |
| 1 | 25.0% | 50.0% | 50.0% | 20.0% | 0.0% | 20.0% | 0.0% |
| Average Rank | 3.50 | 2.00 | 2.00 | 3.20 | 4.75 | 2.80 | 4.50 |

*Total Number of Responses = 5*

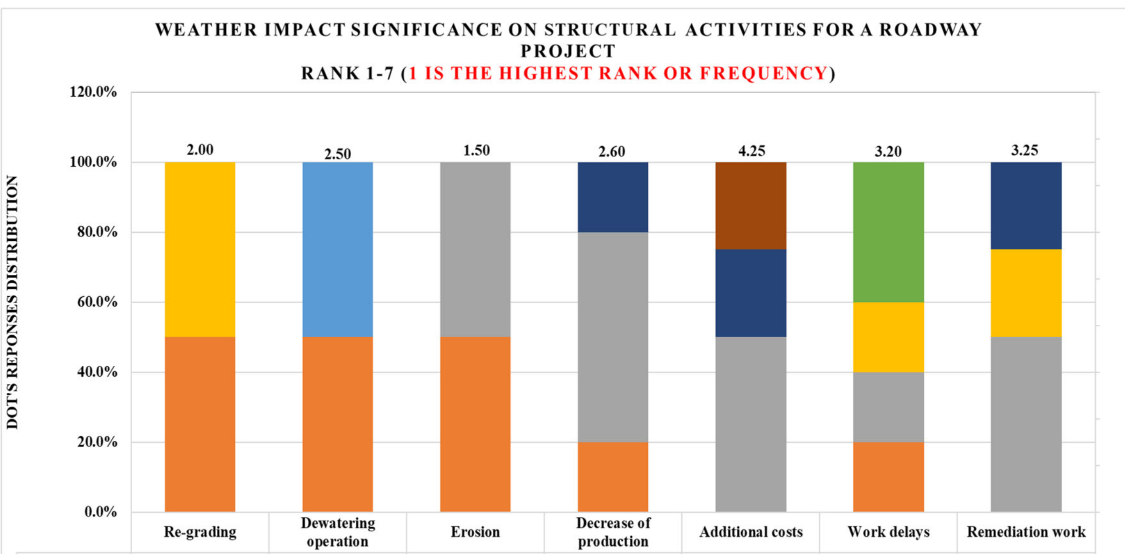
**Figure 3-14. Weather impact factors ranked by DOTs with categorized guidance for surfacing (asphalt) activities for roadway project.**




| | Re-grading | Dewatering operation | Erosion | Decrease of production | Additional costs | Work delays | Remediation work |
|---|---|---|---|---|---|---|---|
| 7 | 0.0% | 0.0% | 0.0% | 0.0% | 25.0% | 0.0% | 0.0% |
| 6 | 0.0% | 0.0% | 0.0% | 40.0% | 25.0% | 0.0% | 25.0% |
| 5 | 0.0% | 0.0% | 25.0% | 0.0% | 25.0% | 20.0% | 0.0% |
| 4 | 25.0% | 25.0% | 0.0% | 0.0% | 0.0% | 40.0% | 0.0% |
| 3 | 25.0% | 25.0% | 25.0% | 0.0% | 0.0% | 20.0% | 50.0% |
| 2 | 25.0% | 0.0% | 0.0% | 40.0% | 25.0% | 0.0% | 25.0% |
| 1 | 25.0% | 50.0% | 50.0% | 20.0% | 0.0% | 20.0% | 0.0% |
| Average Rank | 2.50 | 2.25 | 2.50 | 3.40 | 5.00 | 3.40 | 3.50 |

*Total Number of Responses = 5*

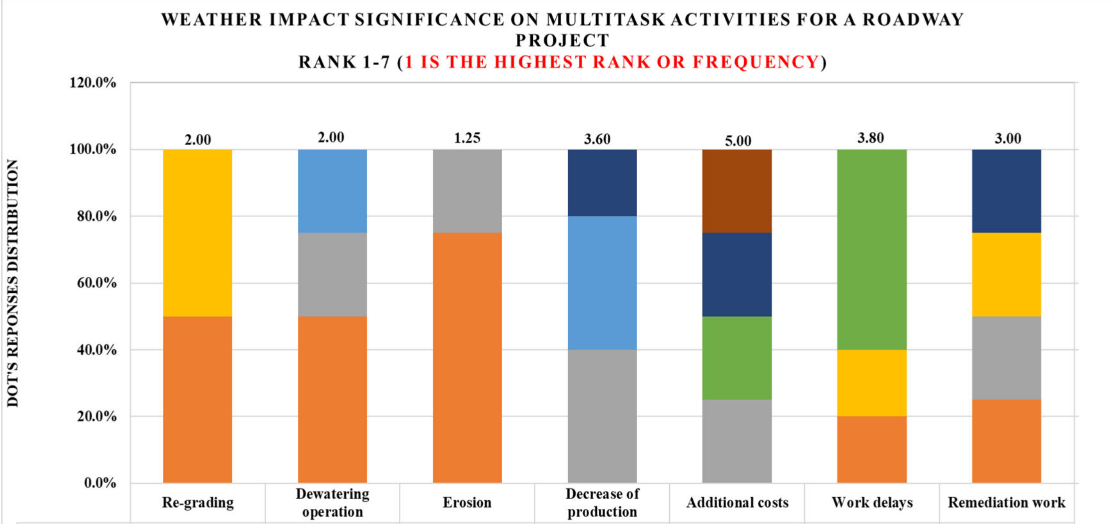
**Figure 3-15. Weather impact factors ranked by DOTs with categorized guidance for surfacing (concrete) activities for roadway project.**




| | Re-grading | Dewatering operation | Erosion | Decrease of production | Additional costs | Work delays | Remediation work |
|---|---|---|---|---|---|---|---|
| 7 | 0.0% | 0.0% | 0.0% | 0.0% | 25.0% | 0.0% | 0.0% |
| 6 | 0.0% | 0.0% | 0.0% | 20.0% | 25.0% | 0.0% | 25.0% |
| 5 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 40.0% | 0.0% |
| 4 | 0.0% | 50.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 3 | 50.0% | 0.0% | 0.0% | 0.0% | 0.0% | 20.0% | 25.0% |
| 2 | 0.0% | 0.0% | 50.0% | 60.0% | 50.0% | 20.0% | 50.0% |
| 1 | 50.0% | 50.0% | 50.0% | 20.0% | 0.0% | 20.0% | 0.0% |
| Average Rank | 2.00 | 2.50 | 1.50 | 2.60 | 4.25 | 3.20 | 3.25 |

*Total Number of Responses = 5*

**Figure 3-16. Weather impact factors ranked by DOTs with categorized guidance for structural activities for roadway project.**



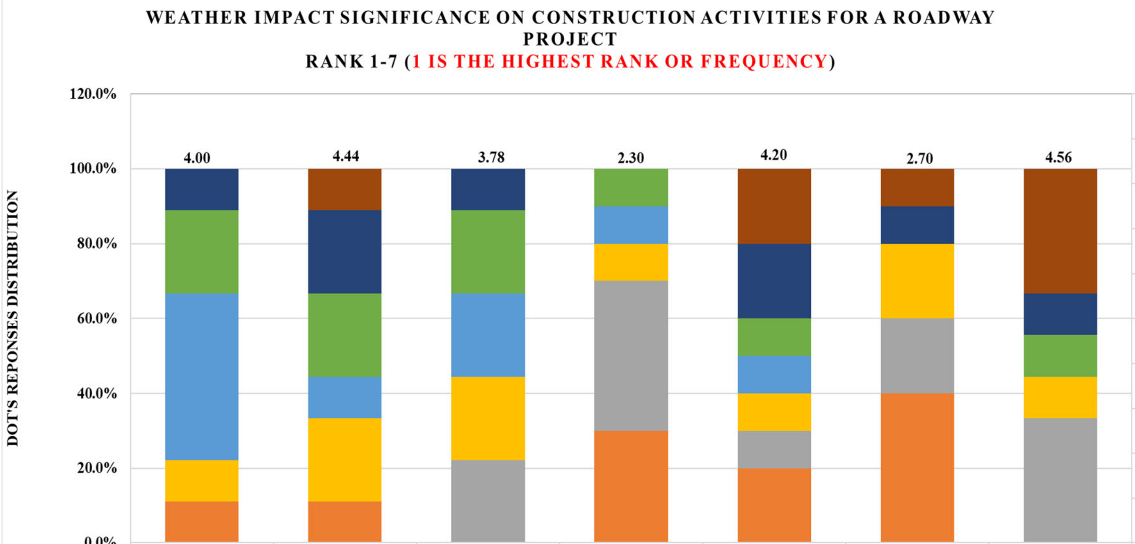

| | Re-grading | Dewatering operation | Erosion | Decrease of production | Additional costs | Work delays | Remediation work |
|---|---|---|---|---|---|---|---|
| 7 | 0.0% | 0.0% | 0.0% | 0.0% | 25.0% | 0.0% | 0.0% |
| 6 | 0.0% | 0.0% | 0.0% | 20.0% | 25.0% | 0.0% | 25.0% |
| 5 | 0.0% | 0.0% | 0.0% | 0.0% | 25.0% | 60.0% | 0.0% |
| 4 | 0.0% | 25.0% | 0.0% | 40.0% | 0.0% | 0.0% | 0.0% |
| 3 | 50.0% | 0.0% | 0.0% | 0.0% | 0.0% | 20.0% | 25.0% |
| 2 | 0.0% | 25.0% | 25.0% | 40.0% | 25.0% | 0.0% | 25.0% |
| 1 | 50.0% | 50.0% | 75.0% | 0.0% | 0.0% | 20.0% | 25.0% |
| Average Rank | 2.00 | 2.00 | 1.25 | 3.60 | 5.00 | 3.80 | 3.00 |

*Total Number of Responses = 5*

**Figure 3-17. Weather impact factors ranked by DOTs with categorized guidance for multitasking activities for roadway project.**

### 3.8.2 AGENCIES WITH NON-WORKDAYS GUIDANCE NOT CATEGORIZED BY PROJECT TYPE

DOTs with guidance for determining non-workdays due to weather conditions, without categorizing by project type indicated that weather impacts such as work delay (2.70) and decrease in production (2.30) are the ones that has the higher significance for construction activities for roadway projects, differing from the DOTs which guidance categorized by project type that ranked weather impacts such as dewatering operation, erosion and re-grading as those with higher importance for roadway projects. Similarly, as Figure 3-18 shows, additional cost (4.20) and remediation work (4.56) were considered the least detrimental for both groups, guidance categorized by project type and non-categorized, in addition to dewatering operations, which was ranked as 4.44 for the latter group.




| | Re-grading | Dewatering operation | Erosion | Decrease of production | Additional costs | Work delays | Remediation work |
|---|---|---|---|---|---|---|---|
| 7 | 0.0% | 11.1% | 0.0% | 0.0% | 20.0% | 10.0% | 33.3% |
| 6 | 11.1% | 22.2% | 11.1% | 0.0% | 20.0% | 10.0% | 11.1% |
| 5 | 22.2% | 22.2% | 22.2% | 10.0% | 10.0% | 0.0% | 11.1% |
| 4 | 44.4% | 11.1% | 22.2% | 10.0% | 10.0% | 0.0% | 0.0% |
| 3 | 11.1% | 22.2% | 22.2% | 10.0% | 10.0% | 20.0% | 11.1% |
| 2 | 0.0% | 0.0% | 22.2% | 40.0% | 10.0% | 20.0% | 33.3% |
| 1 | 11.1% | 11.1% | 0.0% | 30.0% | 20.0% | 40.0% | 0.0% |
| Average Rank | 4.00 | 4.44 | 3.78 | 2.30 | 4.20 | 2.70 | 4.56 |

*Total Number of Responses = 10*

**Figure 3-18. Weather impact factors ranked by DOTs with not categorized guidance for construction activities for roadway project.**

## 3.9 Cost Impact due to Adverse Weather Conditions

When asked if the additional costs carried by delay on roadway project due to adverse weather conditions are tracked at their agency, all 17 states that have any type of guidance to determine non-workdays due to inclement weather stated that they do not track the economic impact of adverse weather in roadway project.

## 3.10 Survey Summary

Findings from the states of practice survey conducted among 50 Departments of Transportation, including the District of Columbia DOT, which aimed to assess the methodologies and practices used by DOT when managing contract duration for highway projects, were presented and summarized in this chapter. The response rate was 51%, corresponding with 30 out of the 51 DOTs providing valuable insights. The survey's key findings can be summarized as follows:

- **Contract Types and Delay Factors:** 83% of the responding DOTs use completion-date contracts, while 67% use calendar-day contracts.

- **Existing Guidance for Determining Non-Working Days:** 60% of the respondents utilize certain guidelines for determining non-working days due to adverse weather.
- **Criteria Values for Non-Working Days:** DOTs use specific criteria values, such as daily rainfall and temperature thresholds, to classify non-working days; weather parameters used to classify non-workdays ranges from 0 to 0.5 in. for precipitation and 30 to 40° F for air temperature.
- **Tools and Parameters for Evaluating Non-Working Days:** 33% of the responding DOTs rely on guidance fitted to their specific geographic zones and administrative regions.
- **Weather's Influence on Construction:** The material shortage, poor project management, and adverse weather are the first three contributors to project delays as reported by the respondents.
- **Cost Implications of Adverse Weather:** 88% of the respondents conduct proactive meetings with contractors to preemptively address delays caused by adverse weather, thereby reducing potential conflicts and legal disputes.

# CHAPTER 4. DETERMINATION OF AAWDS

## 4.1 METHODOLOGY

One of the primary tasks of this project was to determine the weather threshold criteria that fits best when developing guidance to determine AAWDs for the five ALDOT Regions. The state-of-practice survey distributed among the 51 DOTs provided reference on the status of how the effect of adverse weather is perceived and managed by transportation agencies and which criteria and values for precipitation and air temperature are being used when determining non-workdays for roadway project. The main objective of this project was the development of a tool for determining AAWDs with a more reliable and easily-to-update method based on the data obtained from historical climate information, such as daily precipitation and mean air temperature recorded from weather stations distributed throughout each of the five ALDOT Regions. The methods, decision and criteria defined for this objective are presented in the following sections.

### 4.1.1 WEATHER DATA

In comparison to ALDOT studies completed in 1989 and 2003, one point of improvement with this study was to increase the number of representative climate stations used to determine the AAWDs for the ALDOT Regions from five to a larger number of stations, without limiting the number of stations per Region (Figure 4-1). This decision was taken to increase the accuracy of the results when determining the non-workdays representative for each of the five ALDOT Regions. For that reason, it was gathered climate data from the National Centers for Environmental Information (NCEI-NOAA) databases (1) Global Summary of the Day (GSOD) and (2) Global Historical Climatology Network (GHCN). The GSOD was the primary database, and the GHCN was used as a complementary data source, used to increase the number of representative weather stations per ALDOT Region. Figure 4-1 shows some GSOD and GHCN stations are overlapped.

Another main goal of this study was to use more robust historical data, hence one of the first selection criteria established to determine if a weather station could be used for further analysis was that the climate weather stations must have at least 10 years of data. The weather parameters analyzed from the climate stations were daily air temperature (maximum, minimum, and mean) and daily precipitation, which for both databases were downloaded using the following measurement units: precipitation (daily at 0.01 in.) and air temperature (minimum, maximum, and mean at 0.1° F). The steps followed to download the data for each database are detailed in Appendix A in this report, for obtaining weather data from the Global Historical Climatology Network or GHCN database, and Appendix A in an MS thesis by Mejia (2023) for obtaining weather data from the Global Summary of the Day or GSOD database.

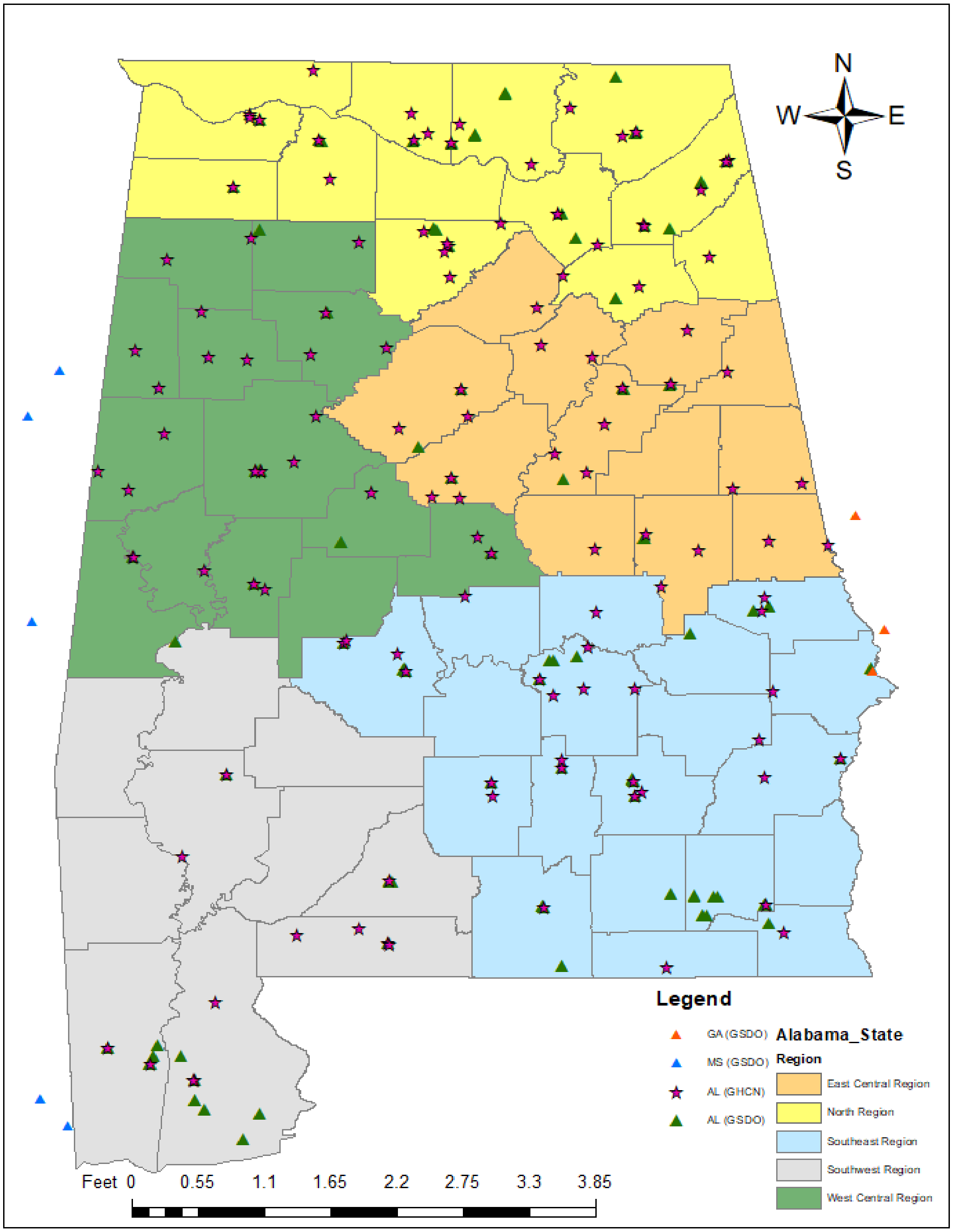



**Figure 4-1. Available climate weather stations from the GSOD database and the overlapped stations from the GHCN database.**

The downloaded data from the GSOD database ranged from 1936 through 2019, whereas the data obtained from the GHCN covered the period from 1900 through 2022. For GSOD stations the weather data from more recent years after 2019 was discarded as they were not representative due to missing data since GSOD database is only produced/updated over a certain time interval. For example, Auburn has two GSOD stations providing data from 8/4/1992 to 6/9/2014 and from 1/1/2006 to 4/8/2020. However, GHCN weather database is maintained and updated daily, and one can download the weather data up to the last workday from NOAA website for the active stations (NCEI-GIS, 2023). Figure 4-1 shows 125 GSOD stations (116 in Alabama, three in Georgia, and six in Mississippi) and 125 GHCN Alabama stations with at least 10 years of data.

#### 4.1.2 Data challenges

An important step performed prior of the processing of the downloaded data was the familiarization with the data format, this process was done by reading the metadata from each database to recognize how the data is presented and the significance of each of the measurement and parameters provided. The metadata is given in detail by Mejia (2023) and was obtained from the NOAA website pages: (1) Global Historical Climatology Network (GHCN) at Drought.gov (GHCN, 2023) and (2) the Dataset Overview for the National Centers for Environmental Information (NCEI) at noaa.gov (NOAA NCEI, 1999) by the User Engagement and Service Branch (DOC/NOAA/NESDIS/NCDC), the National Climatic Data Center (NCDC), National Environmental Satellite, Data, and Information Service (NESDIS), the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce (USDOC), USA.

One of the challenges faced when using different databases was to manage the differences between the format on how the recorded climate data are presented. When comparing the Excel file format of the GSOD versus the GHCN, it was noted that the mean daily precipitation was denoted with the same name for both databases, as “PRCP”, contrary to the mean air temperature. In the GSOD data format, three air temperature measurements are presented, named as follows: (1) “TEMP” = daily mean air temperature, (2) “MIN” = daily minimum temperature, and (3) “MAX” = daily maximum temperature. Whereas the GHCN data format, presents three air temperature measurements as well, but named as: (1) “TOBS” = temperature at the time of observation, (2) “TMAX” = daily maximum temperature, and (3) “TMIN” = daily minimum temperature. For GSOD, TEMP was used, and for GHCN, mean air temperature is calculated as average of TMIN and TMAX. When TMIN or TMAX is missing, TOBS in GHCN is used as mean air temperature; if TOBS is missing, that day is counted for one day with missing air temperature data. For GSOD, if TEMP is missing, mean air temperature is calculated as average of MIN and MAX; when MIN or MAX is missing, it is counted for one day with missing air temperature data.

Another difference encountered was how the missing data was reported, in the case of the GSOD the missing data in the Excel file is annotated as “999.9”, but in the GHCN missing data corresponding to those fields in the Excel file are “blank”. It is important to highlight that other factors differ in format but are not concerning for the results of this study.

#### 4.1.3 DATA MANAGEMENT

The selected climate weather stations were chosen for further analysis after manually ensuring that the downloaded weather stations had records for at least 10 years. The spatial distribution of all climate weather stations obtained from the GSOD and GHCN databases for this study is depicted in Figure 4-1. It is evident that some stations are in the same city/location but a short distance apart, raising the possibility of data duplication. To address this issue, a selection criterion was applied to the overlapping weather stations across Alabama, with a minimum requirement of 10 years or more for the longevity of precipitation and temperature data records. The weather station with the longest data record for each overlapping location was kept for further data analysis. As shown in Table 4-1, three stations at the Dothan Regional Airport location had overlapping weather data. Because of its extensive 73-year data record, the station "72226893843 - DOTHAN RGNL" was chosen for further analysis, while the other stations were excluded.

**Table 4-1. Overlapped stations at the Dothan Regional Airport location (Source: Global Summary of the Day (GSOD) database, NCEI-NOAA).**

| Station ID | Station Name | Begin Date | End Date | Latitude (°) | Longitude (°) | Elevation (M) | No. Years |
|---|---|---|---|---|---|---|---|
| 72226813839 | Dothan Regional Airport | 1/1/2006 | 4/8/2019 | 31.317 | -85.44 | 112.15 | 14 |
| 72226893843 | Dothan RGNL | 12/16/1941 | 6/9/2014 | 31.317 | -85.45 | 122 | 73 |
| 72226899999 | Dothan RGNL | 1/1/2000 | 6/2/2014 | 31.317 | -85.45 | 122 | 14 |

The GSOD had a total of 116 climate stations in the state of Alabama, of which just 83 stations had more than ten years of data, while 402 climate stations were available in the GHCN, from which a total of 60 stations had less than ten years of data. Many GHCN stations also discontinued collecting data many years ago. Only 190 GHCN stations still collected weather data up to 2000. Unfortunately, the distribution of the weather stations from both databases was not even among the five ALDOT Regions, and it was noted that the East Central and West Central Regions were the most deprived. To address this situation, weather station from border states, such as Georgia and Mississippi, were gathered to be included in the study analysis. A total of five stations from Mississippi and two stations from Georgia, all with more than ten years of data were downloaded from the GSOD database and used for further analysis.

## 4.2 Data Processing

### 4.2.1 Classify daily data from weather station

The VBA-powered Excel spreadsheets were used to thoroughly examine and categorize the weather data obtained from the climate stations daily. The primary goal of this process was to differentiate between workdays and non-workdays for construction projects. For this study construction workdays are defined as days other than weekends (Saturdays and Sundays), Alabama's state holidays, and days with adverse weather conditions that are defined using weather threshold conditions. This is because adverse weather days have unfavorable weather conditions for contractors to work on or complete certain construction tasks.

ALDOT calculates contractor's time charges on a working day basis, and it is important to note that only Alabama's legal holidays listed in Table 4-2 were taken into account. These legal holidays plus weekends (Saturdays and Sundays) were incorporated into Excel's VBA code and treated as non-workdays. In Excel-based VBA code developed for this study, the Weekday(Date, 7) function is used to determine which date is a weekend or weekday, where “Date” is in Day/Month/Year format. The function returns the day of the week corresponding to a date. The day is given as an integer, ranging from 1 (Sunday) to 7 (Saturday), by default. When optional parameter 7 is used, Saturday is 1 and Sunday is 2, which is easy for us to program other days.

In terms of legal holidays, it is critical to distinguish between "Fixed" and "Moveable" dates, as they are treated differently. For fixed dates, If the holiday falls on a Saturday, it is observed on the preceding Friday; if it falls on a Sunday, it is observed on the following Monday. For moveable dates, however, the holiday will be observed on the exact day it falls, with no adjustments. The moveable holidays typically occur on Monday except for Thanksgiving which occurs on a Thursday. Another consideration taken in the VBA code was to consider the Juneteenth (June $19^{th}$) only for 2021 and later years, as this holiday was recognized as a federal holiday in 2021. Therefore, there are a total of 12 (before 2021) or 13 (after 2021) Alabama legal holidays.

**Table 4-2. Alabama's legal holidays recognized by ALDOT as non-workday for contractual charge time.**

| ALABAMA'S LEGAL HOLIDAYS | | |
|---|---|---|
| Date | Holiday | Date Condition |
| January 1st | New Year's Day | Fixed |
| 3rd Monday of January | Martin Luther King Jr. Day | Moveable |
| 3rd Monday of February | George Washington & Thomas Jefferson's Birthday | Moveable |
| 4th Monday of April | Confederate Memorial Day | Moveable |
| Last Monday of May | National Memorial Day | Moveable |
| 1st Monday of June | Jefferson Davis's Birthday | Moveable |
| June 19th | Juneteenth | Fixed |
| July 4th | Independence Day | Fixed |
| 1st Monday of September | Labor Day | Moveable |
| 2nd Monday of October | Columbus Day & Fraternal Day & American Indian Heritage Day | Moveable |
| November 11th | Veterans Day | Fixed |
| 4th Thursday of November | Thanksgiving | Moveable |
| December 25th | Christmas Day | Fixed |

#### 4.2.2 NON-WORKDAYS DUE TO ADVERSE WEATHER CLASSIFICATION CRITERIA

The literature review and weather threshold values reported by DOT agencies in the state-of-practice survey served as guide to define the threshold criteria used to classify non-workdays due to adverse weather. Daily precipitation and mean daily air temperature were the weather parameters evaluated to classify workdays and non-workdays from the daily climate data collected. Initially only 12 adverse weather conditions were evaluated, but at the suggestion of ALDOT's project advisory committees, an additional criterion, precipitation > 0.25 in. was added, so a total of 15 weather threshold conditions (P1 to P15) were evaluated to determine non-workdays due to adverse weather (Table 4-3).

The workflow followed for the classification of the climate data to determine non-workdays and workday is presented in Figure 4-2, and showcase the process based on condition 13 or P13, which analyze daily precipitation greater than 0.2 in. and daily mean air temperature lower than 40 °F as thresholds for adverse weather conditions. As the flowchart indicates, the VBA code first validates if there are records of daily precipitation and daily either mean or minimum and maximum air temperature, if not, the day is discarded and counted as day with missing climate data. For days with records of precipitation and temperature, the VBA code first checks if the day is either Saturday or Sunday, then it verifies if the day falls into the observed holidays; if so, the day is classified as a non-workday. If the day is neither a weekend or a legal holiday, then the code checks the recorded daily precipitation and mean daily air temperature and classify as non-workday or workday based on the weather threshold conditions listed in Table 4-3. Once the day is classified, then it is continuous to the next day, then the next month, until the whole year has been processed. This process was done for all the climate stations and for all their period of records.

Multiple climate attributes were computed using VBA that helped in determining the AAWDs process explained in section *4.3 Determining AAWDs for Climate Stations*. Table 4-4 lists the attributes determined for each month after the daily classification of the weather data of a climate station. In Table 4-4, R1, R2, R3, and R5 stand for daily rainfall less than 0.1, 0.2, 0.3, and 0.25 in.; T30, T35, and T40 for daily mean air temperature less than 30, 35, and 40 $^{o}$F, respectively. In addition to station number, year, and month, it determines 15 non-workdays (NWD) and 15 corresponding workdays (WDay) based on 15 thresholds of adverse weather conditions, number of days with missing all data (TotAMiss) and missing rainfall data (TotRainMiss), rainy days (precipitation > 0 in.), average monthly rainfall, average rainfall over rainy days, minimum and maximum rainfall depths, number of days with rainfall > 0.75 in. and the next-day rainfall >0.1 in. or 0.2 in. or 0.25 in. or 0.3 in., number of days for stormwater inspection when rainfall > 0.75 in, and total number of days with missing rainfall or air temperature data in each year. The sum of the non-workdays and workdays in each month should be equal to the number of days in the month (28 to 31 days). Each month has four to five weekends (8 to 10 days), e.g., in 2023 January has nine weekend days, April, July, and December has ten weekend days. Therefore, monthly AWDs are less than 20–23 days without considering legal holidays and adverse weather days.

When the number of days with missing all data and missing rainfall data was determined, weekend days and legal holidays were excluded. It means that if the missing data occurred on weekends or holidays, those days were not considered as missing data since they occurred on non-workdays. We only counted missing data days on potential workdays. Therefore, if the sum of these two missing data days (TotAMiss + TotRainMiss) for a month is greater than one, calculated AWDs for that month was not used for computing average available workdays (AAWDs), which will be discussed in section *4.3 Determining AAWDs for Climate Stations*.

The daily rainfall threshold of 0.25 in. was added to the study in the summer of 20203 based on the comments from the project advisory committee (PAC). Parameters P5, P10, and P15 are new adverse weather parameters. Parameters P1, P6, and P11 take any amount rainfall as a rainy day or adverse weather conditions for construction projects, which is a conservative approach. To determine the 95th percentile rainfall, the US Environmental Protection Agency (USEPA) (2009) suggests removing small rainfall events that are 0.1 in. or less from the data set since these events do not typically cause runoff and could potentially cause the 95th percentile rainfall to be inaccurate (USEPA 2009). The ALDOT Guideline for Operation (GFO 3-73) (ALDOT 2014) requires all ALDOT new development and re-development projects to use the 95th percentile daily rainfall event for calculating runoff volume and peak discharge during drainage design.

**Table 4-3. Parameters (rainfall and air temperature thresholds) for adverse weather conditions for highway construction projects.**

| Parameter No. | Daily Rainfall (in.) | Mean Air temperature (°F) |
|---|---|---|
| 1 or P1 | P > 0 | T< 30 |
| 2 or P2 | P > 0.1 | T< 30 |
| 3 or P3 | P > 0.2 | T< 30 |
| 4 or P4 | P > 0.3 | T< 30 |
| 5 or P5 | P > 0.25 | T< 30 |
| 6 or P6 | P > 0 | T< 35 |
| 7 or P7 | P > 0.1 | T< 35 |
| 8 or P8 | P > 0.2 | T< 35 |
| 9 or P9 | P > 0.3 | T< 35 |
| 10 or P10 | P > 0.25 | T< 35 |
| 11 or P11 | P > 0 | T< 40 |
| 12 or P12 | P > 0.1 | T< 40 |
| 13 or P13 | P > 0.2 | T< 40 |
| 14 or P14 | P > 0.3 | T< 40 |
| 15 or P15 | P > 0.25 | T< 40 |

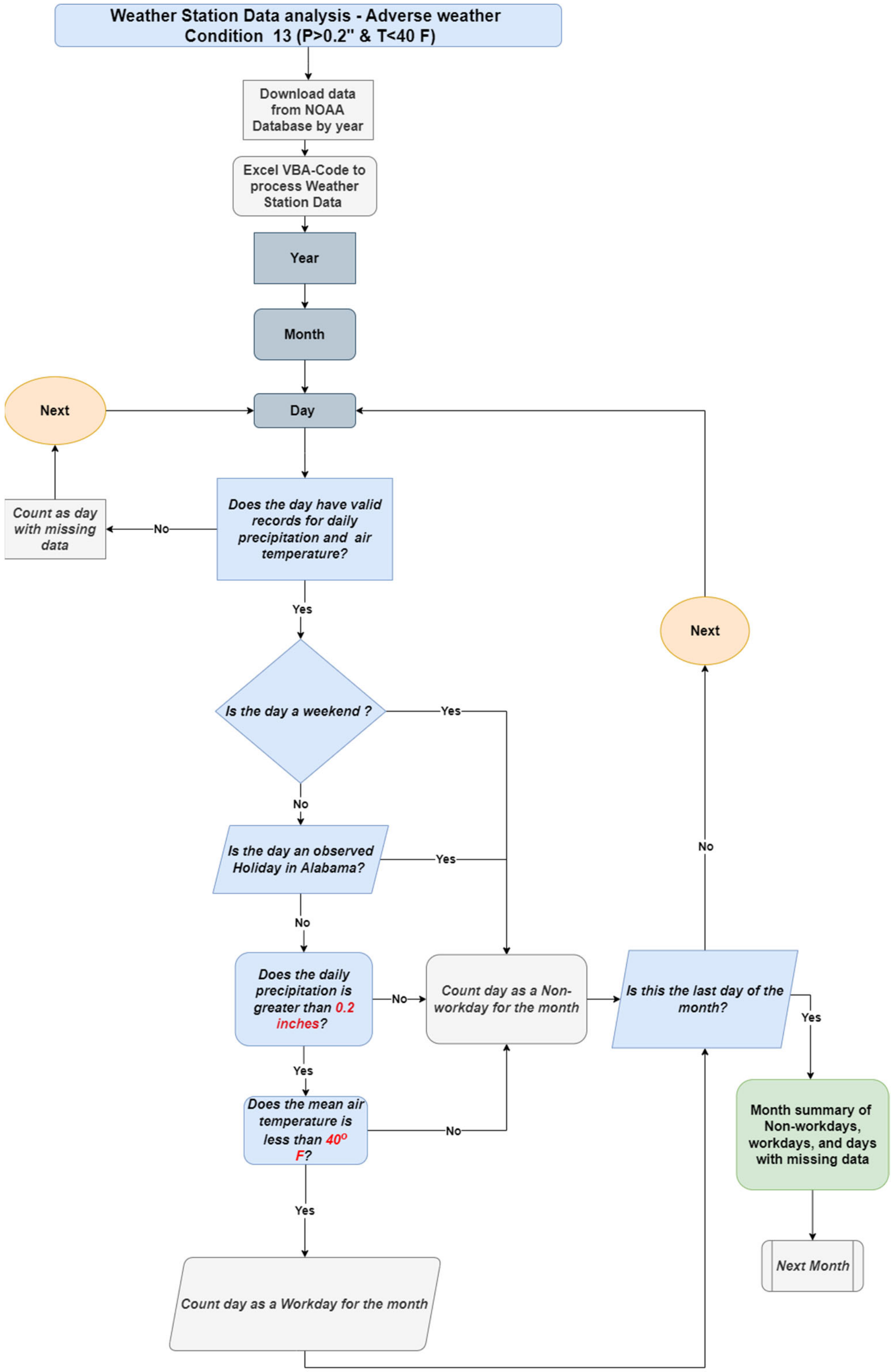



**Figure 4-2. Flowchart of the classification process of the daily climate data to determine non-workdays.**

**Table 4-4. Attributes determined in the classification process of the daily climate data of the selected weather stations to determine non-workdays and workdays.**

| Parameter | Description |
|---|---|
| Station | GSOD or GHCN Station ID (12 or more letters and numbers) |
| Year | Year (four digits) |
| Month | Month |
| NWDR0T30 | Non workdays due to adverse weather- Parameter 1 (P>0 in. & T<30 ºF), weekends, and Alabama holidays in a month |
| NWDR1T30 | Non workdays due to adverse weather- Parameter 2 (P>0.1 in. & T<30 ºF), weekends, and Alabama holidays in a month |
| NWDR2T30 | Non workdays due to adverse weather- Parameter 3 (P>0.2 in. & T<30 ºF), weekends, and Alabama holidays in a month |
| NWDR3T30 | Non workdays due to adverse weather- Parameter 4 (P>0.3 in. & T<30 ºF), weekends, and Alabama holidays in a month |
| NWDR5T30 | Non workdays due to adverse weather- Parameter 5 (P>0.25 in. & T<30 ºF), weekends, and Alabama holidays in a month |
| NWDR0T35 | Non workdays due to adverse weather- Parameter 6 (P>0 in. & T<35 ºF), weekends, and Alabama holidays in a month |
| NWDR1T35 | Non workdays due to adverse weather- Parameter 7 (P>0.1 in. & T<35º F), weekends, and Alabama holidays in a month |
| NWDR2T35 | Non workdays due to adverse weather- Parameter 8 (P>0.2 in. & T<35 ºF), weekends, and Alabama holidays in a month |
| NWDR3T35 | Non workdays due to adverse weather- Parameter 9 (P>0.3 in. & T<30 ºF), weekends, and Alabama holidays in a month |
| NWDR5T35 | Non workdays due to adverse weather- Parameter 10 (P>0.25 in. & T<30 ºF), weekends, and Alabama holidays in a month |
| NWDR0T40 | Non workdays due to adverse weather- Parameter 11 (P>0 in. & T<40º F), weekends, and Alabama holidays in a month |
| NWDR1T40 | Non workdays due to adverse weather- Parameter 12 (P>0.1 in. & T<40 ºF), weekends, and Alabama holidays in a month |
| NWDR2T40 | Non workdays due to adverse weather- Parameter 13 (P>0.2 in. & T<40 ºF), weekends, and Alabama holidays in a month |
| NWDR3T40 | Non workdays due to adverse weather- Parameter 14 (P>0.3 in. & T<40 ºF), weekends, and Alabama holidays in a month |

| | |
|---|---|
| NWDR5T40 | Non workdays due to adverse weather- Parameter 15 (P>0.25 in & T<40 $^o$F), weekends, and Alabama holidays in a month |
| WDayR0T30 | Workdays for Parameter 1 (P>0 in. & T<30 $^o$F) |
| WDayR1T30 | Workdays for Parameter 2 (P>0.1 in. & T<30 $^o$F) |
| WDayR2T30 | Workdays for Parameter 3 (P>0.2 in. & T<30 $^o$ F) |
| WDayR3T30 | Workdays for Parameter 4 (P>0.3 in. & T<30 $^o$F) |
| WDayR5T30 | Workdays for Parameter 5 (P>0.25 in. & T<30 $^o$F) |
| WDayR0T35 | Workdays for Parameter 6 (P>0 in. & T<35 $^o$F) |
| WDayR1T35 | Workdays for Parameter 7 (P>0.1 in. & T<35 $^o$F) |
| WDayR2T35 | Workdays for Parameter 8 (P>0.2 in. & T<35 $^o$F) |
| WDayR3T35 | Workdays for Parameter 9 (P>0.3 in. & T<30 $^o$F) |
| WDayR5T35 | Workdays for Parameter 10 (P>0.25 in. & T<30 $^o$F) |
| WDayR0T40 | Workdays for Parameter 11 (P>0 in. & T<40 $^o$F) |
| WDayR1T40 | Workdays for Parameter 12 (P>0.1 in. & T<40 $^o$F) |
| WDayR2T40 | Workdays for Parameter 13 (P>0.2 in. & T<40 $^o$F) |
| WDayR3T40 | Workdays for Parameter 14 (P>0.3 in. & T<40 $^o$F) |
| WDayR5T40 | Workdays for Parameter 15 (P>0.25 in. & T<40 $^o$F) |
| TotAMiss | Total days with missing data in a month |
| TotRainMiss | Total days with missing rainfall data in a month |
| RainDay | Total days with rainfall >0 in. in a month |
| AvgRain | Average rainfall (in.) per rainy day = Total monthly rainfall / RainyDay |
| AMonRain | Average monthly rainfall (in.) = Total monthly rainfall / Number of days (JM) each month, 28/29 or 30/31 day |
| MinRain | Minimum non-zero rainfall (in.) |
| MaxRain | Maximum rainfall (in.) |
| LRGradR1 | Days with large rainfall (>0.75 in.), next day for rainy day – rainfall 0.1 in. |
| LRGradR2 | Days with large rainfall (>0.75 in.), next day for rainy day - rainfall 0.2 in. |
| LRGradR3 | Days with large rainfall (>0.75 in.), next day for rainy day - rainfall 0.3 in. |
| StInspect | Number of days for stormwater inspection (0.75 in.) in a month |
| TRainMiss | Total days with missing rainfall data per year |
| MonTemM | Total days with missing air temperature data in a month |

### 4.2.3 DIRECT OUTCOMES OF CLIMATE DATA ANALYSIS

The following sections provide examples of the outcomes attained through above mentioned climate data analysis process. Information from one representative weather station with long records for each of the five ALDOT Regions are provided.

#### *East Central Region - Talladega, AL US (USC00018024)*

As an example of the climate attributes determined in the data analysis process, Table 4-5 gives the results obtained from the daily climate records of 2018 of the weather station "Talladega, AL US - USC00018024", located in the East Central Region, analyzed under the climate condition 13 that considers days as adverse weather or non-working day when daily rainfall is greater than 0.2 in. or daily mean air temperature is less than 40°F. For June 2018, a total of 15 non-workdays and 15 workdays were determined, as indicated in the fields "NWDR2T40" and "WDayR2T40". Also, a total of eight rainy days with precipitation greater than 0 in. were identified during this month with an average rain depth of ~0.471 in. with a maximum and minimum precipitation depth registered of 1.35 in and 0.11 in, respectively. Overall, the number of rainy days registered for this station during 2018 was 111 days (TRainDay = 111) and with no missing rainfall data (TAMiss = 0). The LRGradR1,2,3 are three additional useful attributes computed in this process, that can be informative data for future research. These attributes provide the information when large (>0,75 in) precipitation in one day can affect the productivity of the next weekdays, such as for grading construction activity. Adding an additional non-workday after precipitations is greater than 0.75 in. is considered in some studies. For this station a total of 9 days were registered in 2018 affected by the condition of precipitation greater than 0.75 in. and having precipitation 0.1 in. the next day (ToLRGrad - LRGradR1), and 10 and 11 days for the other two conditions LRGradR2 and LRGradR3 in 2018, respectively.

**Table 4-5. Monthly attributes (days or in.) of the daily climate data of the Talladega, AL US - USC00018024 for year 2018.**

| Month | NWDR2T40 | WDayR2T40 | TotAMiss | TotRainMiss | RainDay | AvgRain (in.) | AMonRain (in.) | MinRain (in.) | MaxRain (in.) | LRGradR1 | LRGradR2 | LRGradR3 | StInspect | TRainMiss |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 23 | 8 | 0 | 0 | 6 | 0.208 | 0.040 | 0.04 | 0.35 | 0 | 0 | 0 | 0 | |
| Feb | 15 | 13 | 0 | 0 | 12 | 0.850 | 0.364 | 0.10 | 3.10 | 2 | 2 | 2 | 4 | TRainDay |
| Mar | 16 | 15 | 0 | 0 | 10 | 0.392 | 0.126 | 0.02 | 0.98 | 0 | 1 | 1 | 3 | 111 |
| Apr | 12 | 18 | 0 | 0 | 5 | 1.032 | 0.172 | 0.50 | 2.36 | 1 | 1 | 1 | 2 | TAMiss |
| May | 13 | 18 | 0 | 0 | 12 | 0.454 | 0.176 | 0.10 | 1.35 | 0 | 0 | 0 | 3 | 0 |
| Jun | 15 | 15 | 0 | 0 | 8 | 0.471 | 0.126 | 0.11 | 1.35 | 1 | 1 | 1 | 1 | ToLRGrad |
| Jul | 13 | 18 | 0 | 0 | 10 | 0.505 | 0.163 | 0.06 | 2.10 | 0 | 0 | 0 | 2 | 9 |
| Aug | 13 | 18 | 0 | 0 | 10 | 0.542 | 0.175 | 0.07 | 1.55 | 1 | 1 | 1 | 3 | 10 |
| Sep | 14 | 16 | 0 | 0 | 9 | 0.494 | 0.148 | 0.02 | 1.50 | 1 | 1 | 1 | 3 | 11 |
| Oct | 11 | 20 | 0 | 0 | 4 | 0.475 | 0.061 | 0.06 | 1.00 | 0 | 0 | 0 | 1 | ToInspect |
| Nov | 22 | 8 | 0 | 1 | 12 | 0.696 | 0.278 | 0.06 | 3.35 | 2 | 2 | 2 | 4 | 30 |
| Dec | 20 | 11 | 0 | 0 | 13 | 0.697 | 0.292 | 0.03 | 2.90 | 1 | 1 | 2 | 4 | |

A seasonal pattern of the computed non-workdays for the Talladega, AL US - USC00018024, based on the weather condition 13 (P > 0.2 in. and T < 40°F), can be observed when plotting the results of 2018–2020, where colder months, November through March, tend to have the higher number of non-workdays as expected due to the low temperature of the winter in combination to early spring effects as Figure 4-3 depicts. The workdays ranged from six (February 2022) to 21 (July 2019) days in these three years.

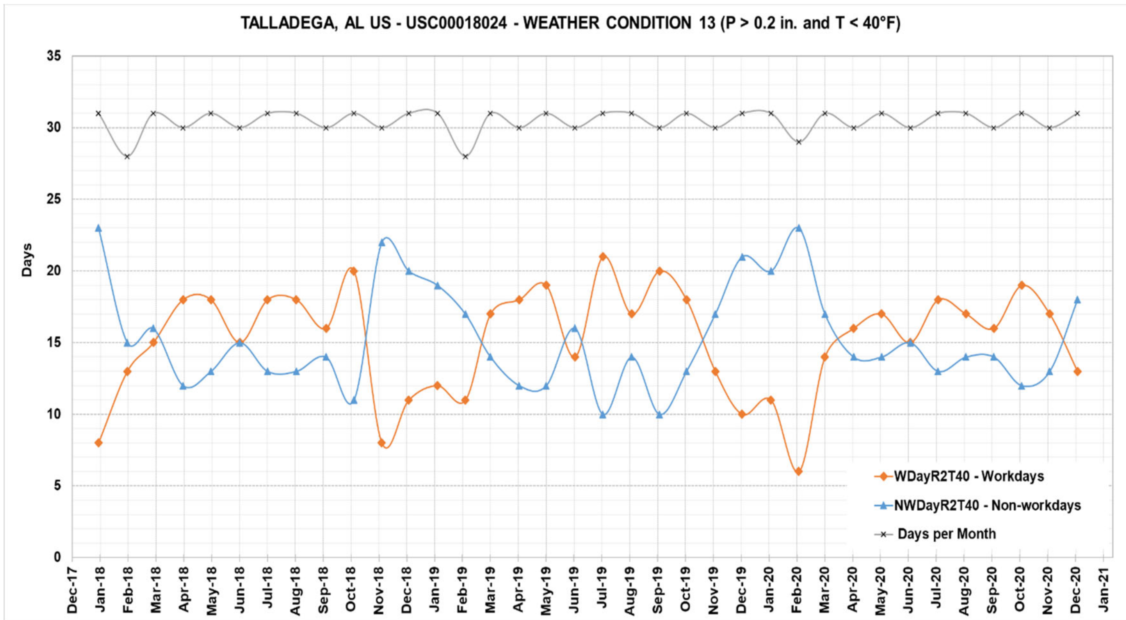



**Figure 4-3. Determined non-workdays and workdays for the Talladega, AL US - USC00018024 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for 2018–2020.**

Figure 4-4 plots the determined average non-working days based on the weather condition 13 for January for the Talladega, AL US - USC00018024 climate station from 1901 to 2020. The weather data covers over 122 years (1900–2022) but it does not have the data for January in 1900, 1911, 2021 and 2022; therefore, only 118 years of weather data were used to determine the non-workdays for January. In the excluded years, 1900, 1911, 2021 and 2022, there were many days with missing weather data, therefore the data did not comply with its validity to be used to determine non-workdays. The computed average non-workdays (ANWDs) for January during this period 1901–1910 and 1912–2020 was 20 days with standard deviation of four days (Figure 4-4). On the other hand, the AWDs for each year (Figure 4-5) were determined as the total number of days in the month (e.g., 31 in January) minus the computed non-working days. The determined AAWDs January for Talladega, AL US - USC00018024 is determined to be 11 days with a standard deviation of four days over 118 years. Even standard deviations from the average non-workdays or workdays, the variations for both are very large. The non-workdays in January ranged from 9 to 29 days and from 2 to 20 days for AWDs.

When calculating the average non-workdays and workdays for June, a more even situation was identified. Figure 4-7 and Figure 4-6 show that during June, an average of 13 days is considered non-workdays versus 17 days available for work in construction activities, with a standard deviation of two days. When compared to January results, the increase in AAWD is due to warmer and drier conditions typical of the summer months, June through August. It is also important to note that for

June the results were computed for the period 1900–1909, 1911–2020, as 1910, 2021 and 2022 were excluded due to missing data. The non-workdays in June ranged from 9 to 20 days and from 10 to 21 days for AWDs at Talladega.

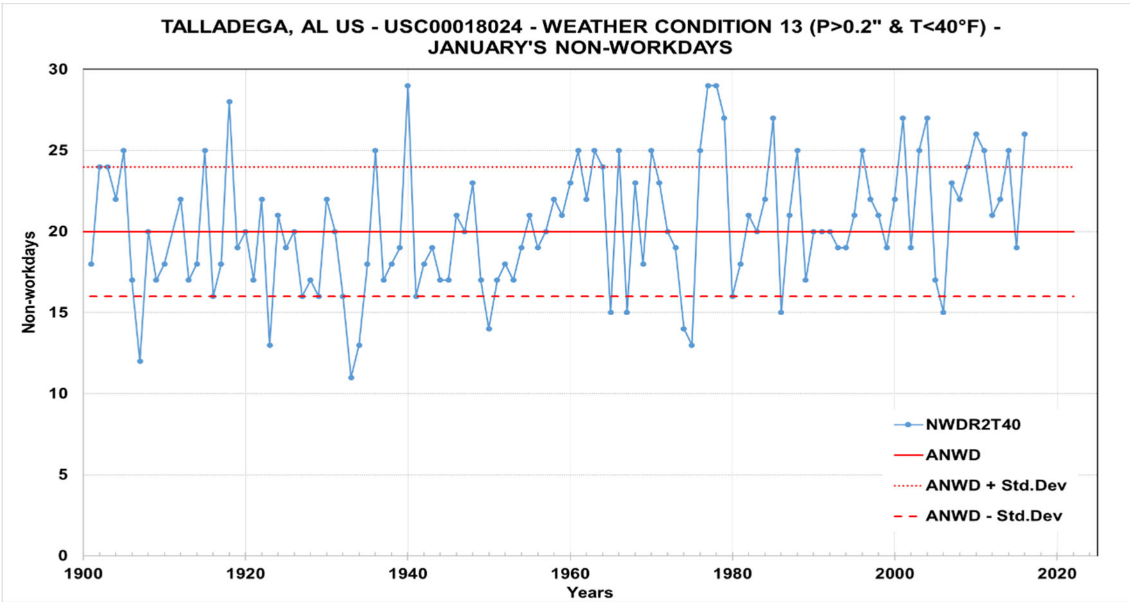



**Figure 4-4. Determined January's average non-workdays for the Talladega, AL US - USC00018024 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1901–1910, 1912–2020.**

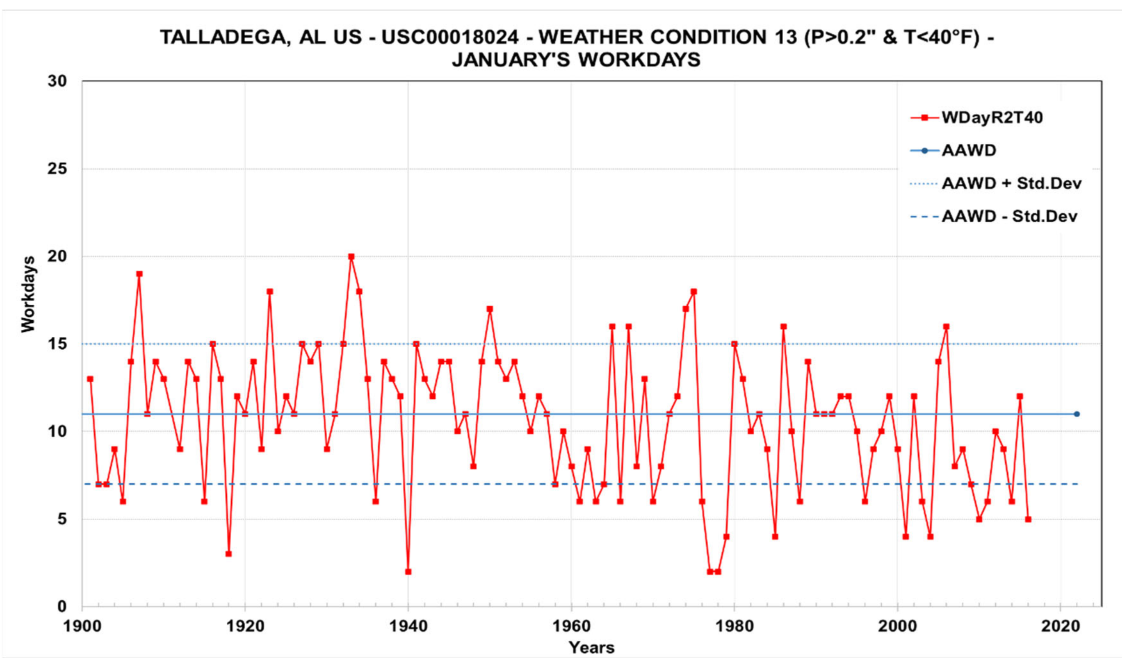



**Figure 4-5. Determined January's average available workdays for the Talladega, AL US - USC00018024 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1901–1910, 1911–2020.**

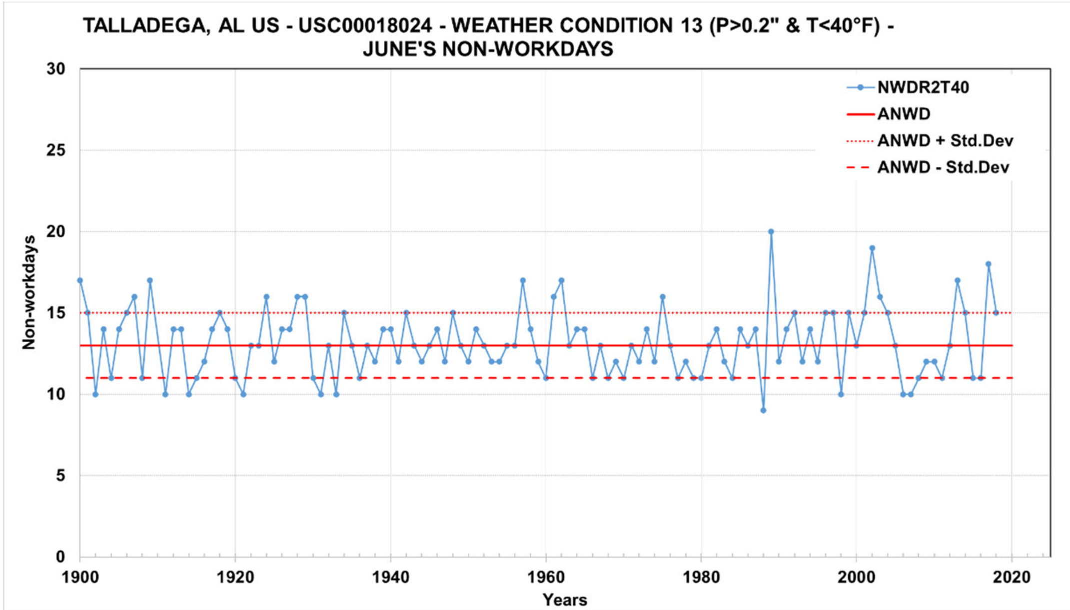



**Figure 4-7. Determined June's average non-workdays for the Talladega, AL US - USC00018024 - Weather Condition 13 (P > 0.2 in. and T < 40 °F) for period of 1900-1909, 1911-2020.**

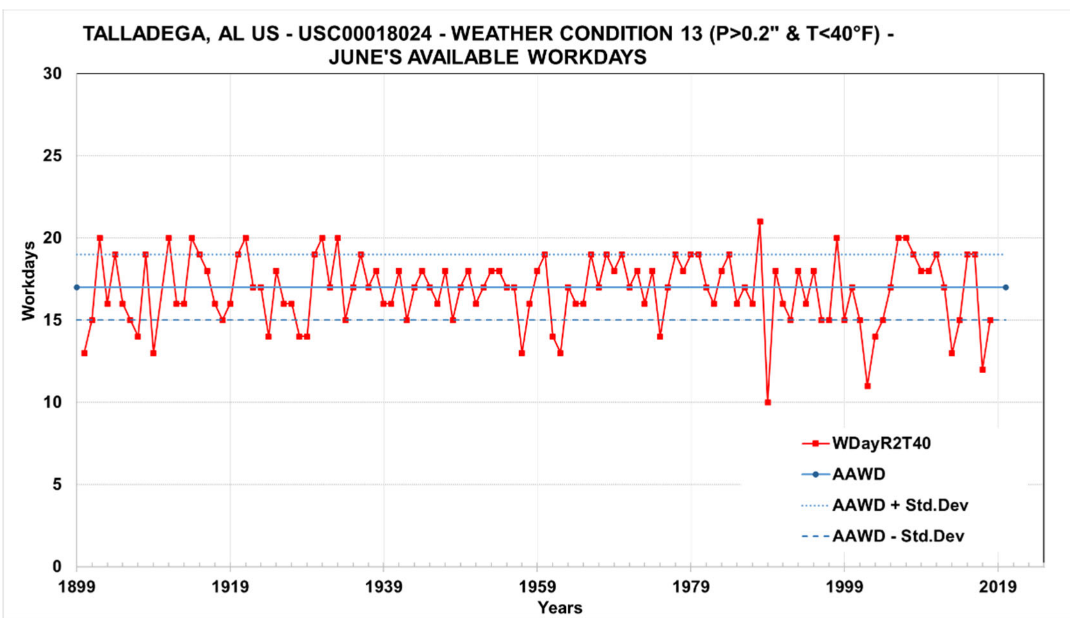



**Figure 4-6. Determined June's average available workdays for the Talladega, AL US - USC00018024 - Weather Condition 13 (P > 0.2 in. and T < 40 °F) for period of 1900-1909, 1911-2020.**

### ***North Region - Huntsville Intl/C.T.Jones Field Airport (72323003856)***

The weather station "Huntsville Intl/C.T.Jones Field Airport, AL US - 72323003856" in the North Region, which was analyzed under the climate condition 13 of daily precipitation greater than 0 in. and daily mean minimum air temperature less than 40°F, provides the results from the daily climate records of 2018 in Table 4-6. There were found to be a total of 15 non-working days (NWDR2T40) and 15 working days (WDayR0T40) in June 2018. With a total of 12 rainy days and an average rain depth of about 0.461 in., with maximum and minimum amounts of 1.63 in. and 0.02 in., respectively. With regard to the entire year 2018, this station recorded 149 rainy days (TRainDay), and there were no missing rainfall data (TAMiss = 0).

**Table 4-6. Classification of the daily climate data of the Huntsville Intl/C.T.Jones Field Airport, AL US – 72323003856 for year 2018.**

| Month | NWDR2T40 | WDayR2T40 | TotAMiss | TotRainMiss | RainDay | AvgRain (in.) | AMonRain (in.) | MinRain (in.) | MaxRain (in.) | LRGradR1 | LRGradR2 | LRGradR3 | StInspect | TRainMiss |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 23 | 8 | 0 | 0 | 10 | 0.164 | 0.053 | 0.01 | 0.82 | 1 | 1 | 1 | 1 | 0 |
| Feb | 15 | 13 | 0 | 0 | 21 | 0.353 | 0.265 | 0.01 | 1.98 | 2 | 3 | 3 | 4 | TRainDay |
| Mar | 13 | 18 | 0 | 0 | 15 | 0.328 | 0.159 | 0.01 | 1.52 | 1 | 1 | 1 | 3 | 149 |
| Apr | 15 | 15 | 0 | 0 | 11 | 0.821 | 0.301 | 0.02 | 4.12 | 0 | 0 | 1 | 3 | TAMiss |
| May | 14 | 17 | 0 | 0 | 12 | 0.348 | 0.135 | 0.01 | 1.26 | 0 | 0 | 0 | 1 | 0 |
| Jun | 15 | 15 | 0 | 0 | 12 | 0.461 | 0.184 | 0.02 | 1.63 | 1 | 1 | 1 | 3 | ToLRGrad |
| Jul | 12 | 19 | 0 | 0 | 8 | 0.263 | 0.068 | 0.01 | 1.11 | 1 | 1 | 1 | 1 | 9 |
| Aug | 11 | 20 | 0 | 0 | 8 | 0.194 | 0.050 | 0.02 | 0.33 | 0 | 0 | 0 | 0 | 12 |
| Sep | 16 | 14 | 0 | 0 | 12 | 0.438 | 0.175 | 0.02 | 1.54 | 0 | 1 | 1 | 3 | 13 |
| Oct | 11 | 20 | 0 | 0 | 10 | 0.243 | 0.078 | 0.02 | 1.01 | 1 | 1 | 1 | 2 | ToInspect |
| Nov | 20 | 10 | 0 | 0 | 14 | 0.389 | 0.182 | 0.01 | 1.10 | 2 | 2 | 2 | 3 | 29 |
| Dec | 19 | 12 | 0 | 0 | 16 | 0.648 | 0.334 | 0.01 | 3.06 | 0 | 1 | 1 | 5 | |

Figure 4-8 displays the non-working days and working days determined for the years 2017 through 2019. Non-working days range from 13 to 24 days during cold and wet months (January through March), whereas they fluctuate between 15 and 20 days during warm and dry months (June through August).

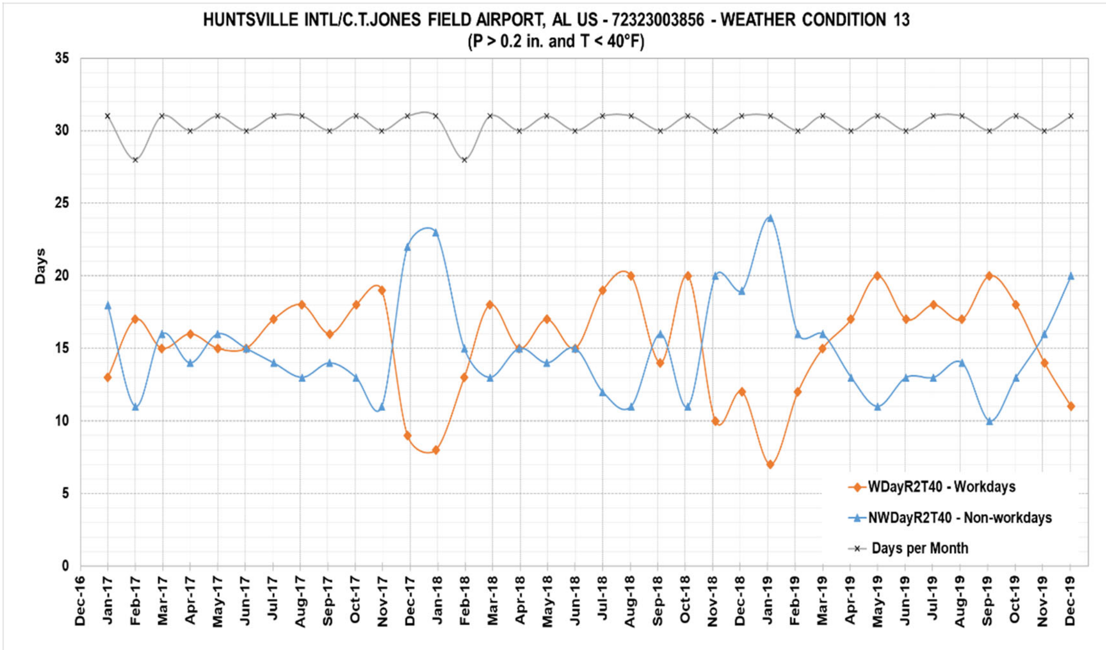



**Figure 4-8. Determined non-workdays and workdays for the Huntsville Intl/C.T.Jones Field Airport, AL US – 72323003856 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for 2017-2019.**

Based on data collected over a 46-year period, from 1973 to 2018, the average non-workdays (ANWDs, Figure 4-9 and Figure 4-11) and Average Available Workdays (AAWDs, Figure 4-10 and Figure 4-12) for January and June for condition 13 (P>0.2 in. and T<40°F) were calculated for the Huntsville Intl/C.T.Jones Field Airport, AL US - 72323003856. The AAWDs for June were estimated to be 17 days with a standard deviation of three days (Figure 4-11), while the AAWDs for January average around eight days with a standard deviation of four days (Figure 4-9). The non-workdays in January ranged from 16 to 30 days and from 1 to 15 days for AWDs. The non-workdays in June ranged from 9 to 18 days and from 12 to 21 days for AWDs over 46 years at Huntsville.

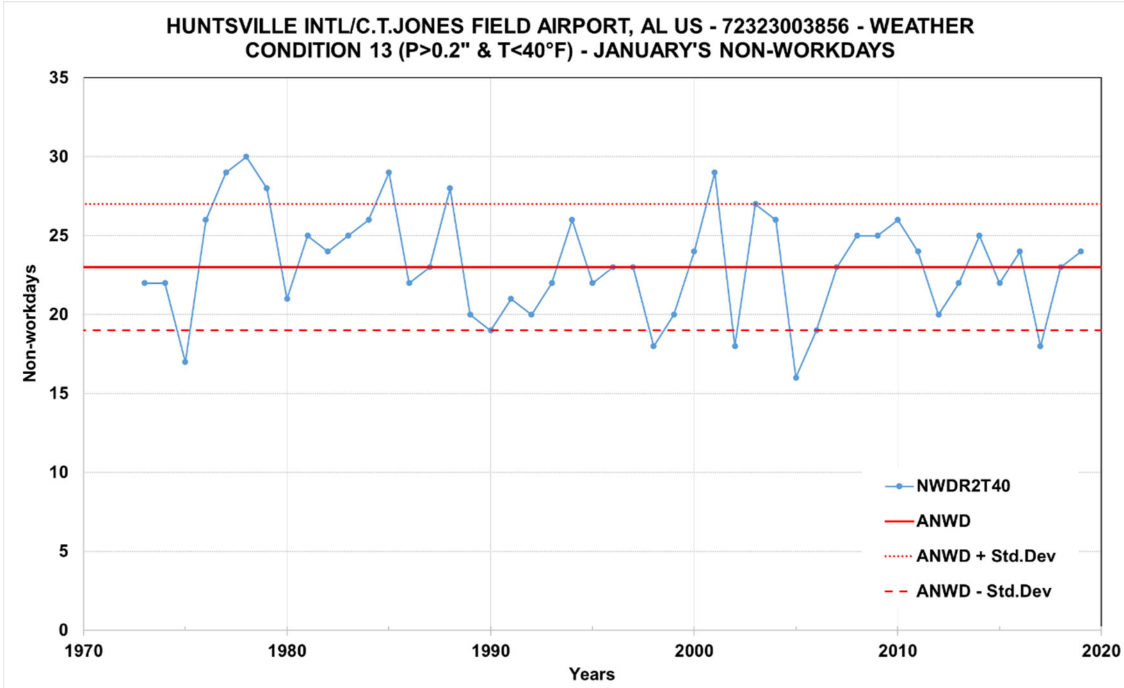



**Figure 4-9. Determined January's average non-workdays for the Huntsville Intl/C.T.Jones Field Airport, AL US – 72323003856 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2018.**

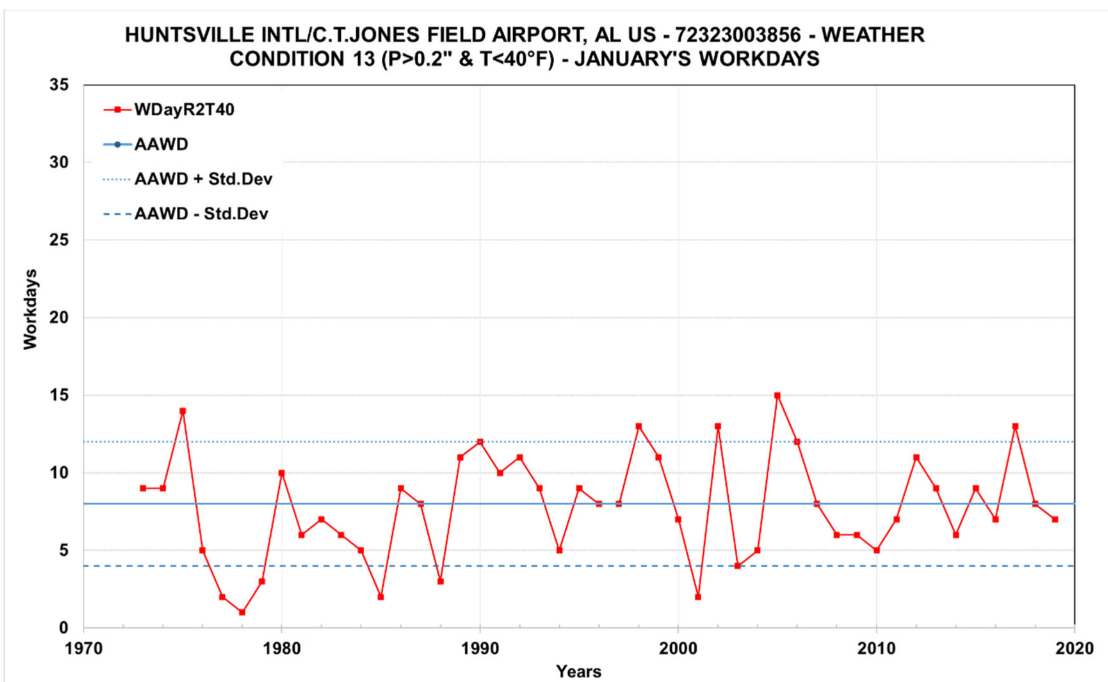



**Figure 4-10. Determined January's average available workdays for the Huntsville Intl/C.T.Jones Field Airport, AL US – 72323003856 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2018.**

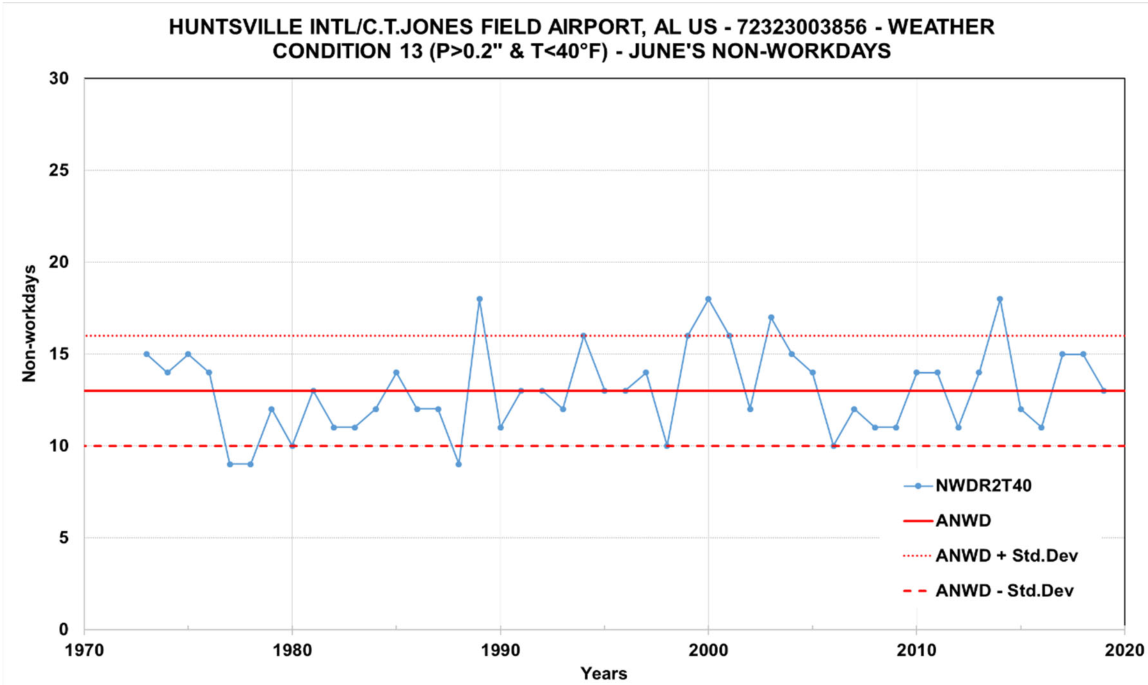



**Figure 4-11. Determined June's average non-workdays for the Huntsville Intl/C.T.Jones Field Airport, AL US – 72323003856 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2018.**

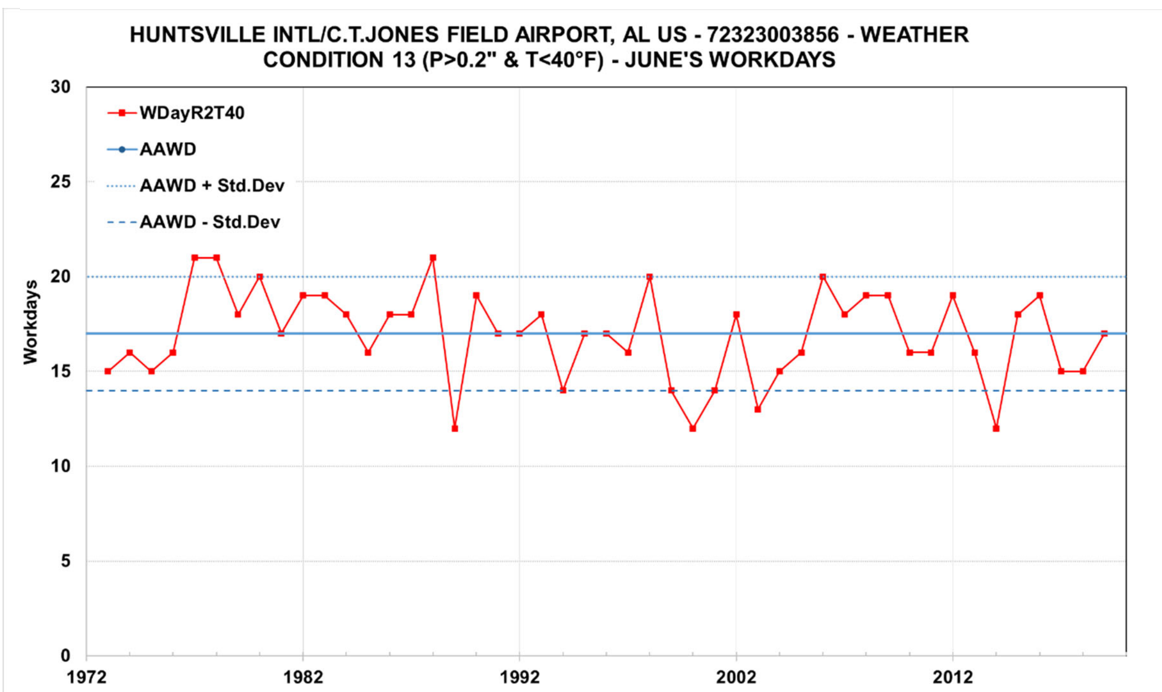



**Figure 4-12. Determined June's average available workdays for the Huntsville Intl/C.T.Jones Field Airport, AL US – 72323003856 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2018.**

### ***West Central Region - Tuscaloosa Municipal Airport (72228693806)***

The weather station located at "Tuscaloosa Municipal ARPT, AL US - 72228693806" in the West Central Region was analysis under specific climatic conditions, corresponding to daily precipitation greater than 0.2 in. and daily mean air temperature less than 40°F (Condition 13). The results derived from this station's daily climate records for 2018 are shown Table 4-7. The station recorded 18 working days (WDayR2T40) and a total of 12 non-working days (NWDR2T40) in June 2018. There were seven rainy days in total during the month, with an average rainfall of roughly 0.260 in. Rainfall totals ranged from 0.01 in. at the lowest to 1.21 in. at the highest. The station recorded 140 rainy days (TRainDay) throughout the entire year 2018, and there were no instances of missing rainfall data (TAMiss = 0).

For the years 2017 through 2019, Figure 4-13 shows the non-workdays and workdays that have been determined. In contrast to the warm and dry months of June through August, when they fluctuate between 10 and 15 days, non-working days range from 16 to 21 days during the cold and wet months of January through March.

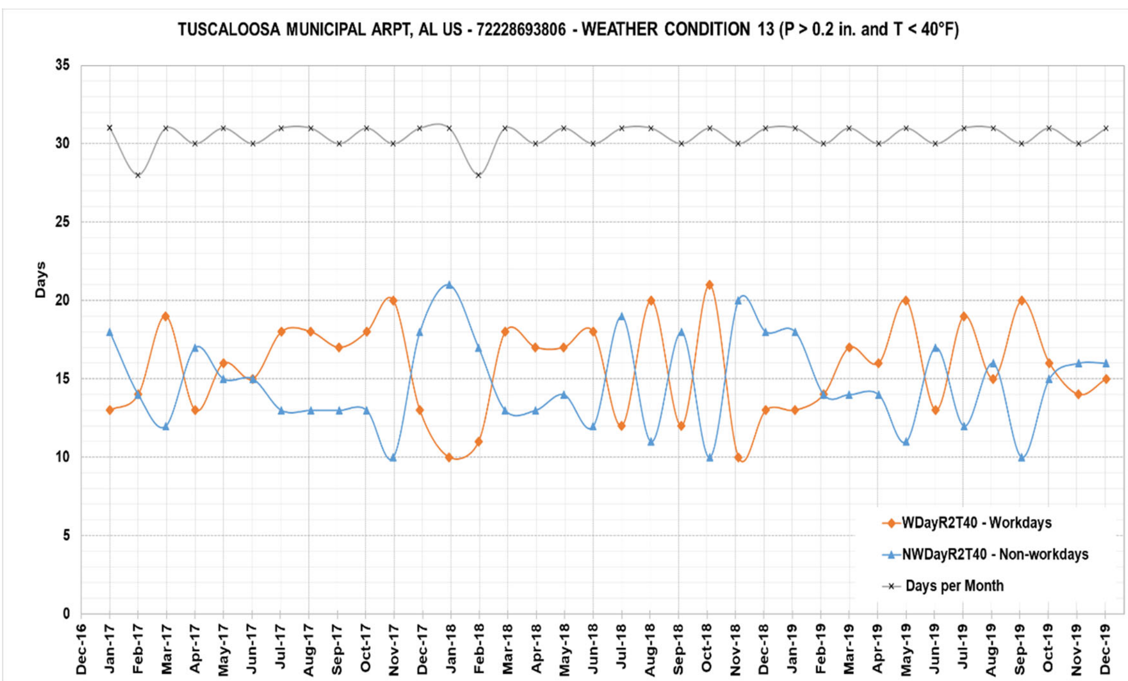



**Figure 4-13. Determined non-workdays and workdays for the Tuscaloosa Municipal ARPT, AL US - 72228693806 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for 2017-2019.**

**Table 4-7. Classification of the daily climate data of the Tuscaloosa Municipal ARPT, AL US - 72228693806 for year 2018.**

| Month | NWDR2T40 | WDayR2T40 | TotAMiss | TotRainMiss | RainDay | AvgRain (in.) | AMonRain (in.) | MinRain (in.) | MaxRain (in.) | LRGradR1 | LRGradR2 | LRGradR3 | StInspect | TRainMiss |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 21 | 10 | 0 | 0 | 8 | 0.230 | 0.059 | 0.02 | 0.46 | 0 | 0 | 0 | 0 | 0 |
| Feb | 17 | 11 | 0 | 0 | 19 | 0.549 | 0.373 | 0.01 | 2.43 | 2 | 2 | 3 | 4 | TRainDay |
| Mar | 13 | 18 | 0 | 0 | 12 | 0.363 | 0.140 | 0.01 | 1.18 | 1 | 1 | 1 | 3 | 140 |
| Apr | 13 | 17 | 0 | 0 | 8 | 1.023 | 0.273 | 0.01 | 3.02 | 1 | 2 | 2 | 3 | TAMiss |
| May | 14 | 17 | 0 | 0 | 13 | 0.374 | 0.157 | 0.01 | 1.47 | 1 | 1 | 1 | 2 | 0 |
| Jun | 12 | 18 | 0 | 0 | 7 | 0.260 | 0.061 | 0.01 | 1.21 | 1 | 1 | 1 | 1 | ToLRGrad |
| Jul | 19 | 12 | 0 | 0 | 14 | 0.827 | 0.374 | 0.05 | 4.39 | 0 | 0 | 1 | 6 | 10 |
| Aug | 11 | 20 | 0 | 0 | 10 | 0.507 | 0.164 | 0.08 | 1.45 | 1 | 1 | 1 | 3 | 11 |
| Sep | 18 | 12 | 0 | 0 | 12 | 0.380 | 0.152 | 0.01 | 1.11 | 1 | 1 | 1 | 2 | 13 |
| Oct | 10 | 21 | 0 | 0 | 6 | 0.193 | 0.037 | 0.01 | 0.91 | 0 | 0 | 0 | 1 | ToInspect |
| Nov | 20 | 10 | 0 | 0 | 15 | 0.438 | 0.219 | 0.01 | 1.28 | 1 | 1 | 1 | 3 | 31 |
| Dec | 18 | 13 | 0 | 0 | 16 | 0.568 | 0.293 | 0.01 | 4.36 | 1 | 1 | 1 | 3 | |

The results presented in Figure 4-14 through Figure 4-17 were derived from the Tuscaloosa Municipal ARPT, AL US - 72228693806 data collected over a 46-year period, from 1973 to 2018. The average number of non-workdays (ANWDs) and average number of workdays (AAWDs) for January and June under condition 13 (daily precipitation greater than 0.2 in. and daily mean air temperature less than 40°F) were calculated during this time. As depicted in Figure 4-15 for January a total of 11 days was computed as AAWDs while 17 days were determined for June (Figure 4-17). The non-workdays in January ranged from 13 to 30 days and from 1 to 20 days for AWDs. The non-workdays in June ranged from 9 to 18 days and from 13 to 24 days for AWDs over 46 years at the Tuscaloosa station.

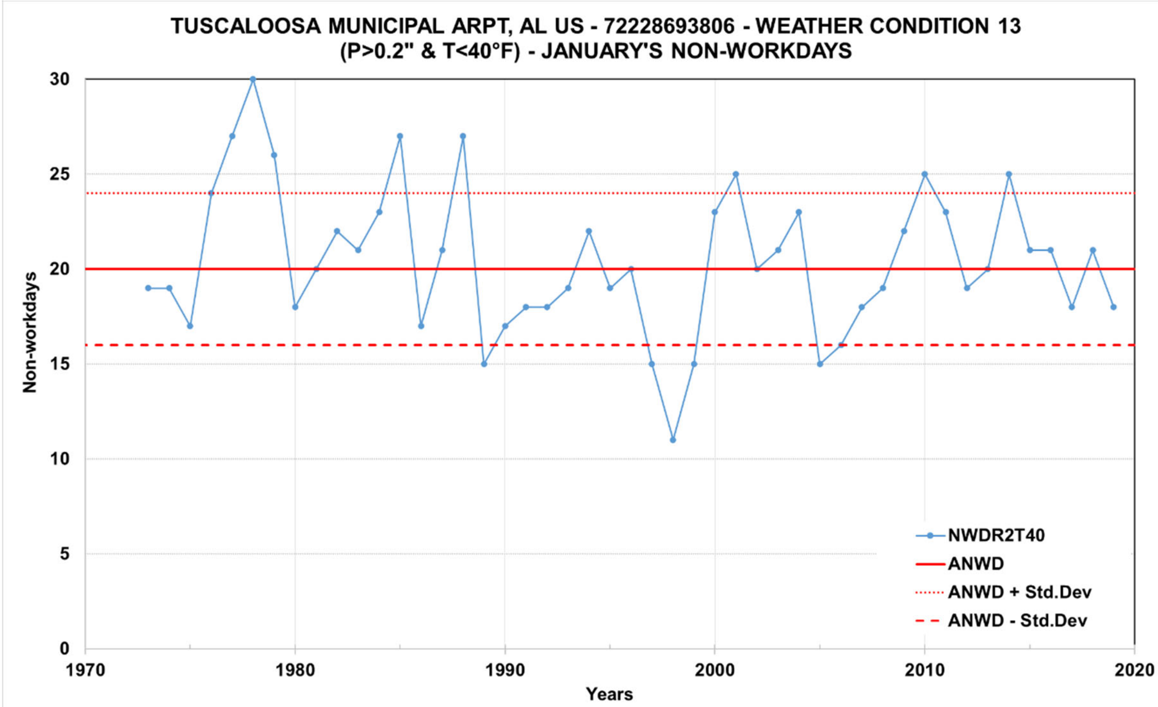



**Figure 4-14. Determined January's average non-workdays for the Tuscaloosa Municipal ARPT, AL US - 72228693806 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2018.**

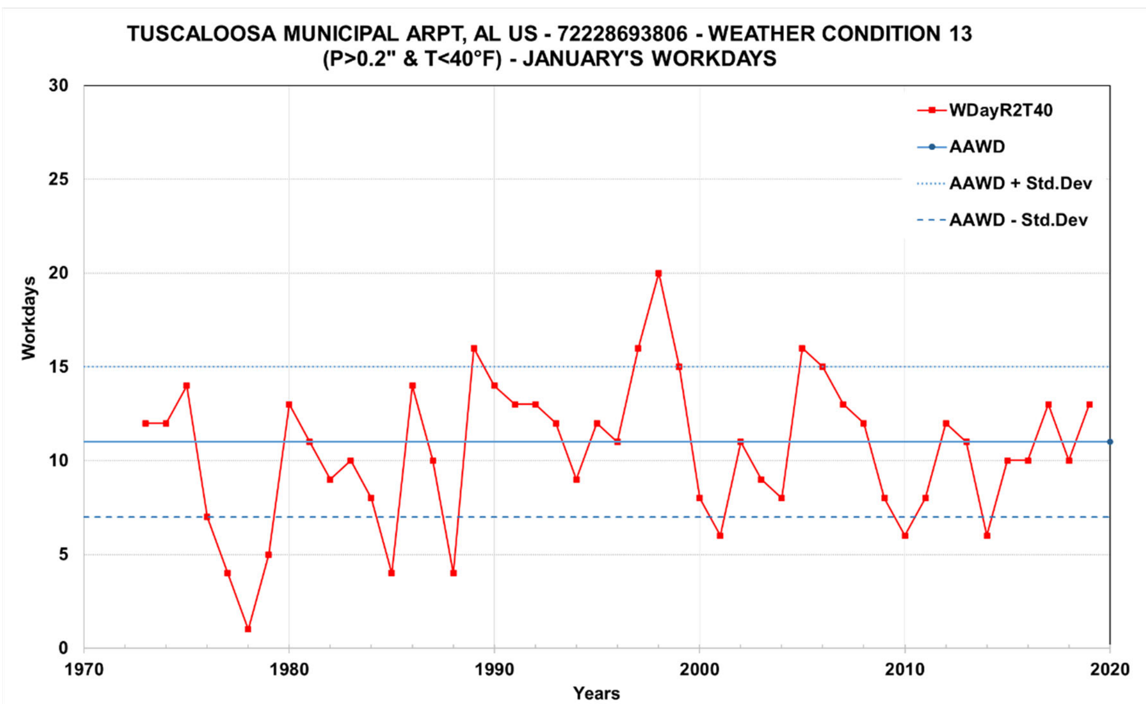



**Figure 4-15. Determined January's average available workdays for the Tuscaloosa Municipal ARPT, AL US - 72228693806 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2018.**

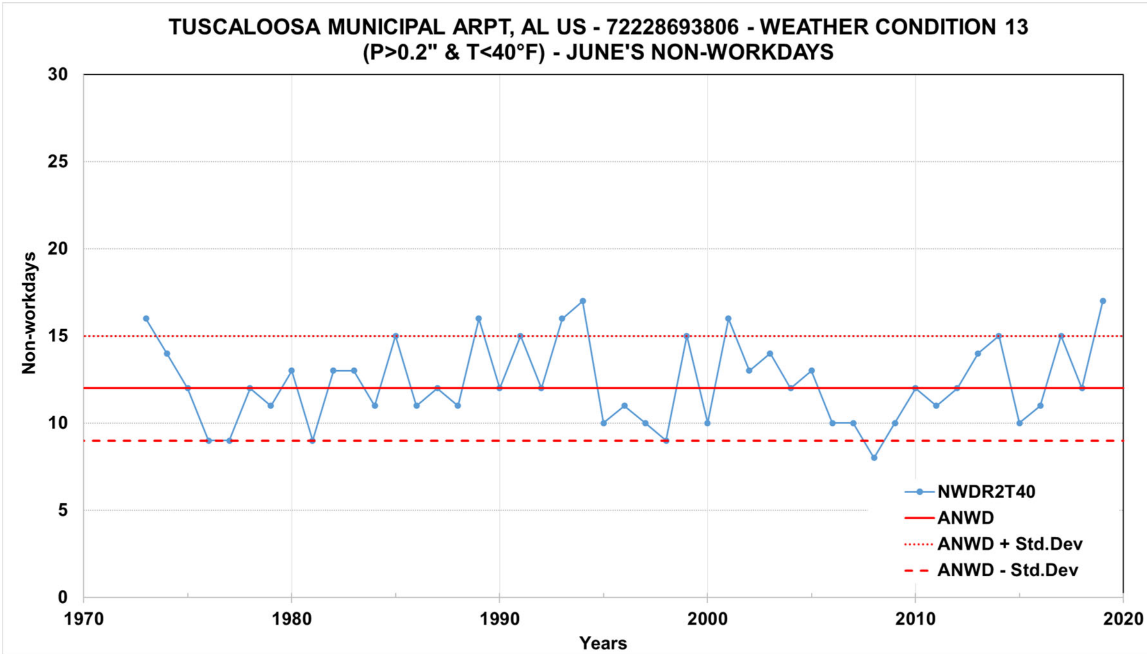



**Figure 4-16. Determined June's average non-workdays for the Tuscaloosa Municipal ARPT, AL US - 72228693806 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2018.**

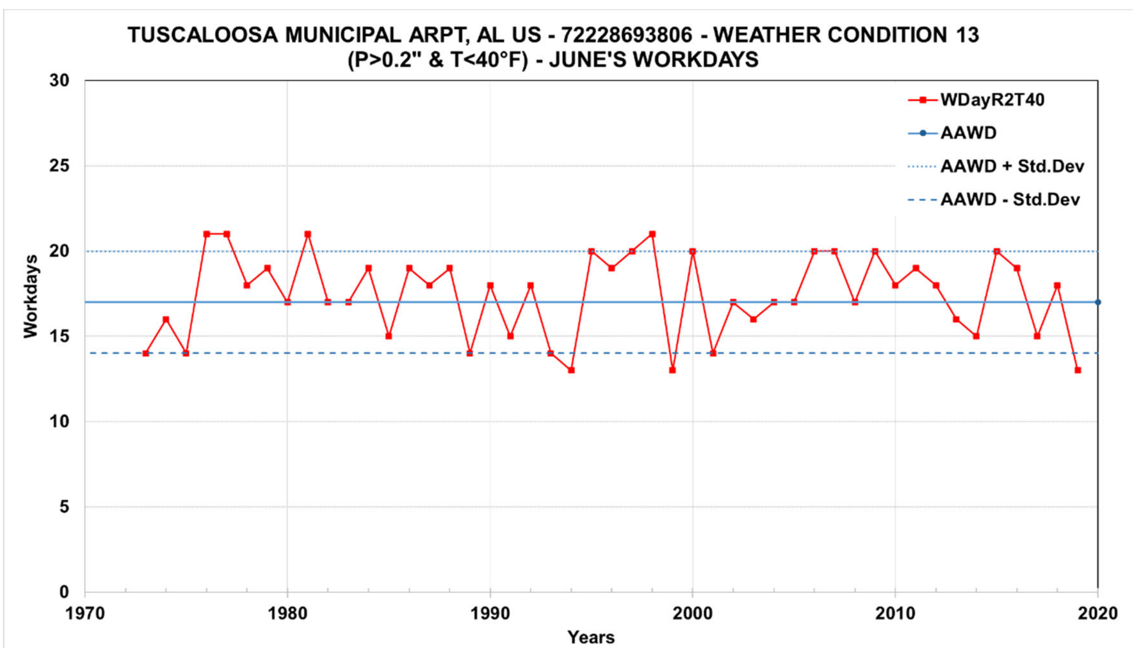



**Figure 4-17. Determined June's average available workdays for the Tuscaloosa Municipal ARPT, AL US - 72228693806 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2018.**

## *Southwest Region - Mobile Regional Airport (72223013894)*

Based on weather condition 13 (P>0.2 in. & T<40°F), the results of processing the data from the weather station at "Mobile Regional Airport, AL US – 72223013894" in the Southwest Region for the year 2018 are shown in Table 4-8. This station recorded a total of 14 non-working days (NWDR2T40) and 16 working days (WDayR2T40) in June 2018. A total of 13 rainy days occurred during the month, with an average rainfall of roughly 0.502 in. From 0.01 in. at the lowest to 1.69 in. at the highest, rain was measured. Notably, there were 149 rainy days (TrainDay) throughout the entire year 2018, and one day with no rainfall data (TAMiss = 1).

**Table 4-8. Classification of the daily climate data of the Mobile Regional Airport, AL US – 72223013894 for year 2018.**

| Month | NWDR2T40 | WDayR2T40 | TotAMiss | TotRainMiss | RainDay | AvgRain (in.) | AMonRain (in.) | MinRain (in.) | MaxRain (in.) | LRGradR1 | LRGradR2 | LRGradR3 | StInspect | TRainMiss |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 19 | 12 | 0 | 0 | 11 | 0.360 | 0.128 | 0.02 | 1.55 | 2 | 2 | 2 | 2 | |
| Feb | 15 | 13 | 0 | 0 | 15 | 0.505 | 0.271 | 0.01 | 2.58 | 2 | 2 | 2 | 4 | TrainDay |
| Mar | 13 | 18 | 0 | 0 | 8 | 0.464 | 0.120 | 0.01 | 1.32 | 0 | 0 | 0 | 1 | 149 |
| Apr | 10 | 20 | 0 | 0 | 8 | 0.386 | 0.103 | 0.02 | 1.25 | 1 | 1 | 1 | 1 | TAMiss |
| May | 13 | 18 | 0 | 0 | 11 | 0.534 | 0.189 | 0.05 | 1.73 | 0 | 0 | 0 | 3 | 0 |
| Jun | 14 | 16 | 0 | 0 | 13 | 0.502 | 0.218 | 0.01 | 1.69 | 4 | 4 | 4 | 3 | ToLRGrad |
| Jul | 15 | 16 | 0 | 0 | 12 | 0.478 | 0.185 | 0.02 | 1.32 | 1 | 1 | 1 | 3 | 12 |
| Aug | 13 | 18 | 0 | 0 | 17 | 0.354 | 0.194 | 0.01 | 1.98 | 1 | 2 | 2 | 2 | 13 |
| Sep | 17 | 13 | 0 | 0 | 15 | 0.349 | 0.175 | 0.01 | 2.15 | 0 | 0 | 0 | 1 | 13 |
| Oct | 10 | 21 | 0 | 0 | 7 | 0.286 | 0.065 | 0.02 | 1.68 | 0 | 0 | 0 | 1 | ToInspect |
| Nov | 17 | 13 | 0 | 0 | 16 | 0.431 | 0.230 | 0.01 | 1.75 | 0 | 0 | 0 | 3 | 28 |
| Dec | 15 | 16 | 0 | 0 | 16 | 0.576 | 0.297 | 0.01 | 3.39 | 1 | 1 | 1 | 4 | 1 |

The distribution of workdays and non-workdays from 2017 to 2019 is depicted in Figure 4-18 of the data. Notably, from June through August, when it was warm and dry, there were 10 to 13 non-working days as opposed to 10 to 14 days during the colder month. When compared with stations further north where low temperatures are more frequently registered, the difference between the cold and warm seasons is not very noticeable. However, weather events like hurricanes and tropical storms like Cindy in June 2017 (which had an impact that can be seen in the Figure 4-18, where a total of 19 non-workdays were computed, leading to an odd result for the summer season) have a bigger impact on the southern region.

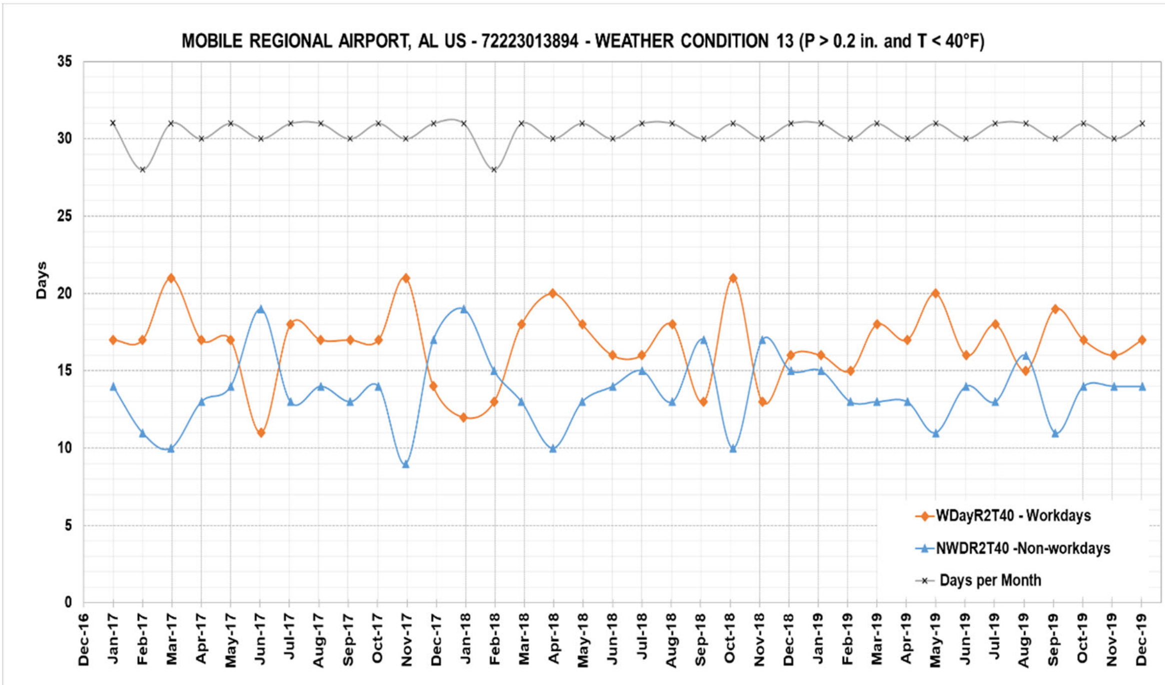



**Figure 4-18. Determined non-workdays and workdays for the Mobile Regional Airport, AL US - 72223013894 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for 2017-2019.**

The results presented in Figure 4-19 through Figure 4-22 were derived from the Mobile Regional Airport, AL US – 72223013894 data collected over a 47-year period, from 1973 to 2019. For condition 13 (P>0.2 in. & T<40°F) the amount of the average AWDs determined was 13 days (Figure 4-20) with a standard deviation of four days for January, while a total of 16 AAWDs (Figure 4-22) for the month of June with a standard deviation of three days. The non-workdays in January ranged from 11 to 27 days and from 4 to 20 days for AWDs. The non-workdays in June ranged from 10 to 20 days and from 10 to 21 days for AWDs over 47 years at the Mobile Regional Airport climate station.

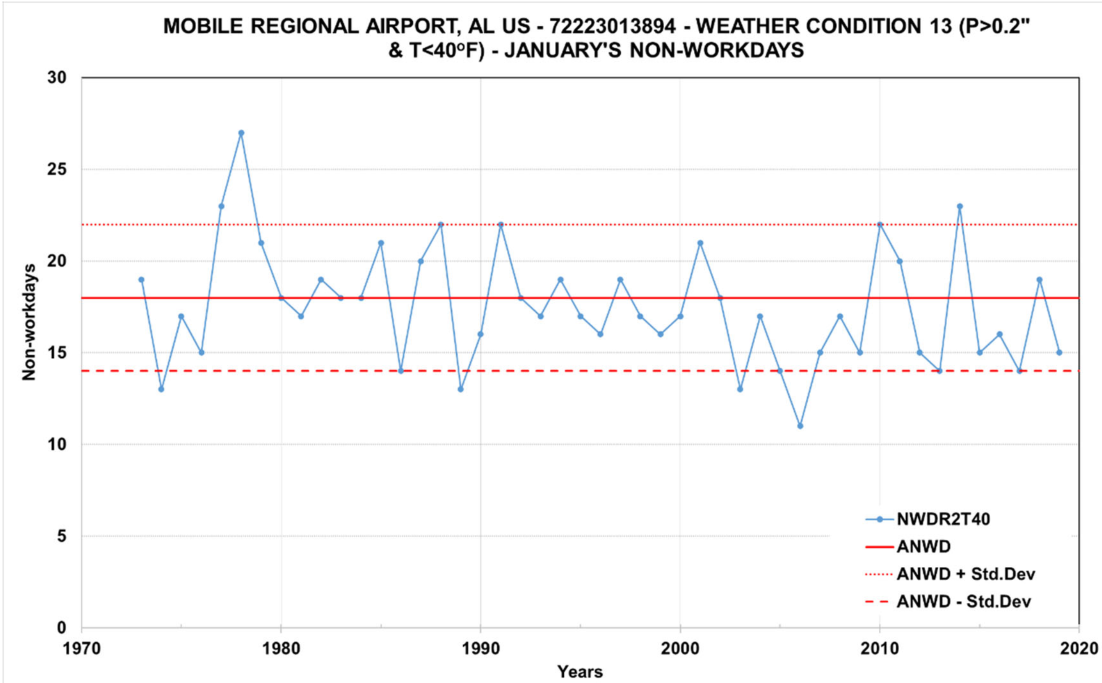



**Figure 4-19. Determined January's average non-workdays for the Mobile Regional Airport, AL US – 72223013894 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2019.**

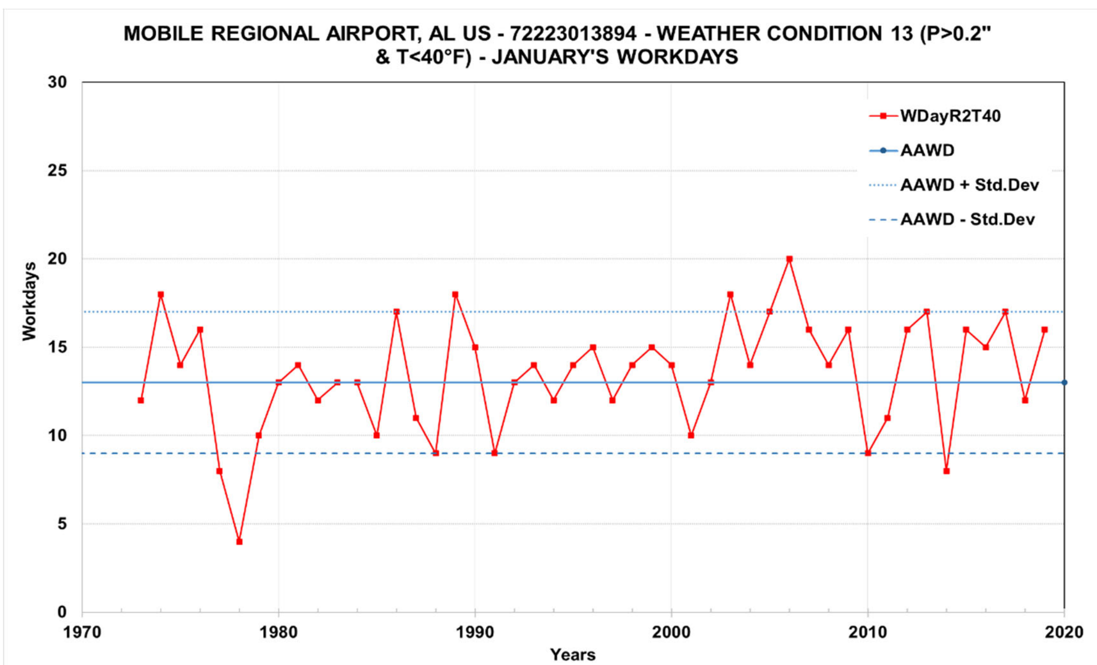



**Figure 4-20. Determined January's average available workdays for the Mobile Regional Airport, AL US – 72223013894 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2019.**

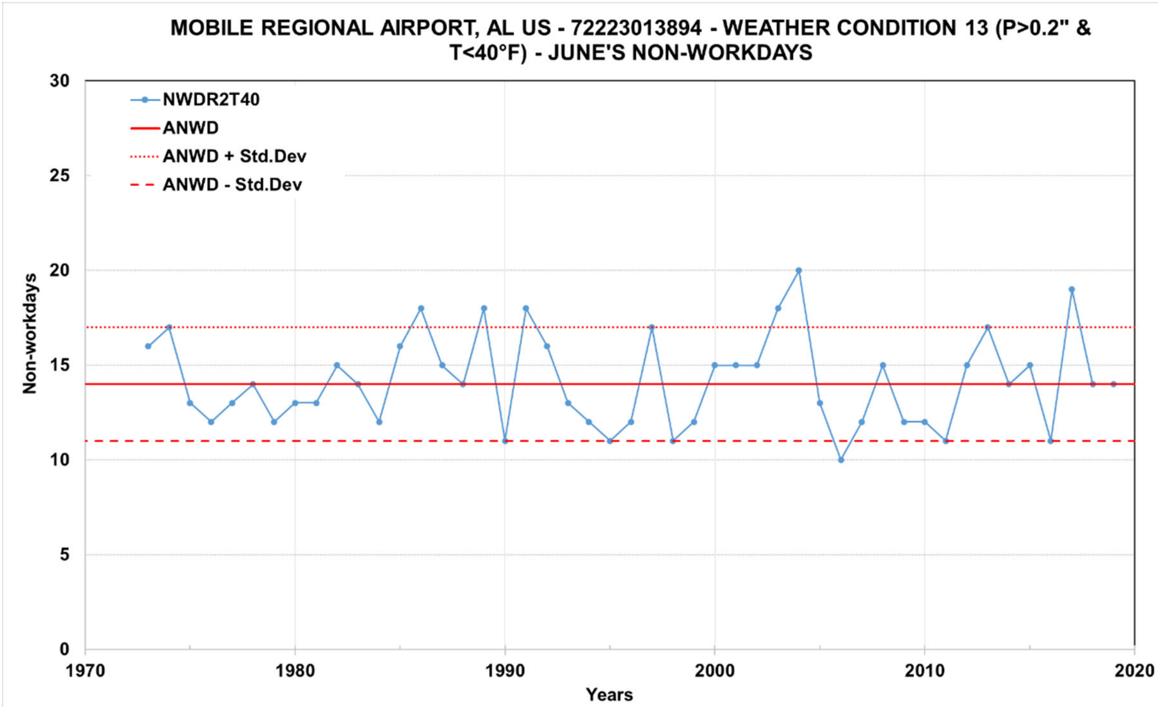



**Figure 4-21. Determined June's average non-workdays for the Mobile Regional Airport, AL US – 72223013894 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2019.**

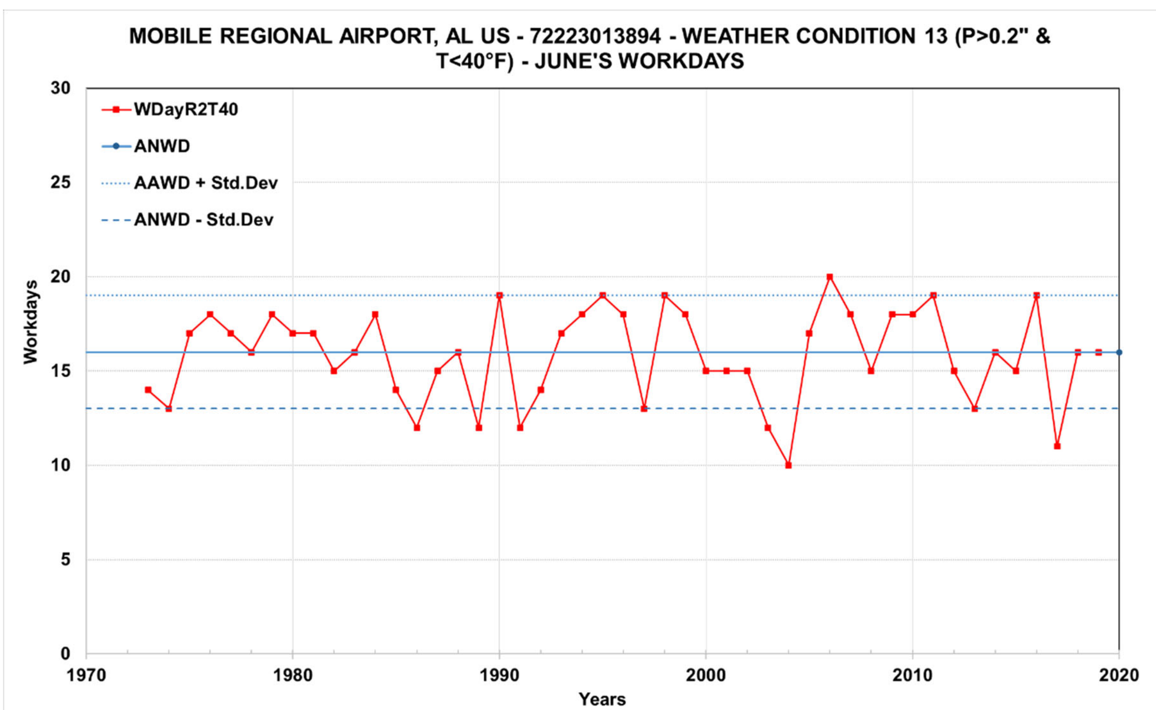



**Figure 4-22. Determined June's average available workdays for the Mobile Regional Airport, AL US – 72223013894 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1973-2019.**

### ***Southeast Region - Lafayette 2 W, AL US (USC00014502)***

Table 4-9 displays the outcomes of processing the data from the weather station at "Lafayette 2 W, AL US - USC00014502" in the Southeast Region for the year 2018 based on weather condition 13 (P>0.2 in. & T40°F). In June 2018, this station recorded 16 working days (WDayR2T40) and a total of 14 non-working days (NWDR2T40). There were 12 rainy days in all during the month, with an average of roughly 0.508 in. of precipitation. Rainfall was measured from 0.01 in. at the lowest to 2.56 in. at the highest. A total of 135 rainy days (TRainDay) and no missing rainfall data (TAMiss = 0) for the entire year of 2018.

The distribution of workdays and non-workdays from 2017 to 2019 is depicted in Figure 4-23. Notably, during the warm and dry months of June through August, the number of non-working days varied between 9 and 14 days. In contracts to the averaged 17 to 22 days determined of non-workdays for the cold and rainy months of January through March.

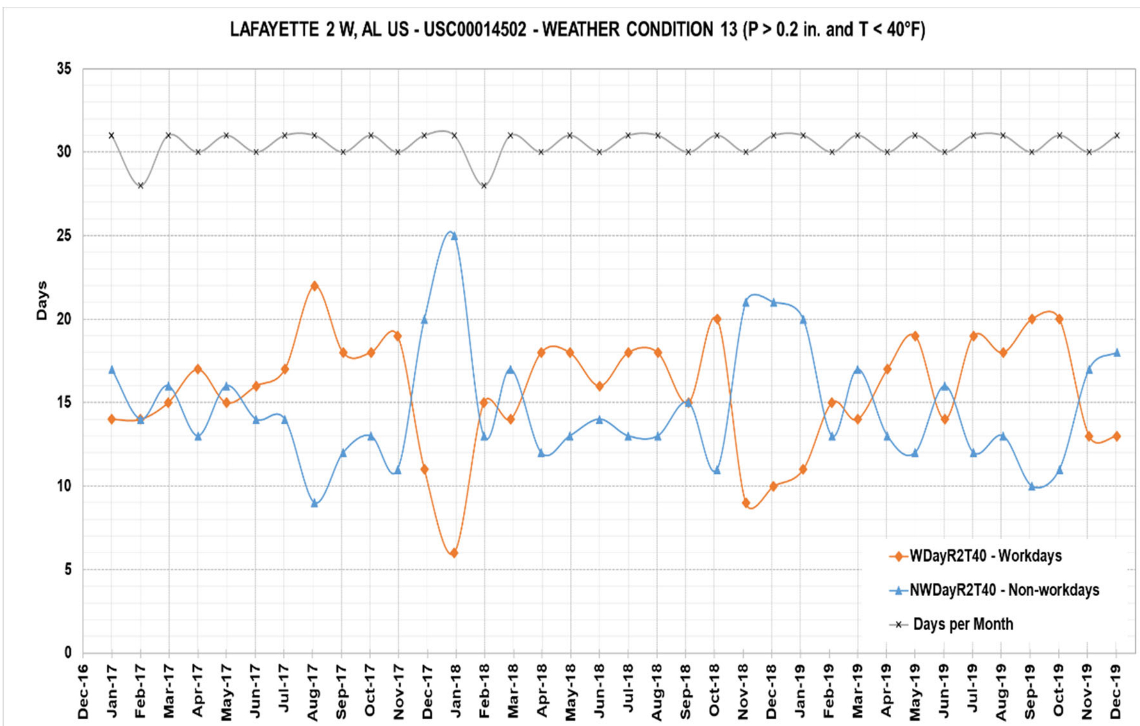



**Figure 4-23. Determined non-workdays and workdays for the Lafayette 2 W, AL US - USC00014502" - Weather Condition 13 (P > 0.2 in. and T < 40°F) for 2017-2019.**

**Table 4-9. Classification of the daily climate data of the Lafayette 2 W, AL US – USC00014502 for year 2018.**

| Month | NWDR2T40 | WDayR2T40 | TotAMiss | TotRainMiss | RainDay | AvgRain (in.) | AMonRain (in.) | MinRain (in.) | MaxRain (in.) | LRGradR1 | LRGradR2 | LRGradR3 | StInspect | TRainMiss |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 25 | 6 | 0 | 0 | 7 | 0.657 | 0.148 | 0.05 | 1.95 | 2 | 2 | 2 | 2 | 0 |
| Feb | 13 | 15 | 0 | 0 | 14 | 0.449 | 0.225 | 0.02 | 1.76 | 1 | 2 | 2 | 3 | TrainDay |
| Mar | 17 | 14 | 0 | 0 | 8 | 0.343 | 0.088 | 0.03 | 0.87 | 0 | 0 | 0 | 1 | 135 |
| Apr | 12 | 18 | 0 | 0 | 9 | 0.410 | 0.123 | 0.02 | 0.94 | 1 | 2 | 2 | 2 | TAMiss |
| May | 13 | 18 | 0 | 0 | 14 | 0.276 | 0.125 | 0.01 | 1.40 | 1 | 1 | 1 | 2 | 0 |
| Jun | 14 | 16 | 0 | 0 | 12 | 0.508 | 0.203 | 0.01 | 2.56 | 1 | 1 | 1 | 3 | ToLRGrad |
| Jul | 13 | 18 | 0 | 0 | 13 | 0.397 | 0.166 | 0.05 | 1.20 | 2 | 2 | 2 | 2 | 14 |
| Aug | 13 | 18 | 0 | 0 | 14 | 0.334 | 0.151 | 0.01 | 1.25 | 1 | 1 | 1 | 2 | 16 |
| Sep | 15 | 15 | 0 | 0 | 10 | 0.504 | 0.168 | 0.02 | 2.13 | 0 | 0 | 0 | 2 | 18 |
| Oct | 11 | 20 | 0 | 0 | 8 | 0.795 | 0.205 | 0.02 | 5.05 | 2 | 2 | 2 | 1 | ToInspect |
| Nov | 21 | 9 | 0 | 0 | 12 | 0.680 | 0.272 | 0.02 | 2.75 | 1 | 1 | 3 | 3 | 29 |
| Dec | 21 | 10 | 0 | 0 | 14 | 0.885 | 0.400 | 0.05 | 3.08 | 2 | 2 | 2 | 6 | 0 |

Records for the Lafayette 2 W, AL US – USC00014502 station range from 1945 to 2020, but there isn't continuous data for the entire period. In order to compute the AAWDs and ANWDs for the month of January, the years 1968, 1992, 1993, and 1994 were excluded due to missing data as shown in Figure 4-24 & Figure 4-25; in the case of June (Figure 4-26 and Figure 4-27), only 1948 was excluded from the 1945–2020 period when computing average non–workdays and AWDs. With a standard deviation of four days for condition 13 (P>0.2 in. & T<40°F), the number of AAWDs determined for January was 11 days, while the number of AAWDs for the month of June was 17 days with a standard deviation of two days. The non-workdays determined for the Lafayette station for the month of January ranged from 10 to 28 days and from 3 to 22 days for AWDs, while for the month of June the non-workdays ranged from 9 to 19 days and from 12 to 21 days for AWDs over 78 years.

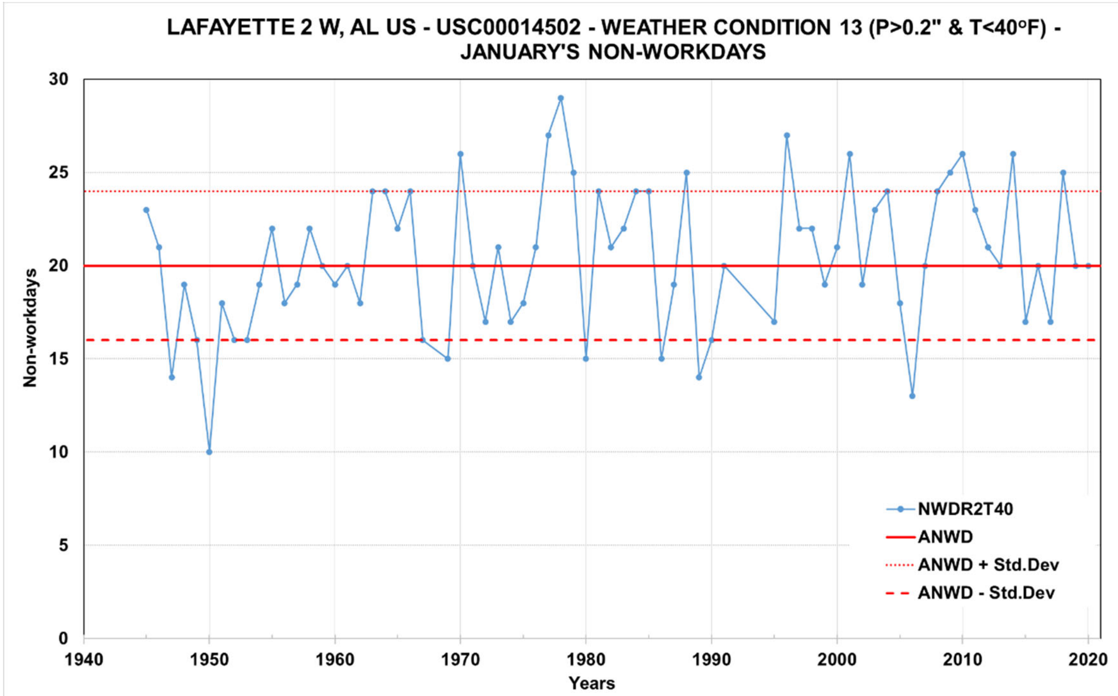



**Figure 4-24. Determined January's average non-workdays for the Lafayette 2 W, AL US - USC00014502 - Weather Condition 13 (P >0.2 in. and T < 40°F) for period of 1945-2020 (except 1968, 1992-1994).**

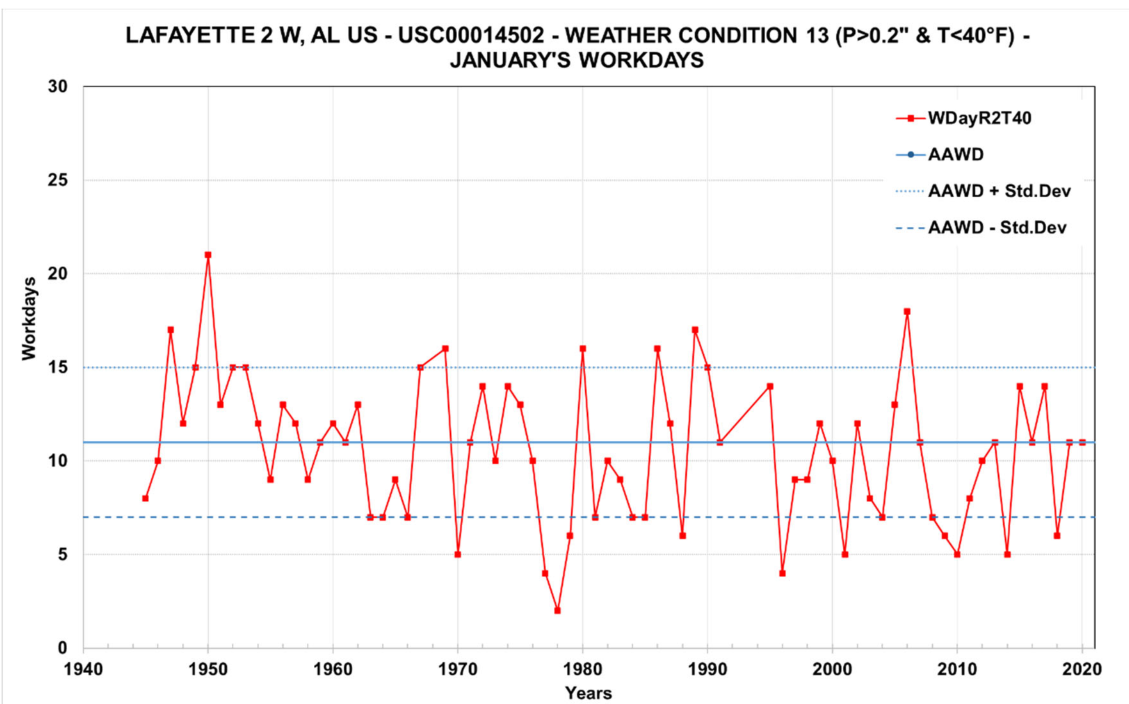



**Figure 4-25. Determined January's average available workdays for the Lafayette 2 W, AL US - USC00014502 - Weather Condition 13 (P >0.2 in. and T < 40°F) for period of 1945-2020 (except 1968, 1992-1994).**

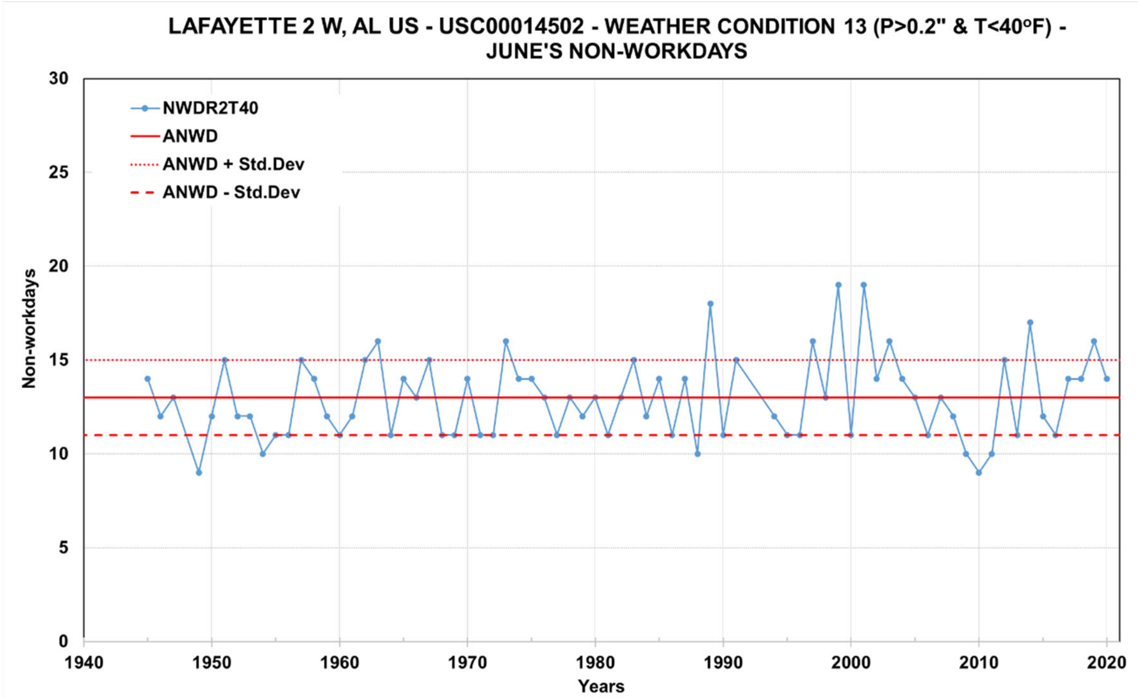



**Figure 4-26. Determined June's average non-workdays for the Lafayette 2 W, AL US - USC00014502 - Weather Condition 13 (P > 0.2 in. and T < 40°F) for period of 1945-2020 (except 1948).**

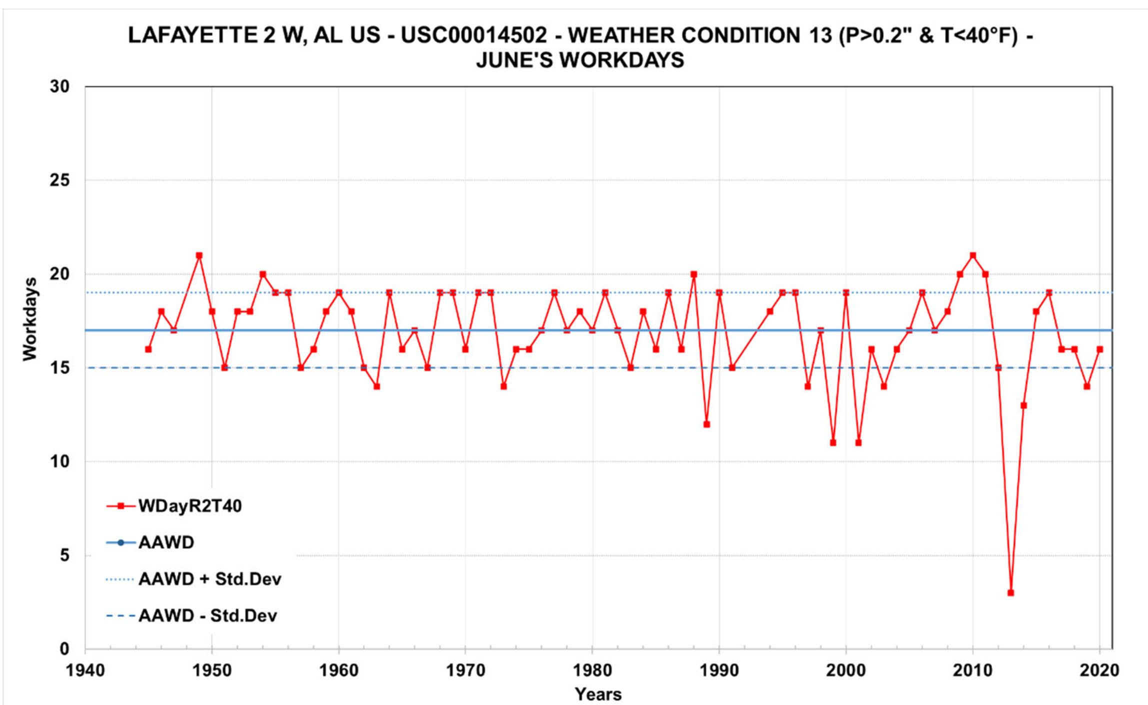



**Figure 4-27. Determined June's average available workdays for the Lafayette 2 W, AL US - USC00014502 - Weather Condition 13 (P >0.2 in. and T < 40°F) for period of 1945-2020 (except 1948).**

## 4.3 Determining AAWDs for Climate Stations

After determining the workdays by calculating non-workdays based on the study criteria and excluding days with missing data, the researcher proceeded to determine the regional Average Available Workdays (AAWDs) for the five ALDOT Regions. Results obtained from the daily data classification were then processed through a selection criterion that determined which stations were suitable to determine AAWDs for ALDOT's Regions. The criteria established for the station's selection was based on the longevity of the valid data processed in the classification process of which stations with at least 10 years of valid data were used to determined AAWDs for the five ALDOT Regions.

Due to missing data, some stations had the discontinued data series; therefore, before computing the regional AAWDs, a data combination process was performed for stations at the same location. This process is explained the *4.3.1 Data combination to determine* AAWDs section below.

### 4.3.1 Data combination to determine AAWDs

The procedure for combining the data from stations whose records weren't continuous consisted of creating an Excel file in which the information from the stations' overlapped records was combined to create a continuous data file that was then used for further analysis. The station ID with the longer records was used to identify the combined file. For instance, two weather stations were found at the ANADALUSIA-OPP MUNICIPAL AIRPORT: (1) the station 72227599999, whose records spanned from 1993 to 2005, and (2) the station 72227553843, whose records covered from 2006 to 2019. Then processed results for these two stations were combined into the station 72227599999 for further analysis. To obtain more continuous weather data, 16 overlapped stations from the GSOD database were processed and combined into eight stations. The information about the process of combining weather stations with overlapped discontinuous data is shown in Table 4-10.

**Table 4-10. Overlapped stations with discontinuous climate data (Source: Global Summary of the Day (GSOD) database, NCEI-NOAA).**

| Overlapped Stations ID | Station Name | Period Of Records | Latitude (. °) | Longitude (. °) | Elevation (M) | No. Years |
|---|---|---|---|---|---|---|
| 72227599999 | Andalusia Opp | 1993-2005 | 31.308752 | -86.393778 | 94.48 | 41 |
| 72227553843 | Andalusia-Opp Municipal Airport | 2006-2019 | 31.30614 | -86.39018 | 97.53 | 14 |
| 72226999999 | Cairns Aaf | 2000-2004 | 31.267 | -85.7 | 92 | 14 |
| 72226903850 | Cairns Army Airfield (Fort Rucker) | 1954-1999 / 2005-2019 | 31.26667 | -85.71667 | 91.74 | 66 |
| 72228599999 | Gadsden Muni | 1999-2005 | 33.967 | -86.083 | 173 | 41 |
| 72228503896 | Gadsden Municipal Airport | 2006-2019 | 33.96667 | -86.08333 | 173.43 | 14 |
| 72226599999 | Maxwell AFB | 2000-2004 | 32.383 | -86.367 | 52 | 14 |
| 72226513821 | Maxwell AFB Airport | 1965-1996 / 2004-2019 | 32.38333 | -86.35 | 52.12 | 85 |
| 72227653820 | Middleton Field Airport | 2006-2019 | 31.41912 | -87.04844 | 79.14 | 14 |
| 72227699999 | Middleton FLD | 1999-2005 | 31.417 | -87.05 | 79 | 21 |
| 72227953852 | Pryor Field Regional ARPT | 2006-2019 | 34.65798 | -86.94343 | 179.11 | 14 |
| 72227999999 | Pryor FLD RGNL | 1999-2005 | 34.653 | -86.945 | 180 | 15 |
| 72226799999 | Troy Muni | 1973-1999 / 2004-2019 | 31.867 | -86.017 | 121 | 14 |
| 72226703878 | Troy Municipal Airport | 2000-2003 | 31.85742 | -86.01025 | 118.55 | 47 |
| 72228693806 | Tuscaloosa Municipal ARPT | 2000-2003 | 33.21217 | -87.61552 | 45.25 | 47 |
| 72228699999 | Tuscaloosa RGNL | 1973-1999 / 2004-2019 | 33.217 | -87.6 | 52 | 14 |

**Table 4-11. Overlapped stations with discontinuous climate data and combined stations. Source: Global Summary of the Day (GSOD) database, NCEI-NOAA.**

| Overlapped Stations ID | Station Name | Period of Records | Combined Station ID | Begin Date | End Date | No. Years |
|---|---|---|---|---|---|---|
| 72227599999 | Andalusia Opp | 1993-2005 | 72227599999 | 1/1/1993 | 12/31/2019 | 26 |
| 72227553843 | Andalusia-Opp Municipal Airport | 2006-2019 | | | | |
| 72226999999 | Cairns Aaf | 2000-2004 | 72226903850 | 1/1/1954 | 12/31/2019 | 65 |
| 72226903850 | Cairns Army Airfield (Fort Rucker) | 1954-1999 / 2005-2019 | | | | |
| 72228599999 | Gadsden Muni | 1999-2005 | 72228599999 | 1/1/1999 | 12/31/2019 | 20 |
| 72228503896 | Gadsden Municipal Airport | 2006-2019 | | | | |
| 72226599999 | Maxwell AFB | 2000-2004 | 72226513821 | 1/1/1965 | 12/31/2019 | 55 |
| 72226513821 | Maxwell AFB Airport | 1965-1999 / 2005-2019 | | | | |
| 72227653820 | Middleton Field Airport | 2006-2019 | 72227699999 | 1/1/1999 | 12/31/2019 | 20 |
| 72227699999 | Middleton FLD | 1999-2005 | | | | |
| 72227953852 | Pryor Field Regional ARPT | 2006-2019 | 72227999999 | 1/1/1999 | 12/31/2019 | 20 |
| 72227999999 | Pryor FLD RGNL | 1999-2005 | | | | |
| 72226799999 | Troy Muni | 1973-1999 / 2004-2019 | 72226799999 | 1/1/1973 | 12/31/2019 | 46 |
| 72226703878 | Troy Municipal Airport | 2000-2003 | | | | |
| 72228693806 | Tuscaloosa Municipal ARPT | 1973-1999 / 2004-2019 | 72228693806 | 1/1/1973 | 12/31/2019 | 46 |
| 72228699999 | Tuscaloosa RGNL | 2000-2003 | | | | |

#### 4.3.2 FINAL STATIONS USED TO COMPUTE ALDOT'S REGIONAL AAWDS

After the data combination process, all the stations that complied with the criteria selection of having at least 10 years of valid daily precipitation and daily air temperature were used to determine the regional AAWDs for all five ALDOT Regions, which are listed in Table 4-12 to Table 4-16 for each Region. There was a total of 88 stations used for determining AAWDs by ALDOT Regions. Figure 4-28 displays the distribution of the chosen weather stations for determining AAWDs for ALDOT's Regions. The maximum number of years of weather data used was 121 for Talladega (East Central Region). There were 45, 28, and 17 stations with more than 30, 50, and 70 years of weather data to determine AAWDs, respectively.

**Table 4-12. Fourteen climate weather stations used to determine AAWDs for the East Central Region.**

| Region | Station ID | Station name | Location | | Period | | No. of years |
|---|---|---|---|---|---|---|---|
| | | | Longitude | Latitude | Start date | End date | |
| EC | 72228013876 | Birmingham International Airport | -86.74490 | 33.56545 | 1973 | 2019 | 46 |
| EC | 72228713871 | Anniston Metropolitan ARPT | -85.84788 | 33.59043 | 1973 | 2019 | 46 |
| EC | 72230053864 | Shelby County Airport | -86.78178 | 33.17835 | 2002 | 2019 | 17 |
| EC | 99999973803 | Talladega 10 NNE | -86.05730 | 33.57210 | 2008 | 2019 | 11 |
| EC | USC00010764 | Bessemer 3 WSW | -87.00770 | 33.39520 | 1978 | 2021 | 43 |
| EC | USC00011288 | Calera | -86.74550 | 33.09440 | 1901 | 2021 | 120 |
| EC | USC00011620 | Childersburg Water Plant | -86.34310 | 33.28500 | 1958 | 2021 | 63 |
| EC | USC00012350 | Dora | -87.05861 | 33.74778 | 2006 | 2020 | 14 |
| EC | USC00013775 | Heflin | -85.60944 | 33.64347 | 1957 | 2021 | 64 |
| EC | USC00014209 | Jacksonville | -85.78115 | 33.82585 | 1949 | 2021 | 72 |
| EC | USC00017020 | Rockford 3 Ese | -86.17580 | 32.87110 | 1955 | 2021 | 66 |
| EC | USC00017999 | Sylacauga 4 Ne | -86.21140 | 33.20530 | 1955 | 2021 | 66 |
| EC | USC00018024 | Talladega | -86.13500 | 33.41630 | 1900 | 2021 | 121 |
| EC | USW00013876 | Birmingham Airport, Al Us | -86.74490 | 33.56545 | 1930 | 2022 | 92 |

**Table 4-13. Twenty-three climate weather stations used to determine AAWDs for the North Region.**

| Region | Station ID | Station name | Location | | Period | | No. of years |
|---|---|---|---|---|---|---|---|
| | | | Longitude | Latitude | Start date | End date | |
| Nor | 72227999999 | Pryor FLD RGNL | -86.94500 | 34.65300 | 1999 | 2019 | 20 |
| Nor | 72228599999 | Gadsden Muni | -86.08300 | 33.96700 | 1999 | 2019 | 20 |
| Nor | 72323003856 | Huntsville Intl/ C.T. Jones Field Airport | -86.78615 | 34.64406 | 1973 | 2019 | 46 |
| Nor | 72323513896 | Northwest Alabama Regional Airport | -87.59971 | 34.74388 | 1973 | 2019 | 46 |
| Nor | 99999963857 | Gadsden 19 N | -85.96210 | 34.28510 | 2005 | 2019 | 14 |
| Nor | 99999963862 | Valley Head 1 SSW | -85.61710 | 34.56530 | 2006 | 2019 | 13 |
| Nor | 99999963867 | Cullman 3 ENE | -86.79630 | 34.19540 | 2006 | 2019 | 13 |
| Nor | 99999963868 | Courtland 2 WSW | -87.34620 | 34.66020 | 2006 | 2019 | 13 |
| Nor | 99999963894 | Muscle Shoals 2 N | -87.63990 | 34.77280 | 2007 | 2019 | 12 |
| Nor | 99999963895 | Russellville 4 SSE | -87.71040 | 34.45350 | 2006 | 2019 | 13 |
| Nor | 99999963896 | Scottsboro 2 Ne | -85.99980 | 34.69410 | 2006 | 2019 | 13 |
| Nor | USC00010063 | Addison | -87.17838 | 34.21096 | 1939 | 2021 | 82 |
| Nor | USC00010260 | Lexington | -87.37195 | 34.96285 | 2005 | 2021 | 16 |
| Nor | USC00010390 | Athens | -86.95080 | 34.77520 | 1942 | 2021 | 79 |
| Nor | USC00011490 | Centre | -85.68460 | 34.15000 | 2003 | 2021 | 18 |
| Nor | USC00013043 | Fort Payne | -85.72360 | 34.44060 | 1936 | 2021 | 85 |
| Nor | USC00013573 | Guntersville | -86.32970 | 34.33440 | 1905 | 2021 | 116 |
| Nor | USC00013575 | Guntersville Number 2 | -86.32940 | 34.33470 | 1996 | 2021 | 25 |
| Nor | USC00013655 | Hanceville | -86.79056 | 34.06081 | 1986 | 2021 | 35 |
| Nor | USC00015635 | Moulton 2 | -87.29900 | 34.48840 | 1958 | 2021 | 63 |
| Nor | USC00016196 | Owens Cross Roads 3 S | -86.44500 | 34.55280 | 2005 | 2021 | 16 |
| Nor | USC00018812 | Vinemont 2 NNW | -86.89881 | 34.25889 | 2008 | 2021 | 13 |
| Nor | USW00063862 | Valley Head 1 SSW, Al Us | -85.61710 | 34.56530 | 2007 | 2022 | 15 |

**Table 4-14. Twenty-four climate weather stations used to determine AAWDs for the Southeast Region.**

| Region | Station ID | Station name | Location | | Period | | No. of years |
|---|---|---|---|---|---|---|---|
| | | | Longitude | Latitude | Start date | End date | |
| SE | 72036163870 | Florala Muni | -86.31200 | 31.04300 | 2006 | 2019 | 13 |
| SE | 72036263874 | Mac Crenshaw Memorial Airport | -86.61410 | 31.84675 | 2006 | 2019 | 13 |
| SE | 72036363872 | Weedon Field Airport | -85.13122 | 31.95163 | 2006 | 2019 | 13 |
| SE | 72223863873 | Hanchey Army Heliport (Fort Rucker) | -85.66667 | 31.35000 | 2006 | 2019 | 13 |
| SE | 72223953861 | Lowe Army Heliport (Fort Rucker) | -85.75111 | 31.35583 | 2009 | 2019 | 10 |
| SE | 72225013829 (GA) | Lawson Aaf Airport | -84.99128 | 32.33732 | 1973 | 2019 | 46 |
| SE | 72225593842 (GA) | Columbus Metro Airport | -84.94218 | 32.51625 | 1973 | 2019 | 46 |
| SE | 72226013895 | Montgomery RGNL (Dannelly FD) Ap | -86.40745 | 32.29970 | 1973 | 2019 | 46 |
| SE | 72226513821 | Maxwell AFB Airport | -86.35000 | 32.38333 | 1965 | 2019 | 54 |
| SE | 72226799999 | Troy Muni | -86.01025 | 0.00000 | 1973 | 2019 | 46 |
| SE | 72226813839 | Dothan Regional Airport | -85.44324 | 31.31767 | 2006 | 2019 | 13 |
| SE | 72226893843 | Dothan RGNL | -85.45000 | 31.31700 | 1973 | 1995 | 22 |
| SE | 72226903850 | Cairns Army Airfield (Fort Rucker) | -85.71667 | 31.26667 | 1954 | 2019 | 65 |
| SE | 72227599999 | Andalusia Opp | -86.39378 | 31.30875 | 1993 | 2019 | 26 |
| SE | 72228403892 | Aburn-Oplka R G Pitts ARPT | -85.43333 | 32.61611 | 2006 | 2019 | 13 |
| SE | 99999923801 | Troy 2 W | -86.00040 | 31.79010 | 2008 | 2019 | 11 |
| SE | 99999963858 | Selma 13 WNW | -87.24220 | 32.45670 | 2005 | 2019 | 14 |
| SE | 99999963897 | Selma 6 SSE | -86.97870 | 32.33490 | 2007 | 2019 | 12 |
| SE | 99999973802 | Highland Home 2 S | -86.31150 | 31.91550 | 2008 | 2019 | 11 |
| SE | USC00011725 | Clayton | -85.45010 | 31.87090 | 1929 | 2021 | 92 |
| SE | USC00013251 | Geneva Number 2 | -85.87080 | 31.03830 | 1977 | 2021 | 44 |
| SE | USC00014502 | Lafayette 2 W | -85.43360 | 32.90690 | 1945 | 2021 | 76 |
| SE | USC00015553 | Montgomery 6 SW | -86.21800 | 32.26000 | 1999 | 2021 | 22 |
| SE | USC00017025 | Rock Mills | -85.29110 | 33.15800 | 1939 | 2021 | 82 |

**Table 4-15. Eight climate weather stations used to determine AAWDs for the Southwest Region.**

| Region | Station ID | Station name | Location | | Period | | No. of years |
|---|---|---|---|---|---|---|---|
| | | | Longitude | Latitude | Start date | End date | |
| SW | 72223013894 | Mobile Regional Airport | -88.24598 | 30.68819 | 1973 | 2019 | 46 |
| SW | 72223513838 | Mobile Downtown Airport | -88.06301 | 30.61465 | 1996 | 2019 | 23 |
| SW | 72227699999 | Middleton FLD | -87.05000 | 31.41700 | 1999 | 2019 | 20 |
| SW | 99999923802 | Thomasville 2 S | -87.73670 | 31.88140 | 2008 | 2019 | 11 |
| SW | 99999963869 | Fairhope 3 Ne | -87.87570 | 30.54850 | 2006 | 2019 | 13 |
| SW | 99999963899 | Brewton 3 NNE | -87.05180 | 31.14490 | 2008 | 2019 | 11 |
| SW | USC00010402 | Atmore | -87.43900 | 31.18200 | 1941 | 2021 | 80 |
| SW | USC00010583 | Bay Minette | -87.78520 | 30.88400 | 1914 | 2020 | 106 |

**Table 4-16. Nineteen climate weather stations used to determine AAWDs for the West Central Region.**

| Region | Station ID | Station name | Location | | Period | | No. of years |
|---|---|---|---|---|---|---|---|
| | | | Longitude | Latitude | Start date | End date | |
| WC | 72041300138 | Posey Field Airport | -87.60000 | 34.26700 | 2008 | 2019 | 11 |
| WC | 72228693806 | Tuscaloosa Municipal ARPT | 33.2119 | 33.21700 | 1973 | 2019 | 46 |
| WC | 72229003881 | NWS Meteorological OBSY | -87.25000 | 32.90000 | 1984 | 1994 | 10 |
| WC | 72234013865 (MS) | Key Field Airport | -88.75073 | 32.33483 | 1973 | 2021 | 48 |
| WC | 72234503866 (MS) | Meridian NAS/MC Cain FD AP | -88.56667 | 32.55000 | 1973 | 2021 | 48 |
| WC | 72330613825 (MS) | Columbus AFB Airport | -88.45000 | 33.65000 | 1973 | 2021 | 48 |
| WC | 99999963891 | Clanton 2 Ne | -86.61150 | 32.85160 | 2007 | 2019 | 12 |
| WC | 99999963892 | Gainesville 2 Ne | -88.13740 | 32.83690 | 2007 | 2019 | 12 |
| WC | 99999963893 | Greensboro 2 WNW | -87.62260 | 32.71690 | 2007 | 2019 | 12 |
| WC | 99999973801 | Northport 2 S | -87.59140 | 33.21250 | 2009 | 2019 | 10 |
| WC | USC00010178 | Aliceville | -88.15500 | 33.12720 | 1941 | 2021 | 80 |
| WC | USC00010505 | Bankhead Lock and Dam | -87.35720 | 33.45270 | 1958 | 2021 | 63 |
| WC | USC00010748 | Berry 3 NW | -87.64875 | 33.69709 | 1941 | 2021 | 80 |
| WC | USC00013645 | Hamilton | -87.99466 | 34.13884 | 1963 | 2020 | 57 |
| WC | USC00014226 | Jasper | -87.31540 | 33.90480 | 1961 | 2021 | 60 |
| WC | USC00016847 | Reform | -88.00528 | 33.37389 | 1939 | 2021 | 82 |
| WC | USC00018517 | Vernon | -88.12750 | 33.73920 | 1939 | 2020 | 81 |
| WC | USC00018673 | Warrior Lock and Dam | -87.83056 | 32.77472 | 1959 | 2021 | 62 |
| WC | USC00018998 | Winfield 2 SW, Al Us | -87.84690 | 33.9107 | 1973 | 2020 | 47 |

Table 4-17 shows the number of the AL (83 stations), GA (2 stations), and MS (3 stations) weather stations used to determine the AAWDs for each of five ALDOT Regions. There are 23 and 24 stations used for the North Region and Southeast Region, but only 8 stations for the Southwest Region. The absence of cities or weather stations or enough data made it difficult to achieve a uniformly distributed station layout. There has been an increase in the amount of weather data compared to earlier studies from 1989 to 2003, which used a single station as a representative for each Region.

**Table 4-17. Spatial distribution of 88 weather stations used to determine AAWDs for ALDOT Regions.**

| Weather Station Spatial Distribution | | | | | |
|---|---|---|---|---|---|
| ALDOT's Region | Weather Station Location (State) | | | Total Stations by Region | Mini/ Maxi /Average years of data |
| | Alabama | Georgia | Mississippi | | |
| North Region | 23 | - | - | 23 | 11/121/60 |
| West Central Region | 16 | - | 3 | 19 | 12/116/34 |
| East Central Region | 14 | - | - | 14 | 10/92/33 |
| Southeast Region | 22 | 2 | - | 24 | 11/106/39 |
| Southwest Region | 8 | - | - | 8 | 10/82/46 |
| Total Stations by State | 83 | 2 | 3 | 88 | 10/121/42 |

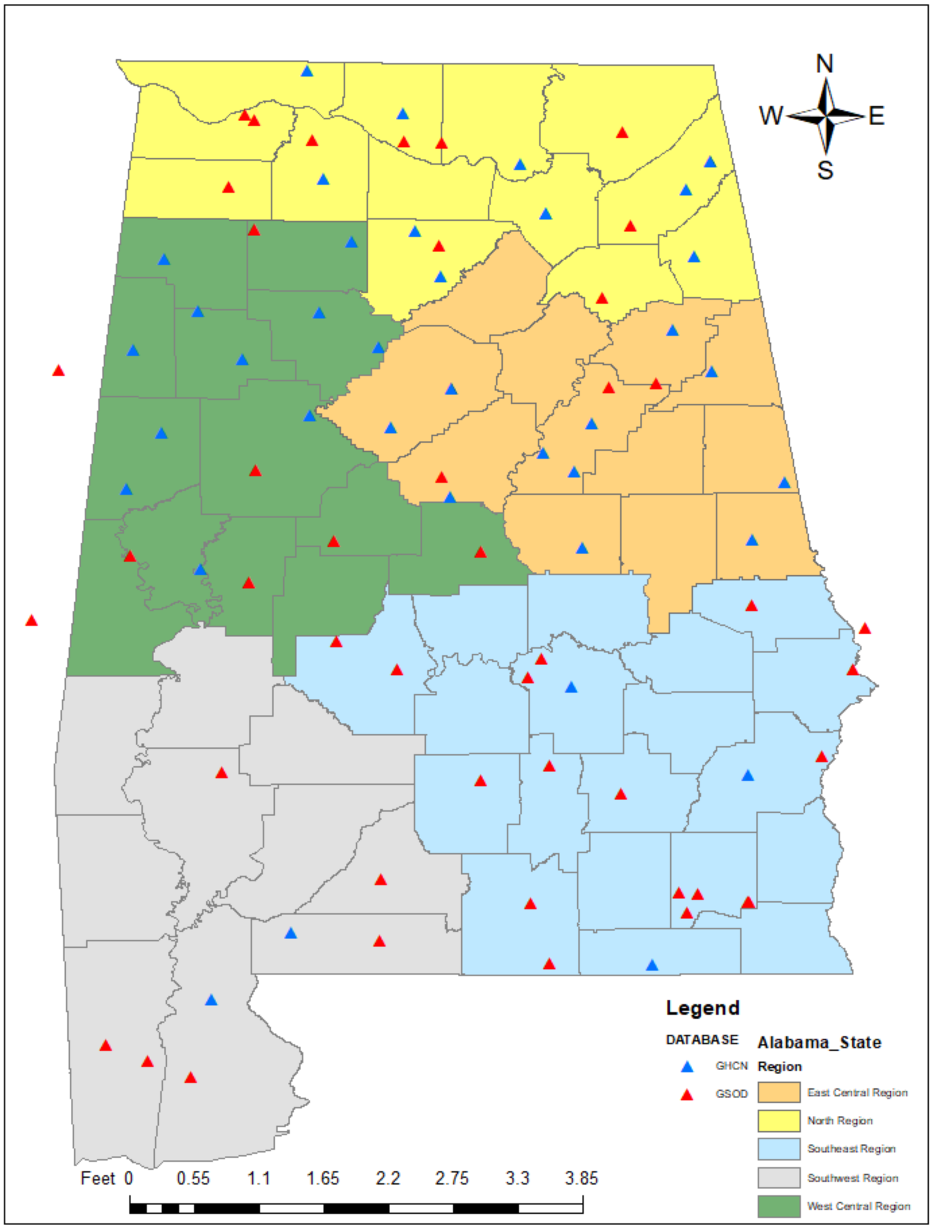



**Figure 4-28. Map showing spatial distribution of the 88 GHCN or GSOD weather stations used to determine AAWDs for five ALDOT Regions.**

#### 4.3.3 DETERMINING AVERAGE AVAILABLE WORKDAYS (AAWDS) FOR CLIMATE STATIONS

Once defined which of the weather stations comply with the selection criteria, each of the selected ones was then processed in Excel using a VBA-code to determine the AAWDs for all months, January through December, based on the data period gathered and for all the adverse weather threshold conditions (P1 - P15, Table 4-3). AWDs for each month in each year are integers and monthly AAWDs are rounded into integers; and standard deviation (StdDev) is also round into integers (days). The flowchart shown in Figure 4-29 presents the workflow followed to compute AAWDs for all the final weather stations.

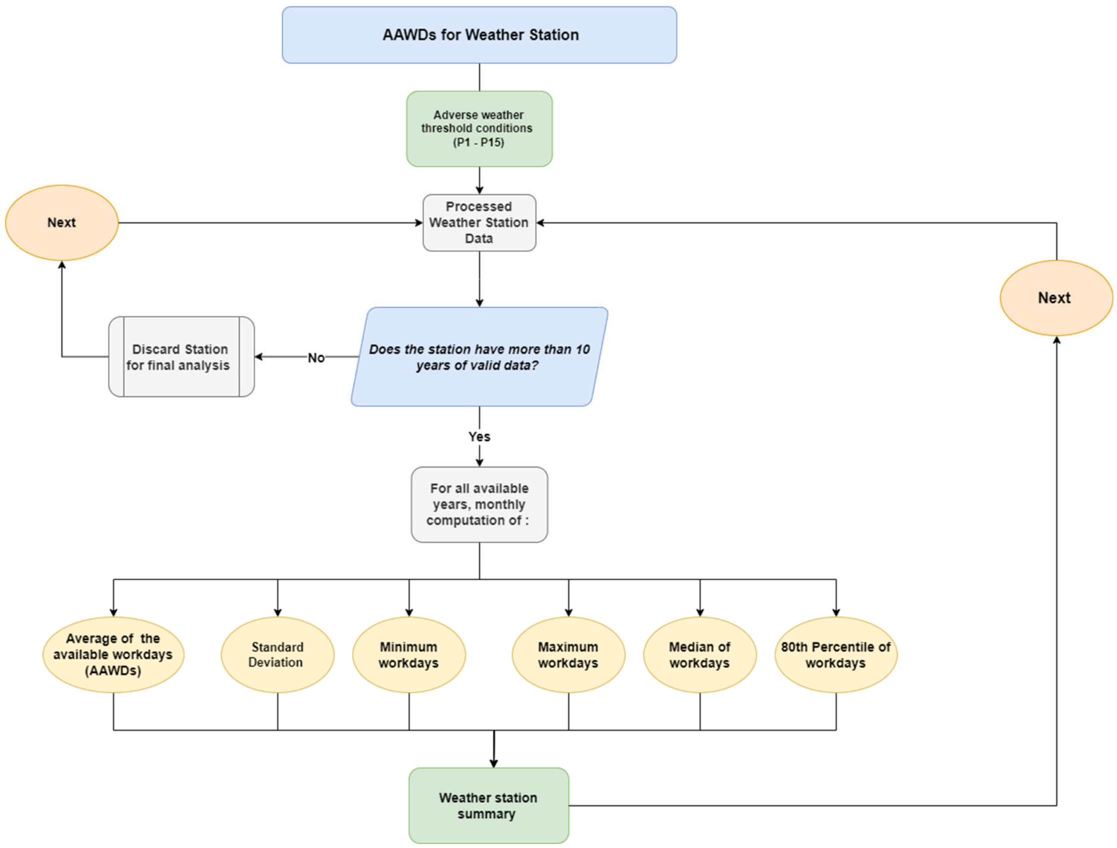



**Figure 4-29. Flowchart process to determine AAWDs for climate stations.**

The list of the attributes determined when computing the AAWDs for all the weather conditions are shown in Table 4-18. Statistical parameters (standard deviation, minimum, maximum, median, 80$^{th}$ percentile, and skew coefficient of AWDs in each month over all available years in each weather station) are determined for each of 15 AAWDs based on 15 adverse weather threshold conditions. The study by North Dakota DOT (Kenner et al. 1998) used the 80$^{th}$ percentile of the AWDs over 30 years as the recommended AWDs for each weather station/location, while ALDOT previous studies used average AWDs. Therefore, AAWDs will be used for this study also. If the median AWD is used, half of AWDs is less than the median value and another half will be greater than the median value. Results in Table 4-19 to Table 4-23 show monthly AAWDs are the same or not much different from the median AWDs. The attribute "N-Years" counts the total number of years of monthly AWDs used to determine AAWD when there are no missing data for the month in those years. If the sum of the two missing data days (TotAMiss + TotRainMiss) for a month is greater than one, calculated AWD for that month was not used for computing AAWD.

**Table 4-18. Attributes determined when computing AAWDs for weather stations.**

| Attributes | Description |
|---|---|
| Station | Station ID |
| Month | Month |
| N-Years | Total number of years of AWDs data used to determine AAWDs |
| M-Years | Total Number of years with monthly AWDs data |
| StdDev | Standard deviation of AAWDs for monthly AWDs |
| Mini | Minimum of monthly AWDs (MinAWD) |
| Max | Maximum of monthly AWDs (MaxAWD) |
| Median | Median of monthly AWDs |
| 80PerT | 80th percentile of monthly AWDs |
| Skew | Skewness coefficient of monthly AWDs |
| WDayR0T30 | AAWDs for Parameter 1 ($P>0$ in. & $T<30^o$ F) |
| WDayR1T30 | AAWDs for Parameter 2 ($P>0.1$ in. & $T<30^o$ F) |
| WDayR2T30 | AAWDs for Parameter 3 ($P>0.2$ in. & $T<30^o$ F) |
| WDayR3T30 | AAWDs for Parameter 4 ($P>0.3$ in. & $T<30^o$ F) |
| WDayR5T30 | AAWDs for Parameter 5 ($P>0.25$ in. & $T<30^o$ F) |
| WDayR0T35 | AAWDs for Parameter 6 ($P>0$ in. & $T<35^o$ F) |
| WDayR1T35 | AAWDs for Parameter 7 ($P>0.1$ in. & $T<35^o$ F) |
| WDayR2T35 | AAWDs for Parameter 8 ($P>0.2$ in. & $T<35^o$ F) |
| WDayR3T35 | AAWDs for Parameter 9 ($P>0.3$ in. & $T<30^o$ F) |
| WDayR5T35 | AAWDs for Parameter 10 ($P>0.25$ in. & $T<30^o$ F) |
| WDayR0T40 | AAWDs for Parameter 11 ($P>0$ in. & $T<40^o$ F) |
| WDayR1T40 | AAWDs for Parameter 12 ($P>0.1$ in. & $T<40^o$ F) |
| WDayR2T40 | AAWDs for Parameter 13 ($P>0.2$ in. & $T<40^o$ F) |
| WDayR3T40 | AAWDs for Parameter 14 ($P>0.3$ in. & $T<40^o$ F) |
| WDayR5T40 | AAWDs for Parameter 15 ($P>0.25$ in. & $T<40^o$ F) |

### *East Central Region - Talladega, AL US - USC00018024*

The AAWDs determined for the “Talladega, AL US - USC00018024” weather station is shown in Table 4-19. This station is in the East Central Region and with records of 122 years, from 1900 to 2022. Not all years were used to determine the monthly AAWDs when some months in some years had missing data, for example, the “N-Years” attribute, the total number of years used for the computations varies from 107 years for December and 119 years for September out of 122 years with monthly AWDs. The standard deviations of AAWDs are small, from two to four days, which are larger in winter months. However, the difference between maximum and minimum AWDs over 107–119 years is larger and up to 18 days (more than three weeks when excluding weekends); the smallest difference is eight days (< 2 weeks) in October. The skewness coefficients are all negative and mean there are more AWDs less than the averages or AAWDs, especially for the months with the skewness < -0.5. Figure 4-30 (a) shows an example distribution of AWDs in May at Talladega with AAWD = 18 days and the skewness coefficient of -0.73 when 112 years of AWDs were used (Table 4-19). There are some smaller AWDs (12–15 days) in May but the frequency is lower (2–5 years).

**Table 4-19. Determined AAWDs and statistical parameters of monthly AWDs for the Talladega, AL US - USC00018024 using P13 (P>0.2 in. & T<40°F) threshold.**

| Talladega, AL US - USC00018024 - P13 (P>0.2 in. & T<40 °F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | N-Years | AAWDs | StdDev | Min. | Max. | Median | 80PerT | Skew |
| 1 | 110/122 | 11 | 4 | 2 | 20 | 11 | 14 | -0.0646 |
| 2 | 108/122 | 11 | 3 | 3 | 18 | 12 | 14 | -0.3598 |
| 3 | 105/122 | 16 | 2 | 9 | 22 | 17 | 19 | -0.2364 |
| 4 | 109/122 | 17 | 2 | 10 | 21 | 17 | 19 | -0.526 |
| 5 | 112/122 | 18 | 2 | 12 | 21 | 18 | 20 | -0.7277 |
| 6 | 115/122 | 17 | 2 | 10 | 21 | 17 | 19 | -0.4916 |
| 7 | 115/122 | 17 | 2 | 10 | 23 | 17 | 19 | -0.2535 |
| 8 | 117/122 | 18 | 2 | 13 | 22 | 19 | 20 | -0.447 |
| 9 | 119/122 | 18 | 2 | 12 | 21 | 18 | 20 | -0.5745 |
| 10 | 113/122 | 19 | 2 | 14 | 22 | 19 | 20 | -0.508 |
| 11 | 111/122 | 15 | 2 | 10 | 21 | 15 | 17 | -0.171 |
| 12 | 107/122 | 12 | 3 | 5 | 20 | 12 | 15 | 0.0257 |

From Figure 4-30 it can be noted that for this station (Talladega) the AAWDs range from 11 to 19 days from January to December while the median of the monthly AWDs ranges between 11 to 19 days as well. Annual AAWDs are 189 days and 51.8% of 365 days. Similarly, important statistical metrics can be observed, such as standard deviation ranging from 2–4 days and the 80th percentile of the monthly AWDs varying from 14 to 20 days. The 80th percentiles are about equal to AAWDS plus corresponding standard deviations. This information is a good guideline that will help ALDOT engineers in decision-making on highway construction projects. The minimum AWDs range from 2 to 14, and the maximum AWDs range from 18 to 23 days. The differences between the maximum and minimum AWDs range from 8 days in October to 18 days in January with average of 12 days (more than two weeks).

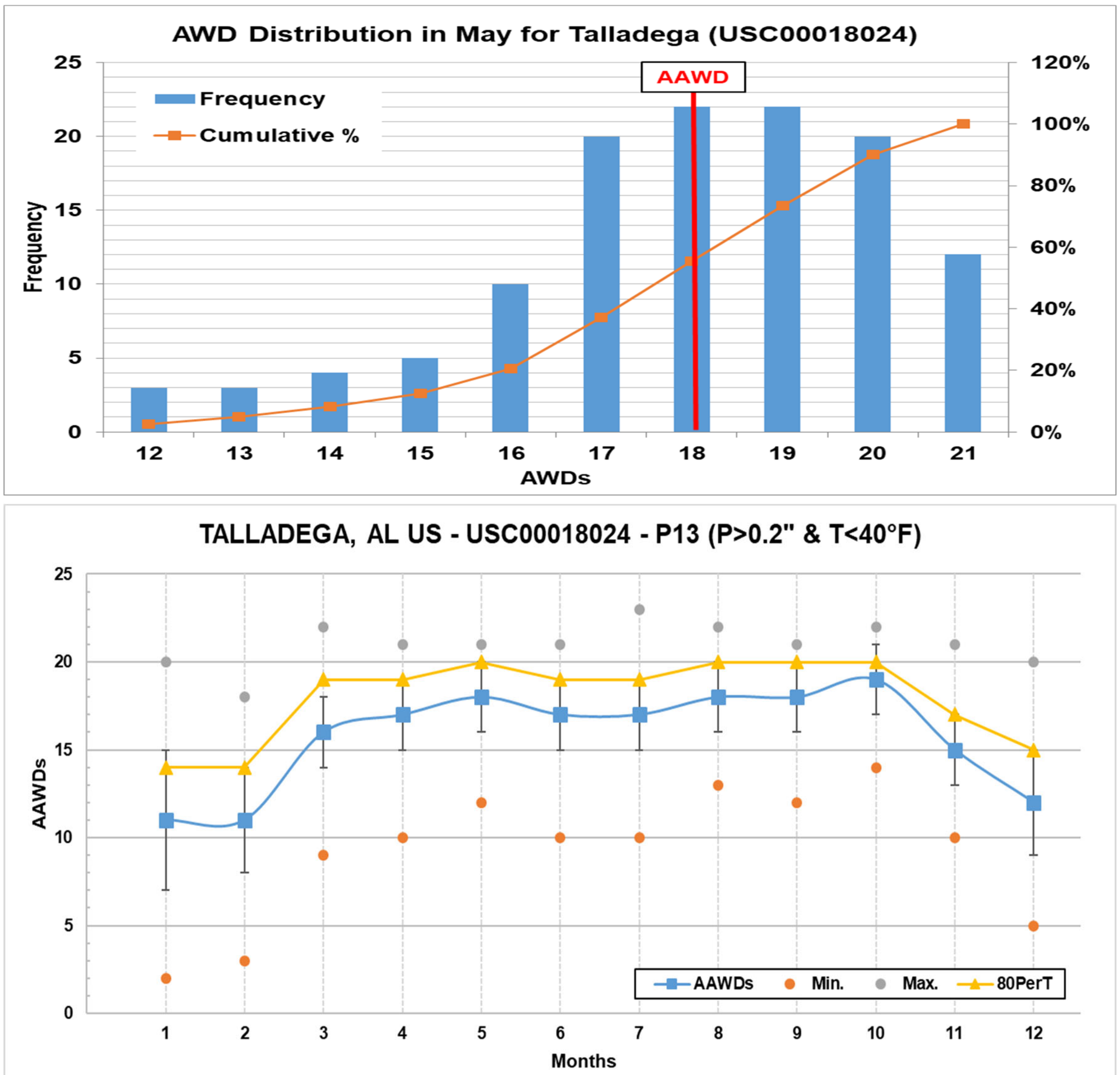



**Figure 4-30. (a) AWD distribution in May and (b) Determined AAWDs and statistical metrics for Talladega, AL US - USC00018024 - P13 (P>0.2" & T<40°F).**

### *North Region - Huntsville Intl/C.T. Jones Field Airport, AL – 72323003856*

The AAWDs for the Huntsville Intl/C.T. Jones Field Airport station in the North Region results are shown in Table 4-20. On this station the dataset spans a lengthy 47-year period, from 1973 to 2019. However, it is important to note that not all these years were used to calculate the monthly AAWDs. According to the "N-Years" attribute, the total years considered for these calculations range between 41 and 45 years (without any missing data). Monthly AAWDs and corresponding statistical parameters. From January to December, the AAWDs at Huntsville airport range from 8 to 19 days. Annual AAWDs are 182 days and 49.9% of 365 days. The median values of AWDs are seasonal, with January having the shortest at 8 days and August having the longest at 21 days. Lower winter temperatures make AAWDs smaller in winter months, e.g., only eight days in January. The standard deviation, which indicates the degree of variation of AWDs from AAWD in each month, varies between two and three days. The 80th percentile, which represents the upper range of computed monthly AAWDs, ranges between 11 and 21 days. The minimum AAWDs range from 1 to 14, and the maximum AWDs range from 15 to 23 days. The differences between the maximum and minimum AWDs range from 7 days in September to 16 days in February.

**Table 4-20. Determined AAWDs and statistical parameters of monthly AWDs for the Huntsville Intl/C.T. Jones Field Airport, AL US – 72323003856 using P13 threshold.**

| Huntsville Intl/C.T. Jones Field Airport, AL US – 72323003856 - P13 (P>0.2 in. & T<40 °F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | N-Years | AAWDs | StdDev | Min. [1] | Max. [1] | Median [1] | 80PerT [1] | Skewness |
| 1 | 43/47 | 8 | 3 | 1 | 15 | 8 | 11 | -0.045 |
| 2 | 42/47 | 10 | 3 | 1 | 17 | 10 | 13 | -0.337 |
| 3 | 43/47 | 16 | 3 | 9 | 21 | 16 | 19 | -0.427 |
| 4 | 42/47 | 16 | 2 | 10 | 20 | 16 | 18 | -0.605 |
| 5 | 42/47 | 18 | 2 | 13 | 21 | 18 | 19 | -0.311 |
| 6 | 41/47 | 17 | 2 | 12 | 21 | 17 | 19 | -0.556 |
| 7 | 41/47 | 18 | 2 | 12 | 21 | 18 | 19 | -0.789 |
| 8 | 43/47 | 19 | 2 | 15 | 23 | 19 | 21 | -0.076 |
| 9 | 45/47 | 18 | 2 | 14 | 21 | 18 | 20 | -0.375 |
| 10 | 44/47 | 18 | 2 | 14 | 22 | 18 | 20 | -0.291 |
| 11 | 42/47 | 14 | 3 | 10 | 19 | 14 | 17 | 0.217 |
| 12 | 43/47 | 10 | 3 | 2 | 17 | 10 | 13 | -0.112 |

Note: [1] means these statistical parameters are for AWDs, e.g., Minimum and Maximum AWDs.

### *West Central Region - Tuscaloosa Municipal ARPT, AL US – 72228693806*

Table 4-21 shows the determined AAWDs at Tuscaloosa Municipal ARPT (West Central Region). The station dataset covers climate data for 47 years, from 1973 to 2019. The number of years used to determine the AAWDs ranged from 37 to 43 years. The monthly AAWDs range from 10 to 18 days. Annual AAWDs are 196 days and 53.7% of 365 days. Metrics such as the ones listed below can help with project planning and decision-making: 1) The median of AWDs has a seasonal pattern with AWDs ranging from 7 to 19 days, 2) standard deviation (1–3 days), 3) 80th percentile (13–21 days), 4) minimum (2–14 days) and maximum (16–23 days). The differences between the maximum and minimum AWDs range from 7 days in October to 14 days in February.

**Table 4-21. Determined AAWDs and statistical parameters of monthly AWDs for the Tuscaloosa Municipal ARPT, AL US – 72228693806 using P13 (P>0.2 in. & T<40°F) threshold.**

| Tuscaloosa Municipal ARPT, AL US – 72228693806 – P13 (P>0.2 in. & T<40 °F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | N-Years | AAWDs | StdDev | Min. | Max. | Median | 80PerT | Skewness |
| 1 | 37/47 | 11 | 3 | 4 | 16 | 11 | 13 | -0.3757 |
| 2 | 37/47 | 12 | 3 | 2 | 16 | 12 | 14 | -1.0568 |
| 3 | 41/47 | 18 | 2 | 12 | 22 | 18 | 19 | -0.3248 |
| 4 | 43/47 | 17 | 2 | 13 | 21 | 17 | 20 | -0.0348 |
| 5 | 39/47 | 18 | 2 | 14 | 22 | 18 | 20 | 0.1105 |
| 6 | 35/47 | 18 | 2 | 13 | 21 | 18 | 20 | -0.5137 |
| 7 | 33/47 | 18 | 3 | 12 | 23 | 18 | 21 | -0.1913 |
| 8 | 38/47 | 19 | 2 | 11 | 22 | 20 | 21 | -1.3923 |
| 9 | 39/47 | 18 | 2 | 12 | 21 | 18 | 19 | -0.8634 |
| 10 | 41/47 | 19 | 2 | 15 | 22 | 19 | 21 | -0.2961 |
| 11 | 39/47 | 15 | 2 | 10 | 20 | 15 | 18 | -0.2674 |
| 12 | 36/47 | 13 | 3 | 8 | 19 | 13 | 15 | -0.0389 |

### *Southwest Region - Mobile Regional Airport, AL US – 72223013894*

Table 4-22 shows the AAWDs calculated for Mobile Regional Airport, AL US - 72223013894. This station is located in the Southwest Region and has 47 years of records from 1973 to 2019. The total years used for the computations varies from 40 years in July to 45 years in May and February. The monthly AAWDs for the 72223013894-climate station range from 14 to 19 days, with the median AWDs ranging from 14 to 20 days. Annual AAWDs are 198 days and 54.2% of 365 days. The standard deviation ranges from 2–3 days, and the 80th percentile ranges from 16 to 21 days. The minimum AWDs range from 4 to 14, and the maximum AWDs range from 19 to 23 days. The differences between the maximum and minimum AWDs range from 8 days in April, September, and October to 16 days in January.

**Table 4-22. Determined AAWDs and statistical parameters of monthly AWDs for the Mobile Regional Airport, AL US – 72223013894 using P13 (P>0.2 in. & T<40°F) threshold.**

| Mobile Regional Airport, AL US – 72223013894- P13 (P>0.2 in. & T<40 °F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | N-Years | AAWDs | StdDev | Min. | Max. | Median | 80PerT | Skewness |
| 1 | 43/47 | 14 | 3 | 4 | 20 | 14 | 16 | -0.6817 |
| 2 | 45/47 | 14 | 3 | 7 | 19 | 14 | 17 | -0.5491 |
| 3 | 41/47 | 18 | 2 | 12 | 23 | 18 | 20 | -0.1823 |
| 4 | 43/47 | 17 | 2 | 12 | 20 | 18 | 19 | -0.6691 |
| 5 | 45/47 | 18 | 2 | 12 | 22 | 18 | 20 | -0.3429 |
| 6 | 41/47 | 16 | 3 | 10 | 20 | 16 | 18 | -0.4828 |
| 7 | 40/47 | 16 | 2 | 11 | 20 | 16 | 18 | -0.1218 |
| 8 | 41/47 | 17 | 2 | 11 | 22 | 17 | 18 | -0.1791 |
| 9 | 41/47 | 17 | 2 | 12 | 20 | 18 | 18 | -0.9302 |
| 10 | 43/47 | 19 | 2 | 14 | 22 | 20 | 21 | -0.9923 |
| 11 | 42/47 | 16 | 2 | 12 | 21 | 16 | 18 | -0.2516 |
| 12 | 42/47 | 16 | 3 | 9 | 21 | 16 | 18 | -0.3065 |

### *Southeast Region - Lafayette 2 W, AL US - USC00014502*

The AAWDs determined for the Lafayette 2 W, AL US - USC00014502 station located in the Southeast Region are presented in Table 4-23. The climate data gathered from this station extends for 75 years, from 1945 to 2021. The number of years used to determine the AAWDs for January was 62 years, while 73 years were used to determine the AAWDs for July. The AAWDs at Lafayette range from 10 to 19 days throughout the year. Annual AAWDs are 192 days and 52.6% of 365 days. The median of AWDs vary by season, with January having the shortest (13 days) and October having the longest (21 days). The standard deviation, which represents the degree of variation of AWDs from AAWDs, ranges from two to four days, being the largest during the coldest months. The 80th percentiles of AWDs range between 13 and 21 days. The minimum AWDs range from 2 to 13, and the maximum AWDs range from 18 to 23 days. The differences between the maximum and minimum AWDs range from 7 days in April to 16 days in January and February.

**Table 4-23. Determined AAWDs for the Lafayette 2 W, AL US - USC00014502 using P13 (P>0.2 in. & T<40°F) threshold.**

| Lafayette 2 W, AL US - USC00014502 - P13 (P>0.2 in. & T<40 °F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | N-Years | AAWDs | StdDev | Min. | Max. | Median | 80PerT | Skewness |
| 1 | 62/75 | 10 | 4 | 2 | 18 | 10 | 13 | 0.036 |
| 2 | 65/75 | 12 | 3 | 2 | 18 | 12 | 15 | -0.456 |
| 3 | 62/75 | 17 | 2 | 12 | 23 | 17 | 18 | 0.428 |
| 4 | 68/75 | 17 | 2 | 13 | 20 | 17 | 18 | -0.026 |
| 5 | 68/75 | 18 | 2 | 12 | 22 | 18 | 20 | -0.518 |
| 6 | 69/75 | 17 | 2 | 11 | 21 | 17 | 19 | -0.647 |
| 7 | 73/75 | 17 | 2 | 11 | 21 | 17 | 19 | -0.292 |
| 8 | 68/75 | 19 | 2 | 13 | 22 | 19 | 20 | -0.440 |
| 9 | 66/75 | 18 | 2 | 13 | 21 | 18 | 19 | -0.635 |
| 10 | 67/75 | 19 | 2 | 12 | 22 | 19 | 21 | -1.047 |
| 11 | 65/75 | 15 | 2 | 9 | 19 | 15 | 17 | -0.349 |
| 12 | 64/75 | 13 | 3 | 4 | 19 | 13 | 15 | -0.442 |

## 4.4 DETERMINING AAWDS FOR ALDOT REGIONS

After the monthly AAWDs of each of the final climate stations in each ALDOT Region were determined, average value and statistical metrics of these monthly AAWDs from all stations in each Region were determined by using the developed Excel VBA code and following the flowchart in Figure 4-31. Statistical metrics include minimum, maximum, median, and 80$^{th}$ percentile of AAWDs and number of years used to determine AAWDs for each month. Table 4-24 shows example results for ALDOT East Central Region, which has 14 stations (Table 4-12). In several months, there is one station used (USC00012350) less than 10 years of data to determine AAWDs due to missing data in some years (even it has 14 years of climate data); therefore, AAWDs for that station in those months were not used to compute average AAWDs for the Region. The standard deviations are small and from zero to two days. Most warmer months (April to October) have almost the same AAWDs from 13 or 14 stations because of zero day for standard deviation, but winter months have large variations. The minimum and maximum AAWDs only differ by one or two days in April to October, but up to six days in January and December. This means AAWDs in summer/fall months can be determined from one station (e.g., with long data record and little missing data) in the Region, which is what ALDOT did in two previous studies (one representative station for each Region). For winter months, it is necessary to use local weather data to determine AAWDs.

Based on the preliminary results presented to ALDOT's committee it was decided to use a daily mean air temperature (T) threshold of 40°F and a daily precipitation (P) greater than 0.2 in. to classify days that are not workable due to adverse weather because most highway construction activities could be impacted by this condition. Determined AAWDs based on adverse weather threshold condition 13 (P13), which considers non-workdays as P > 0.2 in. and T < 40°F, for the East Central Region are shown in Figure 4-32 and in Table 4-25 for North Region, Table 4-26 for West Central Region, Table 4-27 for Southwest Region, and Table 4-28 for Southeast Region. Standard deviations for Southwest and Southeast Regions are small, mostly zero or one day, but are up to three days in January in North Region. The differences of maximum and minimum AAWDs derived from 13 weather stations range from zero days in April and May to seven days in January and December in East Central Region. In the North Region, the differences range from one day (April and May) to seven days (January) with an average of less than 3 days.

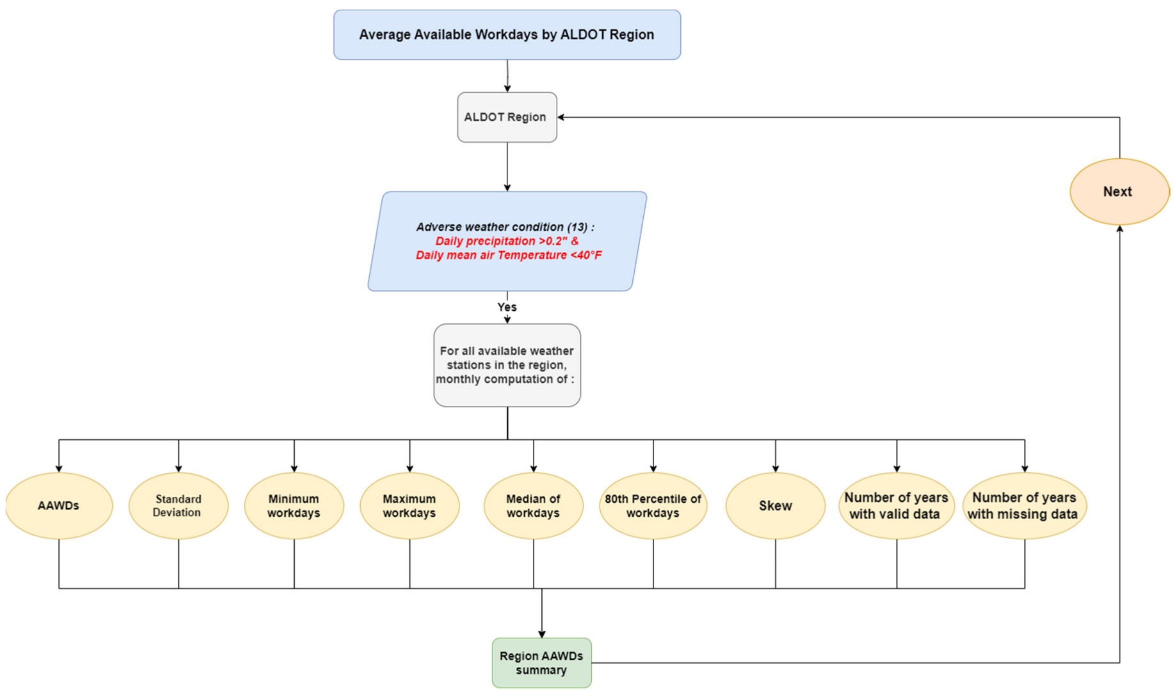



**Figure 4-31. Flowchart used to determine AAWDs for ALDOT Regions.**

**Table 4-24. Average AAWDs and statistical parameters of monthly AAWDs from 14 stations in ALDOT East Central Region based on the threshold condition 13.**

| East Central Region – Average Available Workdays P13 (P>0.2 in. & T<40°F) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | AAWDs | StdDev | Minimum | Maximum | Median | 80th_PerTil | No Stations |
| 1 | 11 | 2 | 9 | 16 | 10 | 11 | 13 |
| 2 | 12 | 1 | 10 | 15 | 11 | 12 | 13 |
| 3 | 17 | 1 | 15 | 18 | 17 | 17 | 13 |
| 4 | 17 | 0 | 17 | 17 | 17 | 17 | 13 |
| 5 | 18 | 0 | 18 | 18 | 18 | 18 | 13 |
| 6 | 17 | 0 | 16 | 17 | 17 | 17 | 13 |
| 7 | 17 | 0 | 17 | 18 | 17 | 17 | 13 |
| 8 | 19 | 1 | 17 | 19 | 19 | 19 | 14 |
| 9 | 18 | 0 | 17 | 18 | 18 | 18 | 14 |
| 10 | 19 | 0 | 18 | 19 | 19 | 19 | 14 |
| 11 | 15 | 1 | 14 | 17 | 15 | 15 | 13 |
| 12 | 13 | 2 | 10 | 17 | 12 | 13 | 13 |

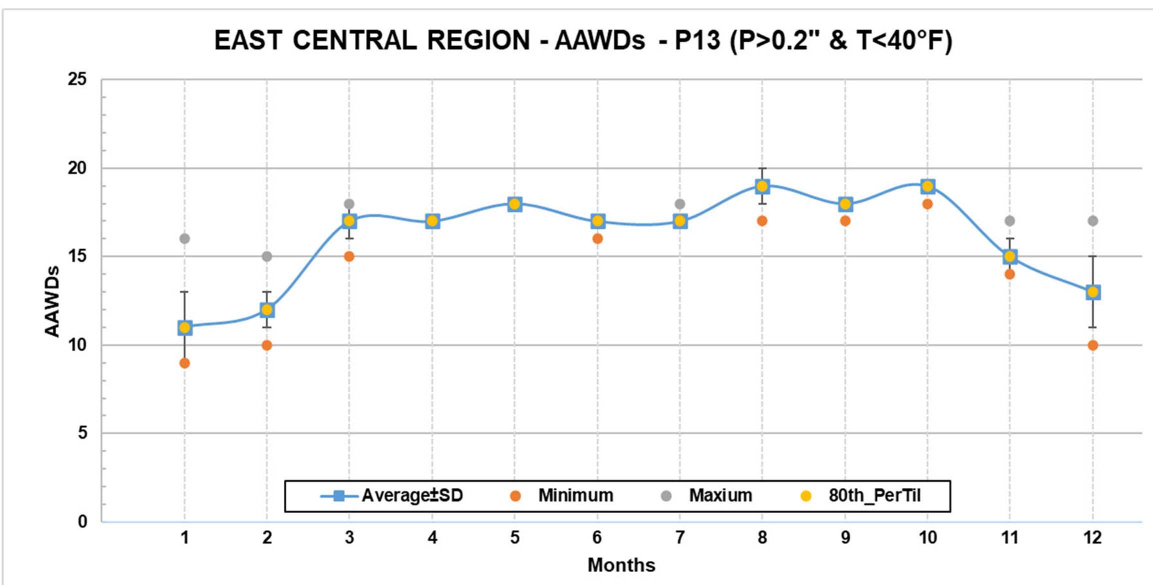



**Figure 4-32. Determined average AAWDs for the East Central Region based on the threshold condition 13.**

**Table 4-25. Determined average AAWDs and statistical parameters of monthly AAWDs for the North Region based on the threshold condition 13.**

| North Region – Average Available Workdays P13 (P>0.2 in. & T<40°F) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | AAWDs | StdDev | Minimum | Maximum | Median | 80th_PerTil | No Stations |
| 1 | 9 | 3 | 6 | 15 | 8 | 11 | 21 |
| 2 | 10 | 2 | 8 | 14 | 10 | 12 | 21 |
| 3 | 16 | 1 | 15 | 18 | 16 | 17 | 22 |
| 4 | 17 | 0 | 16 | 17 | 17 | 17 | 22 |
| 5 | 18 | 0 | 17 | 18 | 18 | 18 | 22 |
| 6 | 17 | 1 | 16 | 18 | 17 | 17 | 21 |
| 7 | 18 | 0 | 17 | 18 | 18 | 18 | 22 |
| 8 | 19 | 0 | 18 | 20 | 19 | 19 | 23 |
| 9 | 18 | 0 | 17 | 19 | 18 | 18 | 23 |
| 10 | 18 | 1 | 18 | 20 | 18 | 19 | 23 |
| 11 | 14 | 1 | 13 | 16 | 14 | 15 | 23 |
| 12 | 11 | 2 | 9 | 16 | 10 | 13 | 21 |

**Table 4-26. Determined average AAWDs and statistical parameters of monthly AAWDs for the West Central Region based on the threshold condition 13.**

| West Central Region – Average Available Workdays P13 (P>0.2 in. & T<40°F) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | AAWDs | StdDev | Minimum | Maximum | Median | $80^{th}$_PerTil | No Stations |
| 1 | 10 | 3 | 6 | 17 | 10 | 11 | 18 |
| 2 | 12 | 2 | 9 | 15 | 12 | 12 | 18 |
| 3 | 17 | 1 | 15 | 18 | 17 | 17 | 18 |
| 4 | 17 | 0 | 16 | 18 | 17 | 17 | 18 |
| 5 | 18 | 0 | 17 | 19 | 18 | 18 | 18 |
| 6 | 17 | 0 | 16 | 18 | 17 | 17 | 18 |
| 7 | 17 | 1 | 16 | 18 | 17 | 18 | 18 |
| 8 | 19 | 0 | 18 | 19 | 19 | 19 | 18 |
| 9 | 18 | 0 | 17 | 18 | 18 | 18 | 18 |
| 10 | 19 | 0 | 18 | 20 | 19 | 19 | 17 |
| 11 | 15 | 1 | 13 | 16 | 15 | 16 | 18 |
| 12 | 13 | 2 | 9 | 17 | 13 | 14 | 18 |

**Table 4-27. Determined average AAWDs and statistical parameters of monthly AAWDs for the Southwest Region based on the threshold condition 13.**

| Southwest Region – Average Available Workdays P13 (P>0.2 in. & T<40°F) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | AAWDs | StdDev | Minimum | Maximum | Median | 80th_PerTil | No Stations |
| 1 | 14 | 2 | 11 | 17 | 14 | 15 | 8 |
| 2 | 14 | 1 | 13 | 16 | 14 | 15 | 8 |
| 3 | 18 | 1 | 17 | 19 | 19 | 19 | 8 |
| 4 | 17 | 1 | 16 | 18 | 17 | 18 | 8 |
| 5 | 17 | 2 | 12 | 19 | 18 | 19 | 8 |
| 6 | 17 | 1 | 16 | 18 | 16 | 17 | 8 |
| 7 | 17 | 1 | 16 | 18 | 17 | 17 | 8 |
| 8 | 17 | 0 | 17 | 18 | 17 | 18 | 8 |
| 9 | 17 | 1 | 16 | 18 | 17 | 18 | 8 |
| 10 | 19 | 1 | 17 | 20 | 19 | 19 | 8 |
| 11 | 16 | 1 | 16 | 17 | 16 | 17 | 8 |
| 12 | 15 | 2 | 12 | 17 | 16 | 17 | 8 |

**Table 4-28. Determined average AAWDs and statistical parameters of monthly AAWDs for the Southeast Region based on the threshold condition 13.**

| Southeast Region – Average Available Workdays P13 (P>0.2 in. & T<40°F) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | AAWDs | StdDev | Minimum | Maximum | Median | 80th_PerTil | No Stations |
| 1 | 13 | 2 | 10 | 18 | 13 | 14 | 21 |
| 2 | 13 | 1 | 11 | 16 | 14 | 14 | 20 |
| 3 | 18 | 1 | 16 | 19 | 18 | 18 | 21 |
| 4 | 17 | 0 | 17 | 18 | 17 | 18 | 20 |
| 5 | 18 | 1 | 17 | 19 | 18 | 19 | 22 |
| 6 | 17 | 1 | 16 | 18 | 17 | 17 | 20 |
| 7 | 17 | 0 | 16 | 18 | 17 | 17 | 19 |
| 8 | 18 | 1 | 17 | 19 | 19 | 19 | 18 |
| 9 | 18 | 1 | 16 | 18 | 18 | 18 | 21 |
| 10 | 19 | 0 | 17 | 20 | 19 | 19 | 22 |
| 11 | 16 | 1 | 15 | 17 | 16 | 17 | 23 |
| 12 | 15 | 2 | 12 | 17 | 15 | 16 | 21 |

## 4.5 PROJECT RESULTS – AAWDS FOR ALDOT REGIONS

The monthly AAWDs based on the adverse weather threshed condition (P13) for all five ALDOT Regions are summarized in Table 4-29 as the results of the project. Annual AAWDs (Table 4-29) are 1985, 192, 193, 198, and 199 days (51–55% of 365 days) for North Region, West Central Region, East Central Region, Southeast Region, and Southwest Region, respectively. Seasonal variations are noticeable between the colder months (January to March) and the warmer months (June to August), as expected. The AAWDs for the North Region, for example, is 9 days in January and 19 days in August, resulting in a significant difference of 11 days. For the Southeast Region and Southwest Region, the determined AAWDs are 13 or 14 days in January and 19 days in October.

When considering the annual AAWDs, projects in northern counties and cities can expect 185 workdays per year, which accounts for 51% of the total 365 days in a year. Conversely, projects in the Southeast Region and Southwest Region can rely on at least 198 workdays per year, equivalent to 54% of the total days in a year. These findings are summarized in Figure 4-33, which provides a visual representation of the monthly differences between the ALDOT Regions. Monthly and annual AAWDs determined for East Central Region and West Central Region are basically the same and can be considered as one climate region (zone). Monthly and annual AAWDs determined for Southeast Region and Southwest Region are also the same and can be considered as another climate region (zone). Therefore, AAWDs for five ALDOT Regions can be considered as three climate zones, the same geographical classifications as 1989 ALDOT study.

The outcomes of three climates zone classification, namely the North Region, Central Regions, and South Regions, are detailed in Table 4-30. Here, it is evident that the differences are minimal when compared to the results obtained from the ALDOT Southwest Region and Southeast Region (Table 4-29), which were combined into the South Regions. Specifically, a total of 200 days (55%) considered AWDs, reflecting a variance of merely 1 and 2 days, respectively. Similarly, the results for the Central Regions, including ALDOT East Central Region and West Central Region, indicate 193 AAWDs, corresponding to 53% of AWDs within a 365-day year. This closely aligns with the West Central results and exactly matches the East Central outcomes, and the comparison is clearly illustrated in Figure 4-34. For three climate zones in Alabama: North Region, Central Regions, and South Regions, annual AWWDs of 185, 193, and 200 days (Table 4-30), respectively. As summarized in Table 4-31, these annual AWWDs are eight (Divisions 1 and 2), five or seven (Divisions 3 to 5), and two–five (Divisions 6 to 9) more days when comparing with AAWDS for corresponding Divisions in ALDOT 1998 and 2003 studies (Table 2-1).

Table 4-32 and Table 4-33 show detailed statistical results of AAWDs for Central Regions and South Regions, that used AAWDs from 31–32 and 26-32 weather stations, respectively. The Standard deviations (StdDev) of AAWDs is only 1–2 days for South Regions and 0–2 days for Central Regions. These AAWDs are derived on average from 31-34 and 45–46 years of climate data for South and Central Regions, respectively, even minimum number of years of the climate data used is 10 years. The maximum number of years of the climate data used is 119 years. Project results are for long-term monthly AAWDs for construction projects in three Alabama climate zones–North, Central, and South.

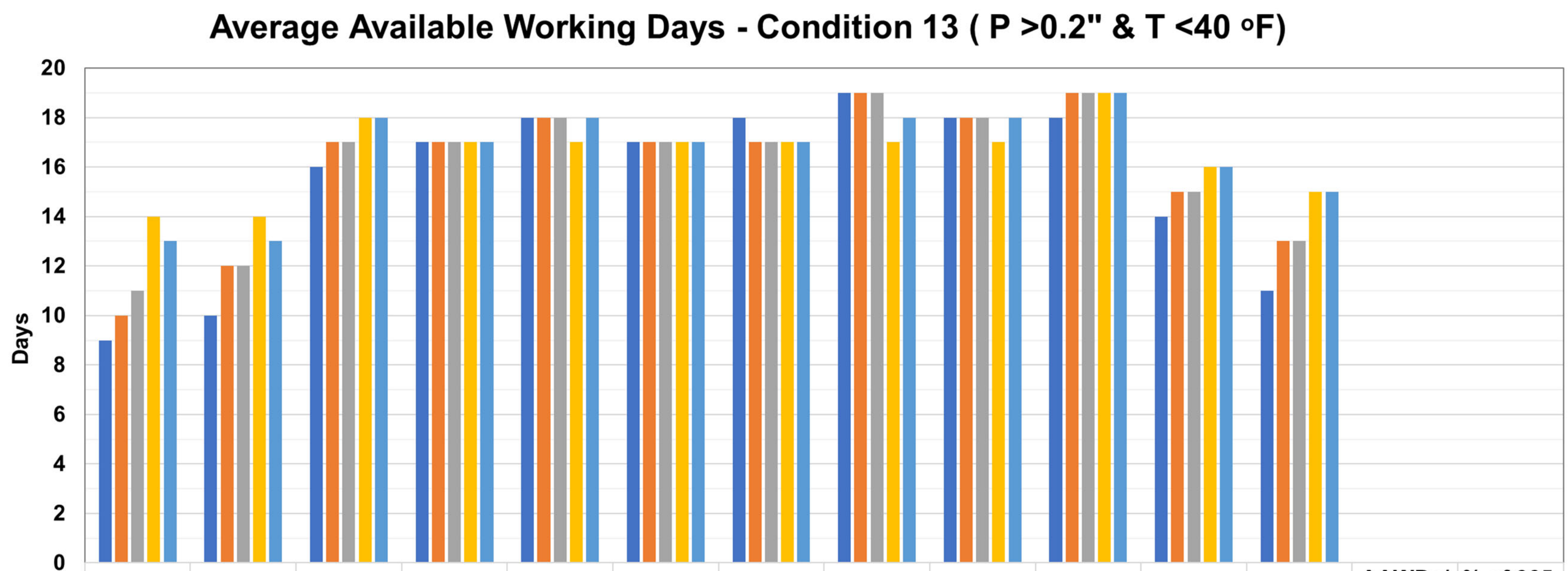
In addition to determine averages and standard deviations of monthly AAWDs from all stations in each ALDOT Region (Table 4-29 and Table 4-30), we also examined minimum and maximum of all monthly AWDs out of all available years from each station. This is because section 4.2.2 direct outcomes of weather data analysis clearly show AWDs from different years have large variations. We should understand and document/quantify these variations of AWDs but not ignore them. Figure 4-35 provide a thorough examination of the minimum and maximum AWDs across the three climate zones - North, Central, and South. First, for each weather station, there are monthly AWDs for all available years (>10 years) and then the minimum and maximum AWDs from those years were determined, which were reported as five example results for five stations from Table 4-19 to Table 4-23. Figure 4-35 depicts the statistical results of the minimum and maximum AWDs for each of these regions, namely the minimum, average, maximum of the minimum monthly AWDs, and minimum, average, and maximum of the maximum monthly AWDs for all stations in each Region.

**Table 4-29. Monthly Average Available Workdays for five ALDOT Regions.**

| AAWDs for Condition 13 (P >0.2 in. & T <40 °F) | | | | | |
|---|---|---|---|---|---|
| Month | North Region | West Central Region | East Central Region | Southwest Region | Southeast Region |
| Jan | 9 | 10 | 11 | 14 | 13 |
| Feb | 10 | 12 | 12 | 14 | 13 |
| March | 16 | 17 | 17 | 18 | 18 |
| April | 17 | 17 | 17 | 17 | 17 |
| May | 18 | 18 | 18 | 17 | 18 |
| June | 17 | 17 | 17 | 17 | 17 |
| July | 18 | 17 | 17 | 17 | 17 |
| Aug | 19 | 19 | 19 | 17 | 18 |
| Sept | 18 | 18 | 18 | 17 | 18 |
| Oct | 18 | 19 | 19 | 19 | 19 |
| Nov | 14 | 15 | 15 | 16 | 16 |
| Dec | 11 | 13 | 13 | 15 | 15 |
| Annual AAWDs | 185 | 192 | 193 | 198 | 199 |
| % of 365[4] days | 51% | 53% | 53% | 54% | 55% |

Figure 4-36 shows the maximum AWDs are similar (especially summer period) and the minimum AWDs have larger variations (4–9 days) for all three Regions. In winter months, AWDs minimums and maximums increase moving south, for example, in the South Regions January average minimum AAWDs is 6 days, while 3 days in the North Region. Figure 4-36 highlights statistical metrics of the differences between the maximum and minimum AWDs for stations in each ALDOT climate zone. The average differences in summer are 7–10 days and up to 13 days in winter months. The maximum difference in summer is 13 days (2.5 weeks) and 20 days (4 weeks) in winter months. Therefore, monthly AWDs can vary significantly from one year to another depending on precipitation and air temperature. For construction project management and planning across diverse Alabama climate zones, using AAWDs by ALDOT Regions (Table 4-29) or three climate zones (Table 4-30) is useful but may not be accurate for some unnormal dry/wet and cold/warm years. It is recommended using VBA-based tools developed for this project to determine AWDs during the project period.

[4] 365 days/year it is used as descriptive measure, even though years with 366 days were considered when determined the AAWDs for ALDOT Regions.




| | Jan | Feb | March | April | May | June | July | Augt | Sept | Oct | Nov | Dec | AAWDs/ Year | % of 365 days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Region | 9 | 10 | 16 | 17 | 18 | 17 | 18 | 19 | 18 | 18 | 14 | 11 | 185 | 51% |
| West Central Region | 10 | 12 | 17 | 17 | 18 | 17 | 17 | 19 | 18 | 19 | 15 | 13 | 192 | 53% |
| East Central Region | 11 | 12 | 17 | 17 | 18 | 17 | 17 | 19 | 18 | 19 | 15 | 13 | 193 | 53% |
| Southwest Region | 14 | 14 | 18 | 17 | 17 | 17 | 17 | 17 | 17 | 19 | 16 | 15 | 198 | 54% |
| Southeast Region | 13 | 13 | 18 | 17 | 18 | 17 | 17 | 18 | 18 | 19 | 16 | 15 | 199 | 55% |

**Figure 4-33. Monthly AAWDs determined for five ALDOT Regions.**

**Table 4-30. Monthly Average Available Workdays in three Alabama climate zones.**

| AAWDs for Condition 13 (P >0.2 in. & T <40°F) | | | |
|---|---|---|---|
| Month | North Region | Central Regions | South Regions |
| Jan | 9 | 11 | 13 |
| Feb | 10 | 12 | 14 |
| March | 16 | 17 | 18 |
| April | 17 | 17 | 17 |
| May | 18 | 18 | 18 |
| June | 17 | 17 | 17 |
| July | 18 | 17 | 17 |
| Aug | 19 | 19 | 18 |
| Sept | 18 | 18 | 18 |
| Oct | 18 | 19 | 19 |
| Nov | 14 | 15 | 16 |
| Dec | 11 | 13 | 15 |
| Annual AAWDs | 185 | 193 | 200 |
| % of 365 days | 51% | 53% | 55% |

**Table 4-31. Comparison of AAWDs in three studies.**

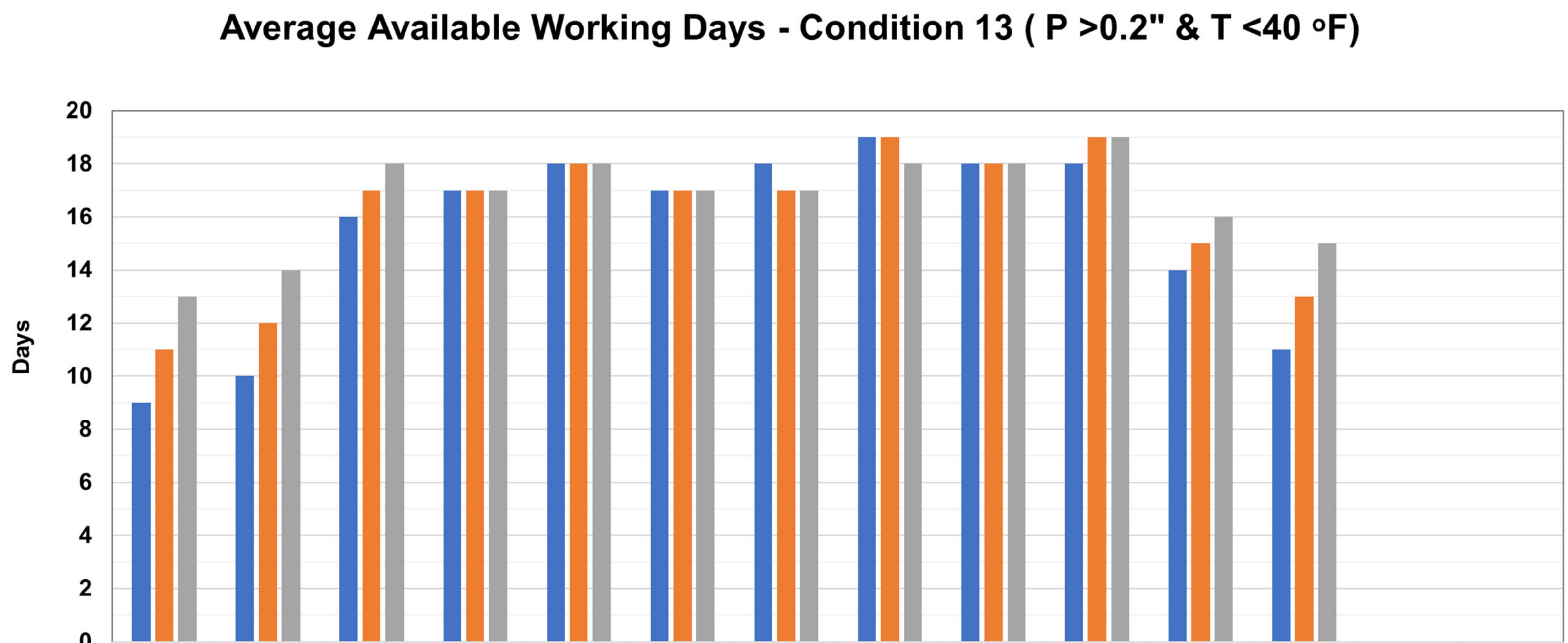
| Study/Zones | North Region | Central Regions | South Regions |
|---|---|---|---|
| 2023 | 185 | 193 | 200 |
| Study/Divisions | Divisions 1-2 | Divisions 3-5 | Divisions 6-9 |
| 1998 | 177 | 188 | 196 |
| Difference | 8 | 5 | 4 |
| Study/Divisions | Divisions 1-2 | Divisions 3-5 | Divisions 6-7, 8-9 |
| 2003 | 177 | 186 | 195, 198 |
| Difference | 8 | 7 | 5, 2 |

**Table 4-32. Determined average AAWDs and statistical parameters of monthly AAWDs for the Central Regions based on the adverse-weather threshold condition 13.**

| Central Regions – Average Available Workdays P13 (P>0.2 in. & T<40°F) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | AAWDs | StdDev | Minimum | Maximum | Median | 80th_PerTil | No Stations |
| 1 | 11 | 3 | 6 | 17 | 10 | 11 | 31 |
| 2 | 12 | 2 | 9 | 15 | 11 | 12 | 31 |
| 3 | 17 | 1 | 15 | 18 | 17 | 17 | 31 |
| 4 | 17 | 0 | 16 | 18 | 17 | 17 | 31 |
| 5 | 18 | 0 | 17 | 19 | 18 | 18 | 31 |
| 6 | 17 | 0 | 16 | 18 | 17 | 17 | 31 |
| 7 | 17 | 0 | 16 | 18 | 17 | 17 | 31 |
| 8 | 19 | 1 | 17 | 19 | 19 | 19 | 32 |
| 9 | 18 | 0 | 17 | 18 | 18 | 18 | 32 |
| 10 | 19 | 0 | 18 | 20 | 19 | 19 | 31 |
| 11 | 15 | 1 | 13 | 17 | 15 | 16 | 31 |
| 12 | 13 | 2 | 9 | 17 | 13 | 13 | 31 |

**Table 4-33. Determined average AAWDs and statistical parameters of monthly AAWDs for the South Regions based on the adverse-weather threshold condition 13.**

| South Regions – Average Available Workdays P13 (P>0.2 in. & T<40°F) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | AAWDs | StdDev | Minimum | Maximum | Median | 80th_PerTil | No Stations |
| 1 | 13 | 1 | 10 | 15 | 13 | 14 | 29 |
| 2 | 14 | 1 | 11 | 15 | 14 | 14 | 28 |
| 3 | 18 | 1 | 16 | 19 | 18 | 19 | 29 |
| 4 | 17 | 0 | 17 | 18 | 17 | 18 | 28 |
| 5 | 18 | 0 | 17 | 19 | 18 | 19 | 30 |
| 6 | 17 | 1 | 16 | 18 | 17 | 17 | 28 |
| 7 | 17 | 1 | 16 | 18 | 17 | 17 | 27 |
| 8 | 18 | 1 | 17 | 19 | 18 | 19 | 26 |
| 9 | 18 | 0 | 17 | 18 | 18 | 18 | 29 |
| 10 | 19 | 0 | 19 | 20 | 19 | 19 | 30 |
| 11 | 16 | 1 | 15 | 17 | 16 | 17 | 31 |
| 12 | 15 | 1 | 12 | 17 | 15 | 16 | 29 |




| | Jan | Feb | March | April | May | June | July | Augt | Sept | Oct | Nov | Dec | AAWDs/ Year | % of 365 days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Region | 9 | 10 | 16 | 17 | 18 | 17 | 18 | 19 | 18 | 18 | 14 | 11 | 185 | 51% |
| Central Regions | 11 | 12 | 17 | 17 | 18 | 17 | 17 | 19 | 18 | 19 | 15 | 13 | 193 | 53% |
| South Regions | 13 | 14 | 18 | 17 | 18 | 17 | 17 | 18 | 18 | 19 | 16 | 15 | 200 | 55% |

**Figure 4-34. Monthly Average Available Workdays or AAWDs determined for three Alabama climate zones.**

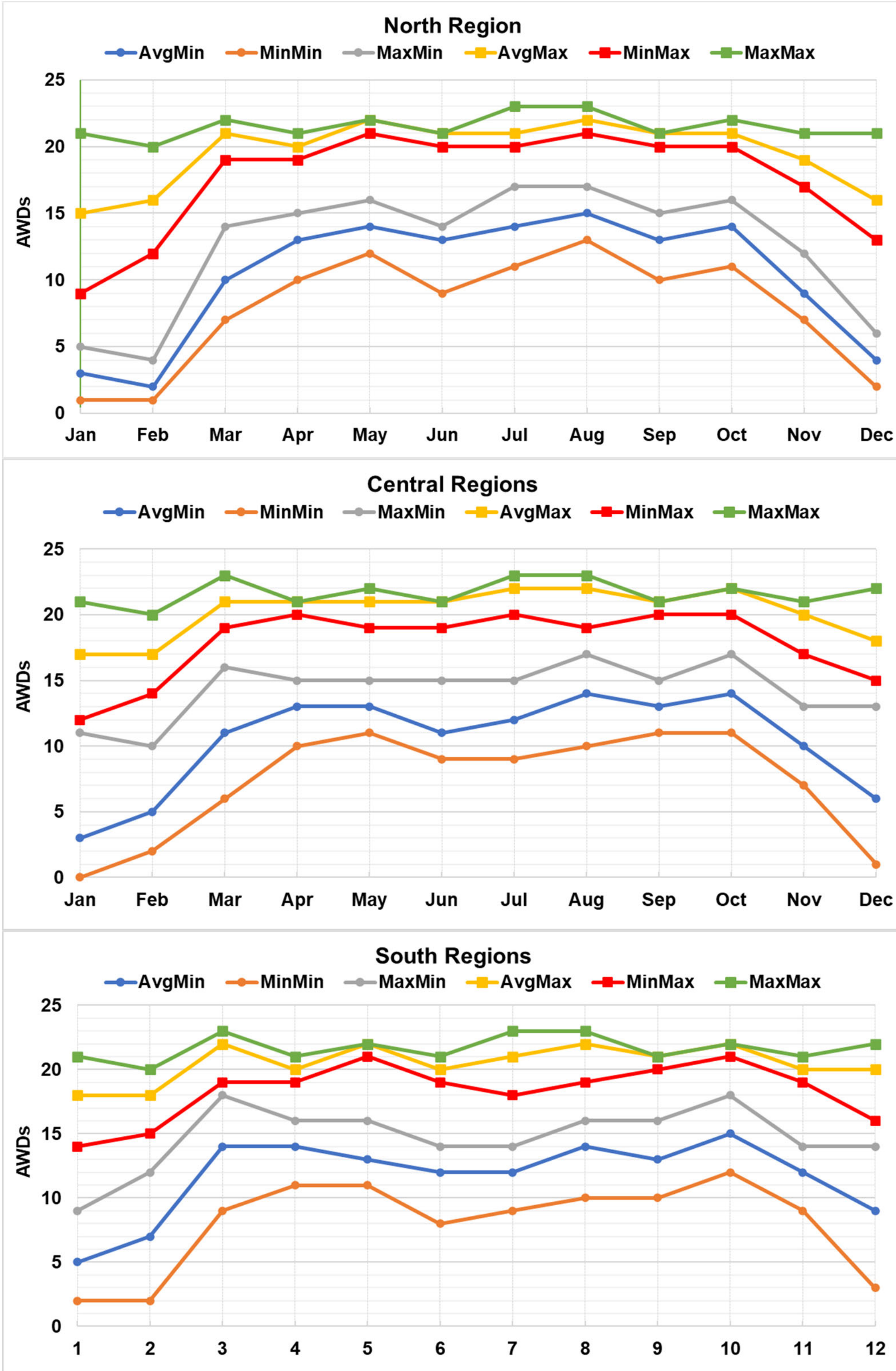



**Figure 4-35. Statistics determined from maximum and minimum of monthly AWDs over years with valid data at all weather stations in three Alabama climate zones.**

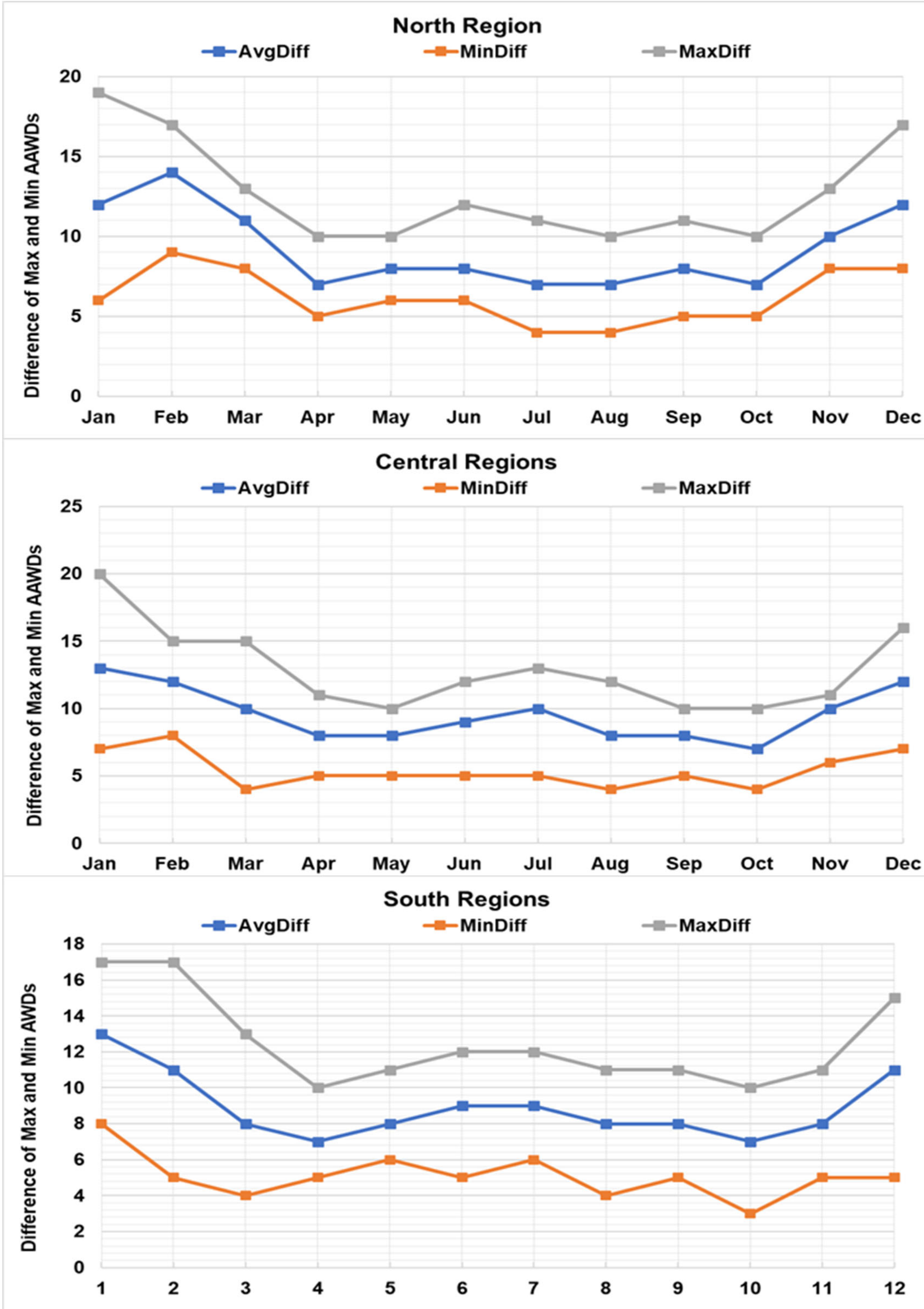



**Figure 4-36. Statistics determined from differences between the maximum and minimum AWDs over years with valid data at all weather stations for three Alabama climate zones.**

## 4.6 Sensitivity Analysis

It is useful to assess the impact of adverse weather conditions on AAWDs. With the determined AAWDs for all the five ALDOT Regions and for all 15 parameters or threshold conditions, we conducted a sensitivity analysis. Specifically, we explored the sensitivity of the threshold condition 13, which involves non-working days when precipitation exceeds 0.2 in. and the daily mean air temperature falls below 40 °F, by fixing the temperature or precipitation then changing another variable.

We held the daily mean air temperature constant at 40 °F, a noticeable trend emerged when precipitation threshold for adverse weather was 0.1 in., 0.2 in., 0.25 in., and 0.3 in. The AAWDs for all Regions consistently increased as the precipitation threshold increased. Additionally, a similar curve pattern emerged, reflecting the impact of seasonal changes among all ALDOT Regions.

Typical results of rainfall sensitivity analysis of the determined AAWDs for the East Central Region for a fixed daily mean air temperature less than 40 °F is shown in Figure 4-37, for the Southwest Region in Figure 4-38, and for the North Region in Figure 4-39.

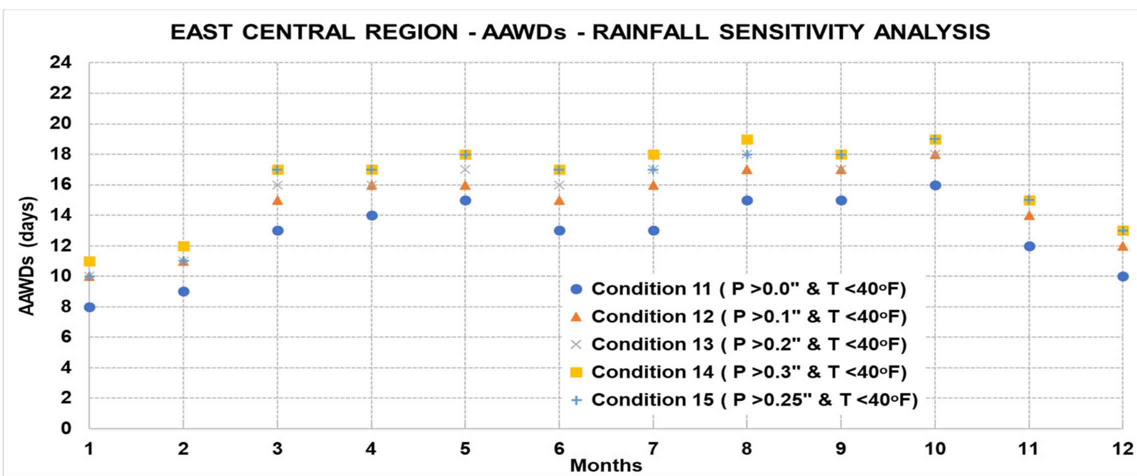



**Figure 4-37. Rainfall sensitivity analysis of the determined AAWDs for the East Central Region for a fixed daily mean air temperature of 40°F.**

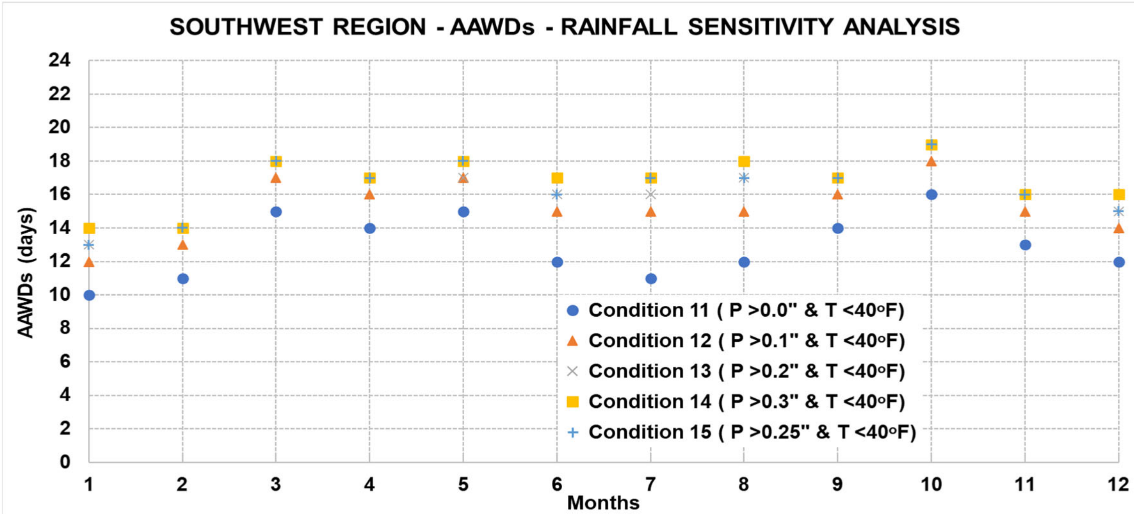



**Figure 4-38. Rainfall sensitivity analysis of the determined AAWDs for the Southwest Region for a fixed daily mean air temperature of 40°F.**

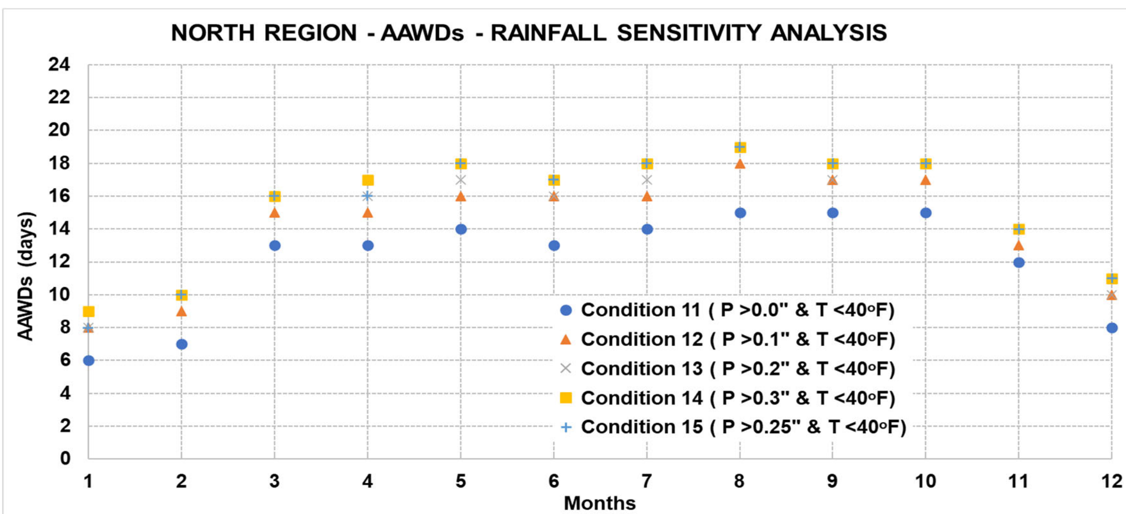



**Figure 4-39. Rainfall sensitivity analysis of the determined AAWDs for the North Region for a fixed daily mean air temperature of 40°F.**

A clear correlation between AAWDs and the temperature threshold across all regions is observed when fixing the precipitation threshold >0.2 in. Typical results are shown in Figure 4-40 for West Central Region, Figure 4-41 for North Region, and Figure 4-42 for Southeast Region. There are larger AAWDs during winter months when the daily mean air temperature changes from 40 °F to 35 °F and 30 °F as adverse weather threshold. From April to October, monthly AAWDs are independent of the temperature thresholds because air temperatures in these months are almost always above 40 °F in Alabama.

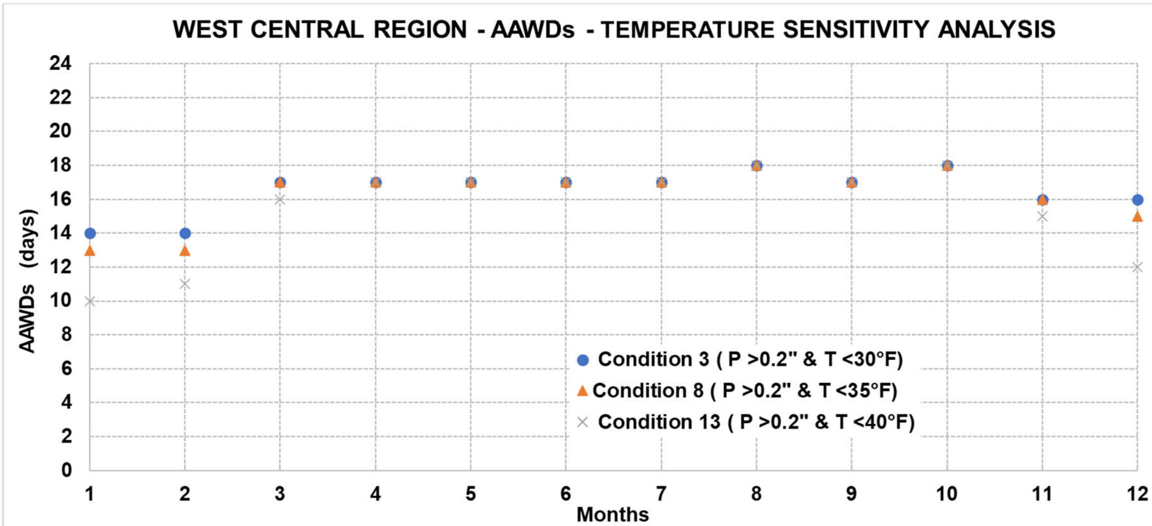



**Figure 4-40. Temperature sensitivity analysis of the determined AAWDs for the West Central Region for a fixed daily precipitation greater than 0.2 in.**

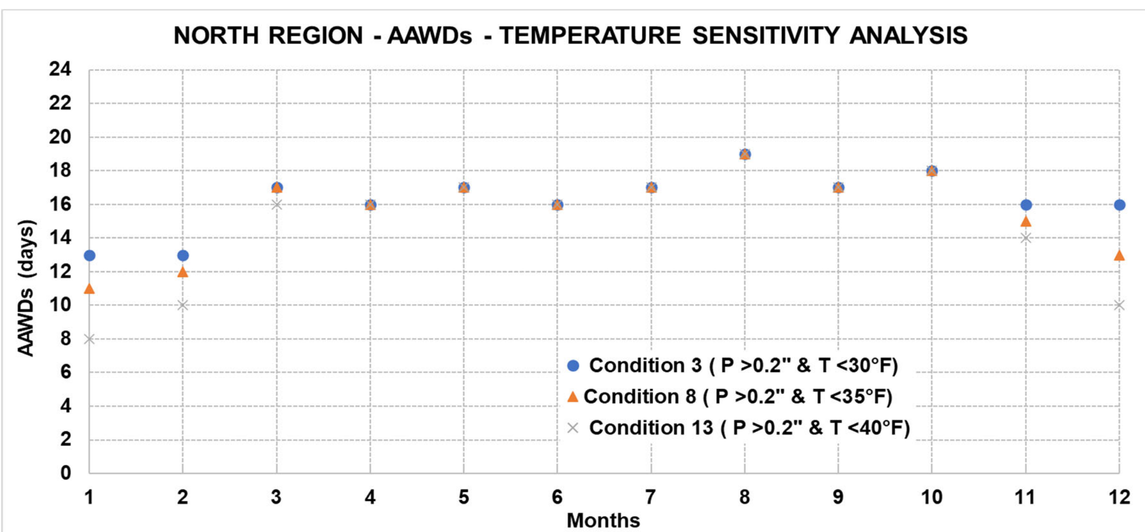



**Figure 4-41. Temperature sensitivity analysis of the determined AAWDs for the North Region for a fixed daily precipitation greater than 0.2 in.**

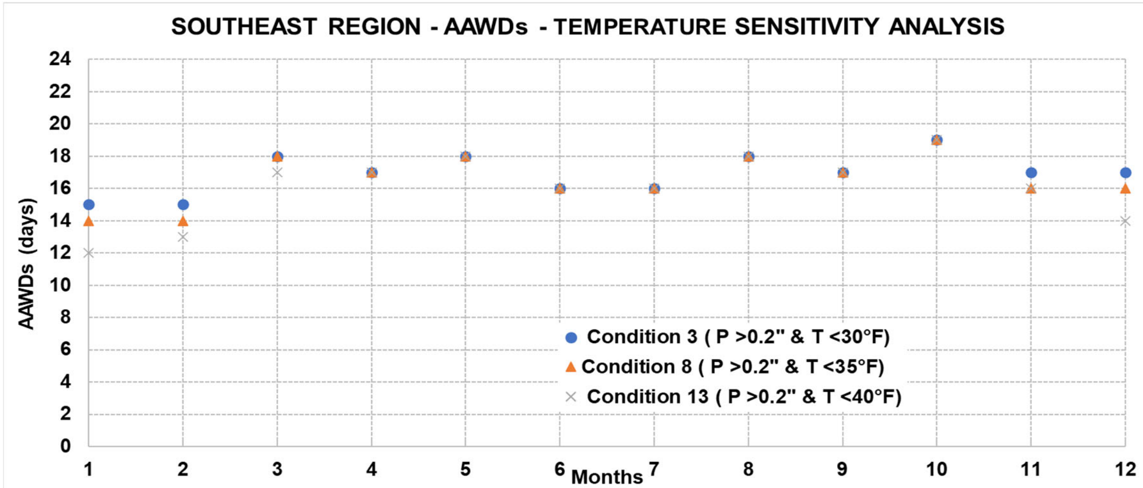



**Figure 4-42. Temperature sensitivity analysis of the determined AAWDs for the Southeast Region for a fixed daily precipitation greater than 0.2 in.**

## 4.7 Guidelines for Future Updates of AAWDs

The central aim of this investigation was to create a resource that ALDOT engineers could rely on to determine contract durations for highway projects while considering the impact of adverse weather conditions. It was therefore crucial to establish an easily accessible and efficient means of obtaining climate data, processing it, and extracting valuable metrics and insights from weather data to aid decision-making in the planning projects. To simplify this effort, an Excel spreadsheet has been developed, capable of processing climate data from the NOAA GHCN database through the implementation of VBA code. This tool calculates the AAWDs for highway projects across all ALDOT Regions using ALDOT engineer selected weather stations.

### 4.7.1 Data retrieval from NOAA database

As outlined in the 4.1 Methodology section, the weather data analyzed in this study spanned from 1900 to 2022 for 38 GHCN stations. There are 14 to 122 years of available data (average 64 years) to process for determining AAWDs. For 50 GSOD stations, there are 11 to 66 years of available data (average 26 years) to process. There are 16 GSOD stations having no corresponding GHCN stations or no longer collecting weather data or missing air temperature data or overlap with existing GHCN stations. Therefore, 34 GHCN new stations corresponding to 34 GSOD stations plus 38 GHCN stations used for the project; a total of 72 GHCN stations (including 3 stations from Mississippi and Georgia, Table 4-34) are compiled for ALDOT to use in future AAWD updates. Since

GSOD data is also not updated regularly but GHCN weather data is, we recommend ALDOT will not use GSOD data for future applications and updates of AAWDs even though the GSOD database was used for the project. The weather data downloaded from GHCN stations are recommended for future use. To ensure the accuracy and relevance of determined AAWDs, it is imperative that users regularly update climate information for subsequent years. Users should keep the climate information in the databases up to date by downloading current data from the NOAA website as explained in *Appendix A: How to obtain weather data from the Global Historical Climatology Network (GHCN) database***.**

**Table 4-34. Spatial distribution of 72 GHCN weather stations with determined AAWDs.**

| Weather Station Spatial Distribution | | | | | |
|---|---|---|---|---|---|
| ALDOT's Region | Weather Station Location (State) | | | Total Stations by Region | Mini/ Maxi /Average years of data |
| | Alabama | Georgia | Mississippi | | |
| North Region | 20 | | | 20 | 15/188/41 |
| West Central Region | 14 | | 2 | 16 | 13/99/56 |
| East Central Region | 14 | | | 14 | 14/123/75 |
| Southeast Region | 14 | 1 | | 15 | 11/94/36 |
| Southwest Region | 7 | | | 7 | 14/109/57 |
| Total Stations by State | 69 | 1 | 2 | 72 | 11/123/52 |

There are two cases or types of ALDOT future applications. The case one is to add more recent weather data to update AAWDs for weather stations used in this project. For example, we downloaded and processed weather data from 1939 to 2021 for Addison, AL; in a future year, e.g., 2031, when ALDOT wants to update AAWDs for Addison, engineers will download GHCN data from 2022 to 2031 and use the VAB-based tool to determine monthly AWDs first and then AAWDs. In worksheet AL_GHCN_Stations (Figure 4-43), column P is “Processed Station” as indicated by a letter “P”. These stations have monthly AWDs determined already from this project. For these stations, it is the case one for ALDOT engineers to extend the record in the future.

The case two is for a particular ALDOT construction project when the closest weather station was not used by this study. There are 130 GHCN weather stations in Alabama that are still active to collect weather data. Only 38 GHCN stations were used first to derive AAWDs for this project. There are 34 GSOD stations that have corresponding GHCN stations. Weather data for these 34 GHCN stations were also downloaded and processed at the end of the project. Therefore, only 72 GHCN stations have the developed monthly AWDs for the case one to extend the record. If the closest station is not one of these 72 stations, ALDOT engineers will download all available data for that station and use the VBA-based tool to determine monthly AWDs and/or AAWDs based on the project needs. For example, there is hypothetical future construction project on AL highway 47/21, where latitude is 31.73434 and longitude is -87.18565, after inputting geographical coordinates for the project (Cells S2 and S3) in worksheet AL_GHCN_Stations, use “Sort by Distance Project” Button, Figure 4-43 shows the nearby weather stations: the first five closest stations are no longer active, and the sixth nearby station at Evergreen Middleton Field or USW00053820 is active and can be used for the study. Evergreen Middleton Field is not a “Processed Station”. It is recommended that ALDOT engineers download all available data, e.g., from 6/1/1997 (first day with data) to 9/29/2023 (current day) to determine AWDs for all these 27 years. Since station USW00053820 was not processed before, it should be added to the end of station list under GHCN_STATION worksheet (Figure 4-44). Basic information (Station index increasing from the last index, Station ID, Start Year, End Year, Station Name) for station USW00053820 must be inputted before running the VBA-Code modules developed. The “Start Year” must be the first year in the downloaded csv data file, otherwise, the VBA code will not work. For example, Evergreen Middleton Field station has been downloaded from 1/1/1998, and the Start Year is 1998. For case one to extend AWDs results, the Start Year is the first year to extend the data, e.g., 2023 for Addison, AL, when the station has been processed to the end of 2022 for this project. The “# Year” is updated automatically. Station ID is connected to the input file (ID.csv) and all output files (IDRes.xlsx for monthly AWDs, IDAAWD.xlsx for AAWD results for all 15 thresholds). The downloaded data file (Order-Number.csv) should be

| K | L | M | N | O | P | Q | R | S | W | X |
|---|---|---|---|---|---|---|---|---|---|---|
| 1St Year | Last Year | # Years | Distance to Project | Station Name | Processed Station | | Project Location | | | |
| 1941 | 2000 | 59 | 1.8 | BEATRICE, AL US | | | Latitude | 31.73434 | | |
| 1967 | 2017 | 50 | 15.5 | PINE APPLE, AL US | | | Longitude | -87.18565 | | |
| 1952 | 2020 | 68 | 20.3 | CLAIBORNE LOCK AND DAM, AL US | | | Shortest distance | 1.8 | miles | |
| 1961 | 2001 | 40 | 21.7 | CAMDEN 3 NW, AL US | | | Nearest City | BEATRICE, AL US | | |
| 1956 | 2004 | 48 | 22.6 | GEORGIANA, AL US | | | 2nd shortest distance | 15.5 | miles | |
| 1997 | 2023 | 26 | 23.2 | EVERGREEN MIDDLETON FIELD, AL US | | | 2nd Nearest City | PINE APPLE, AL US | | |
| 1936 | 2018 | 82 | 24.2 | EVERGREEN, AL US | | | 3rd shortest distance | 20.3 | miles | |
| 1930 | 2000 | 70 | 27.5 | FRISCO CITY 3 SSW, AL US | | | 3rd Nearest City | CLAIBORNE LOCK AND DAM, AL US | | |
| 1980 | 2020 | 40 | 28.2 | MILLERS FERRY LOCK AND DAM, AL US | | | | | | |
| 1939 | 2007 | 68 | 31.3 | WHATLEY, AL US | | | | | | |
| 2008 | 2023 | 15 | 33.9 | THOMASVILLE 2 S, AL US | P | | | | | |
| 1900 | 2023 | 123 | 34.1 | GREENVILLE, AL US | P | | | | | |
| 2006 | 2023 | 17 | 34.4 | MAC CRENSHAW MEMORIAL AIRPORT, GREEI | p | | Sort by Distance to Project | | | |
| 1936 | 2014 | 78 | 34.6 | THOMASVILLE, AL US | | | | | | |
| 1941 | 2022 | 81 | 36.2 | WALLACE 2 E, AL US | | | | | | |
| 1940 | 2015 | 75 | 36.8 | ALBERTA, AL US | | | | | | |
| 1940 | 2023 | 83 | 41.0 | ATMORE, AL US | P | | Sort by Station Name | | | |
| 2008 | 2023 | 15 | 41.5 | BREWTON 3 NNE, AL US | P | | | | | |
| 1977 | 2023 | 46 | 41.7 | BREWTON 3 ENE, AL US | | | | | | |
| 2007 | 2023 | 16 | 43.2 | SELMA 6 SSE, AL US | P | | | | | |
| 1961 | 2023 | 62 | 46.0 | JACKSON, AL US | | | | | | |
| 1980 | 2013 | 33 | 47.0 | JONES BLUFF LOCK AND DAM, AL US | P | | Sort by Station ID | | | |
| 1925 | 2014 | 89 | 47.3 | BREWTON 3 SSE, AL US | | | | | | |
| 1936 | 2023 | 87 | 47.8 | SELMA, AL US | | | | | | |
| 1912 | 2018 | 106 | 48.9 | ANDALUSIA 3 W, AL US | | | | | | |

**Figure 4-43. Portion of worksheet “AL_GHCN_Stations” in AAWDs_GHCN_ALDOT.xlsm spreadsheet to identify the nearby weather stations from a construction project.**

renamed as ID.csv and copied from “Downloads” folder to the current working folder, e.g., “AAWDs-Update”.

### 4.7.2 Excel spreadsheet

A VBA-based spreadsheet tool has been created to process GHCN weather station data downloaded from NOAA. This all-in-one tool was slightly revised or combined from spreadsheets developed/used for this project and has been designed to accommodate various processes, depending on the specific analysis users wish to perform.

The spreadsheet contains GHCN station information in two worksheets. First, the 72 GHCN stations used to obtain the results presented in the study are listed and collected on the worksheet "GHCN_STATION." The worksheet "AL_GHCN_Stations" lists 190 GHCN stations in Alabama (130 still active and 60 were active to 2000–2022). One can sort these GHCN stations by Station ID (Column B) or Station name (Column C) or by distance to project site (Column N) after the project’s latitude and longitude are provided by the user (Figure 4-43). The worksheet shows the computed distance and GHCN station names with three shortest distances to the project site. For example, for the verification project 1 in DeKalb County (Chapter 5), when latitude of 34.570 and longitude of -85.574 are inputted, three nearest weather stations: Valley Head, Valley Head 1 SSW, and Port Payne, were identified.

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Station Index | Station ID | Start Year | End Year | # Years | Station Name | LATITUDE | LONGITUDE | ELEVATION_( | AWDs File Name |
| 65 | 64 | USW00003878 | 1970 | 2022 | 53 | TROY MUNICIPAL AIRPORT | 31.85742 | -86.01025 | 118.6 | USW00003878Res.xlsx |
| 66 | 65 | USW00093806 | 1949 | 2022 | 74 | TUSCALOOSA AIRPORT ASOS | 33.21217 | -87.61552 | 45.3 | USW00093806Res.xlsx |
| 67 | 66 | USW00063862 | 2007 | 2022 | 16 | VALLEY HEAD 1 SSW | 34.5653 | -85.6171 | 310.9 | USW00063862Res.xlsx |
| 68 | 67 | USC00018517 | 1939 | 2022 | 84 | VERNON | 33.74175 | -88.12505 | 90.5 | USC00018517Res.xlsx |
| 69 | 68 | USC00018812 | 2008 | 2022 | 15 | VINEMONT 2 NNW | 34.25889 | -86.89881 | 280.4 | USC00018812Res.xlsx |
| 70 | 69 | USC00018673 | 1959 | 2022 | 64 | WARRIOR LOCK AND DAM | 32.77472 | -87.83056 | 33.5 | USC00018673Res.xlsx |
| 71 | 70 | USW00063872 | 2007 | 2022 | 16 | WEEDON FIELD AIRPORT | 31.95163 | -85.13122 | 86.8 | USW00063872Res.xlsx |
| 72 | 71 | USC00018998 | 1924 | 2022 | 99 | WINFIELD 2 SW, AL US | 33.9107 | -87.8469 | 158.5 | USC00018998Res.xlsx |
| 73 | 72 | USW00053820 | 1998 | 2022 | 25 | EVERGREEN MIDDLETON FIELD | 31.41912 | -87.04844 | 79.1 | USW00053820Res.xlsx |

**Figure 4-44. Portion of worksheet “GHCN_STATION” in AAWDs_GHCN_ALDOT.xlsm spreadsheet to input the information for a weather station from a construction project.**

In the "Main" worksheet, three distinct VBA-code modules are developed and presented, catering to different user needs. Figure 4-45 illustrates how these three options are presented in the tool. In the Main worksheet, users input the station index in A2, which is from column A or Station Index column in the GHCN_STATION worksheet for the station they wish to process and then select one of the following three options.

1. **ALDOT-AWDs (Each Year):** This option allows users to determine monthly AWDs and non-workdays for each of the 15 adverse-weather threshold conditions (Table 4-3) for the selected weather station over all available years that meet the data criteria outlined in section *4.2.2 Non-workdays due to adverse weather classification* criteria. These calculations are based on the classification of daily records reported in the station data, providing results like those presented in *4.2.3 Direct outcomes of climate data* analysis. After inputting the station index, the first data year and the last data year of the station will be shown up in Cell A4 and A5. Station 34 for Huntsville International Airport was selected for testing purposes. It has weather data from 1959 to 2022, but we only downloaded data to 2109 and processed them first. Then we downloaded its weather data from 2020 to 2022 to test extending/expanding the data. In the Main worksheet (Figure 4-45), the user can input the update start year and the update end year as 2020 and 2022. After clicking “1. ALDOT-AWDS (Each Year)”, AWDs for three more years after 2019 are determined by VBA code and added into the AWD results file, i.e., USW00003856Res.xlsx for Huntsville International Airport. After monthly AWDs for a station have been extended to a future year, e.g., 2022 for Huntsville for above testing, the “End Year” information in GHCN_STATION for that station should be updated correspondingly. For the case two of ALODT future applications, it involves a new GHCN station, not one of the 72 used GHCN stations, in addition to adding the station information into GHCN_STATION worksheet, the same Start Year and End Year entered in GHCN_STATION (Figure 4-44) should also be inputted under Update Start Year and Update End Year in Main worksheet (Figure 4-45) since there are no prior results for AWDs.
2. **ALDOT-AAWDs (Over 10 years):** The second option is designed to calculate the Average Available Workdays for all 15 adverse-weather threshold conditions (Table 4-3) for a climate station within the available data period. This considers stations with more than 10 years of valid data; otherwise, the code will not produce results. The results obtained are saved in file “**AAWD.xlsx” (where ** stands for station ID, e.g., USW00053820 for Evergreen Middleton Field) with the same information provided in Figure 4-44. This module also outputs AAWD results and AWDs during the project period into the AAWDs worksheet. If “13” is selected in Cell E15, then AAWDs results for P13, the final threshold for adverse weather conditions adopted by ALDOT, will be output in the AAWDs worksheet. However, users can select any of 15 adverse-weather threshold parameters to output the AWWDs results. In the Main worksheet, users can select the AAWD parameter No. in E15, enter the project start year in E16 and the project end year in E17. The project duration should be within the available years (information on A4 and A5 Cells) with weather data for the station.
3. **ALDOT-AAWDs (Over Defined Years):** To enhance the tool's flexibility, a third VBA code module enables users to specify a limited or defined analysis period for a particular climate station to determine AAWDs. This customization feature allows for a more targeted

examination of weather data within specific timeframes. For example, after extending AWDs results to 2022 for Huntsville, we can determine AAWDs from 2000 to 2020 (Figure 4-45) instead of the whole data period (from 1959 to 2022).

### 4.7.3 Guidelines and Training

To ensure that ALDOT engineers can effectively utilize the tools to derive AAWDs for currently used (72 stations) and future weather stations, necessary guidelines, instructions, and demonstration are provided in Appendix A and B. These instructions will encompass everything from data retrieval from the NOAA website (Appendix A) to the utilization of the VBA-based spreadsheet tools for analysis (Appendix B). Furthermore, to facilitate learning and comprehension, prerecorded webinars or videos will be developed as an educational resource. These videos will offer guidance and demonstrations of the functionality of the spreadsheet tools.

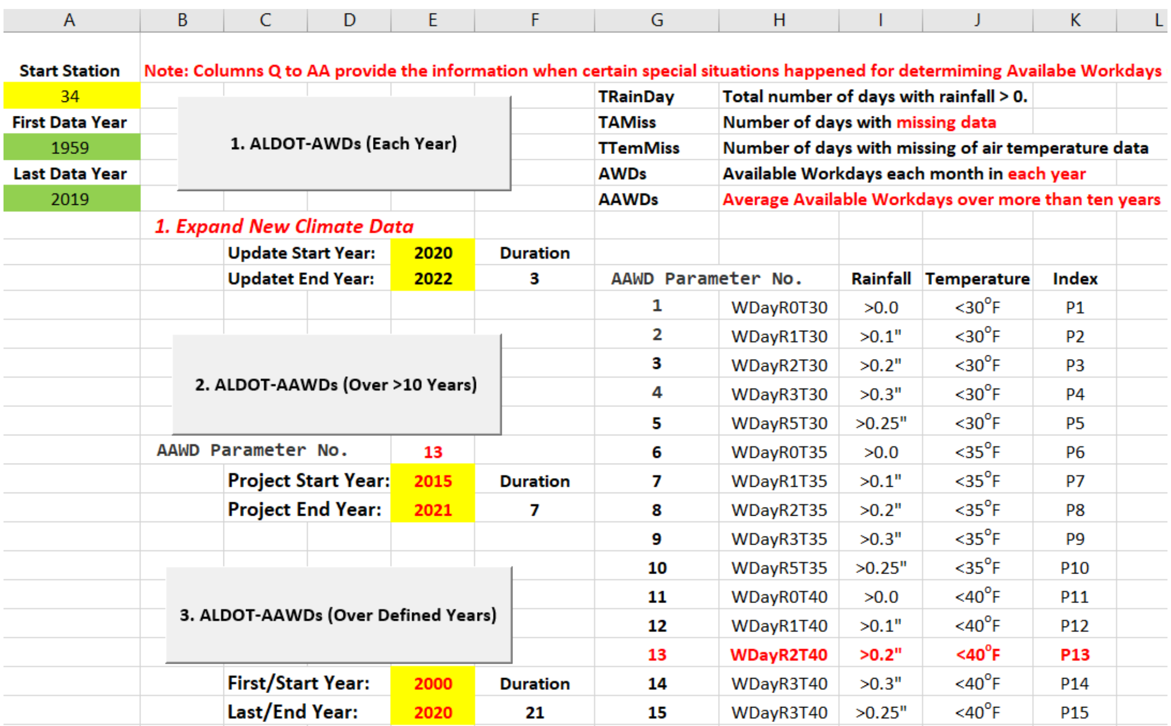



**Figure 4-45. Main worksheet in AAWDs_GHCN_ALDOT.xlsm spreadsheet to input the information and run three VBA modules for a construction project.**

# CHAPTER 5. VERIFICATION OF DEVELOPED TOOL TO DETERMINE AAWDS USING COMPLETED ALDOT'S PROJECTS

To validate and ensure the accuracy of the tool created to determine Average Available Workdays (AAWDs) due to adverse weather for roadway projects, project daily records from five completed representative ALDOT projects, each from a different ALDOT region, were processed. The goal of this task was to test the tool's ability to consider regional variations in weather patterns, particularly in the southern and northern regions, as well as project characteristics and type. When evaluating the AAWDs for finished highway projects, the data from the five ALDOT project daily records were carefully compared with the corresponding data obtained from nearby weather stations. The custom Excel spreadsheet created for this analysis was used to perform the comparison. The main goals of the task were to evaluate the precision of the calculated AAWDs and, in turn, to determine whether any calibration adjustments were required. Table 5-1 shows the information of the five completed project records provided by ALDOT for this verification task. Figure 5-1 shows the spatial distribution of the completed highway projects and the closest weather stations used for the verification process. The methodology and findings for each of the analyzed projects are presented in the following sections (5.1–5.5).

**Table 5-1. Information of ALDOT's projects used for the verification process.**

| No. | Project ID | County | ALDOT Region | Latitude Longitude | Start date-End date | Closest station | Station Name |
|---|---|---|---|---|---|---|---|
| P1 | BRF-0117 (501) | DeKalb County | North | 34.570, -85.574 | 1/13/2018 – 8/25/2021 | USW00063862 | Valley Head 1 SWW |
| P2 | IM-HSIP-I065 (484) | Jefferson County | East Central | 33.710, -86.835 | 3/5/2019 – 9/30/2020 | USW00013876 | Birmingham airport |
| P3 | IM-I022 (312) | Marion County | West Central | 33.959, -87.661 | 10/15/2020 – 8/16/2021 | USC00018998 | Winfield 2 SW |
| P4 | IMF-I085 (339) | Montgomery County | Southeast | 32.362, -86.191 | 4/9/2018 – 10/31/2020 | USC00015553 | Montgomery 6 SW |
| P5 | IM-I065 (491) | Escambia County | Southwest | 31.162, -87.372 | 7/24/2019 – 6/30/2022 | USC00010402 | Atmore |

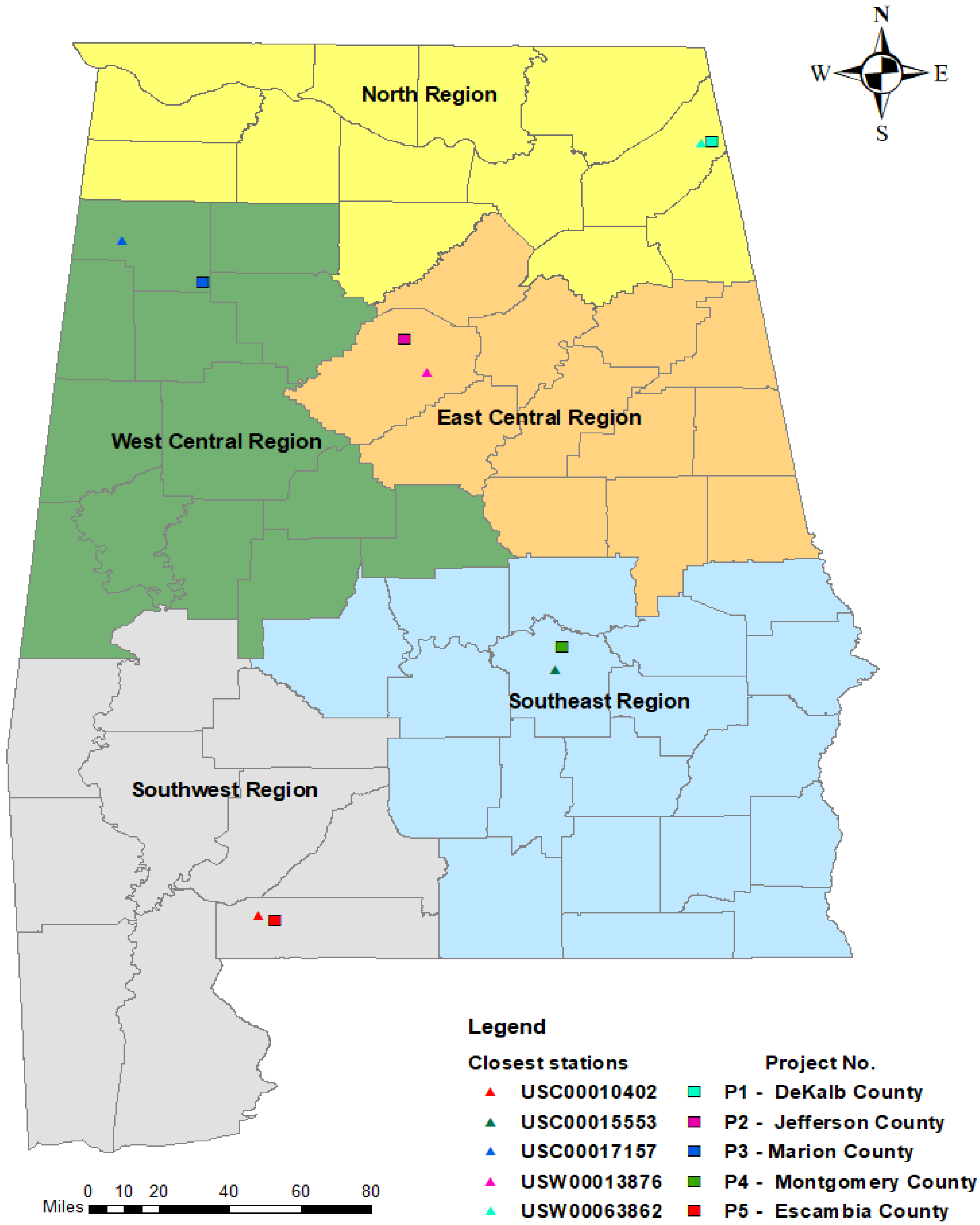



**Figure 5-1. Map showing five ALDOT projects and the closest weather stations used for the verification process.**

## 5.1 VERIFICATION PROCESS

The method used for step-by-step verification is described below:

1. Data gathering: Obtaining daily data from finished highway projects as supplied by ALDOT. ALDOT provided daily records for five completed projects, one for each of the five regions.
2. Retrieving weather-related information from a nearby weather station that corresponds to the project location.
3. Use the developed Excel Spreadsheet to process and determine weather information of the closest weather station for each of the five projects.
4. Comparative analysis: Using the Excel spreadsheet, compare the project's daily records to the corresponding weather information.
5. Assessment of accuracy: The calculated AWDs and non-workdays or NWDs from the weather station are compared to the recorded AWDs and NWDs from the project's records based on what was claimed and/or reported by contractor to ALDOT.
6. Analyzing any discrepancies between calculated and recorded AWDs and NWDs data to determine whether calibration adjustments may be required.

### 5.1.1 PROJECT DAILY RECORDS DATA ANALYSIS

For each completed project, ALDOT representative provided the research team with the following essential information: (1) Contract information, (2) Key dates, (3) Daily work report, and (4) Time charges summary.

This dataset was essential for many aspects of the research. It not only facilitated the ability to locate the nearest weather station, which afterward was used as a base for data comparison and verification, but it also made it possible to fully comprehend the construction activities performed within each project.

The time charges summary, among the data provided by ALDOT, proved to be particularly useful in determining the number of non-workdays and workdays for each project. This data element was utilized for the daily classification process. The data analysis process followed is explained below in details:

I. The project’s Time Charge Summary report was processed to determine the reported/ recorded non-workdays due to adverse weather conditions, state holidays and weekends for the project duration. The notation used in the report corresponds to “1” for workdays or for days that the contractor worked (charged time) on the project and “0” for non-workdays or for days that the contractor did not work on the project. Non-workdays reported due to factors that differed from the above-stated criteria were not considered when determining the total AWDs for each month throughout the project duration. Figure 5-2 presents an example of the project's record format. The project non-workdays were determined monthly throughout the project duration.

II. The AWDs for each month were determined based on the subtraction of the total days per month minus the total non-workdays reported that comply with the study criteria (weekend, Alabama's state holidays, day affected by adverse weather conditions).

III. Two parameters were defined by analyzing the daily records of the projects, 1) Non-workdays due to other factors: considered as those days which time charge is "0", claimed as non-workday, but the conditions are not related to the study criteria (adverse weather, holidays, weekend); for example, in the time charge for March 2018 for project 1 (Figure 5-2), except for weekends, all days from 03-01-2018 through 03-30-2018 were claimed as non-workday due to "Utility conflicts", a factor not related to the study criteria, and therefore not accounted as non-workdays related to the weather factor. 2) Project worked days: defined as the days that based on the project's daily records the time charge is marked as "1", without discriminating if it falls on a holidays or weekends.

**Alabama Department of Transportation**
**Time Charges Summary**
**Contract ID:** 20171201001 **Fed/State Proj No:** BRF-0117(501)

**Kay Ivey**
**Governor**

**John R. Cooper**
**Transportation Director**

**Contractor:** WRIGHT BROTHERS CONSTRUCTION COMPANY, INC.
P. O. BOX 437
CHARLESTON, TN 37310

**County:** DEKALB
**Area:** 01 **District:** 03
**Date:** 03/21/2023

The time charged on the above referenced project from **01/13/2018** to **08/25/2021** **is** 216 day(s).

| Day | Date | Time Charge | No Charge Reason | Day | Date | Time Charge | No Charge Reason March '18 |
|---|---|---|---|---|---|---|---|
| THU | 03/01/2018 | 0 | Utility Conflict | SAT | 03/17/2018 | 0 | Saturday |
| FRI | 03/02/2018 | 0 | Utility Conflict | SUN | 03/18/2018 | 0 | Sunday |
| SAT | 03/03/2018 | 0 | Saturday | MON | 03/19/2018 | 0 | Utility Conflict |
| SUN | 03/04/2018 | 0 | Sunday | TUE | 03/20/2018 | 0 | Utility Conflict |
| MON | 03/05/2018 | 0 | Utility Conflict | WED | 03/21/2018 | 0 | Utility Conflict |
| TUE | 03/06/2018 | 0 | Utility Conflict | THU | 03/22/2018 | 0 | Utility Conflict |
| WED | 03/07/2018 | 0 | Utility Conflict | FRI | 03/23/2018 | 0 | Utility Conflict |
| THU | 03/08/2018 | 0 | Utility Conflict | SAT | 03/24/2018 | 0 | Saturday |
| FRI | 03/09/2018 | 0 | Utility Conflict | SUN | 03/25/2018 | 0 | Sunday |
| SAT | 03/10/2018 | 0 | Saturday | MON | 03/26/2018 | 0 | Utility Conflict |
| SUN | 03/11/2018 | 0 | Sunday | TUE | 03/27/2018 | 0 | Utility Conflict |
| MON | 03/12/2018 | 0 | Utility Conflict | WED | 03/28/2018 | 0 | Utility Conflict |
| TUE | 03/13/2018 | 0 | Utility Conflict | THU | 03/29/2018 | 0 | Utility Conflict |
| WED | 03/14/2018 | 0 | Utility Conflict | FRI | 03/30/2018 | 0 | Utility Conflict |
| THU | 03/15/2018 | 0 | Utility Conflict | SAT | 03/31/2018 | 0 | Saturday |
| FRI | 03/16/2018 | 0 | Utility Conflict | | | | |

**Figure 5-2. Time Charges summary report from completed project used for the verification project.** ***Source: ALDOT***

IV. The weather station closest to the project location was selected for verification. The NOAA database with the most complete valid data for daily precipitation and air temperature throughout the project duration, either the Global Historical Climatology Network (GHCN) or Global Summary of the Day (GDS), was selected for the verification process.

V. The non-workdays and workdays for the chosen climate station were determined using the developed Excel spreadsheet tool by following the procedure and analysis stated in the Methodology section of this report.

VI. By the suggestion from ALDOT project advisory committee, the adverse weather threshold condition used for the comparative analysis was condition 13, which is defined as daily precipitation greater than 0.2 in. and daily mean temperature less than 40° F as adverse weather or non-workdays.

VII. To confirm the consistency of the obtained results and the daily information claimed in the project, a daily comparison between the project's records and the data from the closest station was made.

VIII. The determined AWDs and Non-workdays or NWDs were compared with the daily records for each project.

IX. Comparative graphs and tables were created to assess the differences encountered and the daily records for each project.

## 5.2 Project 1 (DeKalb County - North Region)

Project 1 located in DeKalb County, Alabama, consisted in the replacement of grade, drain, pave and retaining wall of the bridge located at the SR-117 over the west fork of the Little River in Mentone 0.463 (Latitude: 34.570263°, Longitude: -85.574476°). The project extended from January 2018 through August 2021 for about 1320 days (~3 years and 6 months), where the impact of factors such adverse weather and other non-climate related factors determined the total project duration. , The contract time was only 170 workdays. For the verification process the closest weather station selected for analysis was the Valley Head 1 SSW - USW00063862 (34.5653º, -85.6171º), which has records of valid weather data from 2007 through 2022, but for the merit of the comparison and verification years 2018 through 2021 were used. The project information summary in shown in Table 5-2; Figure 5-3shows the location of the project related to the closest stations.

Table 5-3 displays the AAWDs calculated for the "Valley Head 1 SSW - USW00063862". This station is in the North Region. The AAWDs for this station range from 6 to 18 days throughout the year, with the median AAWD ranging from 6 to 18 days, and standard deviation ranging from 2-3 days.

**Table 5-2. DeKalb county ALDOT project (Project 1) information.**

| Project 1 | | | |
|---|---|---|---|
| Fed/State Project No. | BRF-0117(501) | Start Date | 13-Jan-18 |
| Project description | Bridge replacement (grade, drain, pave and retaining wall) | End Date | 8-Aug-21 |
| Location | SR-117 over the west fork of the Little River in Mentone 0.463 (34.570263, -85.574476) | Closest Station ID/Name | Valley Head 1 SSW - USW00063862 |
| ALDOT Region | North | Closest Station Location | 34.5653, -85.6171 |
| Contract time | 170 Days | Climate station data source | Global Historical Climatology Network (GHCN) |

**Table 5-3. Determined AAWDs for the Valley Head 1 SSW station.**

| Valley Head 1 SSW - USW00063862 - P13 (P>0.2 in. & T<40°F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | N-Years | AAWD | StdDev | Min. | Max. | Median | 80PerT | Skew |
| 1 | 13/16 | 6 | 2 | 3 | 12 | 6 | 7 | 1.4558 |
| 2 | 14/16 | 8 | 4 | 1 | 15 | 8 | 10 | -0.0020 |
| 3 | 16/16 | 15 | 2 | 10 | 19 | 15 | 17 | -0.2537 |
| 4 | 16/16 | 17 | 2 | 14 | 19 | 17 | 18 | -0.0698 |
| 5 | 13/16 | 18 | 2 | 15 | 22 | 18 | 19 | 0.6495 |
| 6 | 15/16 | 16 | 3 | 11 | 20 | 17 | 18 | -0.5428 |
| 7 | 15/16 | 18 | 2 | 15 | 21 | 18 | 19 | 0.1129 |
| 8 | 15/16 | 18 | 2 | 15 | 21 | 18 | 20 | -0.3620 |
| 9 | 14/16 | 18 | 2 | 15 | 21 | 18 | 20 | 0.1207 |
| 10 | 15/16 | 18 | 2 | 14 | 22 | 18 | 19 | -0.1716 |
| 11 | 14/16 | 14 | 3 | 8 | 19 | 14 | 17 | -0.0960 |
| 12 | 14/16 | 9 | 3 | 4 | 17 | 9 | 11 | 0.8280 |

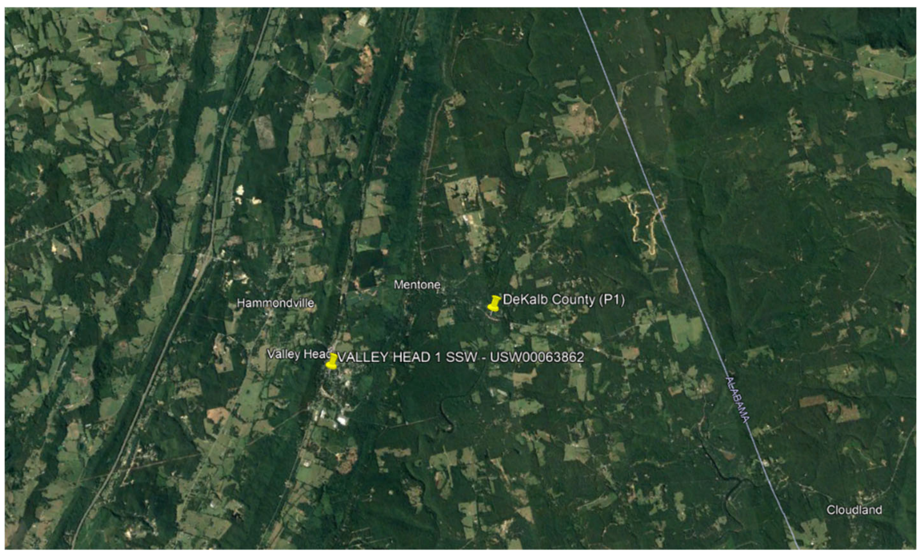




**Figure 5-3. DeKalb County (Project 1) located at the SR-117 over the west fork of the Little River in Mentone 0.463 (Latitude: 34.570263°, Longitude: -85.574476°) and the nearest weather station used for the verification process.**

#### 5.2.1 PROJECT 1 VS. VALLEY HEAD 1 SSW - USW00063862 - COMPARISON RESULTS

A daily classification of the project records for the DeKalb County Project (Pro1) was done to determine the amount of worked days and non-workdays related to adverse weather. A yearly analysis was performed in which the following parameters were determined month by month and then compared with the results obtained from the USW00063862 weather station when processed using the developed Excel tool under the adverse weather threshold condition 13 (P>0.2 in. & T <40°F); The AAWDs determined for this station (Table 5-3) can be used as a base to compare the yearly AWDs/NWDs determined throughout the project duration, allowing for a better understanding of how single weather events, such as hurricanes, can affect construction activities and thus the duration of a project.

The number of days in each month is not constant (28, 29, 30, or 31 days). It is important to note that the standard 31 days in January 2018 was changed to 18 days (Table 5-4) because of the project's start on January 13, 2018. August 2021 was changed to 25 days (Table 5-7) rather than 31 days to reflect the project's completion on August 25, 2021.

Additionally, "USW00063862 - AWDs (P13)" and "USW00063862 - NWDs (P13)," which are the data from the nearest weather station, have been included in the analysis. The AWDs and non-workdays are determined using the weather condition criteria (P13) and VBA code. However, it is important to highlight that results from the closest station are based on the full monthly length. For example, from the Project 1 daily records the determined non-workdays were 7 days based on the 19 days defined by the condition of the project start date, but the non-workdays determined from the USW00063862 (P13) accounted for a total of 16 days out of the 19 days determined for January. This discrepancy is just presented in the months of the start and completion date of the project if these dates don’t have the full month length.

**Table 5-4. DeKalb County (Project 1), 2018 monthly determined parameters for verification process.**

| 2018[5] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 19 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 353 | |
| Project non-workdays (W+H+AW) | 7 | 11 | 9 | 10 | 12 | 11 | 10 | 8 | 11 | 9 | 12 | 18 | 128 | 36% |
| Project weekend & holidays (W+H) | 7 | 9 | 9 | 10 | 9 | 10 | 10 | 8 | 11 | 9 | 10 | 12 | 114 | 32% |
| Project adverse weather (AW) days | 0 | 2 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 2 | 6 | 14 | 4% |
| Project available workdays | 12 | 17 | 22 | 20 | 19 | 19 | 21 | 23 | 19 | 22 | 18 | 13 | 225 | 64% |
| Project worked days | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 9 | 11 | 3% |
| Project non-workdays due to other factors | 12 | 17 | 22 | 20 | 19 | 19 | 21 | 23 | 19 | 22 | 16 | 4 | 214 | 61% |
| USW00063862 - AWDs (P13) | 3 | 13 | 14 | 18 | 19 | 11 | 19 | 19 | 15 | 18 | 9 | 7 | 165 | 47% |
| USW00063862 - NWDs (P13) | 16 | 15 | 17 | 12 | 12 | 19 | 12 | 12 | 15 | 13 | 21 | 24 | 188 | 53% |

[5] Note: W, H, and AW stand for weekends, state holidays, and adverse weather days, respectively. P13 is for adverse weather threshold condition 13: daily rainfall >0.2 in and daily mean temperatures < 40°F.

**Table 5-5. DeKalb County (Project 1), 2019 monthly determined parameters for verification process.**

| 2019 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 365 | |
| Project non-workdays (W+H+AW) | 21 | 20 | 18 | 15 | 14 | 16 | 13 | 15 | 10 | 10 | 17 | 17 | 186 | 51% |
| Project weekend & holidays (W+H) | 9 | 8 | 10 | 8 | 9 | 10 | 9 | 9 | 10 | 8 | 11 | 10 | 111 | 30% |
| Project adverse weather (AW) days | 12 | 12 | 8 | 7 | 5 | 6 | 4 | 6 | 0 | 2 | 6 | 7 | 75 | 21% |
| Project available workdays | 10 | 8 | 13 | 15 | 17 | 14 | 18 | 16 | 20 | 21 | 13 | 14 | 179 | 49% |
| Project worked days | 9 | 4 | 6 | 10 | 9 | 6 | 8 | 7 | 3 | 6 | 9 | 5 | 82 | 22% |
| Project non-workdays due to other factors | 1 | 4 | 7 | 5 | 8 | 8 | 10 | 9 | 17 | 15 | 4 | 9 | 97 | 27% |
| USW00063862 - AWDs (P13) | 4 | 10 | 14 | 17 | 21 | 18 | 19 | 20 | 19 | 17 | 14 | 10 | 183 | 50% |
| USW00063862 - NWDs (P13) | 27 | 18 | 17 | 13 | 10 | 12 | 12 | 11 | 11 | 14 | 16 | 21 | 182 | 50% |

**Table 5-6. DeKalb County (Project 1), 2020 monthly determined parameters for verification process.**

| 2020 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 31 | 29 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 366 | |
| Project non-workdays (W+H+AW) | 20 | 23 | 22 | 11 | 19 | 11 | 13 | 18 | 13 | 12 | 13 | 10 | 185 | 51% |
| Project weekend & holidays (W+H) | 9 | 9 | 9 | 8 | 11 | 8 | 9 | 9 | 8 | 9 | 10 | 9 | 108 | 30% |
| Project adverse weather (AW) days | 11 | 14 | 13 | 3 | 8 | 3 | 4 | 9 | 5 | 3 | 3 | 1 | 77 | 21% |
| Project available workdays | 11 | 6 | 9 | 19 | 12 | 19 | 18 | 13 | 17 | 19 | 17 | 21 | 181 | 49% |
| Project worked days | 11 | 6 | 8 | 18 | 12 | 15 | 17 | 12 | 16 | 8 | 5 | 2 | 130 | 36% |
| Project non-workdays due to other factors | 0 | 0 | 1 | 1 | 0 | 4 | 1 | 1 | 1 | 11 | 12 | 19 | 51 | 14% |
| USW00063862 - AWDs (P13) | 12 | 5 | 13 | 16 | 15 | 13 | 19 | 15 | 18 | 18 | 18 | 10 | 172 | 47% |
| USW00063862 - NWDs (P13) | 19 | 24 | 18 | 14 | 16 | 17 | 12 | 16 | 12 | 13 | 12 | 21 | 194 | 53% |

**Table 5-7. DeKalb County (Project 1), 2021 monthly determined parameters for verification process.**

| | 2021 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 25 | | | | | 237 | |
| Project non-workdays (W+H+AW) | 29 | 24 | 15 | 8 | 10 | 9 | 10 | 7 | | | | | 112 | 47% |
| Project weekend & holidays (W+H) | 11 | 9 | 8 | 8 | 10 | 9 | 10 | 7 | | | | | 72 | 30% |
| Project adverse weather (AW) days | 18 | 15 | 7 | 0 | 0 | 0 | 0 | 0 | | | | | 40 | 17% |
| Project available workdays | 2 | 4 | 16 | 22 | 21 | 21 | 21 | 18 | | | | | 125 | 53% |
| Project worked days | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 0 | 0% |
| Project non-workdays due to other factors | 2 | 4 | 16 | 22 | 21 | 21 | 21 | 18 | | | | | 125 | 53% |
| USW00063862 – AWDs (P13) | 6 | 7 | 17 | 19 | 17 | 16 | 16 | 11 | | | | | 109 | 46% |
| USW00063862 – NWDs (P13) | 25 | 21 | 14 | 11 | 14 | 14 | 15 | 14 | | | | | 128 | 54% |

Throughout the project duration were identified from project's daily records a total of 611 days were claimed as non-workday due to factors related to the study criteria (adverse weather, i.e., rain, too cold, or wet conditions; weekends and state holidays), 223 workdays, and 487 days considered as non-workdays due to other factors non-related to the study criteria, such as utility coordination, punch items, and others. While based on the data of the closest weather station (USW00063862) processed using the weather condition 13 (P>0.2 in. & T<40°F), a total of 690 days were classified as non-workdays and 631 days as AWDs (Figure 5-4). When comparing the results of the USW00063862 versus the project's daily records it can be observed a difference of 79 days for the non-workdays (+13%) and a difference of 408 AWDs (+183%), however when combined the project's workdays (223 days) and the project's non-workdays due to other factors (487 days), it sum up to 710 days, that when compared with determined workdays (631 days) from the weather station results in a difference of 79 days (-11%). These results are shown Figure 5-4.

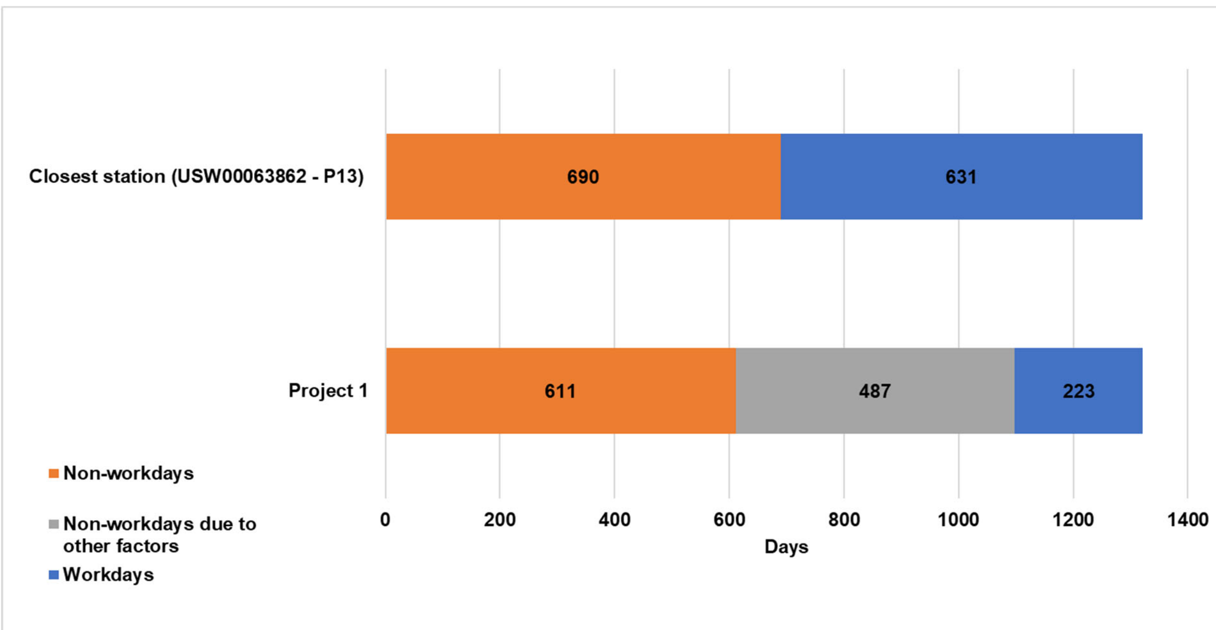



**Figure 5-4. Verification of AWDs and NWDs between Project 1 daily records and from the nearest weather station USW00063862 (P13).**

The recorded worked days and AWDs for Project 1 are plotted in Figure 5-5 month by month. It can be noted that the AWDs for Project 1 were determined by considered all the days per month that were not affected by non-workdays criteria (adverse weather, holidays, weekends), therefore a simpler definition for the project available workdays (PAWDs) = Project worked days + Project non-workdays due to other factors. For example, for the month of February 2019 the project worked days were four, the project non-workdays due to other factors were four, combined sum up to eight days, which is the determined PAWDs for February. This assumes that the contractor recorded all adverse weather days first and then indicated/identified other factors that the contractor did not work on the project. Similarly, it can be observed that the determined AWDs for February 2019 from the closest station, Valley Head 1 SSW- USW00063862 using Weather Condition 13 (P > 0.2 in. and T < 40°F), were determined to be 10 days (i.e., WDayR2T40 on Figure 5-5), which compared to the determined project available workdays is two days greater. A similar analysis was conducted for the non-workdays for both the project 1 daily records and the closest station, shown in Figure 5-6.

A noticeable discrepancy between the AWDs determined from the closest station and the project daily records can be observed at the beginning and end of this project, as from January 2018 through September 2018, all the days were claimed as non-workdays due to other factors, which according to the records the reasons were related to utility conflicts; however, reaching the completion date, from January 2021 through April, 2021 the non-workdays due to other factors were related to “seasonal limitation”, while from May 2021 – August 2021 they were related to factors such as 1) waiting on final inspections, 2) punch items and 3) department actions.

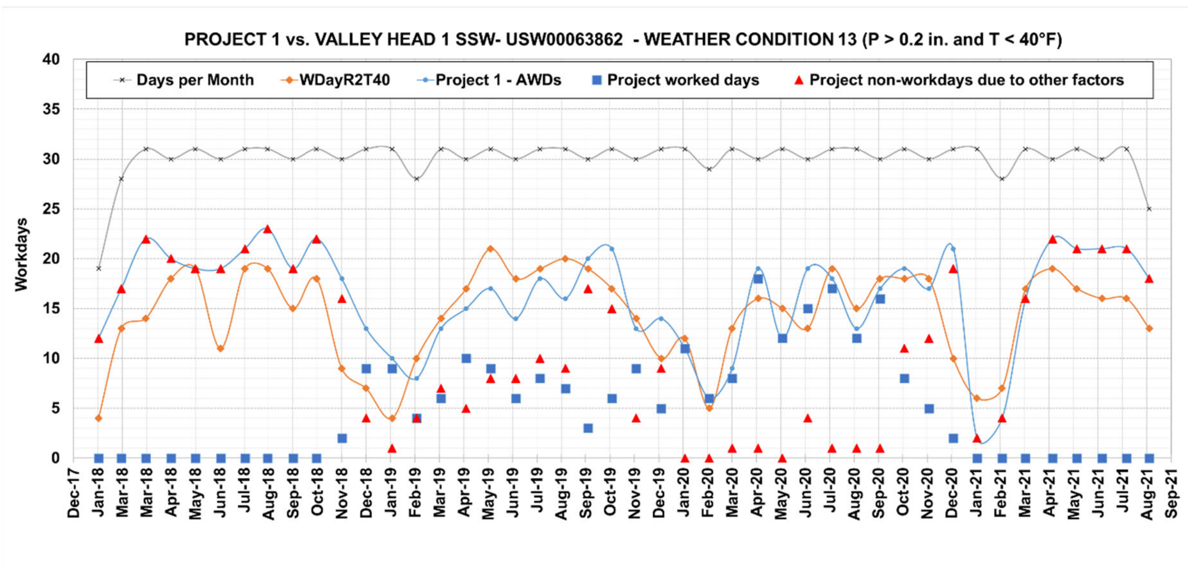



**Figure 5-5. Determined available workdays from Project 1 and Valley Head 1 SSW-USW00063862 weather station including project’s worked days and non-workdays due to other factors.**

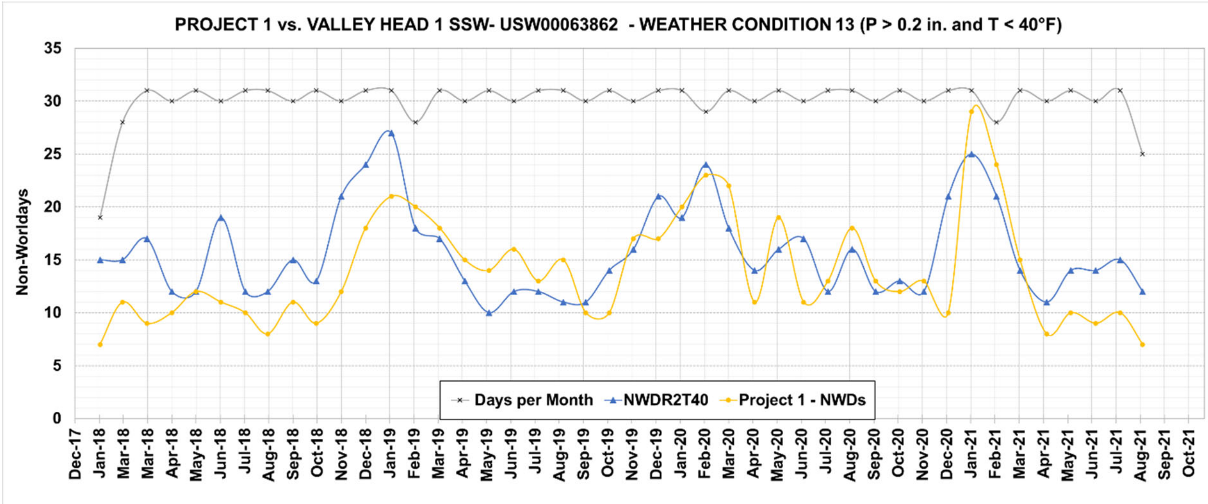



**Figure 5-6. Determined non-workdays for Project 1 and from Valley Head 1 SSW- USW00063862 weather station (NWDR2T40).**

### 5.2.2 Adverse weather verification

#### *Precipitation*

A total of 131 days (Figure 5-7) were recorded as non-working days due to rain during the project duration, however, the contractor did not record/report the rainfall depths on those days, which are only available from the nearest weather station. For those 131 rainy days reported by the contractor, 119 non-working days due to precipitation were determined from USW00063862 climate data (Figure 5-7), that correspond to a discrepancy of 12 days claimed by the contractor with not matching weather data with station USW00063862. If we disregard the information of rainy days reported by the contractor, a total of 362 rainy days, not including weekends neither holiday, were determined from the data processed from USW00063862 weather station (determined using the developed Excel tool). There are 243 rainy days, shown after 119 days that matched the project daily records, that were not claimed as NWDs in the daily records of this project. Basically, when the contractor did not work due to other reasons (e.g., utility conflict), the contractor did not provide information whether it was a rainy day or a cold day. Overall, a difference of 242 days was computed when comparing the 131 days claimed for this project versus the 362 days determined from the closest station for the project duration.

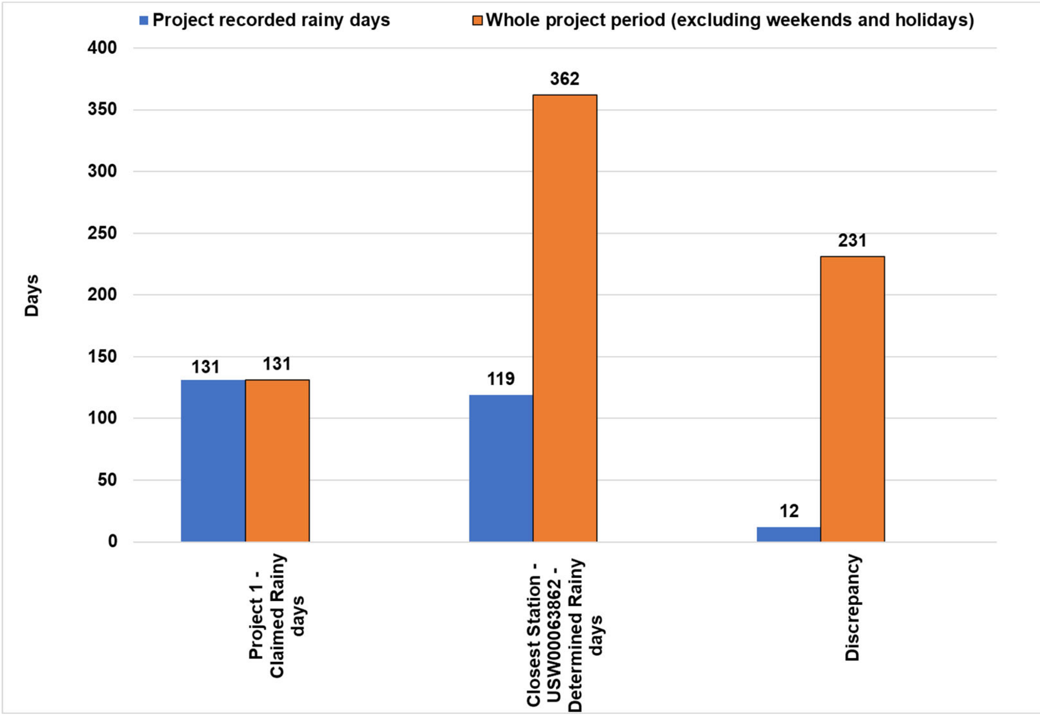



**Figure 5-7. Rainy days as claimed by Project 1, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

The daily rainfall distribution based on the study's weather conditions are shown in Figure 5-8. For 131 rainy days reported by the contractor, there are total of 85 days (3+3+79) with rainfall greater than 0.2 in, but total of 181 (16+7+158) days based on all USW00063862 rainfall data. The large difference was because there were many rainy days that the contractor did not report when the contractor did not work due to other reasons.

There are 44 days classified/recorded by the contractor as wet days. Therefore, there are a total of 175 non-workdays (Figure 5-8) recorded in this project due to factors such as rain and wet. For these days, based on the climate data determined from the station USW00063862, a total of 137 rain days were found. A total of 27 days were added as non-workdays for days on which the precipitation was greater than 0.75 in. by assuming the next day was too wet for the contractor to work; therefore, there were a total of 164 days of non-workdays, for a discrepancy of 11 days.

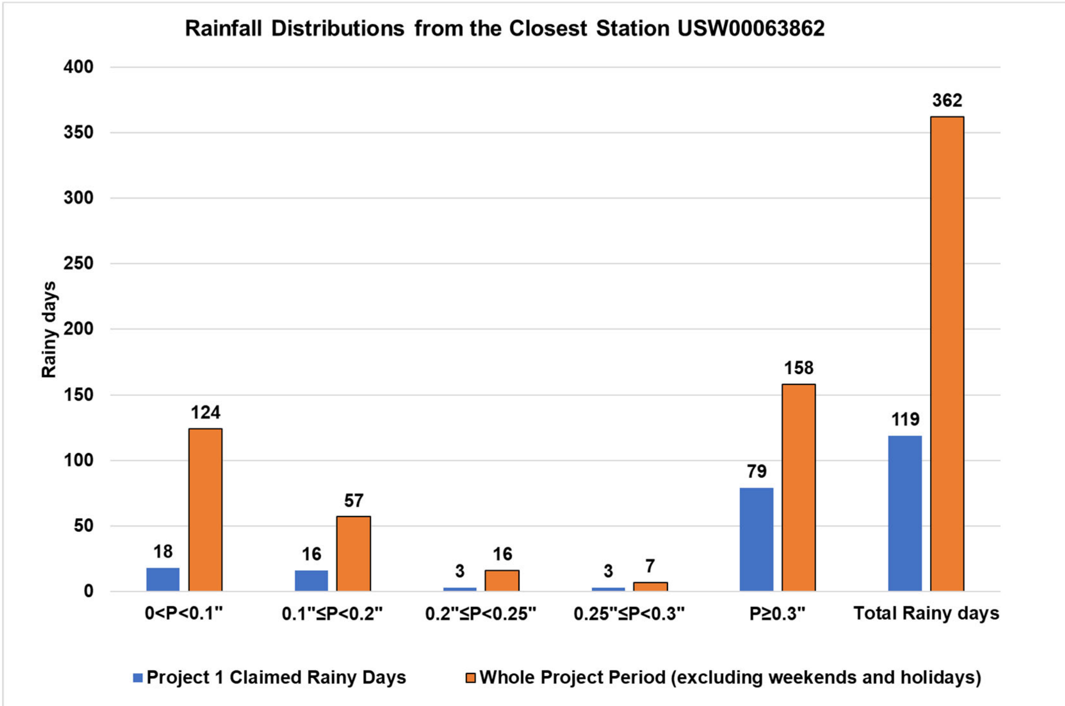



**Figure 5-8. Rainfall distributions of the closest station during the project claimed rainy days and the whole project period (excluding weekends and holidays).**

If we disregard the information of rainy plus wet days reported by the contractor, when determining the rainy days and extra days with P>0.75 in. analyzing the data from the closest station, a total of 436 days were identified as NWDs. Compared with the 175 days claimed by the contractor, it results in a difference of 261 days as shown in Figure 5-10.

Figure 5-9 presents the daily rainfall distribution and the discrepancy obtained with and without considering project's records of rainy and wet days. It can be observed that for precipitation greater than 0.2 in., 89 days (3+3+86) were determined from the project daily records in comparison to 181 (16+7+158) days identified from total the station USW00063862. For duration of this project and based on the closest station, a total of 27 NWDs were added as the registered precipitation was greater than 0.75 in. days. If we disregard the information of rainy plus wet days reported by the contractor, extra 74 NWDs with P>0.75 in. were determined for this project from the climate data of the closest station as shown in Figure 5-9. There were more heavy rainfall days (P>0.75 in) that the contractor did not report when the contractor did not work due to other reasons.

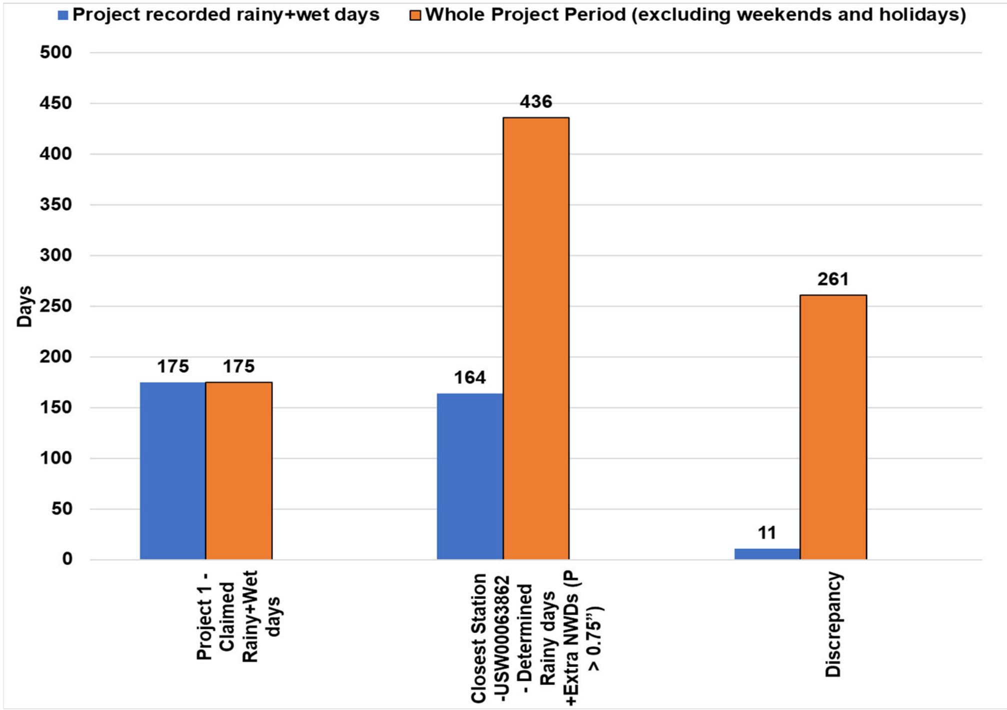



**Figure 5-10. Rainy and wet days as claimed by Project 1, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

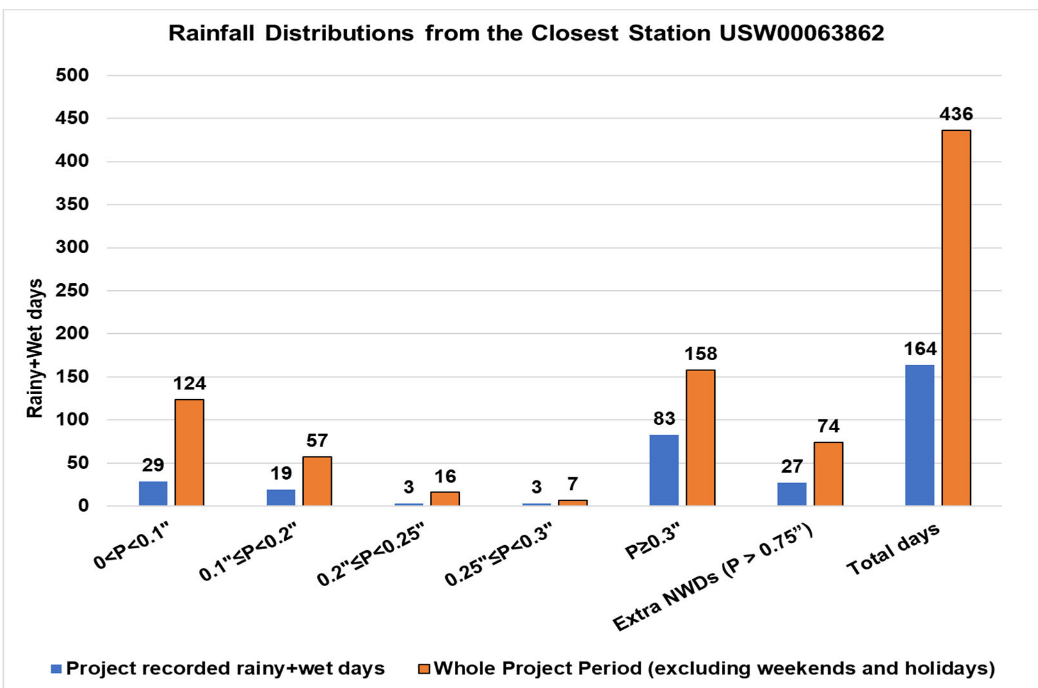



**Figure 5-9. Rainfall distributions of the closest station during the project claimed rainy + wet days and the whole project period (excluding weekends and holidays) + extra NWDs (P>0.75").**

### *Air temperature*

For Project 1, 31 days were reported by the contractor as "Too cold", corresponding to low air temperature that impeded the continuation of the construction activities and claimed as non-workdays thought the project's duration. But, just 21 days were determined as non-workdays due to daily mean air temperature lower than 40°F ($T_{mean}$ on Figure 5-11) from the closest climate station when crossmatched with the days claimed by the contractor, for a difference of 10 days. However, based on the data from the closest station USW00063862 a total of 102 days were determined due to low daily mean air temperatures ($T_{mean}$ <40°F) during the duration of the project, corresponding to a discrepancy of 71 days when compared to the 31 NWDs claimed by the contractors.

The cold days claimed as non-workdays (NWDs) were then classified based on the study criteria for daily mean temperature as shown in Figure 5-12, where for mean air temperatures lower than 40°F but greater than 35°F, a total 9 NWDs where defined based on the project daily records, in comparison to the 59 days determined based on the station climate data. There were many cold days that the contractor did not report when the contractor did not work due to other reasons.

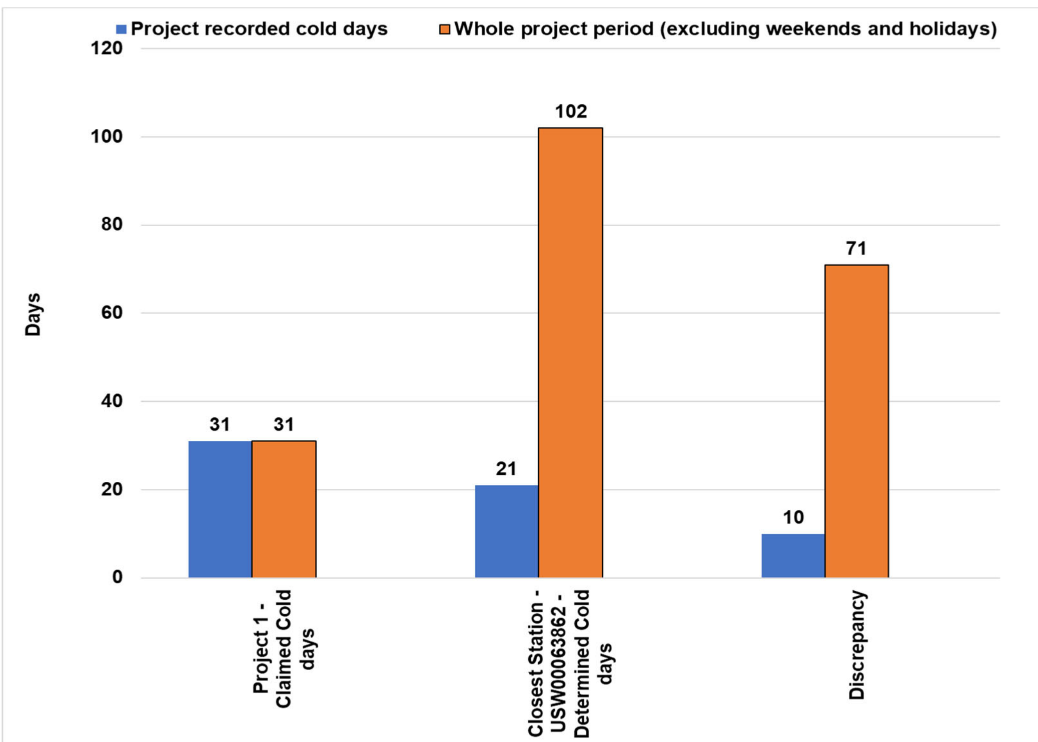



**Figure 5-11. Low temperature (cold) days as claimed by Project 1, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

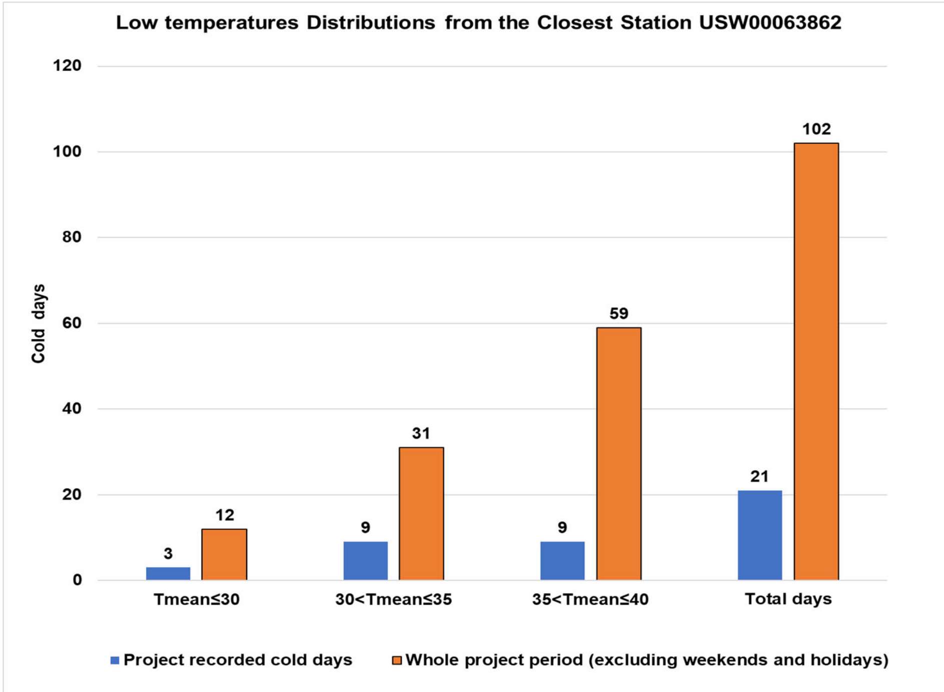



**Figure 5-12. Low temperature distributions of the closest station during the project claimed cold days and the whole project period (excluding weekends and holidays).**

## 5.3 Project 2 (Jefferson County – East Central Region)

Project 2, situated in Jefferson County, Alabama, entailed the planning, resurfacing, guardrail enhancements, and striping work carried out on I-65, spanning from the Mount Olive interchange to a point 0.780 mile north of the SR-160 interchange (Latitude: 33.702775°, Longitude: -86.835836°). This project spanned from March 2019 to September 2020, covering approximately 576 days, which is equivalent to around one year and five months, but the contract time was 230 workdays. The overall project timeline was influenced by various factors, including adverse weather conditions and other non-climate-related elements.

For the verification process, the closest weather station chosen for analysis was Birmingham Airport - USW00013876, with coordinates of (33.56545°, -86.7449°). This station had a weather data record spanning 93 years, from 1930 through 2022. However, for the purpose of comparison and verification, the data from the years 2019 through 2020 were utilized.

A summary of the project information is presented in Table 5-8, while Figure 5-13 depicts the project's location in relation to the nearest weather stations.

**Table 5-8. Jefferson County ALDOT project (Project 2) information.**

| Project 2 | | | |
|---|---|---|---|
| Fed/State Project No. | IM-HSIP-I065(484) | Start Date | 5-Mar-19 |
| Project description | Planning, resurfacing, guardrail improvements, and stripe | End Date | 30-Sep-20 |
| Location | On I-65 from the Mount Olive interchange to 0.780 mile north of the SR-160 interchange 13.399 (33.702775, -86.835836) | Closest Station ID/Name | Birmingham Airport, AL, US - USW00013876 |
| ALDOT Region | East Central | Closest Station Location | 33.56545, -86.7449 |
| Contract time | 230 Days | Climate station data source | Global Historical Climatology Network (GHCN) |

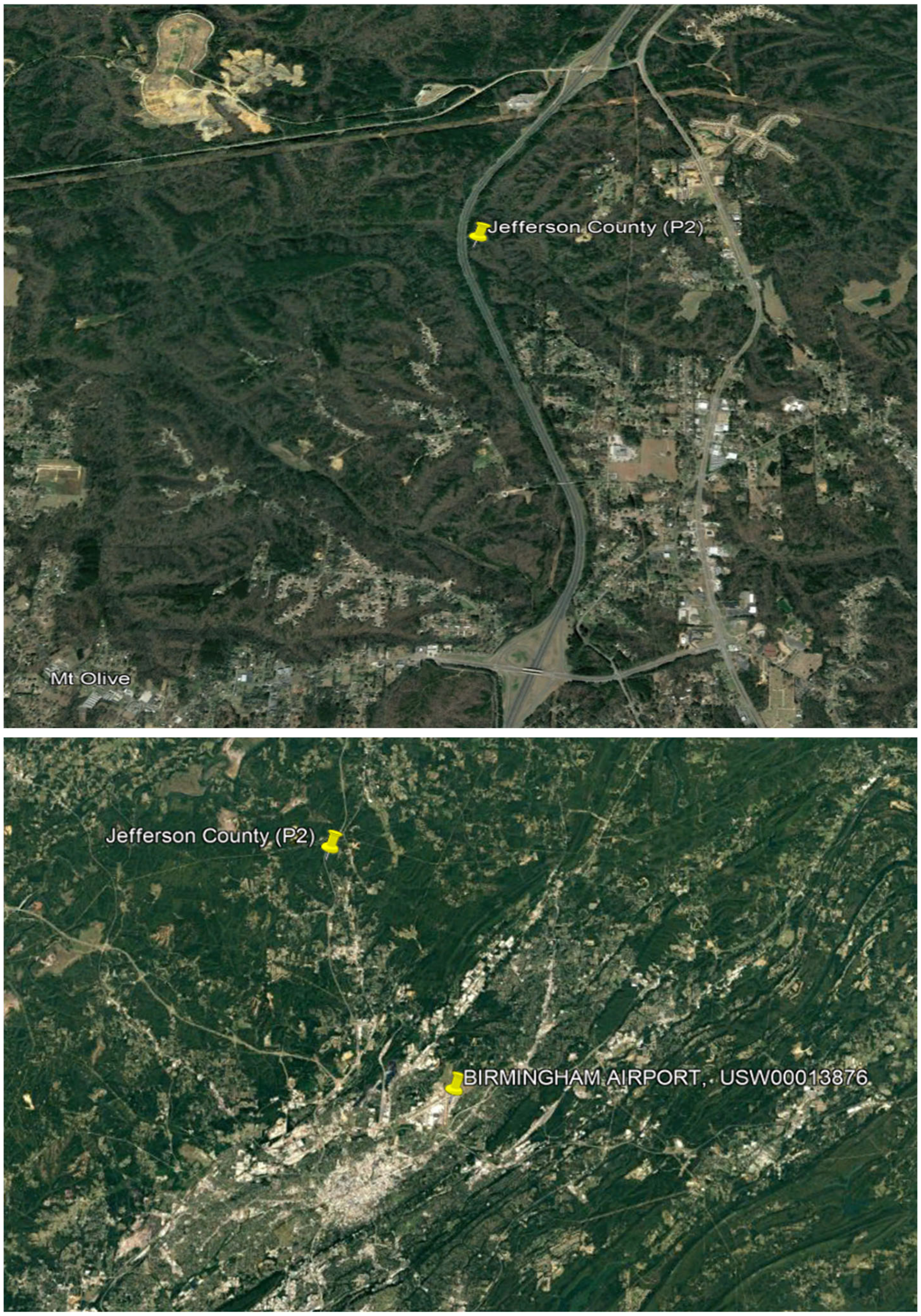



**Figure 5-13. Jefferson County (Project 2) located on I-65 from the Mount Olive interchange to 0.780 mile north of the SR-160 interchange 13.399 (Latitude: 33.702775°, Longitude: -86.835836°) and the nearest weather station used for the verification process.**

### 5.3.1 CLOSEST STATION – BIRMINGHAM AIRPORT - USW00013876 - AAWDS

Table 5-9 presents the computed AAWDs for the Birmingham Airport - USW00013876 station. This station is situated in the East Central Region and has a comprehensive data record spanning 93 years, starting from January 1930 and extending through December 2022. It can be observed that the AAWDs for this station exhibit variations ranging from 10 to 19 days across different months of the year, with the median fluctuating between 10 and 19 days. Key statistical measures, including the standard deviation, which varies from 2 to 3 days, and the 80th percentile of the monthly computed AAWDs, ranging from 13 to 21 days, are also highlighted.

**Table 5-9. Determined AAWDs for Birmingham Airport.**

| Birmingham Airport - USW00013876 - P13 (P>0.2 in. & T<40°F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | N-Years | AAWD | StdDev | Min. | Max. | Median | 80PerT | Skew |
| 1 | 93/93 | 10 | 3 | 1 | 18 | 10 | 13 | -0.2680 |
| 2 | 93/93 | 11 | 3 | 3 | 17 | 12 | 14 | -0.5881 |
| 3 | 93/93 | 16 | 2 | 10 | 22 | 16 | 18 | -0.1323 |
| 4 | 93/93 | 17 | 2 | 12 | 21 | 17 | 19 | -0.4868 |
| 5 | 93/93 | 18 | 2 | 14 | 22 | 18 | 19 | -0.1874 |
| 6 | 93/93 | 17 | 2 | 12 | 21 | 17 | 19 | -0.2384 |
| 7 | 93/93 | 17 | 2 | 11 | 22 | 17 | 19 | -0.1002 |
| 8 | 93/93 | 19 | 2 | 13 | 23 | 19 | 21 | -0.1365 |
| 9 | 92/93 | 18 | 2 | 13 | 21 | 18 | 19 | -0.3728 |
| 10 | 93/93 | 19 | 2 | 15 | 22 | 19 | 20 | -0.1595 |
| 11 | 93/93 | 15 | 2 | 11 | 21 | 15 | 17 | 0.0819 |
| 12 | 93/93 | 12 | 3 | 5 | 19 | 13 | 15 | -0.3331 |

### 5.3.2 PROJECT 2 VS. BIRMINGHAM AIRPORT - USW00013876 - COMPARISON RESULTS

A daily categorization of the records for the Jefferson County Project (P2) was conducted to assess the number of workdays and non-workdays influenced by adverse weather conditions, ultimately impacting the project's duration. A yearly analysis was executed, breaking down various parameters on a month-by-month basis. These results were then compared with data obtained from the Birmingham Airport weather station using a specialized Excel tool, under the adverse weather threshold condition 13 (P>0.2 in. & T <40°F).

The previously determined AAWDs for this station, as outlined in the preceding section, serve as a reference point for evaluating the yearly tally of AWDs and non-workdays throughout the 17 months of the project's duration.

It is worth noting that the monthly durations during the analyzed period were not consistent. Notably, March 2019 deviated from the standard 31-day month, as it was adjusted to 27 days due to the project's commencement on March 5, 2019. For instance, in March 2019 (as shown Table 5-10), the determined Project days/month were 27 days, calculated as 31 days (the typical length of March) minus 5 days (the project's start date). Therefore, all project calculations were based on 27 days. To ensure the accurate analysis and interpretation of subsequent metrics presented in Table 5-10 through Table 5-11, these temporal adjustments are of utmost importance.

Furthermore, the data from the nearest weather station, "USW00013876 - AWDs (P13)" and "USW00013876 - NWDs (P13)," were integrated into the analysis. These metrics encompass AWDs and non-workdays, determined based on the weather condition criteria (P13). Specialized Excel spreadsheets were employed to extract and analyze this data. It's vital to emphasize that the results from the closest station are derived from adjustments made to the month's durations when required. For instance, based on Project 2's daily records, eight non-workdays were determined, considering the adjusted 27-day month linked to the project's start date, while 11 non-workdays were determined from USW00013876 (P13). This disparity is specific to the month of the project's initiation, reflecting the abbreviated month length.

**Table 5-10. Jefferson County (Project 2), 2019 monthly determined parameters for verification process.**

| 2019[6] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | | | 27 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 302 | |
| Project non-workdays (W+H+AW) | | | 8 | 13 | 9 | 11 | 7 | 10 | 7 | 20 | 24 | 31 | 140 | 46% |
| Project weekend & holidays (W+H) | | | 5 | 7 | 6 | 7 | 7 | 9 | 7 | 7 | 10 | 10 | 75 | 25% |
| Project adverse weather (AW) days | | | 3 | 6 | 3 | 4 | 0 | 1 | 0 | 13 | 14 | 21 | 65 | 22% |
| Project available workdays | | | 19 | 17 | 22 | 19 | 24 | 21 | 23 | 11 | 6 | 0 | 162 | 54% |
| Project worked days | | | 19 | 17 | 21 | 19 | 20 | 20 | 23 | 11 | 5 | 0 | 155 | 51% |
| Project non-workdays due to other factors | | | 0 | 0 | 1 | 0 | 4 | 1 | 0 | 0 | 1 | 0 | 7 | 2% |
| USW00013876 - AWDs (P13) | | | 16 | 19 | 20 | 15 | 22 | 19 | 19 | 17 | 15 | 16 | 178 | 59% |
| USW00013876 - NWDs (P13) | | | 11 | 11 | 11 | 15 | 9 | 12 | 11 | 14 | 15 | 15 | 124 | 41% |

[6] Note: W, H, and AW stand for weekends, state holidays, and adverse weather days, respectively. P13 is for adverse weather threshold condition 13: daily rainfall >0.2 in and daily mean temperatures < 40$^{o}$F.

**Table 5-11. Jefferson County (Project 2), 2020 monthly determined parameters for verification process.**

| 2020 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 31 | 29 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | | | | 274 | |
| Project non-workdays (W+H+AW) | 30 | 28 | 22 | 10 | 16 | 11 | 13 | 12 | 11 | | | | 153 | 56% |
| Project weekend & holidays (W+H) | 9 | 9 | 8 | 6 | 11 | 7 | 9 | 10 | 8 | | | | 77 | 28% |
| Project adverse weather (AW) days | 21 | 19 | 14 | 4 | 5 | 4 | 4 | 2 | 3 | | | | 76 | 28% |
| Project available workdays | 1 | 1 | 9 | 20 | 15 | 19 | 18 | 19 | 19 | | | | 121 | 44% |
| Project worked days | 1 | 1 | 9 | 20 | 15 | 19 | 8 | 0 | 0 | | | | 73 | 27% |
| Project non-workdays due to other factors | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 19 | 19 | | | | 48 | 18% |
| USW00013876 - AWDs (P13) | 13 | 10 | 13 | 19 | 17 | 15 | 18 | 13 | 20 | | | | 138 | 50% |
| USW00013876 - NWDs (P13) | 18 | 19 | 18 | 11 | 14 | 15 | 13 | 18 | 10 | | | | 136 | 50% |

Throughout the project's duration, a total of 293 days were identified as non-workdays based on the project's daily records. These non-workdays were attributed to various factors, including adverse weather conditions like rain, extreme cold, or wet conditions, as well as weekends and state holidays. Additionally, there were 228 workdays and 55 days designated as non-workdays due to factors unrelated to the study criteria, such as utility coordination, punch items, and other miscellaneous reasons.

Upon analyzing data from the nearest weather station (USW00013876) using weather condition 13 (P>0.2 in. & T<40°F), it was determined that there were 260 days classified as non-workdays and 316 days as AWDs. A comparison between the results from the weather station and the project's daily records revealed a discrepancy of 33 days for non-workdays (-13%) and of 88 days when compared the AWDs vs. worked days reported by the contractor. However, when combining the project's worked days (228 days) with the project's non-workdays due to other factors (55 days), the total amounted to 283 days, and this compared to the weather station data indicated 316 determined workdays, resulting in a difference of 33 days (+10%). These findings are illustrated in Figure 5-14.

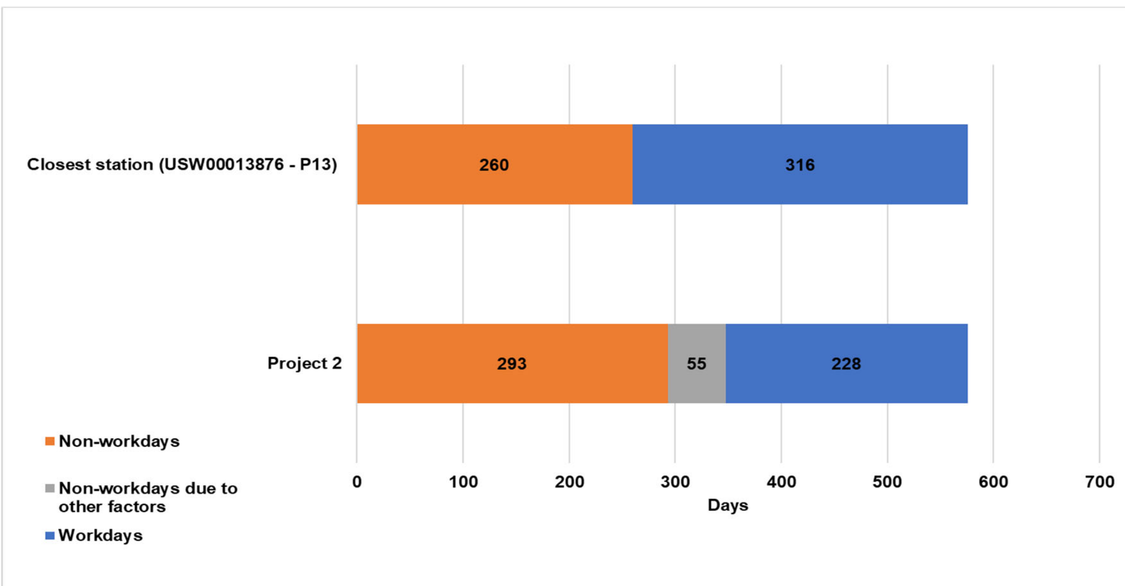



**Figure 5-14. Verification of AWDs and NWDs between Project 2 daily records and from the nearest weather station USW00013876 (P13).**

Figure 5-15 illustrates the recorded worked days and AWDs for Project 2 on a month-by-month basis. It's evident that the determination of AWDs for Project 2 was based on considering all days in each month unaffected by non-workday criteria, which encompassed adverse weather, holidays, and weekends. Therefore, a simplified definition for AWDs in the project context is as follows: AWDs = Project worked days + Project non-workdays due to other factors. To provide an example, in July 2019, there were 20 project worked days, with an additional 4 days designated as project non-workdays due to other factors. The total, 24 days, represents the determined project AWDs for July 2019. This approach assumes that the contractor initially accounted for adverse weather days and subsequently identified other factors that led to non-work on the project.

Similarly, the analysis extends to the determined AWDs for July 2019 obtained from the closest station, Birmingham Airport, utilizing Weather Condition 13 (P > 0.2 in. and T < 40°F). These were determined to be 22 days (referred to as WDayR2T40 in Figure 5-15). When compared to the determined project available workdays, there is a discrepancy of 2 days fewer.

Figure 5-16 presents a similar analysis for non-workdays, both from the Project 2 daily records and the closest station.

An apparent disparity in AWDs is particularly notable during the months of December 2019 through February 2020, where workdays ranged from 0 to 1 day. This was primarily due to the majority of days being categorized as non-workdays attributable to adverse weather conditions, specifically related to low air temperature ("Too Cold"), according to the records. Additionally, as the project approached its completion date from July 2020 through September 2020, the non-workdays due to other factors were associated with "Punch items" and "Waiting on Final Inspection."

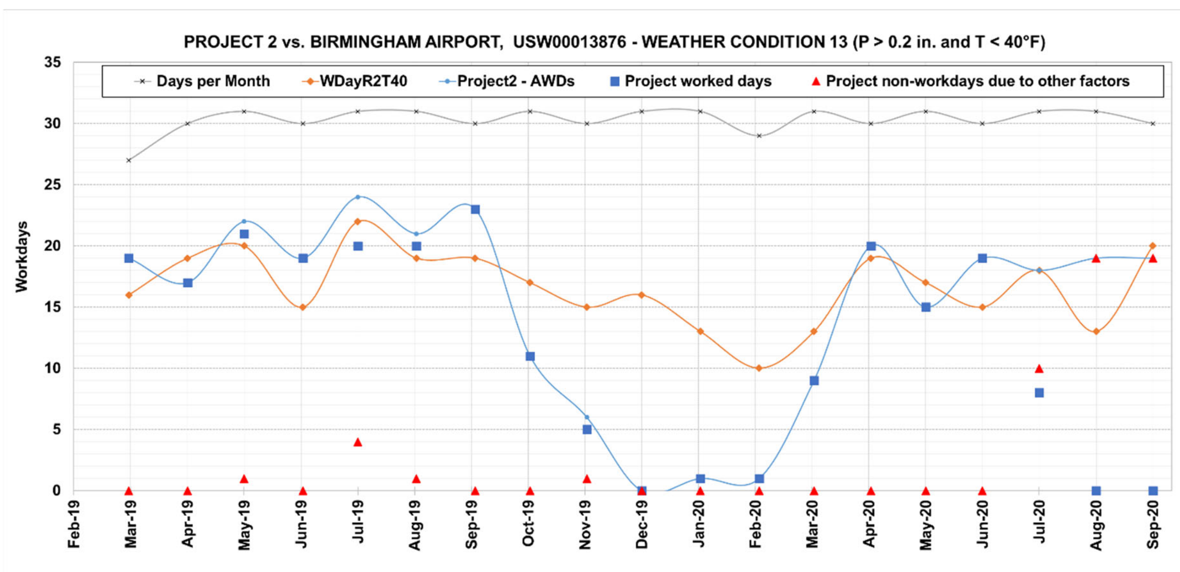



**Figure 5-15. Determined available workdays from Project 2 and Birmingham Airport - USW00013876 weather station including project's worked days and non-workdays due to other factors.**

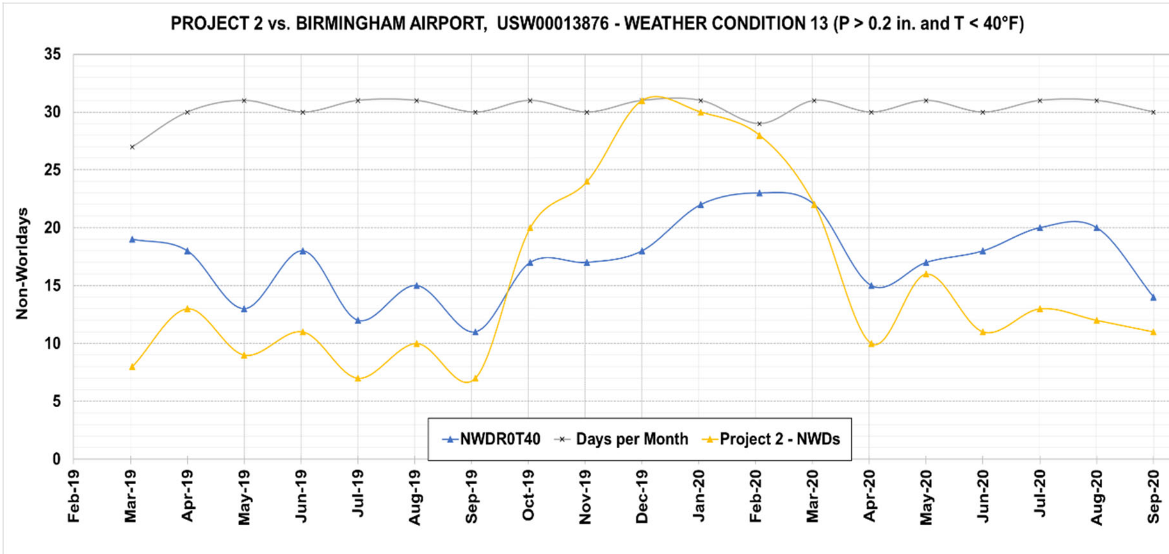



**Figure 5-16. Determined non-workdays for Project 2 and from Birmingham Airport - USW00013876 weather station (NWDR2T40).**

### 5.3.3 Adverse weather verification

#### *Precipitation*

In Figure 5-17 a total of 78 days were documented as non-working days due to rain throughout the project's timeline. However, it's worth noting that the contractor failed to record or report the exact rainfall depths on these days, leaving this data only available from the nearest weather station.

Of the 78 rainy days reported by the contractor, climate data from Birmingham Airport station (Figure 5-17) indicated 69 non-working days due to precipitation. This reveals a discrepancy of 9 days between the contractor's claims and the weather data from station USW00013876, which do not align.

If we exclude the rainy days reported by the contractor, a total of 198 rainy days (excluding weekends and holidays) were determined from the data processed from USW00013876 weather station, utilizing the developed Excel tool. Among these, there were 129 rainy days, occurring after the initial 69 days that matched the project's daily records, that were not categorized as non-working days in the project's daily records. Essentially, when the contractor abstained from work for other reasons, such as utility conflicts or punch list items, no information was provided to distinguish between a rainy day or a cold day.

In summary, a discrepancy of 120 days arose when comparing the 78 days claimed by the contractor for this project against the 198 days determined from the closest weather station's data for the project's entire duration.

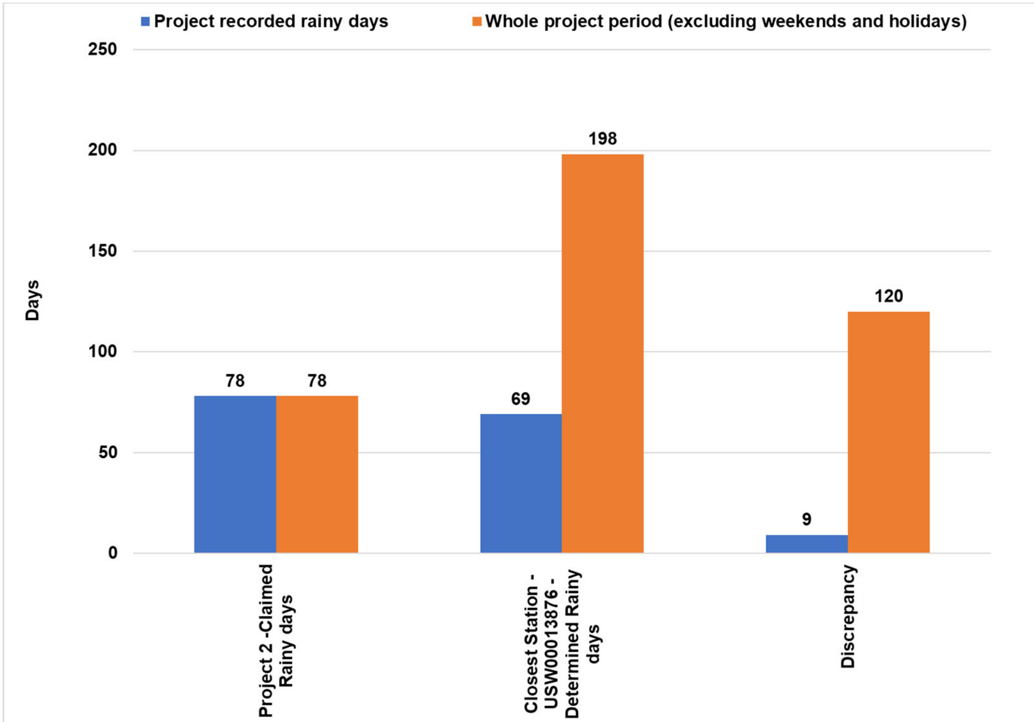



**Figure 5-17. Rainy days as claimed by Project 2, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

Figure 5-18 depicts the daily rainfall distribution based on the study's weather conditions. There are 49 days (2+7+40) with rainfall greater than 0.2 in. for the 78 rainy days reported by the contractor, but a total of 106 (9+13+84) days based on all USW00063862 rainfall data. The large difference was due to the contractor failing to report on many rainy days and failing to work for other reasons.

The contractor has categorized 15 days as wet days in their records. Consequently, a total of 93 non-working days (as shown in Figure 5-20) have been documented in this project due to various factors such as rain and wet conditions. From the climate data collected from station USW00013876, it was determined that there were a total of 76 rainy days. In addition, 18 days were included as non-working days when precipitation exceeded 0.75 in., assuming that the following day would be too wet for the contractor to work. Therefore, the total number of non-working days amounted to 94, resulting in a discrepancy of 1 day.

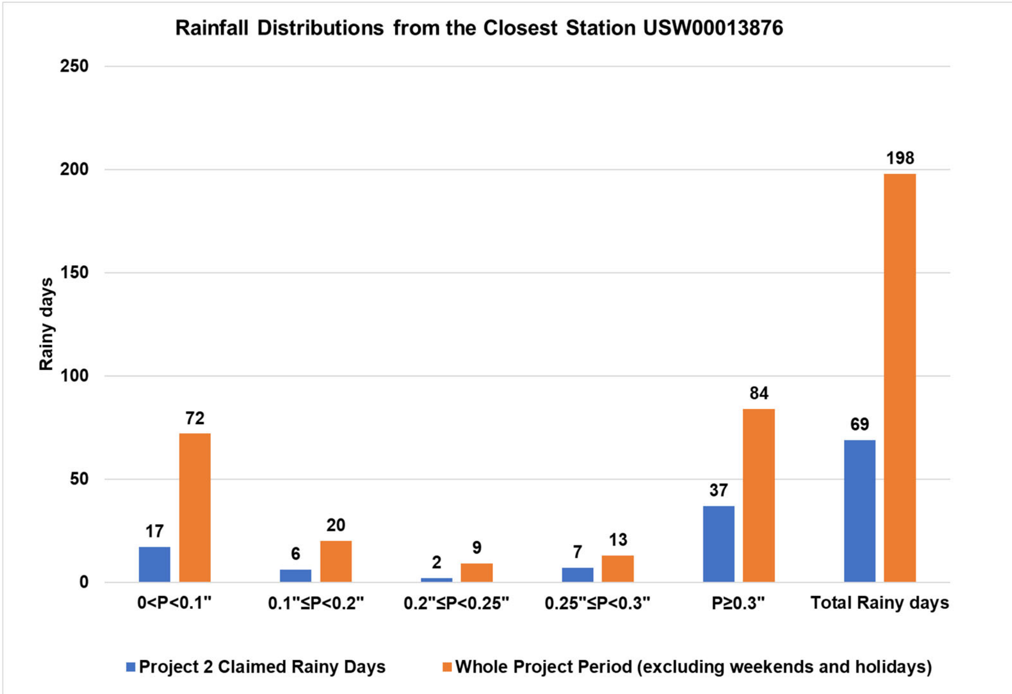



**Figure 5-18. Rainfall distributions of the closest station during the project claimed rainy days and the whole project period (excluding weekends and holidays).**

If we exclude the information regarding rainy and wet days reported by the contractor when determining rainy days and additional days with precipitation exceeding 0.75 in. using data from the closest weather stations, we find that 49 days were added due to precipitation greater than 0.75 in. Consequently, a total of 247 non-working days (198 from the weather station data plus 49) were identified. This stands in stark contrast to the 93 days claimed by the contractor, resulting in a discrepancy of 154 days, as illustrated in Figure 5-20.

Figure 5-19 depicts the daily distribution of rainfall and the disparities observed when considering or disregarding the project's records of rainy and wet days. It is evident that for precipitation greater than 0.2 in., 49 days (comprising 2, 7, and 40 days) were identified from the project's daily records, compared to 109 days (consisting of 9, 13, and 84 days) determined from the data of weather station USW00013876. Over the project's duration and based on the nearest weather station's data, a total of 49 non-working days were added due to recorded precipitation exceeding 0.75 in. However, when we exclude the contractor's reports of rainy and wet days, an additional 49 non-working days with precipitation greater than 0.75 in. were determined from the weather station's climate data (Figure 5-19). This discrepancy indicates that there were more heavy rainfall days (P>0.75 in.) when the contractor did not work due to other reasons, which were not reported by the contractor.

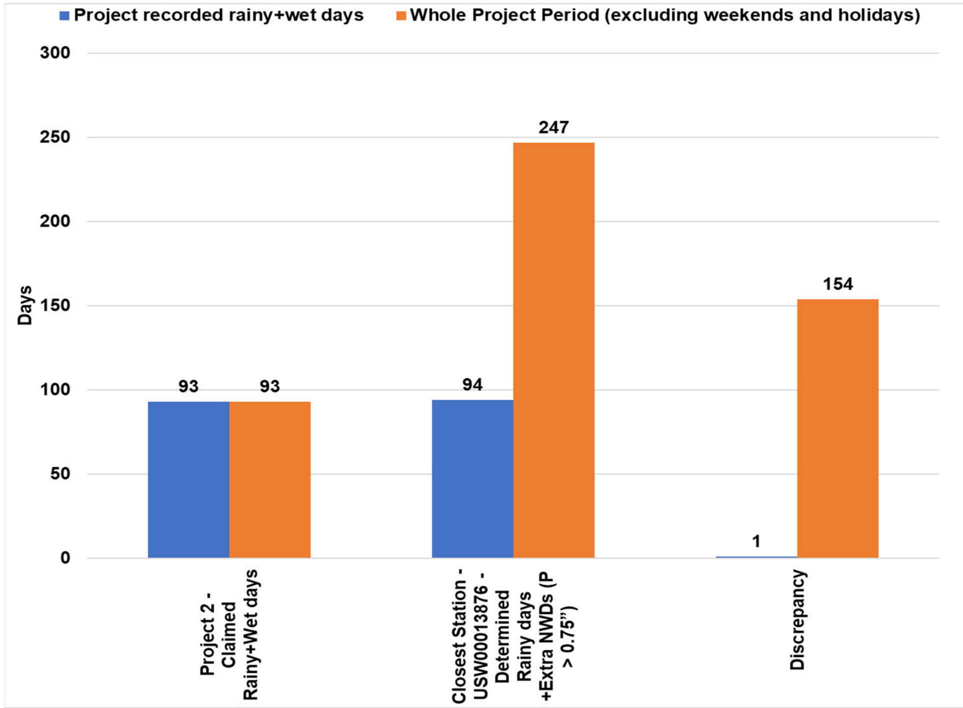



**Figure 5-20. Rainy and wet days as claimed by Project 2, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

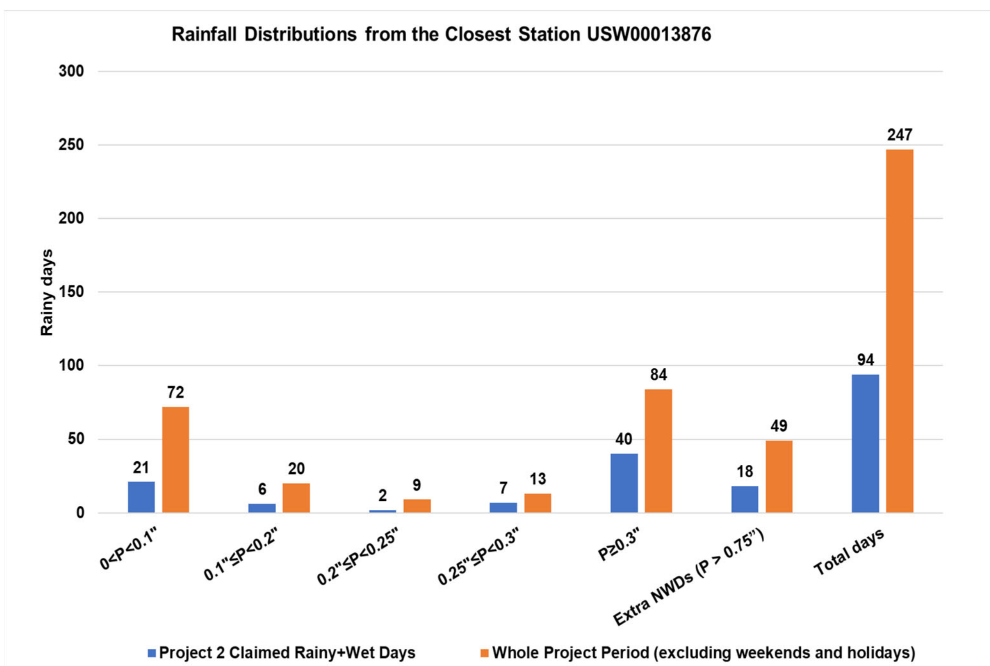



**Figure 5-19. Rainfall distributions of the closest station during the project claimed rainy + wet days and the whole project period (excluding weekends and holidays) + extra NWDs (P>0.75").**

### *Air temperature*

In Project 2, the contractor recorded 44 days as "Too cold," indicating that construction activities were hindered by low air temperatures, and these days were classified as non-workdays throughout the project's duration. However, when these contractor-reported days were compared to data from the nearest climate station, only 7 days were identified as non-workdays due to a daily mean air temperature lower than 40°F (referred to as $T_{mean}$ in Figure 5-21). This resulted in a significant difference of +37 days.

Nonetheless, when considering data from the closest station, USW00063862, a total of 9 days were determined to have low daily mean air temperatures ($T_{mean}$ <40°F) during the project's duration. This discrepancy of 35 days, compared to the 44 non-workdays claimed by the contractors, may arise from the contractor's use of the minimum or lowest air temperature of the day as opposed to the mean temperature (which is the average of the minimum and maximum daily temperature) as utilized in the study.

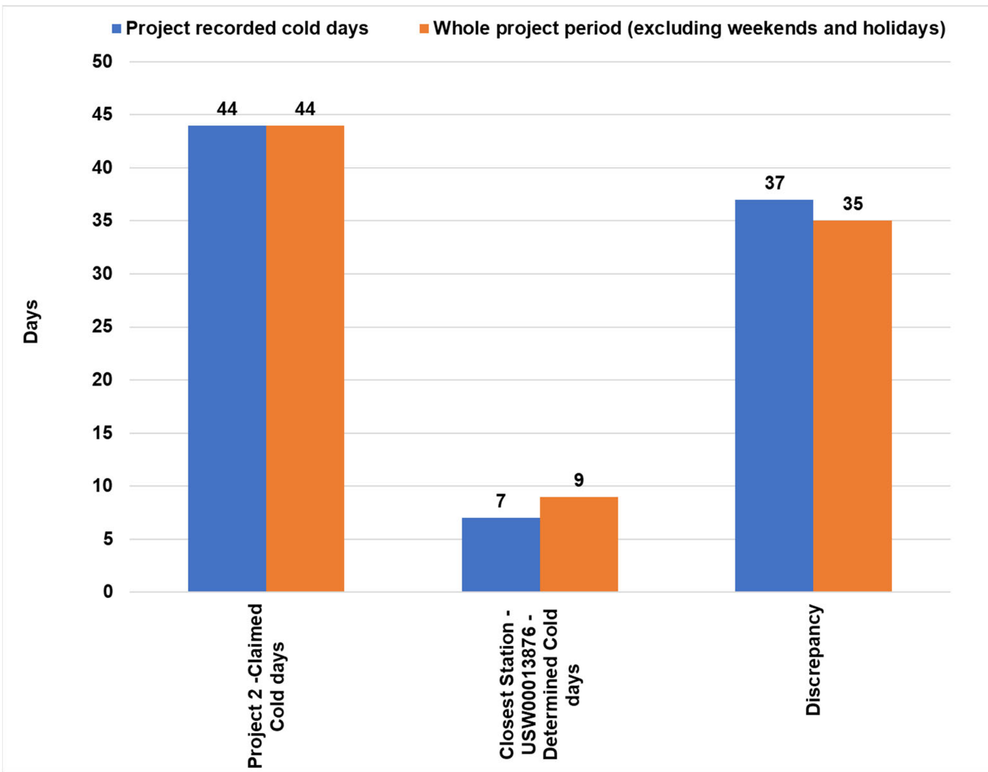



**Figure 5-21. Low temperature (cold) days as claimed by Project 2, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

The cold days claimed as non-workdays NWDs were subsequently categorized according to the study's criteria for daily mean temperature, as illustrated in Figure 5-22. In cases where the mean air temperature fell below 40°F but remained above 35°F, a total of 4 NWDs were identified based on the project's daily records. This contrasted with the six days determined using climate data from the station. However, no non-workdays were found due to daily mean temperatures below 30°F based on the station's records.

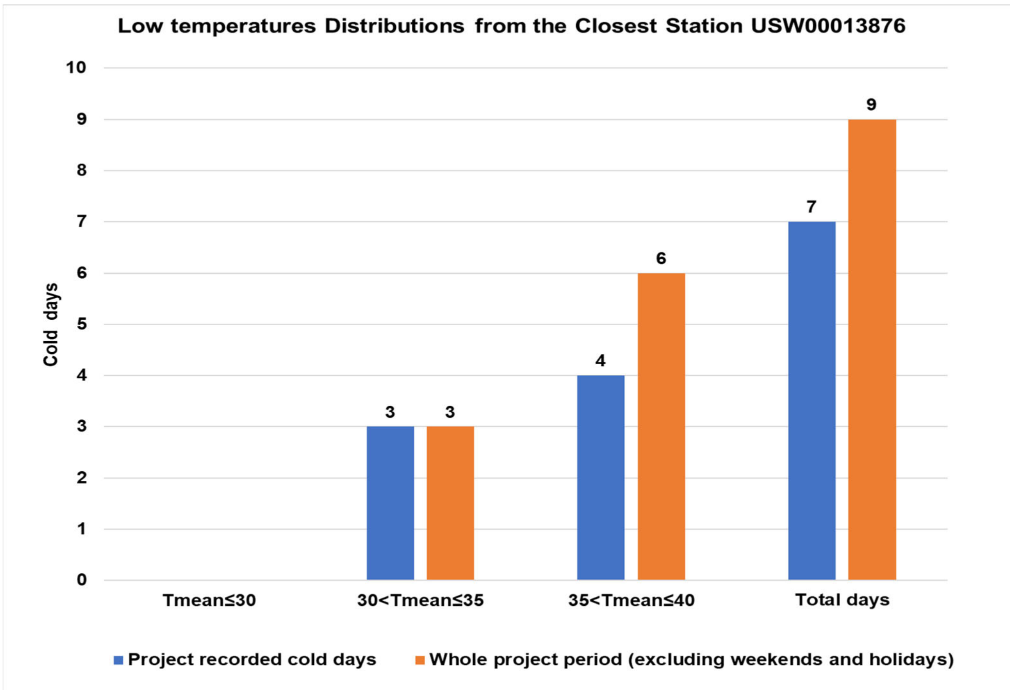



**Figure 5-22. Low temperature distributions of the closest station during the project claimed cold days and the whole project period (excluding weekends and holidays).**

## 5.4 PROJECT 3 (MARION COUNTY – WEST CENTRAL REGION)

Project 3, which was located in Marion County, Alabama, involved a range of activities such as planning, widening, resurfacing, installing guardrails, and stripping on I-22. The project extended from the SR-233 overpass at MP 34.460 to the Walker County line at 3.999 (Latitude: 33.959383°, Longitude: -87.66118°). It spanned from October 15th, 2020, to August 31, 2021, covering approximately 321 days, equivalent to roughly eight and a half months, but the contract time was 85 workdays. The project's overall timeline was influenced by various factors, including adverse weather conditions and non-climate-related factors.

To carry out the verification process, we selected the nearest weather station for analysis, which was Winfield 2 SW, AL US - USC00018998, situated at coordinates (33.9107°, -87.8469°). This weather station had a comprehensive weather data record spanning 98 years, from 1924 through 2022. However, for the sake of comparison and verification, we focused on data from the years 2020 through 2021.

Table 5-12 provides a summary of the project details, and Figure 5-23 offers a visual representation of the project's location in relation to the closest weather station.

**Table 5-12. Marion County ALDOT project (Project 3) information.**

| Project 3 | | | |
|---|---|---|---|
| Fed/State Project No. | IM-I022(312) | Start Date | 15-Oct-20 |
| Project description | Planning, widening, resurfacing, guardrail, and stripe | End Date | 31-Aug-21 |
| Location | On I-22 from the SR-233 overpass (MP 34.460) to the Walker County line 3.999 (33.959383, -87.66118) | Closest Station ID/Name | WINFIELD 2 SW, AL US - USC00018998 |
| ALDOT Region | West Central | Closest Station Location | 33.9107, -87.8469 |
| Contract time | 85 Days | Climate station data source | Global Historical Climatology Network (GHCN) |


**Figure 5-23. Marion County (Project 3) located on I-22 from the SR-233 overpass (MP 34.460) to the Walker County line 3.999 (Latitude: 33.959383°, Longitude: -87.66118°) and the nearest weather station used for the verification process.**

### 5.4.1 CLOSEST STATION – WINFIELD 2 SW, AL US - USC00018998 - AAWDS

Table 5-13 displays the calculated AAWDs for the weather station identified as " Winfield 2 SW, AL US - USC00018998”. This station is located in the West Central Region and boasts a comprehensive data record spanning an impressive 98 years, commencing from January 1924 and extending through December 2022.

As demonstrated in Table 5-13, the AAWDs for this station exhibit fluctuations, varying from 12 to 19 days across different months of the year. The median AAWD, on the other hand, ranges between 12 and 19 days. The table also highlights key statistical measures, including the standard deviation, which varies from 2 to 6 days, corresponding the largest to the cold months, December and January and the 80th percentiles of the monthly computed AAWDs, which range from 16 to 21 days.

**Table 5-13. Determined AAWDs and attributes for the Winfield 2 SW, AL US.**

| Winfield 2 SW, AL US- USC00018998 - P13 (P>0.2 in. & T<40 °F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | N-Years | AAWDs | StdDev | Min. | Max. | Median | 80PerT | Skew |
| 1 | 85/91 | 12 | 6 | 0 | 20 | 13 | 17 | -0.310 |
| 2 | 83/91 | 12 | 4 | 2 | 18 | 12 | 16 | -0.324 |
| 3 | 85/91 | 16 | 3 | 10 | 21 | 16 | 18 | -0.464 |
| 4 | 87/91 | 17 | 2 | 11 | 20 | 17 | 19 | -0.351 |
| 5 | 87/91 | 18 | 2 | 13 | 22 | 18 | 19 | -0.447 |
| 6 | 89/91 | 17 | 2 | 11 | 21 | 17 | 19 | -0.342 |
| 7 | 87/91 | 17 | 2 | 10 | 22 | 17 | 19 | -0.332 |
| 8 | 84/91 | 19 | 2 | 15 | 23 | 19 | 21 | -0.133 |
| 9 | 87/91 | 18 | 2 | 13 | 21 | 18 | 19 | -0.580 |
| 10 | 84/91 | 19 | 2 | 11 | 22 | 19 | 20 | -1.105 |
| 11 | 88/91 | 15 | 3 | 7 | 20 | 16 | 17 | -0.682 |
| 12 | 86/91 | 13 | 5 | 2 | 21 | 13 | 17 | -0.173 |

#### 5.4.2 PROJECT 3 VS. WINFIELD 2 SW, AL US - USC00018998 - COMPARISON RESULTS

A detailed daily assessment of the records for Marion County Project (P3) was conducted to analyze the impact of adverse weather conditions on the number of workdays and non-workdays, ultimately affecting the project's timeline. Under the project duration from October 15, 2020, to August 31, 2021, a yearly analysis was performed, breaking down various parameters on a month-to-month basis. These results were then compared to data obtained from the Winfield 2 SW, AL US-USC00018998 weather station using a developed Excel tool, utilizing the adverse weather threshold condition 13 (P>0.2 in. & T <40 °F).

The AAWDs previously determined for this station, as detailed in the previous section, served as a reference for assessing the yearly count of AWDs and non-workdays over the 321-day project duration. This comparison enhances our understanding of how individual weather events, such as hurricanes and storms, can impact construction activities and subsequently influence project timelines.

It's important to note that the monthly durations during the analyzed period were not consistent. Specifically, October 2020 differed from the standard 31-day month because it was adjusted to 17 days to accommodate the project's commencement on October 15, 2020. For instance, in October 2020 (as indicated in Table 5-14), the calculated Project days/month were 17 days, derived from subtracting 14 days (the time prior to the project's start date) from the typical 31-day month of March. Therefore, all project calculations for this month were based on a 17-day timeframe. These temporal adjustments are crucial to ensure accurate analysis and interpretation of the subsequent metrics presented in Table 5-14 and Table 5-15.

Moreover, data from the nearest weather station, "USC00018998 - AWDs (P13)" and "USC00018998 - NWDs (P13)," were integrated into the analysis. These metrics encompass AWDs and non-workdays, determined based on the adverse weather threshold condition 13 (P > 0.2 in. & $T_{mean}$ < 40 °F). The study's developed Excel spreadsheets were used to extract and analyze this data. It's essential to emphasize that the results from the closest station are based on adjustments made to the month's durations, when necessary, as in the case of October 2020. For example, according to Project 3's daily records, 7 non-workdays and 10 worked days were determined, considering the adjusted 17-day month linked to the project's start date. In contrast, 7 non-workdays and 10 AWDs were determined from USC00017157 (P13) for October 2020. This difference is specific to the month of the project's initiation and reflects the shortened month length.

**Table 5-14. Marion County (Project 3), 2020 monthly determined parameters for verification process.**

| 2020[7] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | | | | | | | | | | 17 | 30 | 31 | 78 | |
| Project non-workdays (W+H+AW) | | | | | | | | | | 7 | 12 | 28 | 47 | 60% |
| Project weekend & holidays (W+H) | | | | | | | | | | 5 | 10 | 9 | 24 | 31% |
| Project adverse weather (AW) days | | | | | | | | | | 2 | 2 | 19 | 23 | 29% |
| Project available workdays | | | | | | | | | | 10 | 18 | 3 | 31 | 40% |
| Project worked days | | | | | | | | | | 9 | 16 | 3 | 28 | 36% |
| Project non-workdays due to other factors | | | | | | | | | | 1 | 2 | 0 | 3 | 4% |
| USC00018998 - AWDs (P13) | | | | | | | | | | 10 | 18 | 12 | 40 | 51% |
| USC00018998 - NWDs (P13) | | | | | | | | | | 7 | 12 | 19 | 38 | 49% |

[7] Note: W, H, and AW stand for weekends, state holidays, and adverse weather days, respectively. P13 is for adverse weather threshold condition 13: daily rainfall >0.2 in and daily mean temperatures < 40°F.

**Table 5-15. Marion County (Project 3), 2021 monthly determined parameters for verification process.**

| 2021 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | | | | | 243 | |
| Project non-workdays (W+H+AW) | 22 | 18 | 12 | 9 | 13 | 10 | 10 | 9 | | | | | 103 | 42% |
| Project weekend & holidays (W+H) | 10 | 9 | 4 | 9 | 8 | 10 | 10 | 9 | | | | | 69 | 28% |
| Project adverse weather (AW) days | 12 | 9 | 8 | 0 | 5 | 0 | 0 | 0 | | | | | 34 | 14% |
| Project available workdays | 9 | 10 | 19 | 21 | 18 | 20 | 21 | 22 | | | | | 140 | 58% |
| Project worked days | 8 | 8 | 19 | 4 | 12 | 0 | 3 | 2 | | | | | 56 | 23% |
| Project non-workdays due to other factors | 1 | 2 | 0 | 17 | 6 | 20 | 18 | 20 | | | | | 84 | 35% |
| USC00018998 - AWDs (P13) | 12 | 8 | 15 | 19 | 15 | 13 | 14 | 17 | | | | | 113 | 47% |
| USC00018998 - NWDs (P13) | 19 | 20 | 16 | 11 | 16 | 17 | 17 | 14 | | | | | 130 | 53% |

Throughout the project's duration, a total of 150 days were recorded as non-workdays based on the project's daily records. These non-workdays were categorized according to predefined criteria, including adverse weather conditions, weekends, and state holidays. Additionally, there were 84 workdays, while 87 days were designated as non-workdays due to reasons unrelated to the study criteria, such as utility coordination, punch items, and other factors not related to the weather.

Upon analyzing data from the nearest weather station (USC00018998) using the adverse weather threshold condition 13 (P > 0.2 in. & T < 40°F), it was determined that there were 168 days classified as non-workdays and 153 days as AWDs. A comparison between the results from the weather station and the project's daily records revealed a discrepancy of 18 days for non-workdays (representing an 10.7% difference) and a difference of 69 days when comparing the project's worked days to the determined AWDs (+45%). However, when combining the project's workdays (84 days) with the project's non-workdays due to other factors (87 days), the total amounted to 171 days, resulting in a difference of 19 days (-13%) compared to the AWDs. These findings are visually depicted in Figure 5-24.

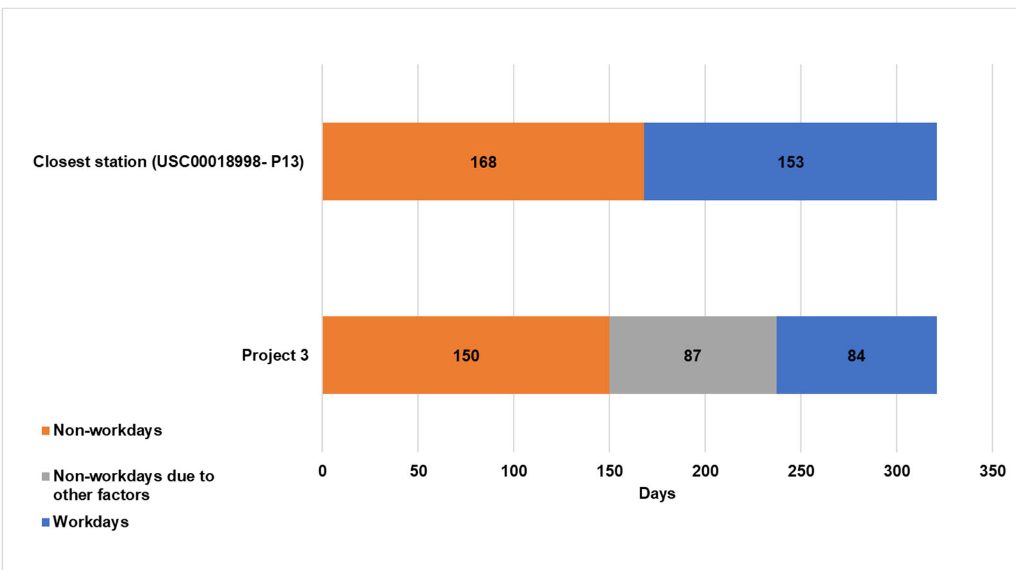



**Figure 5-24. Verification of AWDs and NWDs between Project 3 daily records and from the nearest weather station USC00018998 (P13).**

Figure 5-25 provides a visual representation of the recorded worked days and AWDs for Project 3, presented on a month-by-month basis. It's clear that the calculation of AWDs for Project 3 was based on considering all days in each month that were unaffected by non-workday criteria, including adverse weather, holidays, and weekends. Therefore, a simplified definition for AWDs within the project context can be expressed as follows: AWDs = Project worked days + Project non-workdays due to other factors. To illustrate, in April 2021, there were 4 project worked days, and an additional 17 days were designated as project non-workdays due to other factors. The total, 21 days, represents the determined project AWDs for April 2021. This methodology assumes that the contractor initially accounted for adverse weather days and subsequently identified other factors that resulted in non-workdays on the project.

Similarly, the analysis extends to the determined AWDs for April 2021 obtained from the nearest station, the Winfield 2 SW station, using Weather Condition 13 (P > 0.2 in. and T < 40°F). According to this analysis, there were 19 days classified as AWDs (referred to as WDayR2T40 in Figure 5-25). When compared to the determined project available workdays, there is a discrepancy of 2 days fewer.

Figure 5-26 presents a parallel analysis for non-workdays, considering data from both Project 3's daily records and the closest weather station.

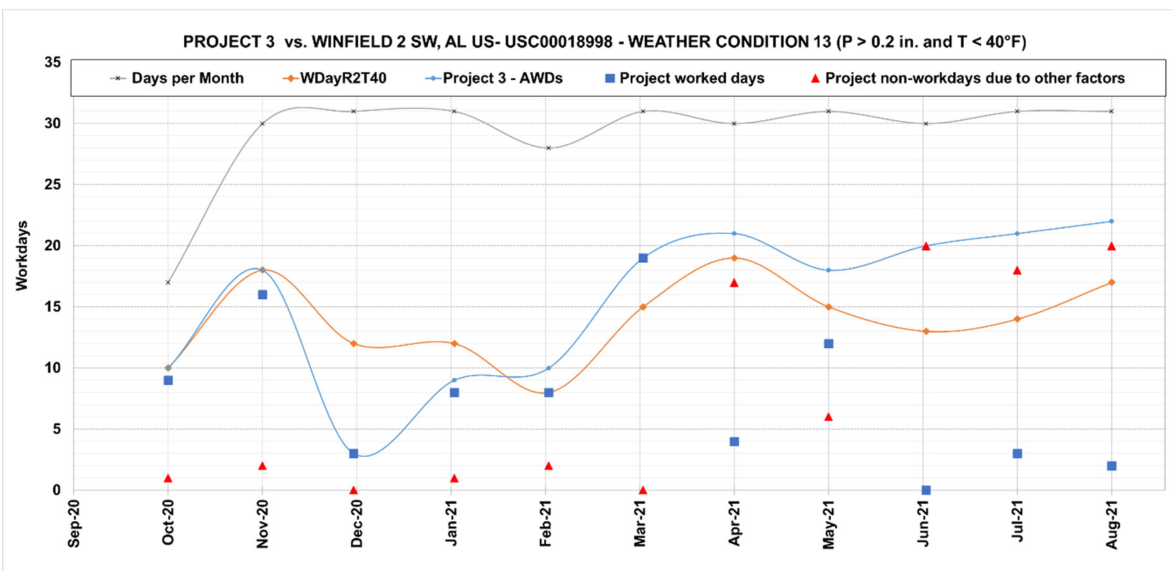



**Figure 5-25. Determined available workdays from Project 3 and Winfield 2 SW - USC00018998 weather station including project's worked days and non-workdays due to other factors.**

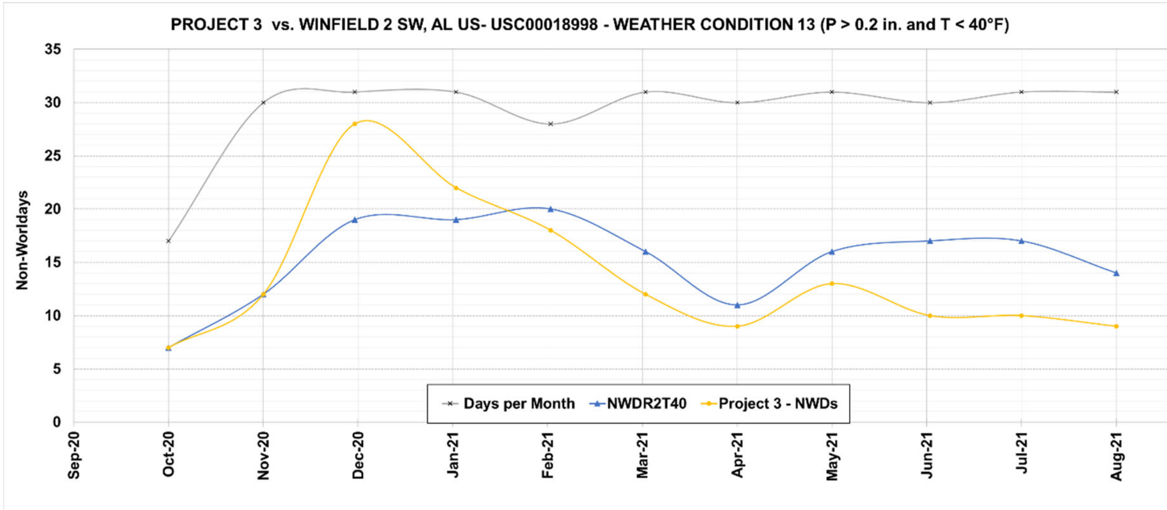



**Figure 5-26. Determined non-workdays for Project 3 and Winfield 2 SW - USC00018998weather station (NWDR2T40).**

### 5.4.3 Adverse weather verification

***Precipitation***

Figure 5-27 reveals that a total of 29 days were recorded as non-working days due to rain throughout the project's duration by the contractor. However, it's essential to note that the contractor did not document or report the specific rainfall depths on these days, leaving this information solely available from the nearest weather station for the verification process.

Out of the 29 rainy days reported by the contractor, climate data from USC00018998 (as depicted in Figure 5-27) indicated 24 non-working days due to precipitation. This indicates a discrepancy of 5 days between the contractor's claims and the weather data from the closest station.

If we exclude the rainy days reported by the contractor, a total of 105 rainy days (excluding weekends and holidays) were determined from the data processed from USC00018998 weather station, utilizing the developed Excel tool. Among these, there were 81 rainy days, occurring after the initial 24 days that matched the project's daily records, which were not categorized as non-working days in the project's daily records. Essentially, when the contractor refrained from work for other reasons, such as utility conflicts or punch list items, no information was provided to distinguish between a rainy day and a cold day.

In summary, a discrepancy of 76 days arose when comparing the 29 days claimed by the contractor for this project against the 105 days determined from the closest weather station's data for the project's entire duration.

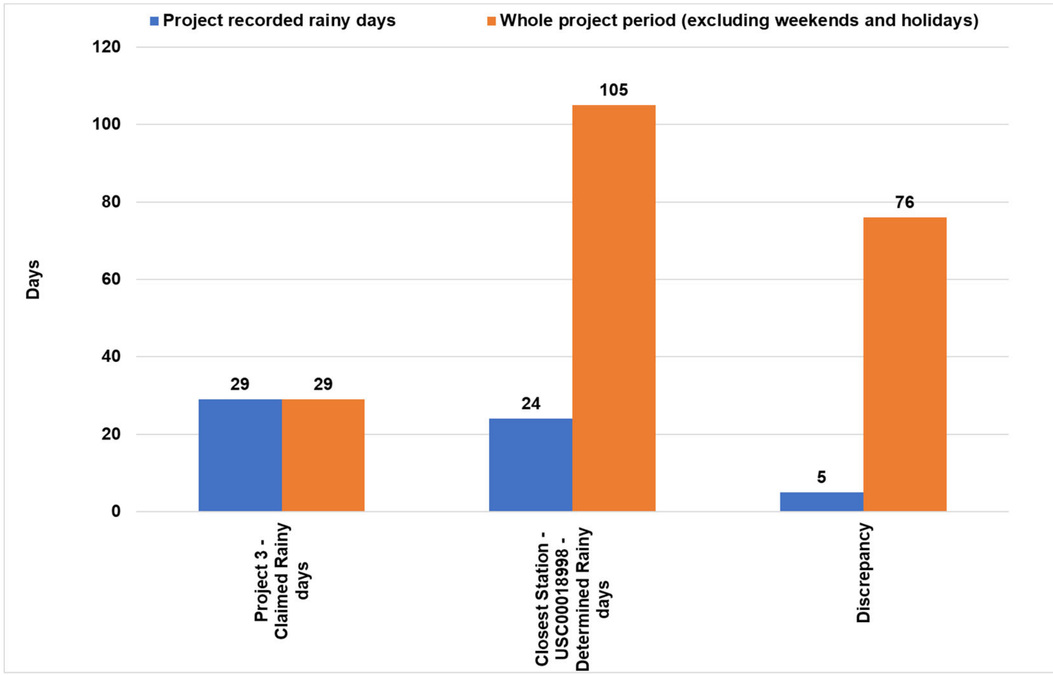



**Figure 5-27. Rainy days as claimed by Project 3, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

The daily rainfall distribution based on the study's weather conditions is depicted in Figure 5-29. For the 24 rainy days reported by the contractor, there are 17 days (1+2+14) with rainfall greater than 0.2 in., but a total of 68 (4+4+60) days based on all USC00018998 rainfall data. The large disparity was caused by the contractor's failure to report on numerous rainy days and failure to work for other reasons.

The contractor has only classified one day as a wet day in their records. As a result, a total of 30 non-working days (as displayed in Figure 5-28) have been documented in this project due to various factors such as rain and wet conditions. Based on the climate data collected from station USC00018998, it was determined that there were 25 NWDs. This calculation involved adding 24 rainy days to 1 days with precipitation greater than 0.75 in. during the period claimed by the contractor that were affected by either rain or wet conditions, resulting in a discrepancy of 5 days.

Excluding the information regarding rainy and wet days reported by the contractor when determining rainy days and additional days with precipitation exceeding 0.75 in. using data from the closest weather stations, we find that 33 days were added due to precipitation greater than 0.75 in. Consequently, a total of 138 non-working days (105 rain days + 33 extra days due to P>0.75 in.) were identified from the weather station data. This starkly contrasts with the 30 days claimed by the contractor, resulting in a discrepancy of 108 days, as illustrated in Figure 5-28.

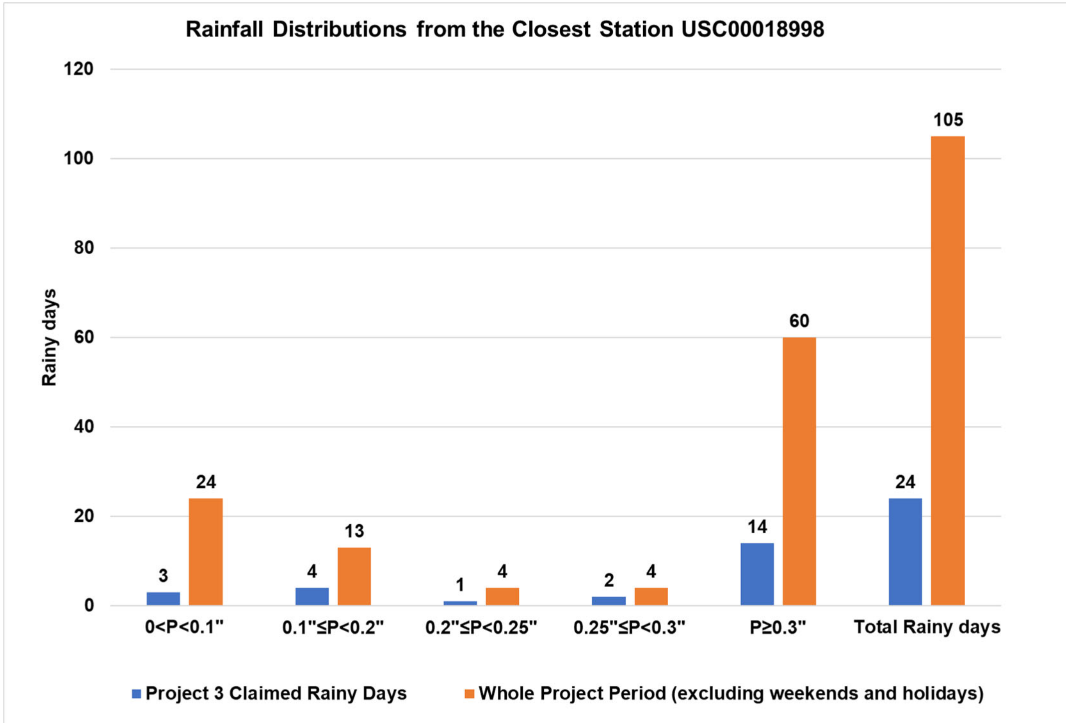



**Figure 5-29. Rainfall distributions of the closest station during the project claimed rainy days and the whole project period (excluding weekends and holidays).**

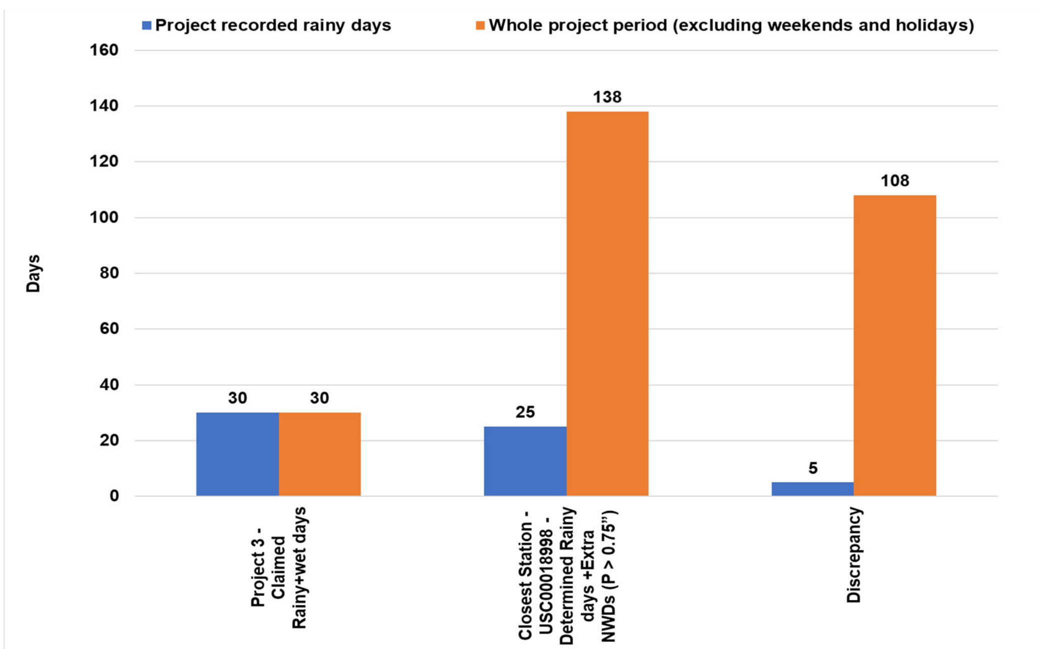



**Figure 5-28. Rainy and wet days as claimed by Project 3, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

Figure 5-30 illustrates the daily distribution of rainfall and the disparities observed when considering or disregarding the project's records of rainy and wet days. It is evident that for precipitation greater than 0.2 in., 19 days (comprising 1, 2, and 16 days) were identified from the project's daily records, compared to 67 days (consisting of 7, 5, and 55 days) determined from the weather station USC00018998 data. Over the project's duration and based on the nearest weather station's data, a total of 5 non-working days were added due to recorded precipitation exceeding 0.75 in. based on the claimed days by the contractor. However, when we exclude the contractor's reports of rainy and wet days, an additional 33 non-working days with precipitation greater than 0.75 in. were determined from the weather station's climate data, as depict in Figure 5-30. This discrepancy indicates that there were more heavy rainfall days (P>0.75 in.) when the contractor did not work due to other reasons, which were not reported by the contractor.

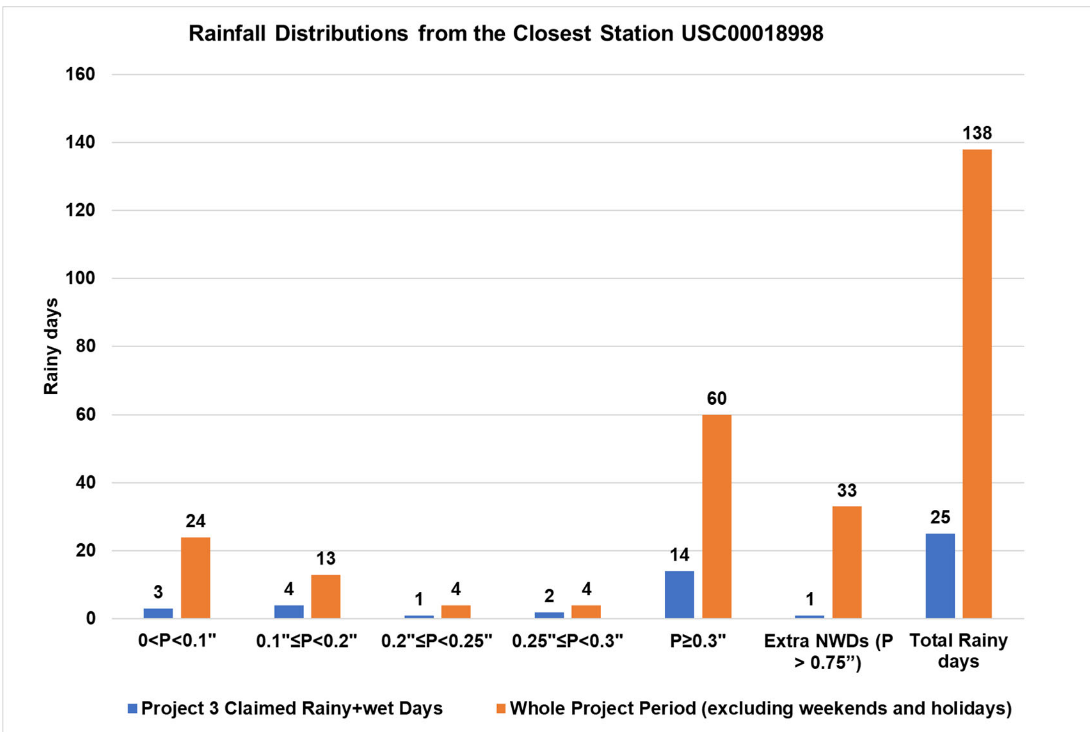



**Figure 5-30. Rainfall distributions of the closest station during the project claimed rainy + wet days and the whole project period (excluding weekends and holidays) + extra NWDs (P>0.75 in.).**

### *Air temperature*

In Project 3, the contractor documented 27 days as "Too cold," indicating that construction activities were impeded by low air temperatures, and these days were marked as non-workdays throughout the project's timeline. However, upon comparing these contractor-reported days with data from the nearest climate station, only 9 days were confirmed as non-workdays due to a daily mean air temperature lower than 40°F (referred to as $T_{mean}$ in Figure 5-31). This resulted in a significant disparity of 18 days.

Nevertheless, when considering data from the closest station, USC00018998, a total of 32 days were identified as having low daily mean air temperatures ($T_{mean}$ < 40°F) during the project's duration, representing a discrepancy of 5 days when compared to the contractor's reported "Too cold" days.

The cold days claimed as non-workdays NWDs were then classified using the study's criteria for daily mean temperature, as shown in Figure 5-32. Based on the project's daily records, a total of 5 NWDs were identified when the mean air temperature fell below 40°F but remained above 35°F. This contrasts with the 18 days determined using the station's climate data for the same temperature conditions range ($35<T_{mean}\leqslant 40$).

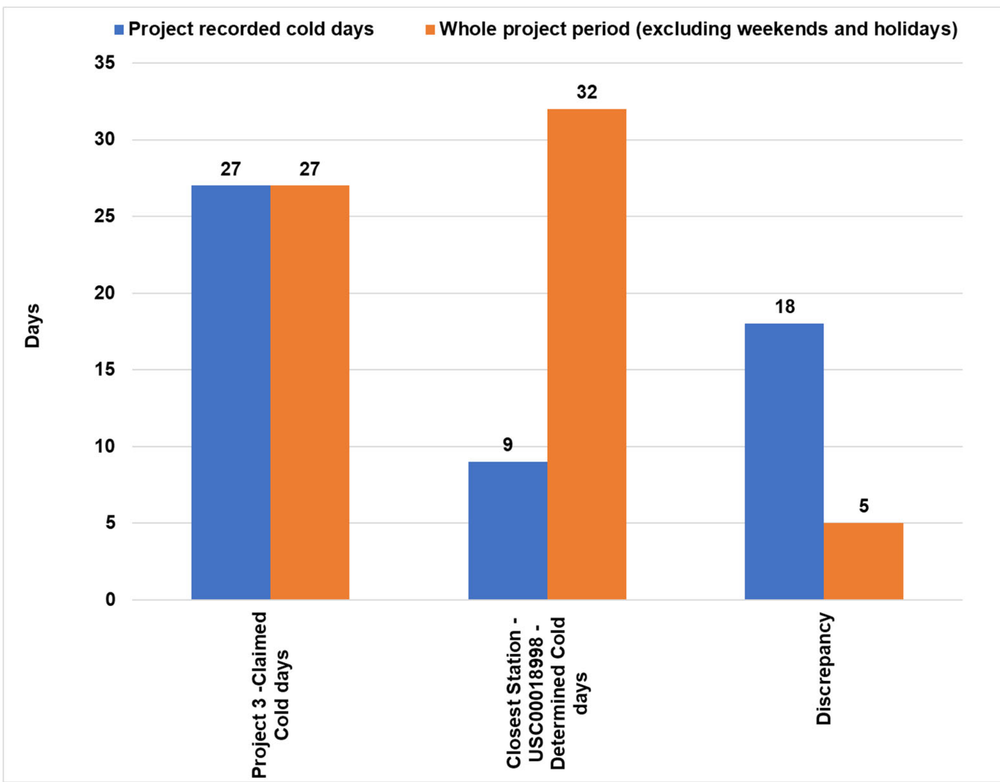



**Figure 5-31. Low temperature (cold) days as claimed by Project 3, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

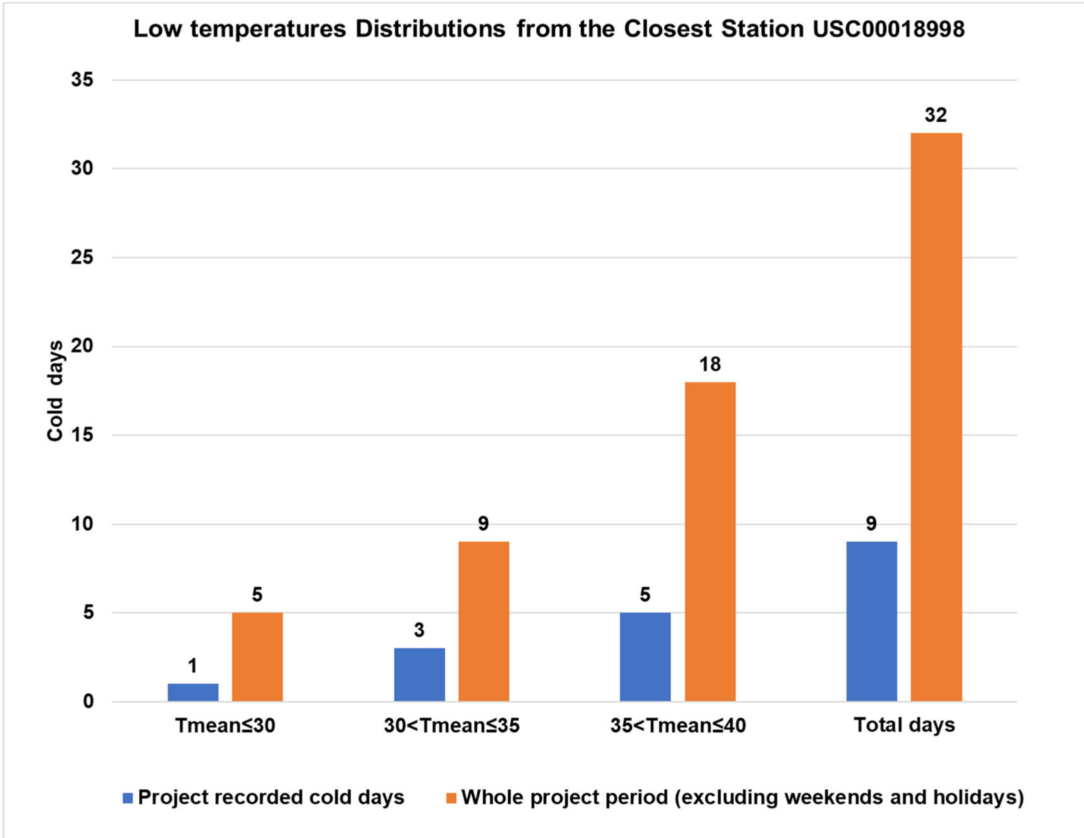



**Figure 5-32. Low temperature distributions of the closest station during the project claimed cold days and the whole project period (excluding weekends and holidays).**

## 5.5 PROJECT 4 (MONTGOMERY COUNTY – SOUTHEAST REGION)

Project 4, located in Montgomery County, Alabama, involved pavement rehabilitation and intersection improvements on I-85 from SR-8 to SR-271 and on SR-8 at I-85 from Woodmere Boulevard to Monticello Drive in Montgomery (Latitude: 32.362247°, Longitude: -86.190786°). This project extended from September 4th, 2018, to October 31, 2020, encompassing a duration of 937 days, approximately 2 years and 6 months, but the contract time was 180 workdays. The overall timeline of the project was influenced by various factors, including adverse weather conditions and non-climate-related factors.

For the verification process, we selected the nearest weather station for analysis, which was Montgomery 6 SW - USC00015553, located at coordinates (32.26 °, -86.218°). This weather station maintained a comprehensive weather data record spanning 22 years, from 1999 through 2022. However, for the purpose of comparison and verification, our focus was on data from the years 2018 through 2020.

Table 5-16 presents a summary of the project's details, while Figure 5-33 provides a visual representation of the project's location in relation to the nearest weather stations.

**Table 5-16. Montgomery County ALDOT project (Project 4) information.**

| Project 4 | | | |
|---|---|---|---|
| Fed/State Project No. | IMF-I085(339) | Start Date | 9-Apr-18 |
| Project description | Pavement rehabilitation and intersection improvements | End Date | 31-Oct-20 |
| Location | On I-85 from SR-8 to SR-271 and on SR-8 at I-85 from Woodmere Boulevard to Monticello drive in Montgomery 4.377 (32.362247, -86.190786) | Closest Station ID/Name | Montgomery 6 SW - USC00015553 |
| ALDOT Region | Southeast | Closest Station Location | 32.26, -86.218 |
| Contract time | 180 Days | Climate station data source | Global Historical Climatology Network (GHCN) |

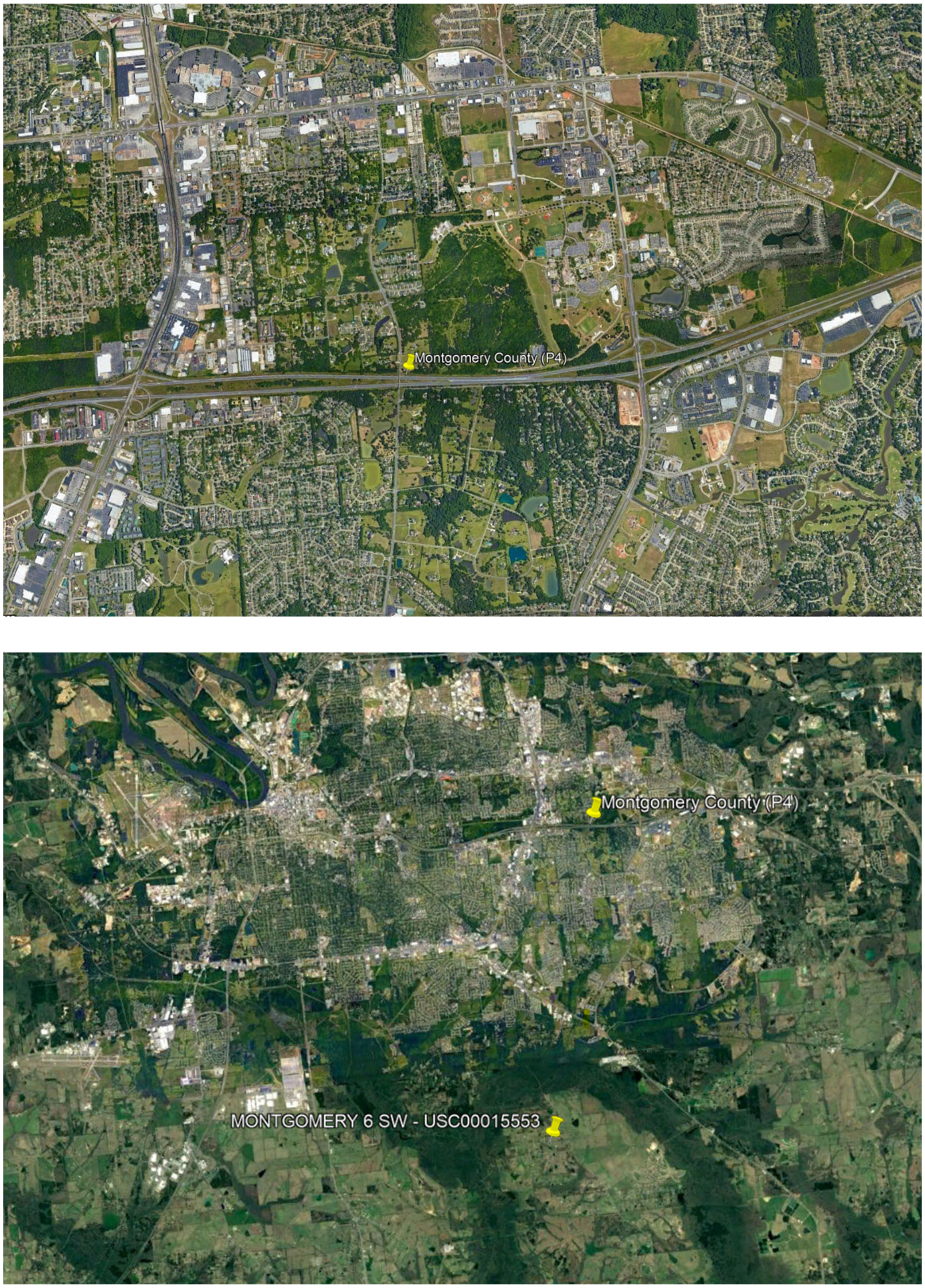



**Figure 5-33. Montgomery County (Project 4) located on I-85 from SR-8 to SR-271 and on SR-8 at I-85 from Woodmere Boulevard to Monticello drive in Montgomery 4.377 (Latitude: 32.362247°, Longitude: -86.190786°) and the nearest weather station used for the verification process.**

### 5.5.1 CLOSEST STATION – MONTGOMERY 6 SW - USC00015553 - AAWDS

Table 5-17 presents the computed AAWDs for the weather station designated as "Montgomery 6 SW - USC00015553". This station is situated in the Southeast Region and boasts an extensive data record spanning an impressive 22-year period, commencing from January 1999, and continuing through December 2022.

As depicted in Table 5-17, the AAWDs for this station exhibit fluctuations, ranging from 16 to 18 days across various months of the year. In contrast, the median varies between 16 and 18 days. Additionally, the table provides insight into key statistical measures, including the standard deviation, which ranges from 2 to 4 days, and the 80th percentile of the monthly computed AAWDs, which varies from 18 to 20 days.

**Table 5-17. Determined AAWDs for the Montgomery 6 SW.**

| Montgomery 6 SW - USC00015553 - P13 (P>0.2 in. & T<40°F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | N-Years | AAWD | StdDev | Min. | Max. | Median | 80PerT | Skew |
| 1 | 22/22 | 18 | 2 | 11 | 21 | 18 | 20 | -1.3238 |
| 2 | 21/22 | 16 | 4 | 6 | 22 | 17 | 19 | -0.9760 |
| 3 | 22/22 | 16 | 3 | 10 | 21 | 16 | 18 | 0.0208 |
| 4 | 22/22 | 17 | 2 | 13 | 20 | 17 | 19 | -0.1981 |
| 5 | 22/22 | 17 | 5 | 0 | 22 | 18 | 20 | -2.5268 |
| 6 | 22/22 | 17 | 3 | 11 | 21 | 18 | 19 | -0.9255 |
| 7 | 22/22 | 17 | 4 | 7 | 22 | 18 | 19 | -1.0665 |
| 8 | 22/22 | 17 | 3 | 12 | 22 | 18 | 20 | -0.1476 |
| 9 | 22/22 | 16 | 4 | 6 | 22 | 17 | 19 | -1.1751 |
| 10 | 22/22 | 17 | 3 | 12 | 21 | 17 | 19 | -0.5155 |
| 11 | 22/22 | 17 | 3 | 11 | 20 | 17 | 19 | -0.6616 |
| 12 | 22/22 | 17 | 2 | 11 | 21 | 17 | 19 | -0.4005 |

### 5.5.2 PROJECT 4 VS. MONTGOMERY 6 SW - USC00015553 - COMPARISON RESULTS

We conducted a detailed daily analysis of records for the Montgomery County Project (P4) to assess how adverse weather conditions impacted workdays and non-workdays, ultimately affecting the project's timeline. We performed a yearly breakdown of various parameters on a month-to-month basis and compared these findings to data from the Montgomery 6 SW - USC00015553 weather station using a specialized Excel tool, under the adverse weather threshold condition 13 (P>0.2 in. & T <40°F).

The AAWDs determined for this station, as explained in the previous section, served as a reference for evaluating the yearly count of AWDs and Non-workdays over the 937-day project duration. This comparison enhances our understanding of how unpredictable weather events, like hurricanes and storms, can impact construction activities and, consequently, project timelines.

It's important to note that the monthly durations during this analyzed period varied. For example, April 2018 deviated from the standard 30-day month because it was adjusted to 22 days due to the project's start on April 9, 2018. For April 2018 (as indicated in Table 5-18), the calculated Project days/month were 22 days, calculated by subtracting 8 days (the period before the project's start date) from the typical 30-day April. Therefore, all project calculations for this month were based on a 22-day timeframe. These adjustments are critical for accurate analysis and interpretation of the subsequent metrics in Table 5-18 and Table 5-20.

Furthermore, data from the nearest weather station, "USC00015553- AWDs (P13)" and "USC00015553- NWDs (P13)," were integrated into the analysis. These metrics include AWDs and non-workdays, determined based on weather condition criteria 13 ($P>0.2$ in. & $T_{mean}<40°F$). The study's Excel spreadsheets were used to extract and analyze this data. It's essential to highlight that results from the closest station are adjusted for month durations, as needed, such as in April 2018. For example, according to Project 4's daily records, 9 non-workdays and 13 worked days were determined, considering the adjusted 22-day month related to the project's start date. In contrast, 8 non-workdays and 14 AWDs were determined from USC00015553 (P13) for April 2018. This difference is specific to the month when the project began and reflects the shortened month length.

Another notable finding is that for October 2018 (Table 5-18), the project's worked days were determined to be 23 days based on the project's daily records. However, when calculating AWDs for this project, it was determined to be 20 days. This discrepancy of 3 days can be attributed to the contractor working on weekends to compensate for the days lost during available workdays (weekdays).

**Table 5-18. Montgomery County (Project 4), 2018 monthly determined parameters for verification process.**

| 2018[8] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | | | | 22 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 267 | |
| Project non-workdays (W+H+AW) | | | | 9 | 9 | 9 | 10 | 8 | 13 | 11 | 18 | 19 | 106 | 40% |
| Project weekend+ Holidays (W+H) | | | | 6 | 9 | 9 | 10 | 8 | 11 | 8 | 9 | 12 | 82 | 31% |
| Project adverse weather (AW) days | | | | 3 | 0 | 0 | 0 | 0 | 2 | 3 | 9 | 7 | 24 | 9% |
| Project available workdays | | | | 13 | 22 | 21 | 21 | 23 | 17 | 20 | 12 | 12 | 161 | 60% |
| Project worked days | | | | 0 | 9 | 17 | 16 | 18 | 14 | 23 | 9 | 8 | 114 | 43% |
| Project non-workdays due to other factors | | | | 13 | 13 | 4 | 5 | 5 | 3 | 0 | 3 | 4 | 50 | 19% |
| USC00015553 - AWDs (P13) | | | | 14 | 14 | 16 | 18 | 17 | 11 | 18 | 16 | 15 | 139 | 52% |
| USC00015553 - NWDs (P13) | | | | 8 | 17 | 14 | 13 | 14 | 19 | 13 | 14 | 16 | 128 | 48% |

[8] Note: W, H, and AW stand for weekends, state holidays, and adverse weather days, respectively. P13 is for adverse weather threshold condition 13: daily rainfall >0.2 in and daily mean temperatures < 40$^{o}$F.

**Table 5-19. Montgomery County (Project 4), 2019 monthly determined parameters for verification process.**

| 2019 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 365 | |
| Project non-workdays (W+H+AW) | 14 | 15 | 16 | 12 | 9 | 11 | 9 | 9 | 10 | 10 | 12 | 12 | 139 | 52% |
| Project weekend + Holidays (W+H) | 9 | 8 | 10 | 8 | 9 | 11 | 9 | 9 | 10 | 8 | 10 | 11 | 112 | 42% |
| Project adverse weather (AW) days | 5 | 7 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 27 | 10% |
| Project available workdays | 17 | 13 | 15 | 18 | 22 | 19 | 22 | 22 | 20 | 21 | 18 | 19 | 226 | 85% |
| Project worked days | 11 | 12 | 15 | 16 | 18 | 0 | 2 | 5 | 11 | 6 | 15 | 6 | 117 | 44% |
| Project non-workdays due to other factors | 6 | 1 | 0 | 2 | 4 | 19 | 20 | 17 | 9 | 15 | 3 | 13 | 109 | 41% |
| USC00015553 - AWDs (P13) | 17 | 16 | 18 | 19 | 20 | 16 | 21 | 19 | 20 | 19 | 15 | 16 | 216 | 81% |
| USC00015553 - NWDs (P13) | 14 | 12 | 13 | 11 | 11 | 14 | 10 | 12 | 10 | 12 | 15 | 15 | 149 | 56% |

**Table 5-20. Montgomery County (Project 4), 2020 monthly determined parameters for verification process.**

| 2020 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 31 | 29 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | | | 305 | |
| Project non-workdays (W+H+AW) | 10 | 10 | 9 | 9 | 11 | 9 | 8 | 10 | 9 | 9 | | | 94 | 35% |
| Project weekend + Holidays (W+H) | 10 | 10 | 9 | 9 | 11 | 9 | 8 | 10 | 9 | 9 | | | 94 | 35% |
| Project adverse weather (AW) days | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0% |
| Project available workdays | 21 | 19 | 22 | 21 | 20 | 21 | 23 | 21 | 21 | 22 | | | 211 | 79% |
| Project worked days | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0% |
| Project non-workdays due to other factors | 21 | 19 | 22 | 21 | 20 | 21 | 23 | 21 | 21 | 22 | | | 211 | 79% |
| USC00015553 - AWDs (P13) | 12 | 11 | 16 | 17 | 16 | 13 | 17 | 20 | 14 | 17 | | | 153 | 57% |
| USC00015553 - NWDs (P13) | 19 | 18 | 15 | 13 | 15 | 17 | 14 | 11 | 16 | 14 | | | 152 | 57% |

During the project's duration, a total of 339 days were marked as non-workdays, as per the project's daily records. These non-workdays were classified based on specific criteria, including adverse weather conditions, weekends, and state holidays. Additionally, 231 workdays were recorded, while 370 days were designated as non-workdays due to various reasons unrelated to the predefined criteria, such as utility coordination, punch items, and other factors unrelated to adverse weather.

Upon analyzing data from the nearest weather station (USC00015553) using weather condition 13 (P>0.2 in. & T<40°F), it was found that there were 429 days classified as non-workdays (NWDs) and 508 days as AWDs. A comparison between the weather station's results and the project's daily records revealed a discrepancy of 90 days for non-workdays (~21% difference) and a difference of 277 days when comparing the project's worked days to the determined AWDs (~55% difference). However, when combining the project's workdays (231 days) with the non-workdays due to other factors (370 days), the total reached 601 days, resulting in a difference of 93 days (-18%) compared to the AWDs. These findings are visually presented in Figure 5-34.

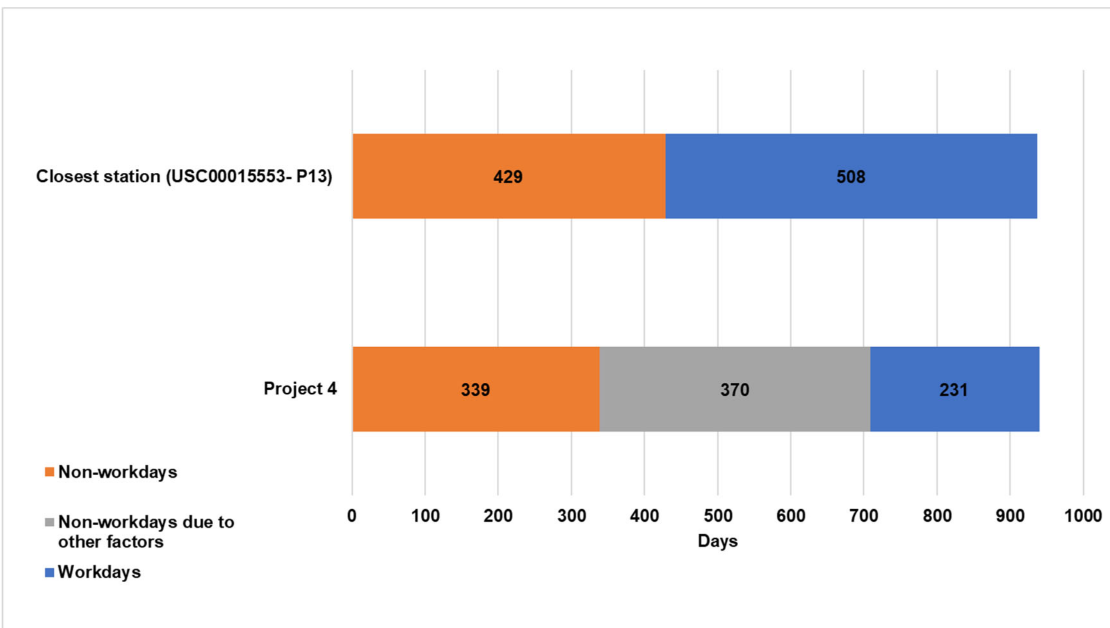



**Figure 5-34. Verification of AWDs and NWDs between Project 3 daily records and from the nearest weather station USC00017157 (P13).**

Figure 5-35 visually represents the recorded worked days and available workdays for Project 4, month by month. It's evident that Project 4's AWDs were calculated by considering all days in each month unaffected by non-workday criteria, including adverse weather, holidays, and weekends. Therefore, we can define AWDs in the project context as follows: AWDs = Project worked days + Project non-workdays due to other factors. For example, in February 2019, there were 12 project worked days, and an additional 3 days were designated as project non-workdays due to other factors. This resulted in a total of 15 days, representing the determined project AWDs for February 2019. This approach assumes that the contractor initially accounted for adverse weather days and later identified other factors leading to non-workdays on the project.

Similarly, the analysis extends to the determined AWDs for February 2019 obtained from the nearest weather station, Montgomery 6 SW - USC00015553, using Weather Condition 13 (P > 0.2 in. and T < 40°F). According to this analysis, there were 16 days classified as AWDs (referred to as WDayR2T40 in Figure 5-35. When compared to the determined project AWDs, there is a discrepancy of 1 day fewer.

Figure 5-36 provides a similar analysis for non-workdays, considering data from both Project 4's daily records and the closest weather station.

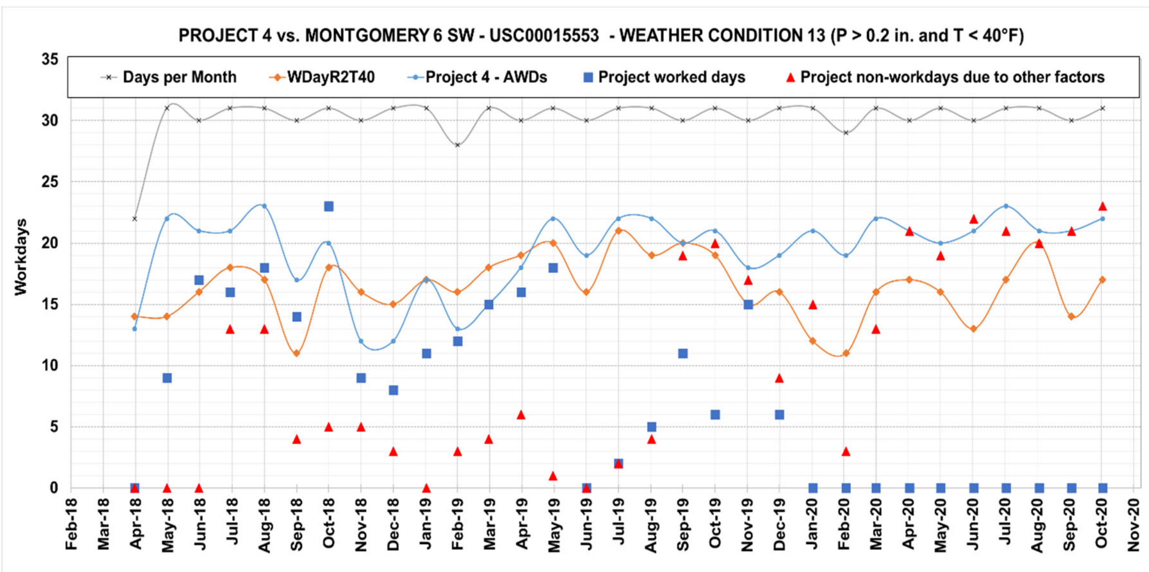



**Figure 5-35. Determined available workdays from Project 4 and Montgomery 6 SW - USC00015553 weather station including project's worked days and non-workdays due to other factors.**

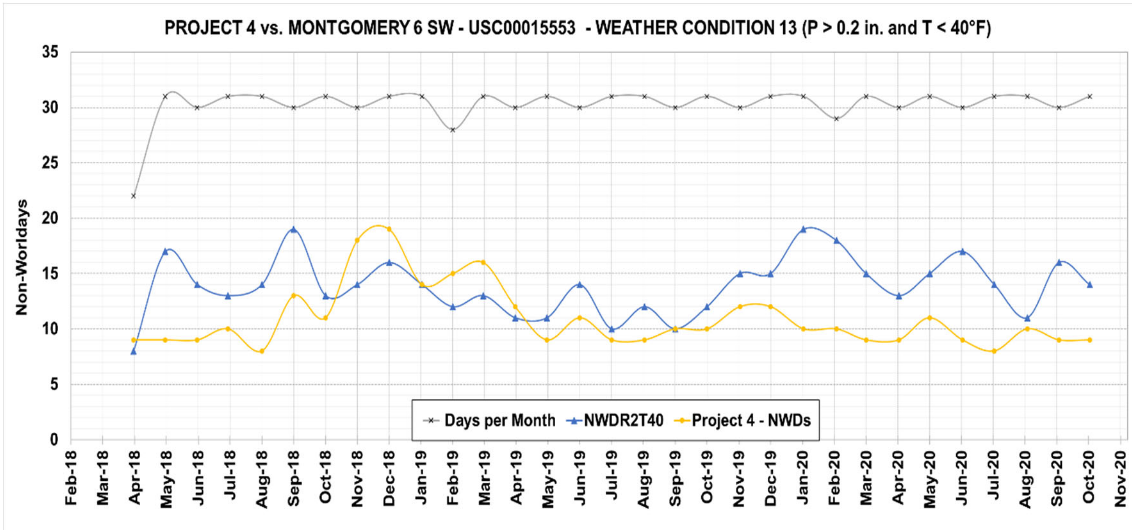



**Figure 5-36. Determined non-workdays for Project 4 and Montgomery 6 SW - USC00015553 weather station (NWDR2T40).**

### 5.5.3 ADVERSE WEATHER VERIFICATION

#### *Precipitation*

Figure 5-37 reveals that the contractor recorded 22 days as non-working days due to rain during the project's duration. However, it's important to note that the contractor did not document the specific rainfall depths on these days, making this information only available from the nearest weather station for verification.

Out of the 22 rainy days reported by the contractor, climate data from USC00015553 (as shown in Figure 5-37) indicated 21 non-working days due to precipitation. This results in a discrepancy of 1 day between the contractor's claims and the weather data from the closest station.

If we exclude the rainy days reported by the contractor, a total of 347 rainy days (excluding weekends and holidays) were determined from the data processed from USC00015553 weather station, using our Excel tool. Among these, 326 rainy days occurred after the initial 21 days that matched the project's daily records, but they were not categorized as non-working days in the project's records. Essentially, when the contractor refrained from work for other reasons, such as utility conflicts or punch list items, no information was provided to distinguish between a rainy day and a cold day.

In summary, there is a 325-day discrepancy when comparing the contractor's reported days for this project against the days determined by the closest weather station's data for the project's entire duration.

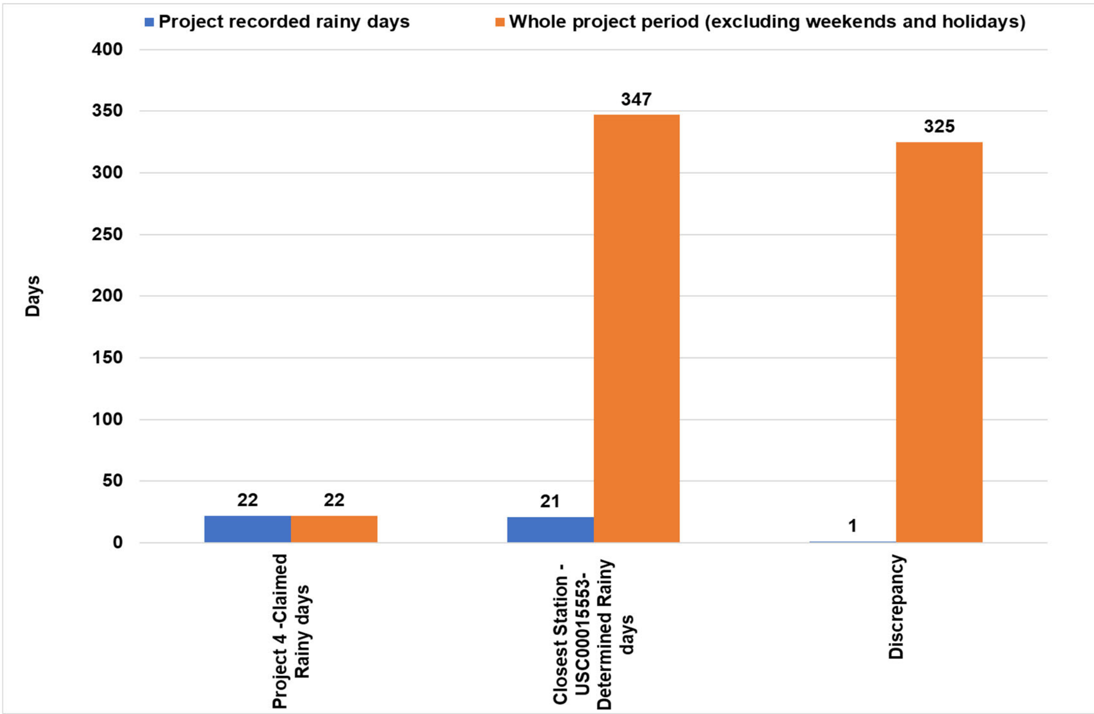



**Figure 5-37. Rainy days as claimed by Project 4, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

Figure 5-38 depicts the daily rainfall distribution based on the study's weather conditions. There are 14 days (1+2+11) with rainfall greater than 0.2 in. for the 21 rainy days reported by the contractor that matched the climate station data, but a total of 177 (14+21+142) days based on all USC00015553 rainfall data. The contractor's failure to report on numerous rainy days and failure to work for other reasons contributed to the large disparity.

The contractor has claimed 17 days as wet days in their records. Consequently, a total of 45 non-working days (as shown in Figure 5-40) have been documented in this project due to various factors such as rain and wet conditions. Based on the climate data collected from station USC00015553, it was determined that there were 40 non-working days (NWDs). This calculation involved adding 35 rainy days to 5 days with precipitation greater than 0.75 in. during the period claimed by the contractor that were affected by either rain or wet conditions, resulting in a discrepancy of 5 days.

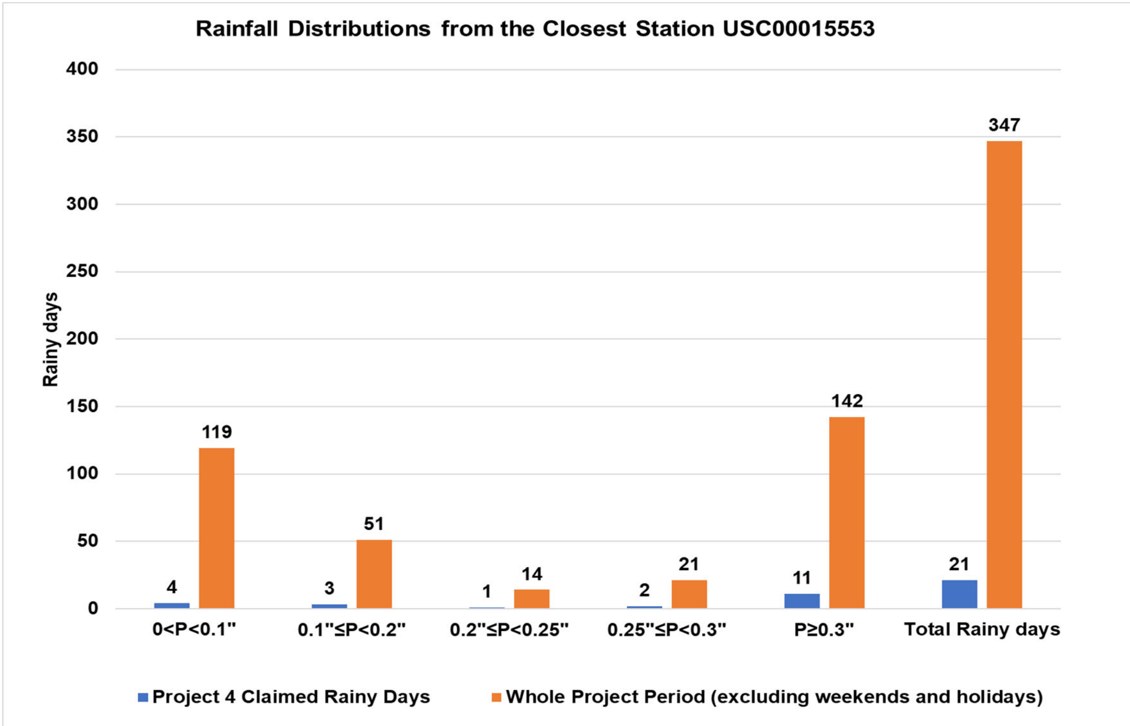



**Figure 5-38. Rainfall distributions of the closest station during the project claimed rainy days and the whole project period (excluding weekends and holidays).**

Excluding the information regarding rainy and wet days reported by the contractor when determining rainy days and additional days with precipitation exceeding 0.75 in. using data from the closest weather stations, we find that 70 days were added due to precipitation greater than 0.75 in. Consequently, a total of 417 non-working days (347 rainy days + 70 extra days due to P>0.75 in) were identified from the weather station data. This significantly differs from the 45 days claimed by the contractor, resulting in a discrepancy of 372 days, as illustrated in Figure 5-40.

Figure 5-39 depicts the daily distribution of rainfall and the disparities observed when considering or disregarding the project's records of rainy and wet days. For precipitation greater than 0.2 in., 21 days (comprising 1, 3, and 17 days) were identified from the project's daily records, compared to 177 days (consisting of 14, 21, and 142 days) determined from the weather station USC00015553 data. Over the project's duration and based on the nearest weather station's data, a total of 5 non-working days were added due to recorded precipitation exceeding 0.75 in. based on the days claimed by the contractor. However, when we exclude the contractor's reports of rainy and wet days, an additional 70 non-working days with precipitation greater than 0.75 in. were determined from the weather station's climate data, as depicted in Figure 5-39. This discrepancy indicates that there were more heavy rainfall days (P>0.75 in.) when the contractor did not work due to other reasons, which were not reported by the contractor.

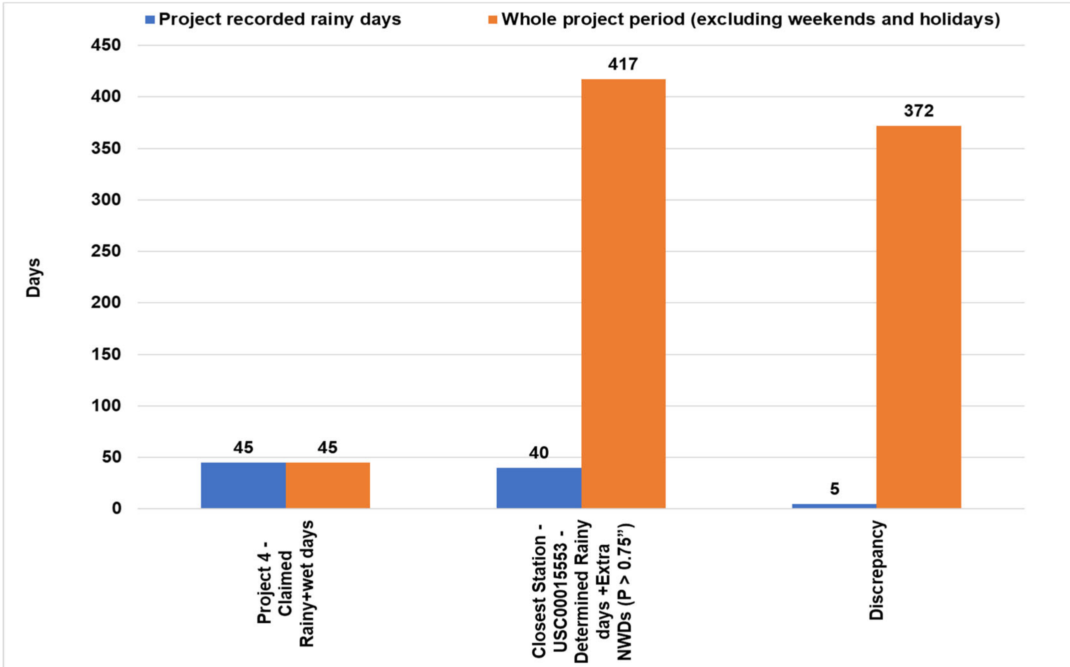



**Figure 5-40. Rainy and wet days as claimed by Project 4, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

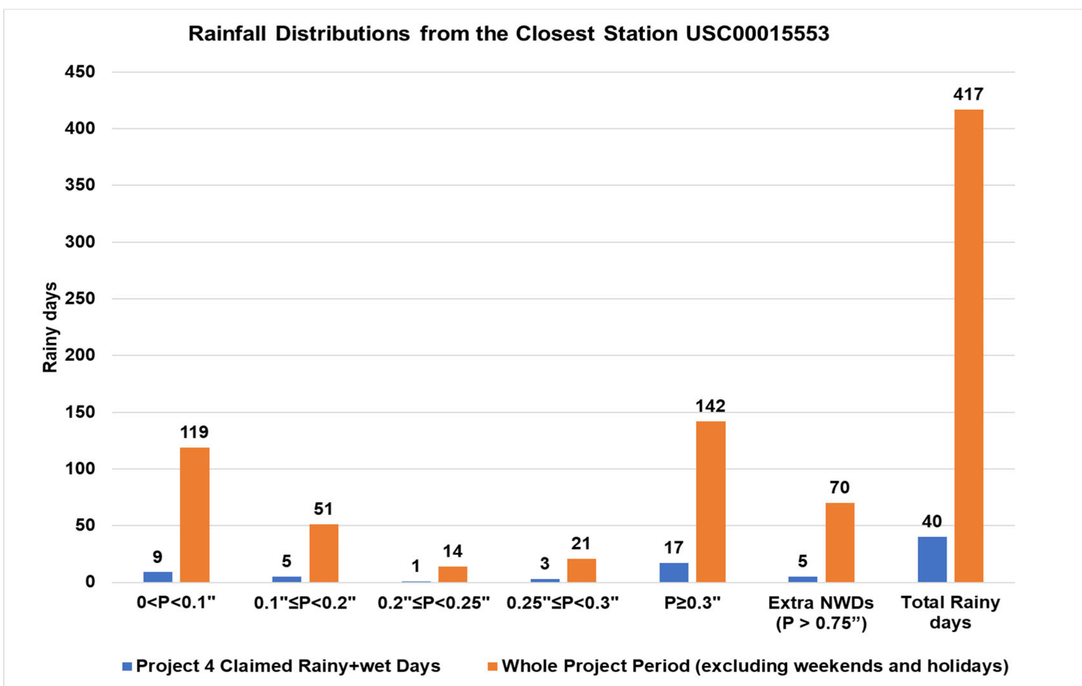



**Figure 5-39. Rainfall distributions of the closest station during the project claimed rainy + wet days and the whole project period (excluding weekends and holidays) + extra NWDs (P>0.75").**

### *Air temperature*

In Project 4, the contractor recorded just two days as "Too cold," indicating that low air temperatures hindered construction activities, and these days were designated as non-workdays throughout the project's timeline. However, when comparing these contractor-reported days with data from the nearest climate station, no days were confirmed as non-workdays due to a daily mean air temperature lower than 40°F (referred to as $T_{mean}$ in Figure 5-41).

Nonetheless, when considering data from the closest station, USC00015553, a total of 73 days had low daily mean air temperatures ($T_{mean}$ <40°F) during the project's duration, this resulted in a significant difference of 71 days when compared to the contractor's reported "Too cold" days. The contractor's failure to report on numerous cold days and failure to work for other reasons contributed to the large disparity.

The cold days classified as non-workdays (NWDs) were further categorized using the study's criteria for daily mean temperature, as shown in Figure 5-42. Based on the project's daily records, a total of 0 NWDs were identified when the mean air temperature fell below 40°F but remained above 35°F. In contrast, the station's climate data indicated 3 days that met these criteria.

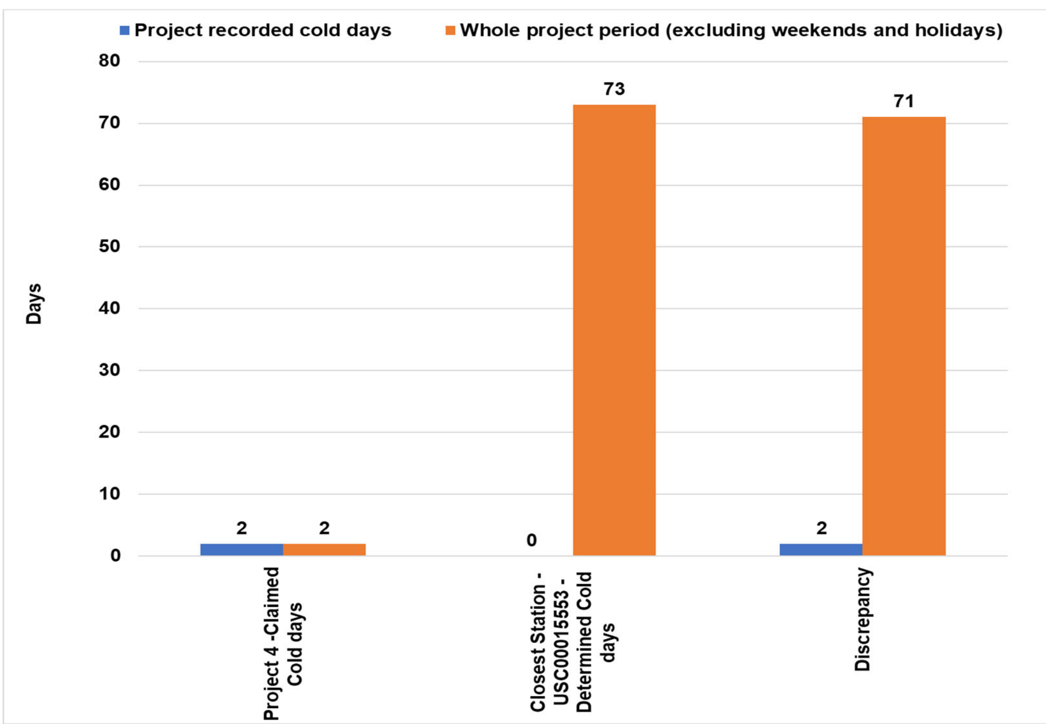



**Figure 5-41. Low temperature (cold) days as claimed by Project 4, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

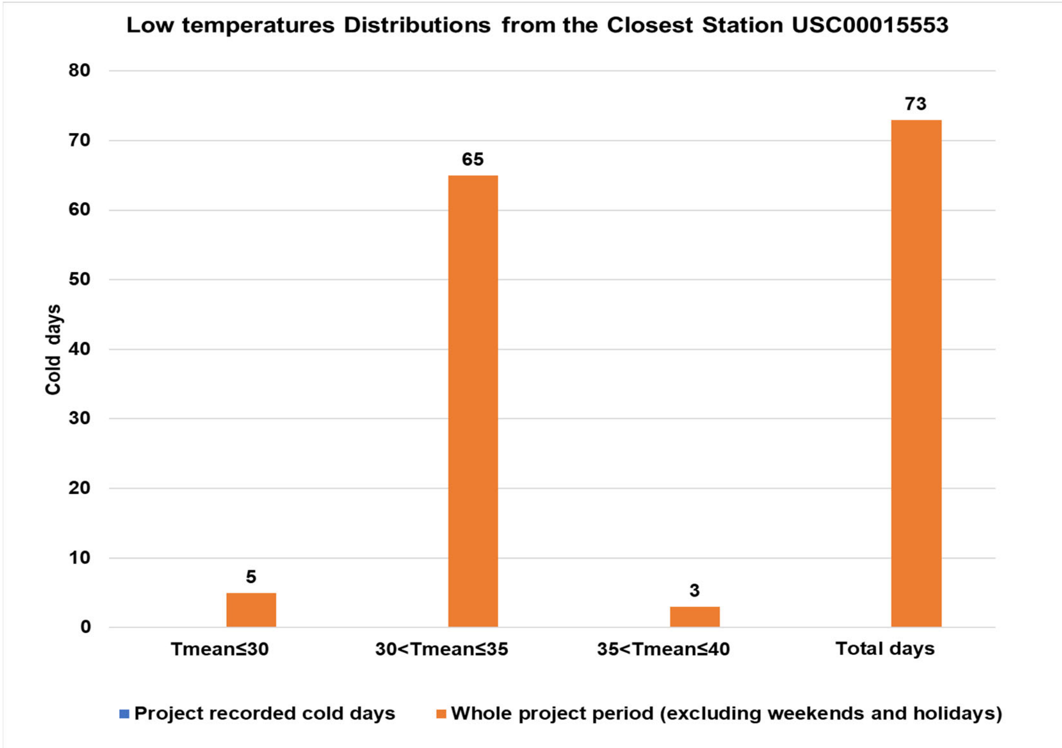



**Figure 5-42. Low temperature distributions of the closest station during the project claimed cold days and the whole project period (excluding weekends and holidays).**

## 5.6 PROJECT 5 (ESCAMBIA COUNTY – SOUTHWEST REGION)

Project 5, situated in Escambia County, Alabama, encompassed activities such as planning, resurfacing, and traffic striping on I-65, stretching from the SR-21 interchange in Martinsville to 0.400 miles north of the CR-40 junction (Latitude: 31.161779°, Longitude: -87.37162). This project had a timeline spanning from July 24, 2019, to June 30, 2022, covering a duration of 1073 days, roughly equivalent to 3 years and 11 months, but the contract time was 240 workdays. The overall project timeline was subject to various influences, including adverse weather conditions and non-climate-related factors.

To facilitate the verification process, we opted for the nearest weather station, Atmore, AL - USC00010402, located at coordinates (31.182°, -87.439°). This weather station boasted an extensive weather data record covering 63 years, ranging from 1941 to 2022. However, our focus for comparison and verification was directed toward data from the years 2018 through 2022.

Table 5-21 summarizes key details of the project, while Figure 5-43 offers a visual representation of the project's location concerning the nearest weather stations.

**Table 5-21. Escambia County ALDOT project (Project 5) information.**

| Project 5 | | | |
|---|---|---|---|
| Fed/State Project No. | IM-I065(491) | Start Date | 24-Jul-19 |
| Project description | Planning, resurfacing, and traffic stripe | End Date | 30-Jun-22 |
| Location | On I-65 from the SR-21 interchange in Martinsville to 0.400 mile north of the junction of CR-40 13.264 (31.161779, -87.37162) | Closest Station ID/Name | ATMORE, AL - USC00010402 |
| ALDOT Region | Southwest | Closest Station Location | 31.182, -87.439 |
| Contract time | 240 Days | Climate station data source | Global Historical Climatology Network (GHCN) |

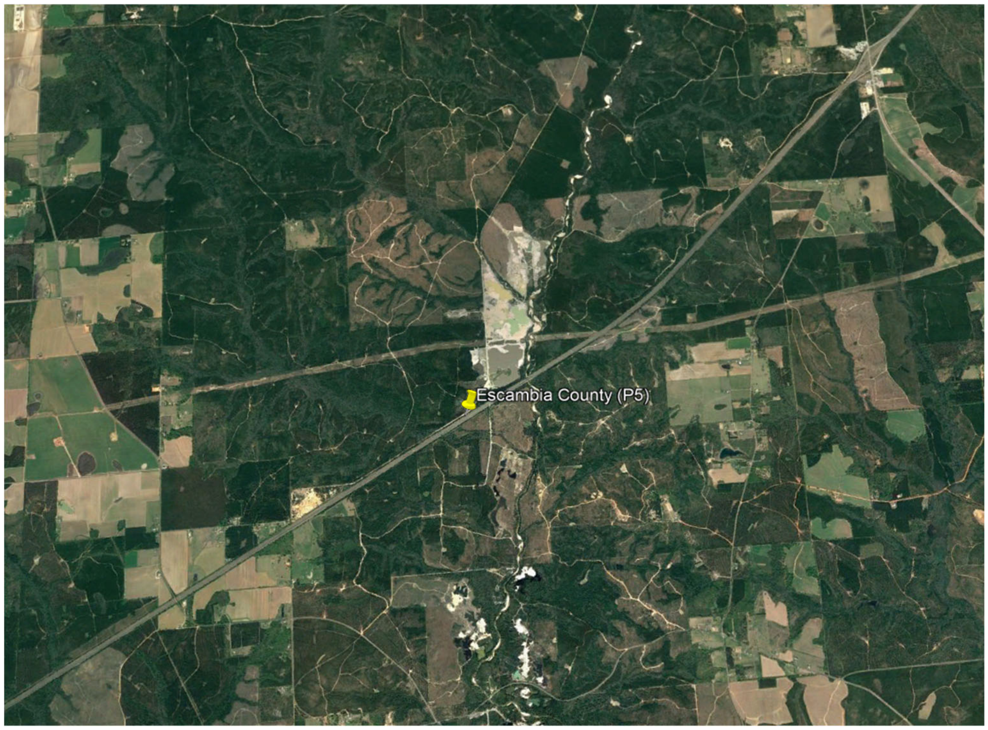




**Figure 5-43. Escambia County (Project 5) located on I-65 from the SR-21 interchange in Martinsville to 0.400 mile north of the junction of CR-40 13.264 (Latitude: 31.161779°, Longitude: -87.37162) and the nearest weather station used for the verification.**

#### 5.6.1 CLOSEST STATION – ATMORE, AL - USC00010402 - AAWDS

Table 5-22 displays the calculated AAWDs for the weather station denoted as "Atmore, AL - USC00010402". This station, located in the Southwest Region, boasts a robust data record spanning an impressive 63-year period, commencing from January 1941, and extending through December 2022.

As shown in Table 5-22, AAWDs for this station exhibit variations, fluctuating from 12 to 17 days across different months of the year. In contrast, the median AWDs consistently fall between 16 and 17 days. The table also offers valuable insights into key statistical measures, encompassing the standard deviation, which ranges from 2 to 8 days, and the 80th percentile of the monthly computed AAWDs, which varies from 18 to 20 days.

**Table 5-22. Determined AAWDs for the Atmore, AL.**

| Atmore, AL - USC00010402 - P13 (P>0.2 in. & T<40°F) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Month | N-Years | AAWD | StdDev | Min. | Max. | Median | 80PerT | Skew |
| 1 | 63/63 | 17 | 2 | 9 | 21 | 17 | 18 | -0.7505 |
| 2 | 63/63 | 16 | 4 | 0 | 22 | 17 | 19 | -2.3880 |
| 3 | 60/63 | 17 | 3 | 0 | 23 | 17 | 19 | -2.5071 |
| 4 | 63/63 | 16 | 3 | 6 | 21 | 16 | 18 | -0.7954 |
| 5 | 63/63 | 12 | 8 | 0 | 21 | 16 | 18 | -0.8784 |
| 6 | 63/63 | 17 | 3 | 8 | 21 | 17 | 20 | -0.7608 |
| 7 | 63/63 | 16 | 3 | 9 | 22 | 17 | 19 | -0.5496 |
| 8 | 63/63 | 17 | 3 | 9 | 21 | 17 | 20 | -0.7431 |
| 9 | 63/63 | 16 | 4 | 0 | 22 | 17 | 19 | -2.1083 |
| 10 | 60/63 | 17 | 3 | 7 | 21 | 17 | 19 | -1.3028 |
| 11 | 63/63 | 16 | 3 | 7 | 21 | 16 | 18 | -0.7993 |
| 12 | 63/63 | 17 | 3 | 10 | 21 | 17 | 19 | -0.3394 |

#### 5.6.2 PROJECT 5 VS. ATMORE, AL - USC00010402 - COMPARISON RESULTS

We conducted a thorough daily analysis of the records for Escambia County Project (P5) to assess how adverse weather conditions impacted workdays and non-workdays, ultimately influencing the project's timeline. This project spanned from July 24th, 2019, to June 30th, 2022. We conducted a yearly breakdown of various parameters on a month-to-month basis and compared these findings to data from the Atmore, AL - USC00010402 weather station using a specialized Excel tool, specifically under the adverse weather threshold condition 13 (P>0.2 in. & T <40°F).

The AAWDs previously determined for this station, as explained in the previous section, served as a reference for evaluating the yearly count of AWDs and non-workdays over the 1073-day project duration. This comparison enhances our understanding of how unpredictable weather events, such as hurricanes and storms, can impact construction activities and, consequently, project timelines.

It's important to note that the monthly durations during this analyzed period varied. For instance, July 2019 deviated from the standard 31-day month because it was adjusted to 8 days due to the project's commencement on July 24, 2019. For July 2019 (as indicated in Table 5-23), the calculated Project days/month were 8 days, calculated by subtracting 23 days (the period before the project's start date) from the typical 31-day July. Therefore, all project calculations for this month were based on an 8-day timeframe. These adjustments are crucial for ensuring the accurate analysis and interpretation of the subsequent metrics in Table 5-23 and Table 5-26.

Furthermore, data from the nearest weather station, "USC00010402- AWDs (P13)" and "USC00010402- NWDs (P13)," were integrated into the analysis. These metrics include AWDs and non-workdays, determined based on weather condition criteria 13 (P > 0.2 in. & $T_{mean}$ < 40 °F). The study's Excel spreadsheets were used to extract and analyze this data. It's essential to highlight that results from the closest station are adjusted for month durations, as needed, such as in July 2019. For example, according to Project 5's daily records, 2 non-workdays and 0 worked days were determined, considering the adjusted 8-day month related to the project's start date. In contrast, 2 non-workdays NWDs and 6 AWDs were determined from USC00015553 (P13) for July 2019. This difference is specific to the month when the project began and reflects the shortened month length.

**Table 5-23. Escambia (Project 5), 2019 monthly determined parameters for verification process.**

| 2019[9] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | | | | | | | 8 | 31 | 30 | 31 | 30 | 31 | 161 | |
| Project non-workdays (W+H+AW) | | | | | | | 2 | 9 | 7 | 11 | 11 | 19 | 59 | 37% |
| Project weekend + holidays (W+H) | | | | | | | 2 | 9 | 7 | 8 | 10 | 11 | 47 | 29% |
| Project adverse weather (AW) days | | | | | | | 0 | 0 | 0 | 3 | 1 | 8 | 12 | 7% |
| Project available workdays | | | | | | | 6 | 22 | 23 | 20 | 19 | 12 | 102 | 63% |
| Project worked days | | | | | | | 0 | 0 | 0 | 1 | 14 | 5 | 20 | 12% |
| Project non-workdays due to other factors | | | | | | | 6 | 22 | 23 | 19 | 5 | 7 | 82 | 51% |
| USC00010402 - AWDs (P13) | | | | | | | 6 | 17 | 19 | 17 | 14 | 19 | 92 | 57% |
| USC00010402 - NWDs (P13) | | | | | | | 2 | 14 | 11 | 14 | 16 | 12 | 69 | 43% |

[9] Note: W, H, and AW stand for weekends, state holidays, and adverse weather days, respectively. P13 is for adverse weather threshold condition 13: daily rainfall >0.2 in and daily mean temperatures < 40$^{o}$F.

**Table 5-24. Escambia (Project 5), 2020 monthly determined parameters for verification process.**

| 2020 | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 31 | 29 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 366 | |
| Project non-workdays (W+H+AW) | 19 | 15 | 13 | 9 | 13 | 17 | 19 | 15 | 14 | 13 | 16 | 28 | 191 | 52% |
| Project weekend + Holidays (W+H) | 10 | 9 | 8 | 6 | 11 | 8 | 9 | 10 | 9 | 9 | 10 | 9 | 108 | 30% |
| Project adverse weather (AW) days | 9 | 6 | 5 | 3 | 2 | 9 | 10 | 5 | 5 | 4 | 6 | 19 | 83 | 23% |
| Project available workdays | 12 | 14 | 18 | 21 | 18 | 13 | 12 | 16 | 16 | 18 | 14 | 3 | 175 | 48% |
| Project worked days | 7 | 10 | 13 | 18 | 18 | 12 | 10 | 16 | 13 | 13 | 14 | 0 | 144 | 39% |
| Project non-workdays due to other factors | 5 | 4 | 5 | 3 | 0 | 1 | 2 | 0 | 3 | 5 | 0 | 3 | 31 | 8% |
| USC00010402 - AWDs (P13) | 13 | 14 | 21 | 16 | 19 | 15 | 17 | 16 | 16 | 20 | 18 | 17 | 202 | 55% |
| USC00010402 - NWDs (P13) | 18 | 15 | 10 | 14 | 12 | 15 | 14 | 15 | 14 | 11 | 12 | 14 | 164 | 45% |

**Table 5-25. Escambia (Project 5), 2021 monthly determined parameters for verification process.**

| | 2021 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | 365 | |
| Project non-workdays (W+H+AW) | 31 | 28 | 30 | 14 | 16 | 10 | 10 | 10 | 9 | 11 | 10 | 17 | 196 | 54% |
| Project weekend + Holidays (W+H) | 12 | 9 | 8 | 9 | 11 | 10 | 10 | 9 | 9 | 11 | 10 | 10 | 118 | 32% |
| Project adverse weather (AW) days | 19 | 19 | 22 | 5 | 5 | 0 | 0 | 1 | 0 | 0 | 0 | 7 | 78 | 21% |
| Project available workdays | 0 | 0 | 1 | 16 | 15 | 20 | 21 | 21 | 21 | 20 | 20 | 14 | 169 | 46% |
| Project worked days | 0 | 0 | 0 | 14 | 4 | 0 | 0 | 0 | 0 | 1 | 15 | 6 | 40 | 11% |
| Project non-workdays due to other factors | 0 | 0 | 1 | 2 | 11 | 20 | 21 | 21 | 21 | 19 | 5 | 8 | 129 | 35% |
| USC00010402 - AWDs (P13) | 13 | 12 | 19 | 18 | 15 | 18 | 15 | 15 | 16 | 15 | 19 | 19 | 194 | 53% |
| USC00010402 - NWDs (P13) | 18 | 16 | 12 | 12 | 16 | 12 | 16 | 16 | 14 | 16 | 11 | 12 | 171 | 47% |

**Table 5-26. Escambia (Project 5), 2022 monthly determined parameters for verification process.**

| | 2022 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Days/ Year | % of Year |
| Project days/month | 31 | 28 | 31 | 30 | 31 | 30 | | | | | | | 181 | |
| Project non-workdays (W+H+AW) | 26 | 25 | 19 | 16 | 18 | 12 | | | | | | | 116 | 64% |
| Project weekend + Holidays (W+H) | 11 | 9 | 8 | 10 | 10 | 9 | | | | | | | 57 | 31% |
| Project adverse weather (AW) days | 15 | 16 | 11 | 6 | 8 | 3 | | | | | | | 59 | 33% |
| Project available workdays | 5 | 3 | 12 | 14 | 13 | 18 | | | | | | | 65 | 36% |
| Project worked days | 0 | 0 | 8 | 9 | 9 | 10 | | | | | | | 36 | 20% |
| Project non-workdays due to other factors | 5 | 3 | 4 | 5 | 4 | 8 | | | | | | | 29 | 16% |
| USC00010402 - AWDs (P13) | 16 | 16 | 19 | 17 | 16 | 17 | | | | | | | 101 | 56% |
| USC00010402 - NWDs (P13) | 15 | 12 | 12 | 13 | 15 | 13 | | | | | | | 80 | 44% |

During the project's timeline, a total of 562 days were categorized as non-workdays, as indicated by the project's daily records. These non-workdays were grouped according to specific criteria, including adverse weather conditions, weekends, and state holidays. Additionally, 240 workdays were logged, while 271 days were labeled as non-workdays due to various unrelated reasons, such as utility coordination, punch items, and factors unrelated to adverse weather.

Upon scrutinizing data from the nearest weather station (USC00010402) using weather condition 13 (P>0.2 in. & T<40°F), it was determined that there were 484 days classified as non-workdays NWDs and 589 days designated as AWDs. A comparison between the weather station's findings and the project's daily records uncovered a variance of 78 days for non-workdays (approximately a 16% difference) and a difference of 349 days when comparing the project's worked days to the determined AWDs (a difference of about 59%). However, when combining the project's workdays (240 days) with the non-workdays due to other factors (271 days), the total count reached 511 days, resulting in a difference of 78 days (approximately 13%) in comparison to the AWDs. These findings are visually depicted in Figure 5-44.

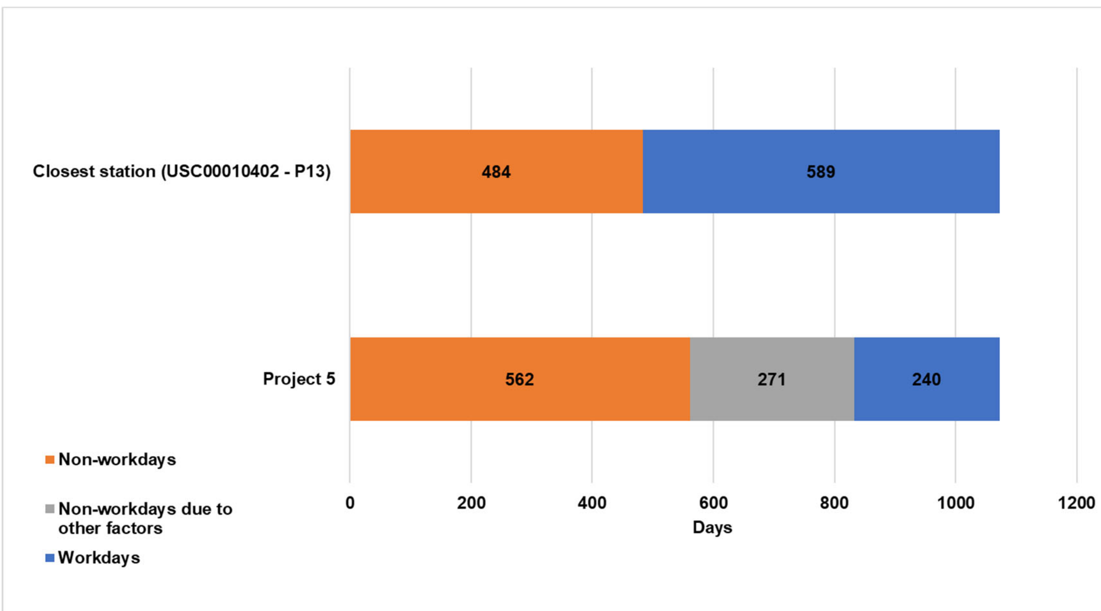



**Figure 5-44. Verification of AWDs and NWDs between Project 3 daily records and from the nearest weather station USC00017157 (P13).**

Figure 5-45 visually depicts the monthly breakdown of worked days and AWDs for Project 5. The computation of AWDs for Project 5 involved considering all days in each month that were unaffected by non-workday criteria, including adverse weather, holidays, and weekends. In the context of the project, AWDs can be defined as follows: AWDs = Project worked days + Project non-workdays due to other factors. To illustrate, in September 2020, there were 13 project worked days, with an additional 5 days designated as project non-workdays due to other factors. This resulted in a total of 18 days, representing the determined project AWDs for September 2020. This methodology assumes that the contractor initially accounted for adverse weather days and subsequently identified other factors leading to non-workdays on the project.

Similarly, the analysis extends to the determined AWDs for September 2020 obtained from the nearest weather station, Atmore, AL - USC00010402, using Weather Condition 13 (P > 0.2 in. and T < 40°F). According to this analysis, there were 20 days classified as AWDs (referred to as WDayR2T40 in Figure 5-45). When compared to the determined project available workdays, there is a discrepancy of 4 days more.

Figure 5-46 provides a parallel analysis for non-workdays, considering data from both Project 4's daily records and the closest weather station.

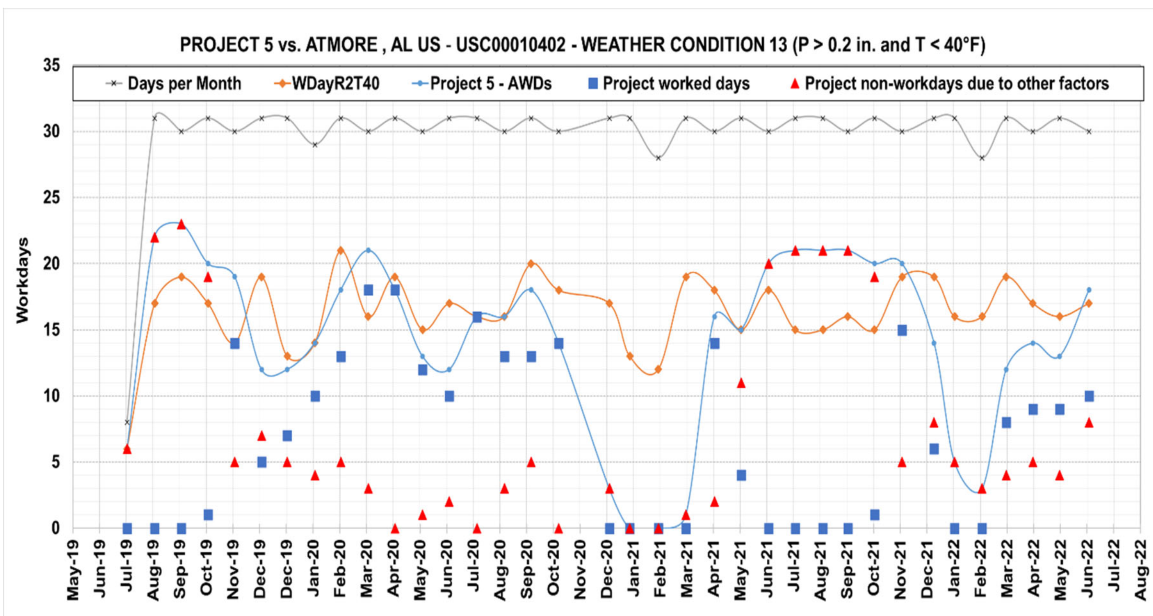



**Figure 5-45. Determined available workdays from Project 5 and Atmore, AL - USC00010402 weather station including project's worked days and non-workdays due to other factors.**

A significant discrepancy between the AWDs determined from the closest station and the project's daily records is evident at the project's commencement and conclusion. From July 2019 through September 2019, all days were marked as non-workdays due to other factors, with the records citing reasons related to “Resurfacing Start-Up Delay” as noted in the project’s daily records. However, a similar situation arises towards the project's completion, from June 2021 through September 2021, where the non-workdays due to other factors were related to “Department Action” according to the project's records.

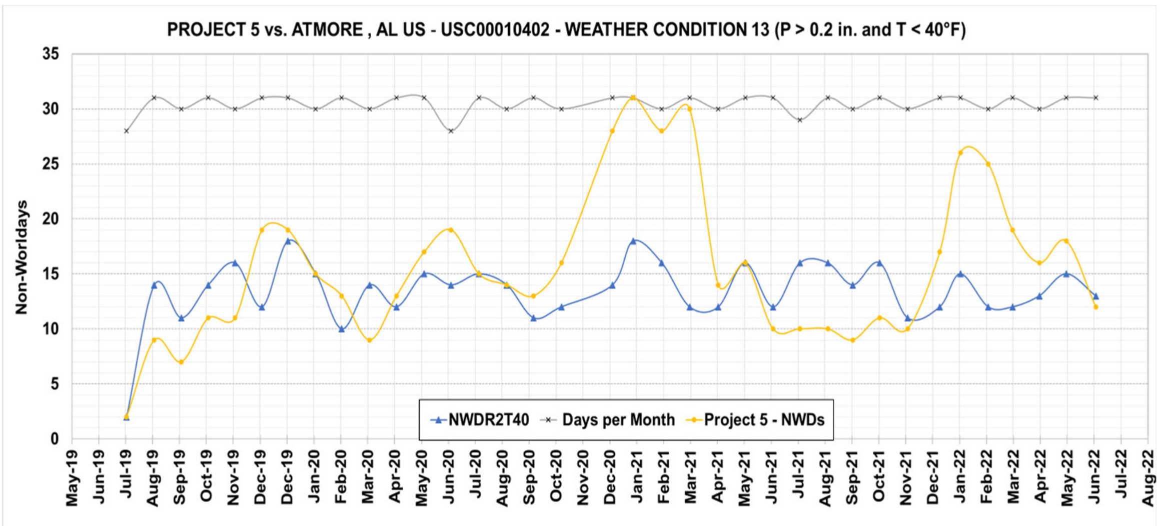



**Figure 5-46. Determined non-workdays for Project 5 and Atmore, AL - USC00010402 weather station (NWDR2T40).**

#### 5.6.3 ADVERSE WEATHER VERIFICATION

***Precipitation***

In Figure 5-47, it can be noted that for this project 124 days were claimed as non-working days due to rain throughout the project's timeline based on the contractor’s report. It's crucial to note that specific rainfall measurements were not recorded by the contractor, relying instead on the nearest weather station for such data.

Out of the 124 rainy days reported by the contractor, data from USC00010402 (depicted in Figure 5-47) confirmed 77 non-working days attributed to precipitation. This shows a discrepancy of 47 days between the contractor's report and the weather station's records.

By excluding the contractor-reported rainy days, our analysis identified a total of 354 rainy days (excluding weekends and holidays) based on USC00010402 weather station data. Among these, 277 rainy days occurred after the initial 77 days matching the project's daily records but were not categorized as non-working days in the project's records. Essentially, when the contractor refrained from work for reasons other than rain, such as utility conflicts or punch list items, the distinction was not documented.

In summary, a significant 230-day disparity emerges when comparing the contractor's reported non-working days with the data from the nearest weather station for the project's entire duration.

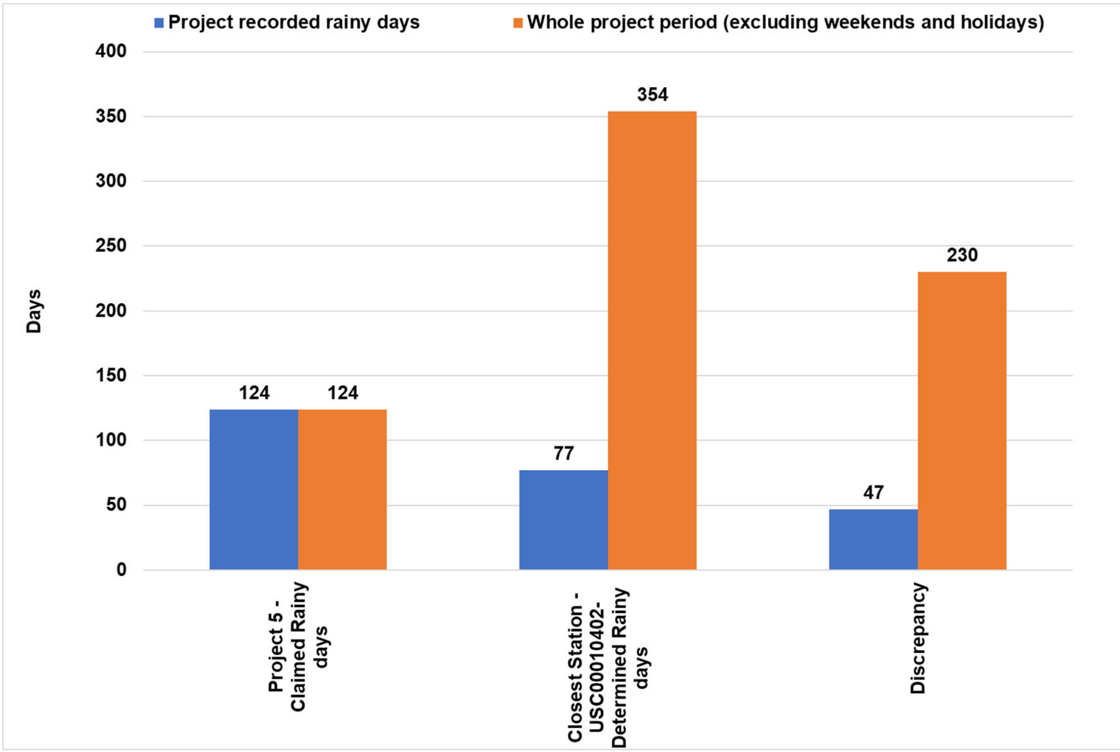



**Figure 5-47. Rainy days as claimed by Project 5, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

Figure 5-48 depicts the daily rainfall distribution based on the study's weather conditions. There are 37 days (4+0+33) with rainfall greater than 0.2 in.  for the 77 days determined from the station that matched the reported rainy days by the contractor, but a total of 184 (23+11+150) days based on the USC00010402 rainfall data. The contractor's failure to report on numerous rainy days and failure to work for other reasons contributed to the large disparity.

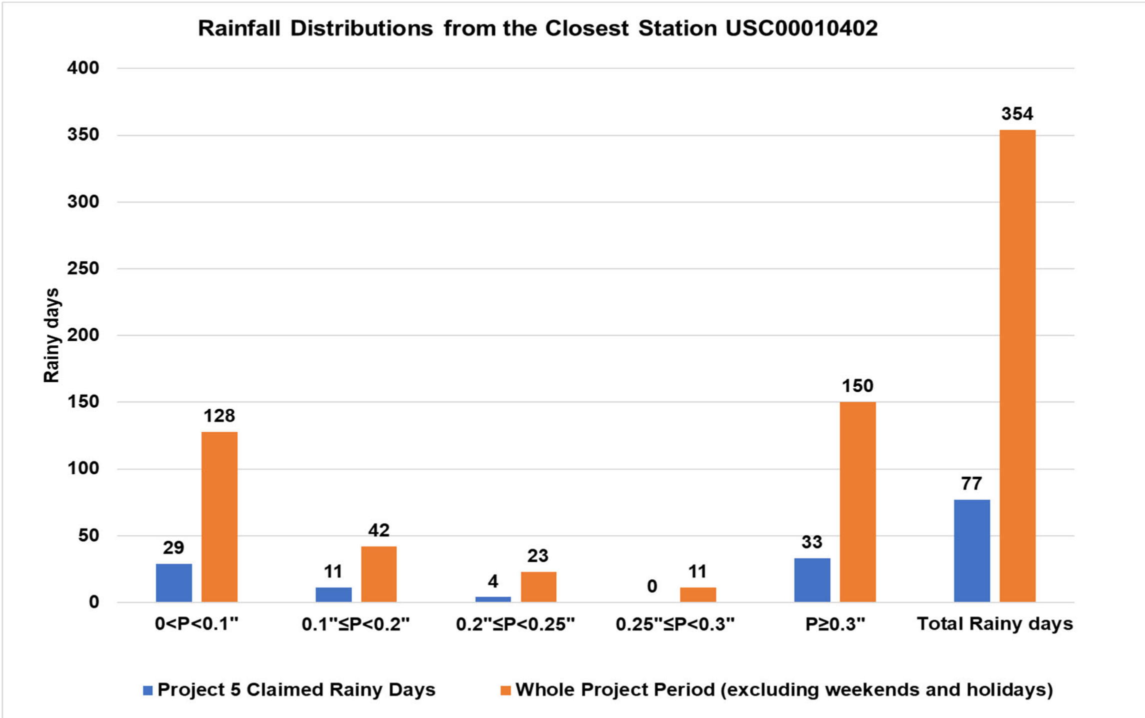



**Figure 5-48. Rainfall distributions of the closest station during the project claimed rainy days and the whole project period (excluding weekends and holidays).**

The contractor's records indicate 4 days marked as wet days. As a result, a total of 128 non-working days (as depicted in Figure 5-49) have been recorded in this project due to various factors, including rain and wet conditions. However, analysis of climate data from station USC00010402 reveals 95 non-working days NWDs. This calculation includes 78 rainy days and 17 days with precipitation exceeding 0.75 in. during the contractor's reported period affected by rain or wet conditions, resulting in a 33-day discrepancy.

When we exclude the contractor's reported rainy and wet days from our analysis of precipitation exceeding 0.75 in. using data from the nearest weather stations, we identify 86 additional non-working days. Consequently, a total of 440 non-working days (354 rainy days + 86 days due to P>0.75 in.) were determined from the weather station data. This differs significantly from the 45 days claimed by the contractor, resulting in a notable 312-day discrepancy, as shown in Figure 5-49.

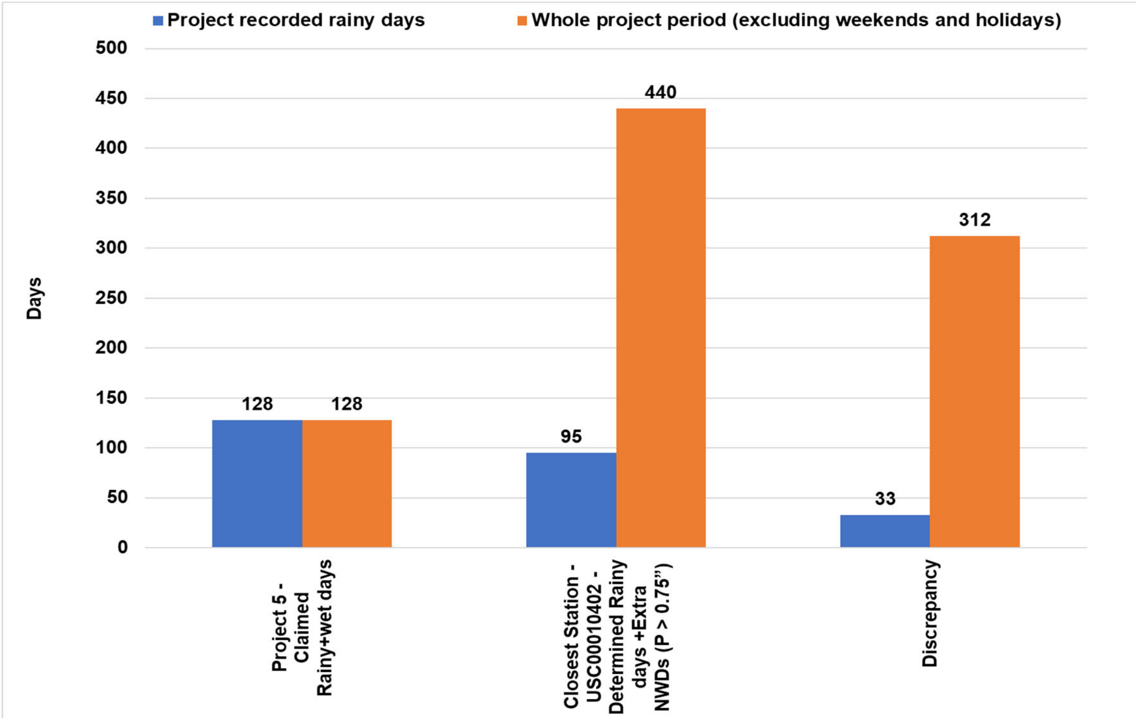



**Figure 5-49. Rainy and wet days as claimed by Project 5, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

Figure 5-50 illustrates the daily distribution of rainfall and the disparities evident when considering or disregarding the project's records of rainy and wet days. It's evident that for precipitation exceeding 0.2 in., 38 days (comprising 4, 0, and 34 days) were identified in the project's daily records, whereas the weather station USC00010402 data revealed 184 days (consisting of 23, 11, and 150 days). Throughout the project's timeline, the nearest weather station's data identified 17 non-working days due to recorded precipitation exceeding 0.75 in. based on the contractor's reported days. However, upon excluding the contractor's reports of rainy and wet days, we found an additional 86 non-working days with precipitation exceeding 0.75 in. from the weather station's climate data, as depicted in Figure 5-50. This discrepancy suggests that there were more days with heavy rainfall (P>0.75 in.) when the contractor didn't work due to other reasons, which went unreported by the contractor.

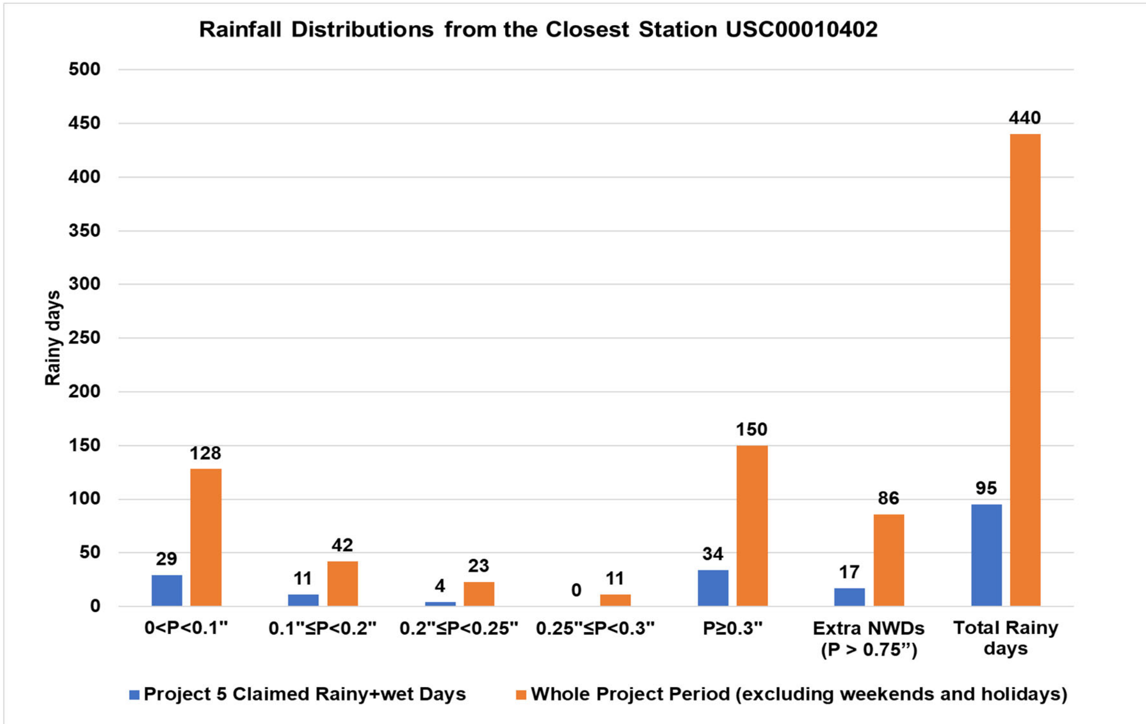



**Figure 5-50. Rainfall distributions of the closest station during the project claimed rainy + wet days and the whole project period (excluding weekends and holidays) + extra NWDs (P>0.75").**

### *Air temperature*

In Project 5, the contractor marked 100 days as "Too cold," signifying that low air temperatures were a hindrance to construction operations, and they designated these days as non-workdays throughout the project's timeline. However, upon reviewing data from the nearest climate station, only 8 days were validated as non-workdays due to a daily mean air temperature lower than 40°F (referred to as $T_{mean}$ in Figure 5-51).

However, when examining data from USC00010402, the closest station, it was determined that a total of 23 days experienced low daily mean air temperatures ($T_{mean}$ <40°F) during the project's duration. This resulted in a substantial difference of -77 days when compared to the contractor's reported "Too cold" days. The contractor's omission to report numerous cold days and their failure to work for other reasons contributed significantly to this substantial gap. Additionally, the disparity may be attributed to the consideration of minimum air temperature instead of the mean daily air temperature for classifying NWDs due to air temperature.

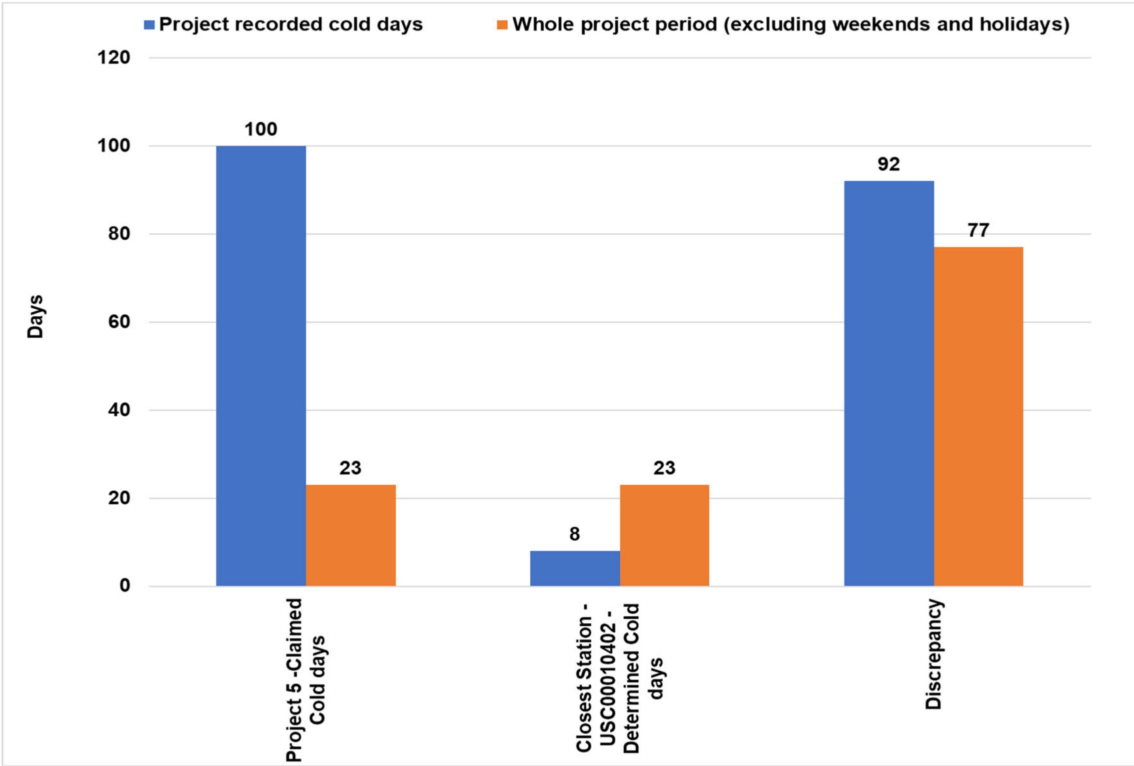



**Figure 5-51. Low temperature (cold) days as claimed by Project 4, determined using rainfall data from the nearest station within the project's duration (excluding weekends and holidays), along with the observed discrepancies.**

The days categorized as non-workdays NWDs due to cold conditions were further classified using the study's criteria for daily mean temperature, as depicted in Figure 5-52. Based on the project's daily records, a total of 6 NWDs were identified when the mean air temperature dropped below 40°F but remained above 35°F. In contrast, the station's climate data indicated 18 days that met these temperature criteria.

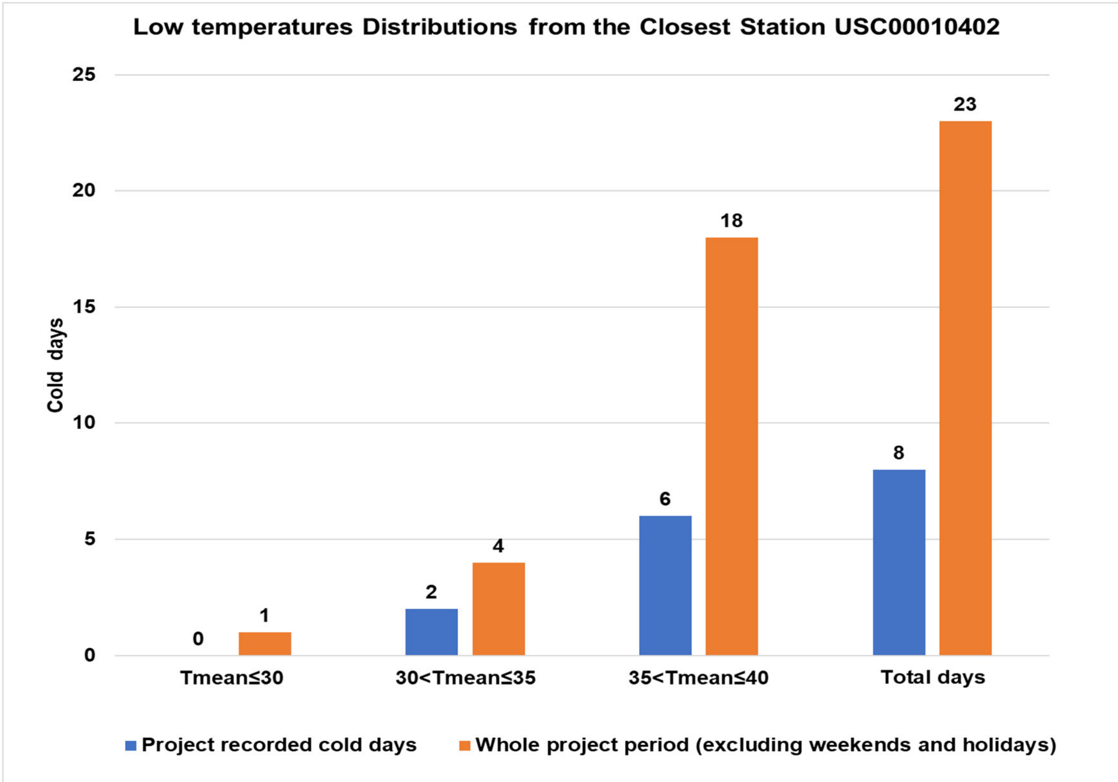



**Figure 5-52. Low temperature distributions of the closest station during the project claimed cold days and the whole project period (excluding weekends and holidays).**

# CHAPTER 6. SUMMARY AND CONCLUSIONS

## 6.1 SUMMARY

This project aimed to develop a more robust method for determining AAWDs across the five ALDOT Regions, facilitating accurate contract duration calculations for highway construction projects. The project used long-term local climate data and advanced data processing techniques, resulting in a valuable Excel-based tool for ALDOT engineers. The key project objective of the study was introduced in Chapter 1, which is to develop a tool that aims in the optimization of highway contract planning by considering adverse weather conditions. This method would not only utilize accurate long-term rainfall and temperature databases over 10 or more years for project regions and tasks but also allow ALDOT engineers to update AAWDs with up-to-date data in the future, thus improving project duration predictions.

The literature review in Chapter 2 focused on the gathering and analysis of information related to 1) the consequences of the impact of weather on construction operations, 2) how others previous studies analyzed the contract time determination systems, and 3) manuals, guidance and tools developed by other US states to take into account the effects of unpredictable weather influence in the highway projects. "Development of Working Day Weather Charts for Transportation Construction in South Dakota" study was reviewed in depth such as key findings and methodology, which is directly and closely related to this research. The variances in AAWDs from two previous ALDOT analyses, conducted in 1989 and 2003, were reviewed to highlight the influences of temperature and rainfall patterns in Alabama's various regions. Methods adopted by other DOT agencies in the U.S. to mitigate weather-related delays in construction was also evaluated, e.g., the regression equation developed by Woods et al. (2006) for TxDOT, which accounts for factors like monthly precipitation and temperature.

A survey was conducted among 50 DOTs as well as the District of Columbia DOT. The survey's aim was to gather insights on the current methodologies and practices employed by DOT engineers in evaluating non-working days attributed to adverse weather conditions. Out of the 51 DOT agencies contacted, 30 responded, giving a response rate of 51%. The survey was created to study different factors related to the influence of adverse weather in roadway construction and they can be summarized as follow:

1. The type of contract and delay factors identified by DOTs.
2. The existing guidelines followed by state DOTs in determining non-working days due to adverse weather.
3. Criteria values used by DOTs to define non-working days.

4. Additional tools and parameters used by DOTs to evaluate non-working days due to weather.
5. The perception of DOTs on weather's influence on construction activities.
6. The monitoring of the cost implications of adverse weather by DOT agencies.

The project's methodologies, elaborating on the objectives, purposes, tools, and sources used in the research in determining AAWDs for highway projects in the five ALDOT Regions were presented in Chapter 4. A key decision taken in this study that come from previous ALDOT studies was the decision to use a broader range of climate stations, expanding from the five climate stations previously used in 1989 and 2003 studies to 88 weather stations: 83 in Alabama, 2 from Georgia and 3 from Mississippi. This was to ensure more accurate results and a better representation of each ALDOT Region's weather patterns. Weather data with at least 10 years of valid precipitation and air temperature measurements were sourced from the National Centers for Environmental Information (NCEI-NOAA), primarily from the Global Summary of the Day (GSOD) and the Global Historical Climatology Network (GHCN) databases. The data collected for this study covered records from 1900 through 2022.

Based on the insights of the state-of-practice survey conducted among fifty DOTs, 15 adverse-weather threshold conditions (Table 4-3) were defined and tested to determine AAWDs in Alabama. The daily precipitation thresholds are greater than 0 in. (any amount of rainfall), 0.1 in., 0.2 in., 0.25 in. (a quarter of inch), and 0.3 in.; and daily mean air temperature is less than 30, 35, and 40 $^{o}$F. From the preliminary results presented to ALDOT research advisory committee, it was decided that the adverse-weather threshold condition 13 or P13 should be used to derive AAWD results presented for the study and classifies non-workdays as those on which daily precipitation are greater than 0.2 in. and/or daily mean air temperature is less than 40°F.

The research team developed several Excel spreadsheet tools to process the downloaded weather data in two different formats (from GSOD and GHCN database). The tool first counts for weekends and Alabama legal holidays (Table 4-2) and then adverse weather days as non-workdays in each month. It addressed the nuances of "Fixed" and "Moveable" holidays, including the recognition of Juneteenth as a federal holiday in 2021. It derives various attributes (Table 4-4) from weather data, e.g., monthly non-workdays and AWDs, days with missing all the data or miss rainfall data, and large rainfall days (>0.75 in), etc. Direct results from weather data analysis at five representative stations (one for each ALDOT Region) were presented first, and then AAWDs were determined and presented from monthly AWDs over 10 or more years of weather data. AAWDs in each ALDOT Region were derived from all weather stations inside each Region (Table 4-17). There are 23, 19, 14, 24, and 8 weather stations were used for North Region, West Central Region, East Central Region, Southeast Region, and Southwest Region, respectively. The monthly AAWDs for each of 88 weather stations were determined first using 10 to 122 years of available daily precipitation and mean air temperature data. Average values and statistical metrics of these monthly AAWDs from all stations were then determined for each Region to generate the final project results by Regions or climate zones. To further improve the utility for ALDOT engineers, specific tools and guidelines for future use were developed for easily updating AAWDs for the weather stations used in this study and determining AAWDs for new stations nearby to any future projects.

The sensitivity analyses were performed to evaluate the influence of adverse weather conditions on AAWDs, providing valuable insights. The analysis involved assessing variations by maintaining constant values for specific weather parameters: daily precipitation exceeding 0.2 in. by changing temperature from 30, 35, to 40 °F, and daily mean air temperature below 40 °F by changing daily precipitation from 0 in, 0.1 in, 0.2 in, 0.25 in, and 0.3 in.

A validation process was presented in Chapter 5 and to validate the robustness and precision of the developed AAWD tool by comparing with the daily project records provided by ALDOT from five completed representative ALDOT projects (each representing a different region). These projects were chosen to account for regional climatic disparities, especially between the southern and northern zones. The process followed for the verification of the developed tools can be summarized as follows:

- **Weather Data:** For each project's geographical location, weather-related data was extracted from the nearest climate station from NOAA-GHCN database.
- **Data processing using Excel Spreadsheet:** The closest weather station data was processed to determine monthly Available Workdays (AWDs) and Non-workdays (NWDs) for each project duration using the developed VBA-coded Excel spreadsheet.
- **Comparative Assessment:** The daily project record on which the contractors claimed workdays and non-workdays for various condition, including weather related, were set side by side with the corresponding weather information derived from the closest stations data.
- **Precision Evaluation:** The spreadsheet calculated AWDs and NWDs were compared with those reported in the projects' logs.
- **Calibration Consideration:** Any discernable discrepancies between the spreadsheet-generated data and the project logs were described and analyzed (presented as various graphs for easy understanding and comparison). This was done to determine if there is a need for calibration adjustments in the AAWD tool.

## 6.2 Conclusions

Based on the state-of-practice survey (30 DOTs responded), the completion-date and calendar-day contracts were primarily used by DOTs and the construction type is a critical factor in determining project duration. While 60% of the responding states have guidelines (like tools, charts, or contract language) in place for identifying non-working days due to adverse weather, 40% lack such guidance. The material shortage, poor project management, and adverse weather conditions are the top three contributors to delays in DOTs projects. One quarter or more (≥ 25%) of respondents ranked these three factors as the highest contributor (Figure 3-4). Work delays and decreased production are highlighted as significant influences by adverse weather conditions. Most of the DOTs rely on working-day weather charts, supplemented by the expertise of the project manager, to do the contract planning. The survey also finds various criteria and thresholds utilized by different states to classify days as non-working due to adverse weather conditions. One outstanding finding from the survey was that, despite recognizing the importance of weather conditions, all 17 states with guidelines to determine non-working days due to adverse weather do not actively track the cost implications of these weather-related delays.

The project has successfully achieved its primary objective of developing a more robust and easily updatable method for determining Average Available Workdays or AAWDs for highway construction projects in five ALDOT Regions. By leveraging long-term local climate data and advanced data processing techniques, we have provided ALDOT engineers with a valuable tool for accurately assessing contract durations while accounting for adverse weather conditions, weekends, and legal holidays.

One notable improvement over previous ALDOT studies was the increased number of representative climate stations, enhancing the accuracy of AAWD calculations. A total of 88 GSOD or GHCN stations in Alabama and adjacent states (MS/GA) from the National Centers for Environmental Information (NCEI-NOAA) databases were used. Up to 121 years of weather data for a weather station was used to determine AWWDs and on average 42 years of the weather data were used per station. The VBA-powered Excel spreadsheets were developed and tested to classify weather data and distinguish between workdays and non-workdays, considering weekends, legal holidays, and adverse weather conditions. The adverse-weather threshold condition for the final project results was defined as daily mean precipitation greater than 0.2 in. and daily mean temperature less than 40°F as non-workdays.

Average AAWDs from January to December for five ALDOT Regions were determined and presented in Table 4-29. Monthly AAWDs range from 9 days in January in the North Region to a maximum of 19 days in August to October in each ALDOT Region. The standard deviations of average AAWDs from all stations in a Region are small and from 0 to 2 days. Most warmer months

(April to October) have almost the same AAWDs because of 0 day for standard deviation, but winter months have large variations on AAWDs. This means AAWDs in summer/fall months can be determined from one weather station (e.g., with long data record and little missing data) in the Region, which is what ALDOT did in two previous studies (one representative station for each Region). For winter months, it is necessary to use local weather data to determine AAWDs.

Annual AAWDs (Table 4-29) are 185, 192, 193, 198, and 199 days (51–55% of 365 days) for North Region, West Central Region, East Central Region, Southeast Region, and Southwest Region, respectively. It was further found that AAWDs can be grouped into three climate zones in Alabama: North Region, Central Regions, and South Regions with annual AWWDs of 185, 193, and 200 days (Table 4-30), respectively. These annual AWWDs are eight (Divisions 1 and 2), five or seven (Division 3 to 5), and two–five (Divisions 6 to 9) more days when comparing with ALDOT 1998 and 2003 studies (Table 2-1).

The maximum difference of AWDs over available years in summer is 13 days (2.5 weeks) and 20 days (4 weeks) in winter months. Therefore, monthly AWDs can vary significantly from one year to another, depending on precipitation and air temperature. For construction project management and planning across diverse Alabama climate zones, using AAWDs by ALDOT Regions (Table 4-29) or three climate zones (Table 4-30) is useful but may not be accurate for some unnormal dry/wet and cold/warm years. It is recommended using VBA-based tools developed for this project to determine monthly AWDs during the project period. This approach was used for the verification process (Chapter 5) over the project duration.

A verification process was conducted and completed to confirm and ensure the accuracy of the tool created for AAWD determination. Daily records of five completed representative ALDOT projects, each from a different ALDOT Region, were analyzed and compared with AWDs and NWDs determined from the nearest weather station so that it confirmed the precision of the calculated AAWDs and indicated that no calibration adjustments were required. When comparing contractor recorded non-workdays due to the study criteria (adverse weather, i.e., rain, too cold, or wet conditions, weekends, and state holidays) with non-workdays derived from weather data from the closest station on the same days, there are small discrepancies. Large discrepancies exist over the whole project period because there were a large number of non-workdays due to other factors non-related to the study criteria, such as utility coordination, punch items, and others; for those days, contactors did not record any adverse weather conditions so that no data to compare with derived information from the closest weather station.  The project durations were typically much longer than required workdays to complete construction tasks because many non-workdays were not due to adverse weather conditions but other factors (e.g., utility conflicts, curing time, punch list, department action, waiting on final inspections, cleanup work, contractor vacation, waiting on

ALDOT decision, etc.). For rainy days, contractors did not record any rainfall depths, and it seemed any amounts of rainfall (>0 in) were considered non-workdays due to rainfall.

For ALDOT to perform efficient contract duration calculations, aiding in project planning and decision-making, the Excel-based tools, combined with climate data, and guidelines to determine and update AAWDs from many weather stations in Alabama are provided to ALDOT as computer files with the summary information given in Appendix B. This enhances ALDOT's capacity to manage highway construction projects effectively across diverse weather conditions and Regions while ensuring the accuracy of AAWD calculations through a rigorous verification process.

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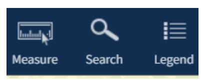
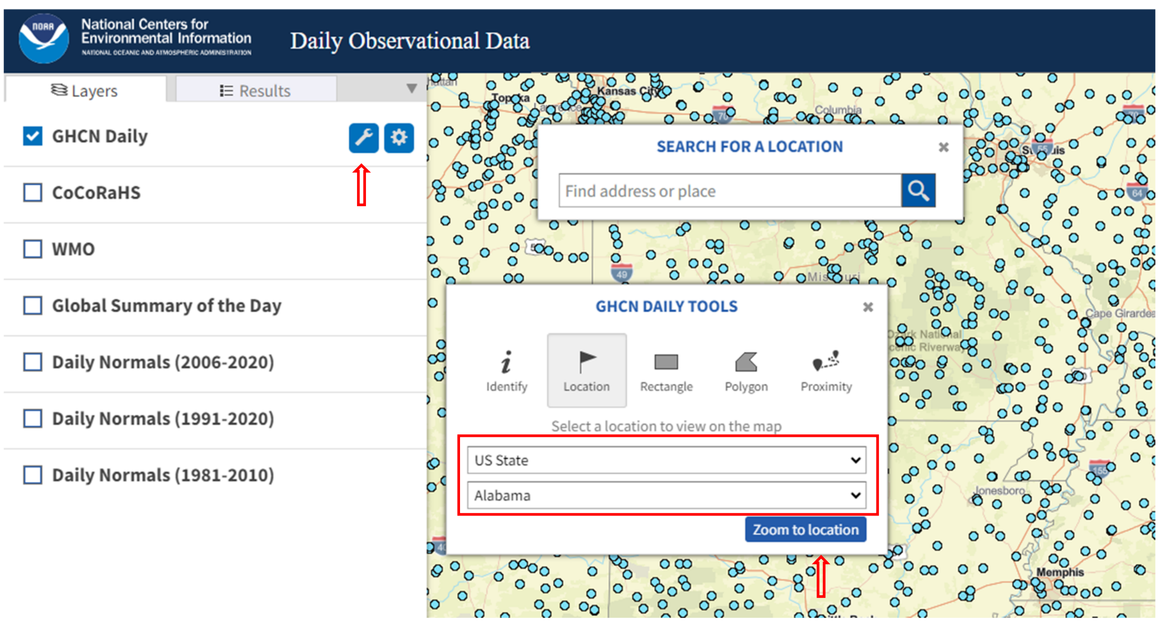
# APPENDIX A: HOW TO OBTAIN WEATHER DATA FROM THE GLOBAL HISTORICAL CLIMATOLOGY NETWORK (GHCN) DATABASE

The steps to download the data from the GHCN database were the following:

1. Go to the NOAA website. National Centers for Environmental Information (NCEI) (https://www.ncei.noaa.gov/)
2. From the menu bar select “Services” and from the drop-down menu select the option “Maps”
3. From the map viewers option go to the “Climate Monitoring” section and select the “Daily” from the Observations options. The direct link to “Daily Observation Data” is https://www.ncei.noaa.gov/maps/daily/. The "SEARCH FOR A LOCATION” window shows automatically on the map and can be activated by clicking on “Search” on the top right corner of the  map.

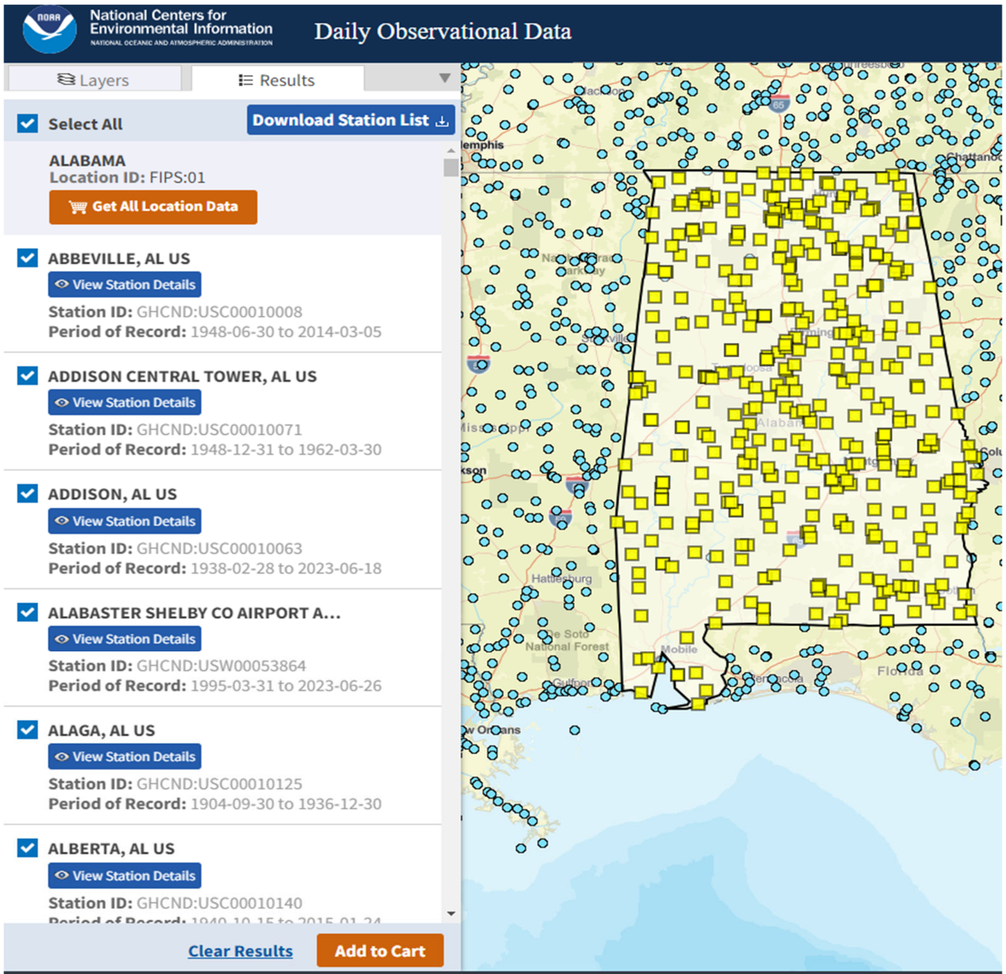






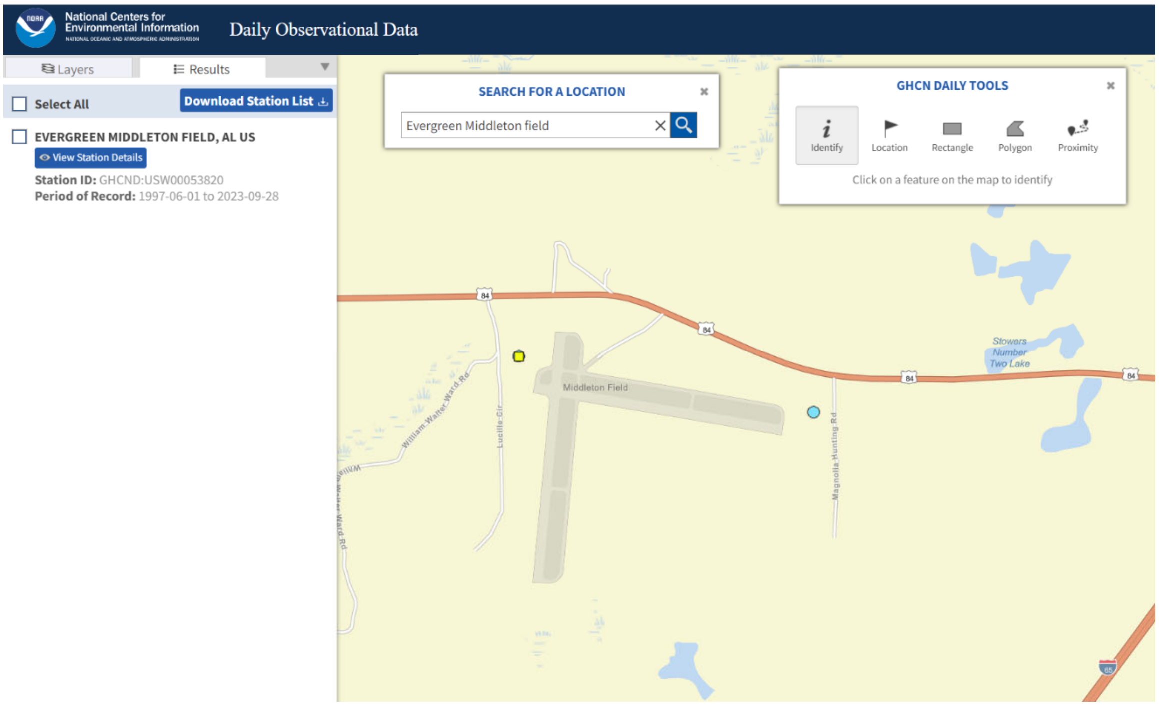
4. Then select the “GHCN Daily” layer and press on the wrench symbol that will display the “GHCN DAILY TOOLS” window. Select to look up the data by “Location” and then indicate the type as by “US State” and proceed to select the state, e.g., Alabama, and click on “Zoom to location” to download all available stations in a state. On the left panel, it lists all selected stations showing Station Name, Station ID, and Period of Record.

The period of record is an important information for one to make the decision whether the data covers the construction project duration or satisfies the study criteria (e.g., > 10 years) so that the station can be used for the study or not.



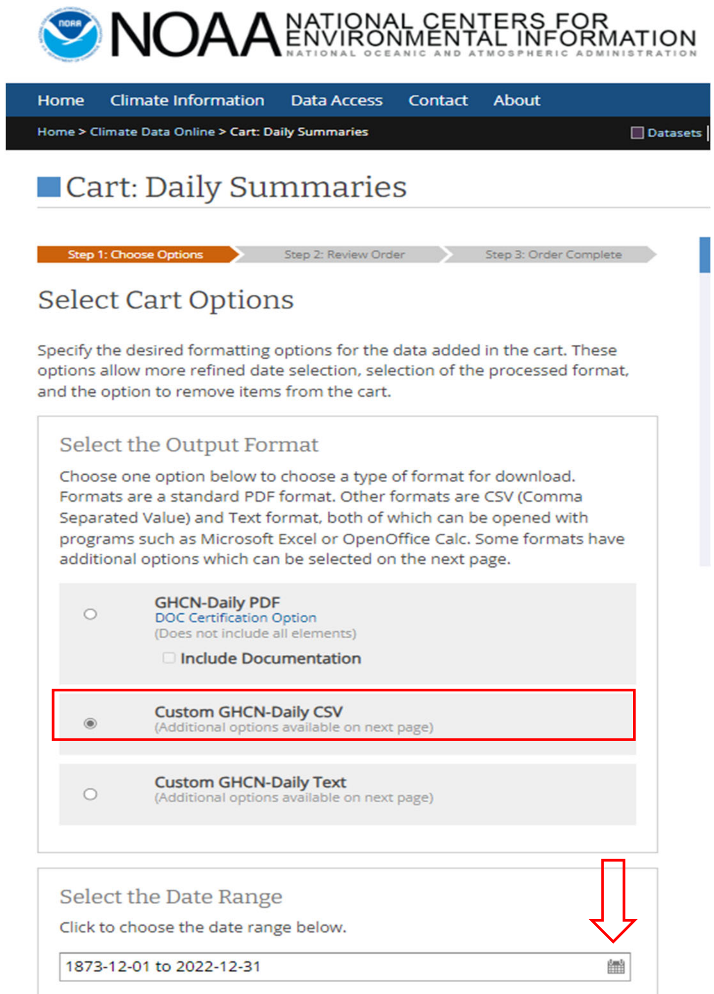

5. When a user wants to download the data for a specific station, under "SEARCH FOR A LOCATION" window, one can also type the location/city name (e.g., type Troy to find out any GHCN stations near Troy, AL) or station name, e.g., Talladega, to show all options related to Talladega, select the one desired station, e.g., Talladega, AL, USA, to zoom into the location and show GHCN stations nearby, and then use Identify tool from "GHCN DAILY TOOLS" to select a specific weather station. For example, one tries to find "EVERGREEN MIDDLETON FIELD, AL US" station, when one types "Evergreen" or "Evergreen Middleton", the search will not show any related location in Alabama, until one types "Evergreen Middleton Field", it shows two related locations: Middleton Field, Evergreen, AL, USA and Middleton Field, AL, USA. Select either one will show Middleton

Field with two GHCN stations. Using Identify tool to select one of them, only one option is an active station having the data from 6/1/1997 to 9/28/2023, Which can be used for the study to determine AAWDs.

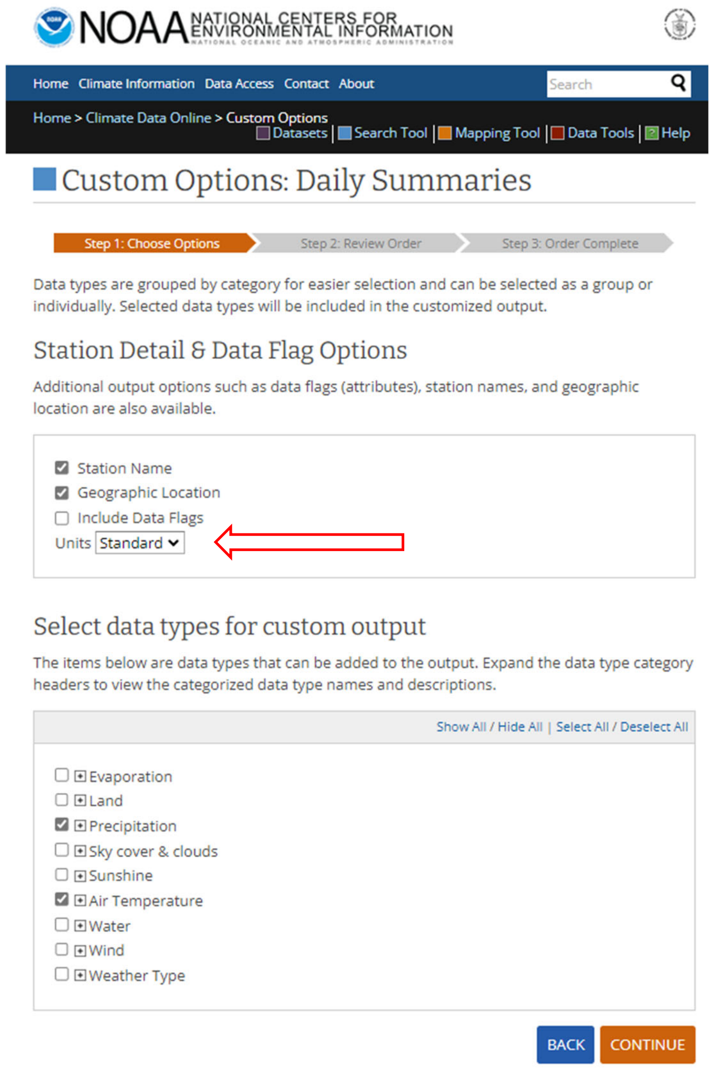



6. A map showing the available weather stations will be displayed and the specific weather station(s) that satisfies the study criteria can be selected. Once selected the station(s) proceed to click on “Add to Cart” on the left bottom corner of the screen.

7. In the cart option select the output format as “Custom GHCN-Daily CSV” and then indicate date range of the desired years of data (click/use the calendar defining the start and end date, month, and year) and then click on the “Continue” button.

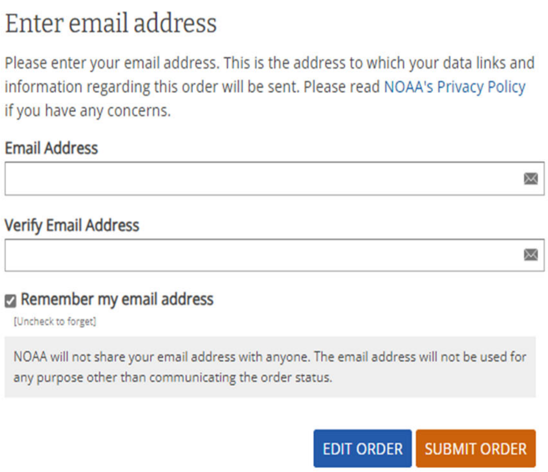



8. Custom options will be presented, as for the *Station Detail & Data Flag Options* select the “Station Name”, “Geographic Location” and for “Standard” for Units; the data type for output “Precipitation” and “Air Temperature” categories must be selected, then click on the “Continue” button.

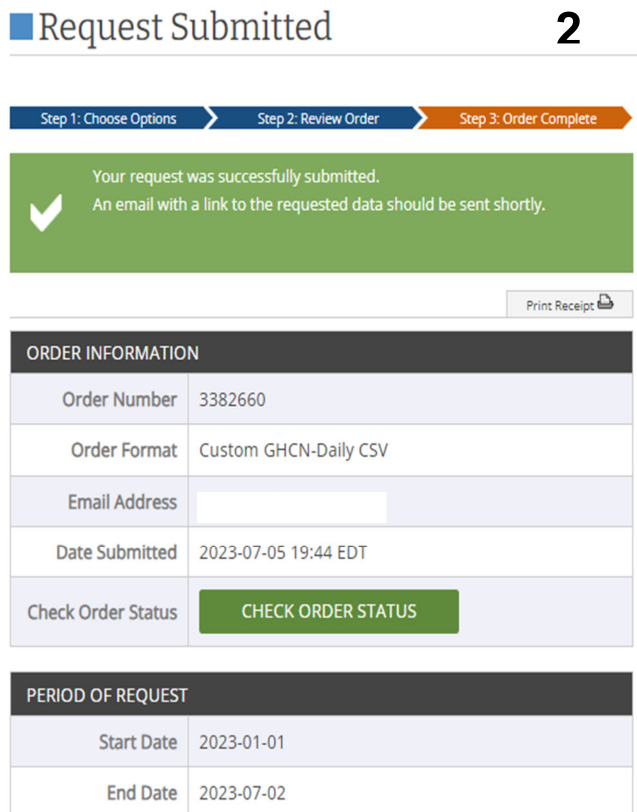



9. An email address will be asked to send the requested data, input and confirm the email address, and then click on “Submit Order”. First an email including the order number will be sent, then a second email will be sent indicating that the order has been processed, and this last email will contain the hyperlinked file from where the data will be downloaded in an Excel csv File (order-number.csv). In this study, the csv file by the order number is renamed as “station-number.csv”, e.g., USC00018024.csv for Talladega.

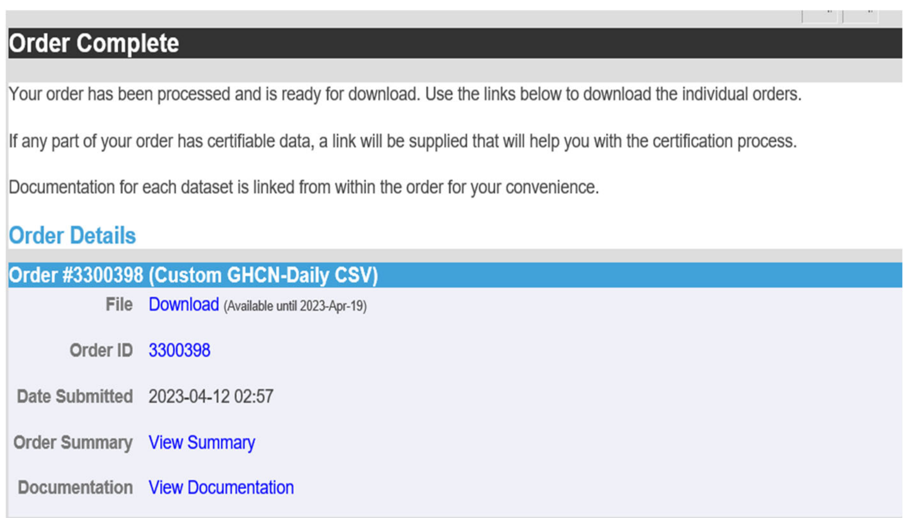
1


Enter email address
Please enter your email address. This is the address to which your data links and information regarding this order will be sent. Please read NOAA's Privacy Policy if you have any concerns.
Email Address
Verify Email Address
Remember my email address
[Uncheck to forget]
NOAA will not share your email address with anyone. The email address will not be used for any purpose other than communicating the order status.
EDIT ORDER
SUBMIT ORDER

2


Request Submitted
Step 1: Choose Options
Step 2: Review Order
Step 3: Order Complete
Your request was successfully submitted.
An email with a link to the requested data should be sent shortly.
Print Receipt
ORDER INFORMATION
Order Number 3382660
Order Format Custom GHCN-Daily CSV
Email Address
Date Submitted 2023-07-05 19:44 EDT
Check Order Status
CHECK ORDER STATUS
PERIOD OF REQUEST
Start Date 2023-01-01
End Date 2023-07-02

3


Order Complete
Your order has been processed and is ready for download. Use the links below to download the individual orders.
If any part of your order has certifiable data, a link will be supplied that will help you with the certification process.
Documentation for each dataset is linked from within the order for your convenience.
Order Details
Order #3300398 (Custom GHCN-Daily CSV)
File Download (Available until 2023-Apr-19)
Order ID 3300398
Date Submitted 2023-04-12 02:57
Order Summary View Summary
Documentation View Documentation

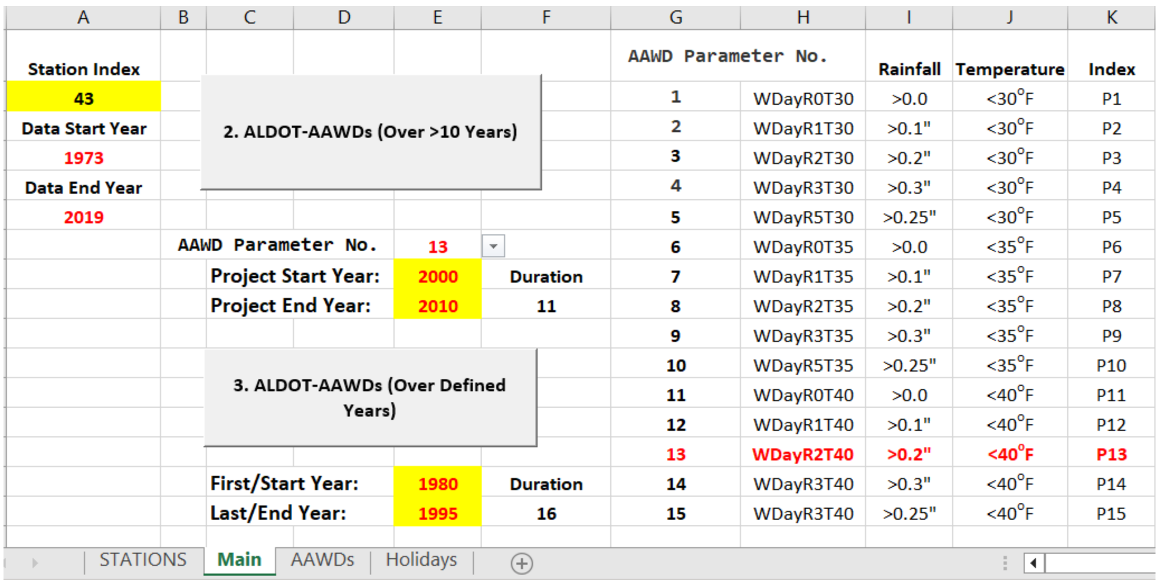
# APPENDIX B: ELECTRONIC FILES PROVIDED FOR ALDOT

A data folder will be provided to ALDOT for its future use. The folder name is AAWDs-ALDOT with three sub-folders: (1) Report, (2) ResultsFiles, and (3) AWWDs-Update. The Report sub-folder will have the project report PDF file and a few training videos recorded for ALDOT. The videos include: (1) GHCN.mp4 to show ALDOT engineers how to download weather data from NOAA website following steps in Appendix A. (2) AAWDsResults.mp4 to show ALDOT engineers how to generate monthly AAWDs for one of 88 stations or one of ALDOT Region or Alabama climate zone for a selected threshold condition (P1-P15) of adverse weather. (3) FutureAWDs.mp4 to expand weather data and redetermine AWDs and AAWDs for an existing station (72 GHCN stations) or a new station near a future construction project site.

The ResultsFiles sub-folder includes the derived results of monthly available workdays or AWDs for 88 GSOD or GHCN weather stations (Figure 4-28, from Table 4-12 to Table 4-16) used in this study. These 88 data files are saved in its subfolder “Res”. Each file includes monthly AWDs from January to December derived from 15 threshold conditions as adverse weather conditions (non-workdays) (defined in Table 4-3) and corresponding attribute information defined in Table 4-4. Three spreadsheets with VBA codes are provided to ALDOT if they want to view monthly average available workdays (AAWDs) for any of these 88 stations, for one of five ALDOT Regions, and for one of three Alabama climate zones (north, central, and south) for one of 15 threshold conditions. This is because the report only presents the derived results for parameter 13 (P>0.2” and T<40 $^{o}$F).

The first spreadsheet in the sub-folder is AAWDs_ALDOT.xlsm. It contains four worksheets: (1) STATIONS lists the information for 88 weather stations. (2) Main worksheet is shown in Figure B.1, (3) AAWDs worksheet will display results for ALDOT to review, and (4) Holidays worksheet lists ALDOT state holiday information used in the project to determine non-workdays. On the “Main” worksheet, one can select one station out of 88 weather stations (See more information in the STATION worksheet), e.g., station 43 for Huntsville International Airport, then it shows the start year and end year with weather data. Using click button “2. ALDOT-AAWDs (Over >10 year)”, it will determine AAWDs for 15 parameters and corresponding statistical summaries (standard deviation, minimum and maximum AWDs, 80$^{th}$ percentile of AWDs, and skewness coefficients from all AWDs over 10 or more years of available weather data years) for that station. One can select the AAWD parameter No., e.g., 13, and a construction project start year and end year (e.g., 2000 to 2010) to allow VAB code to save results in the AAWDs worksheet. The project start and end year must be between the data start and end year. It allows a project duration up to 20 years. The AAWDs worksheet shows those results mentioned above and also plots monthly AWDs over the project duration (one graph for each five-year period, Figure B.2).

The click button 2 will use VBA code to determine AAWDs over all data years, e.g., 47 years for Huntsville. The click button “3. ALDOT-AAWDs (over Defined Years)” will determine AAWDs over the selected period by inputting the first/start and last/end year, e.g., one wants to determine AAWDs over 21 years from 1980 to 1995 (see Figure B.1). The corresponding results of AAWDs are also saved in the AAWDs worksheet. Those AWDs for the construction project period are still there if the click button 2 is used before. AAWD results for all 15 threshold parameters are also saved as Excel spreadsheet files in ResultsFiles folder, e.g., 72323003856AAWD.xlsx for AAWDs in Huntsville using all 47 years of available climate data, and 72323003856AAWD1980-1995.xlsx for AAWDs derived from 1980 to 1995 climate data.



| A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|
| Station Index | | | | | | AAWD Parameter No. | | Rainfall | Temperature | Index |
| 43 | | 2. ALDOT-AAWDs (Over >10 Years) | | | | 1 | WDayR0T30 | >0.0 | <30°F | P1 |
| Data Start Year | | | | | | 2 | WDayR1T30 | >0.1" | <30°F | P2 |
| 1973 | | | | | | 3 | WDayR2T30 | >0.2" | <30°F | P3 |
| Data End Year | | | | | | 4 | WDayR3T30 | >0.3" | <30°F | P4 |
| 2019 | | | | | | 5 | WDayR5T30 | >0.25" | <30°F | P5 |
| | AAWD Parameter No. | | | 13 | | 6 | WDayR0T35 | >0.0 | <35°F | P6 |
| | | Project Start Year: | | 2000 | Duration | 7 | WDayR1T35 | >0.1" | <35°F | P7 |
| | | Project End Year: | | 2010 | 11 | 8 | WDayR2T35 | >0.2" | <35°F | P8 |
| | | | | | | 9 | WDayR3T35 | >0.3" | <35°F | P9 |
| | | 3. ALDOT-AAWDs (Over Defined Years) | | | | 10 | WDayR5T35 | >0.25" | <35°F | P10 |
| | | | | | | 11 | WDayR0T40 | >0.0 | <40°F | P11 |
| | | | | | | 12 | WDayR1T40 | >0.1" | <40°F | P12 |
| | | | | | | 13 | WDayR2T40 | >0.2" | <40°F | P13 |
| | | First/Start Year: | | 1980 | Duration | 14 | WDayR3T40 | >0.3" | <40°F | P14 |
| | | Last/End Year: | | 1995 | 16 | 15 | WDayR3T40 | >0.25" | <40°F | P15 |

STATIONS | Main | AAWDs | Holidays

**Figure B.1 The worksheet “Main” for AAWDs_ALDOT.xlsm spreadsheet.**

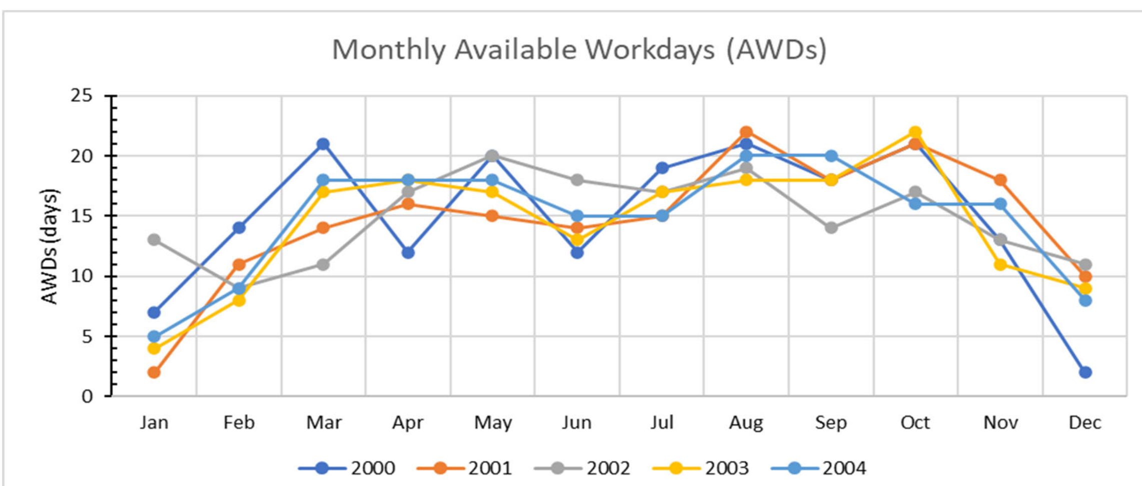



**Figure B.2 Example plot of AWDs during the construction project period in the AAWDs worksheet.**

The second and third optional spreadsheets in ResultsFiles sub-folder for ALDOT to use are: Results_Analysis_ByRegion.xlsm (Figure B.3) and Results_Analysis_ByZone.xlsm. In this report, AAWDs for the threshold condition P13, which is daily rainfall greater than 0.2 in. and daily mean air temperature less than 40 °F as adverse weather conditions for non-workdays, were determined for each of five ALDOT Regions (Table 4-29) and for three Alabama climate zones (Table 4-30). If ALDOT is interested in finding AWWDs for other 14 threshold conditions defined in Table 4-3, one can use one of these two spreadsheets to get AAWDs by Region or Zone. The spreadsheet is password protected, and ALDOT only needs to enter the necessary information or input data to get results: select start station number by ALDOT Region (see the information below the click button) and AAWD parameter number (1–15), then click the button to run the VBA program. Two message boxes will appear to indicate “The program is successfully run” and “The result file is: Region-SW-AAWD-P12.xlsx” (example results for Southwest or SW Region for parameter 12). One can then open and view the result file, which will be discussed in the training video. The spreadsheet to output AAWDs by climate zone is almost the same as the one by ALDOT Region as shown in Figure B.3.

| A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|
| | | By station (1), region (2), or All (3, 4) | | | Start Station | AAWD Partameter No. | AAWD Partameter No. | | Rainfall | Temperature |
| | | 2 | | | 62 | 13 | 1 | WDayR0T30 | >0.0 | <30°F |
| Index | Region | Stations | Longitude | Latitude | End Station | Region | 2 | WDayR1T30 | >0.1" | <30°F |
| 1 | EC | 72228013876 | -86.74490 | 33.56545 | 69 | | 3 | WDayR2T30 | >0.2" | <30°F |
| 2 | EC | 72228713871 | -85.84788 | 33.59043 | (see H26 -I30) | | 4 | WDayR3T30 | >0.3" | <30°F |
| 3 | EC | 72230053864 | -86.78178 | 33.17835 | | | 5 | **WDayR5T30** | >0.25" | <30°F |
| 4 | EC | 99999973803 | -86.05730 | 33.57210 | | | 6 | WDayR0T35 | >0.0 | <35°F |
| 5 | EC | USC00010764 | -87.00770 | 33.39520 | | | 7 | WDayR1T35 | >0.1" | <35°F |
| 6 | EC | USC00011288 | -86.74550 | 33.09440 | | | 8 | WDayR2T35 | >0.2" | <35°F |
| 7 | EC | USC00011620 | -86.34310 | 33.28500 | | | 9 | WDayR3T35 | >0.3" | <35°F |
| 8 | EC | USC00012350 | -87.05861 | 33.74778 | | | 10 | **WDayR5T35** | >0.25" | <35°F |
| 9 | EC | USC00013775 | -85.60944 | 33.64347 | | | 11 | WDayR0T40 | >0.0 | <40°F |
| 10 | EC | USC00014209 | -85.78115 | 33.82585 | | | 12 | WDayR1T40 | >0.1" | <40°F |
| 11 | EC | USC00017020 | -86.17580 | 32.87110 | | | 13 | WDayR2T40 | >0.2" | <40°F |
| 12 | EC | USC00017999 | -86.21140 | 33.20530 | | | 14 | WDayR3T40 | >0.3" | <40°F |
| 13 | EC | USC00018024 | -86.13500 | 33.41630 | | | 15 | **WDayR5T40** | >0.25" | <40°F |
| 14 | EC | USW00013876 | -86.74490 | 33.56545 | | | | | | |
| 15 | Nor | 72227999999 | -86.94500 | 34.65300 | | | | | | |
| 16 | Nor | 72228599999 | -86.08300 | 33.96700 | | | | | | |
| 17 | Nor | 72323003856 | -86.78615 | 34.64406 | | | | | | |
| 18 | Nor | 72323513896 | -87.59971 | 34.74388 | | | ALDOT-AAWDs-By Region | | | |
| 19 | Nor | 99999963857 | -85.96210 | 34.28510 | | | | | | |
| 20 | Nor | 99999963862 | -85.61710 | 34.56530 | | | | | | |
| 21 | Nor | 99999963867 | -86.79630 | 34.19540 | | | | | | |
| 22 | Nor | 99999963868 | -87.34620 | 34.66020 | | **Region** | **Start Station** | **End Station** | **Short Name of Region** | |
| 23 | Nor | 99999963894 | -87.63990 | 34.77280 | | **East Central Region** | **1** | **14** | **EC** | |
| 24 | Nor | 99999963895 | -87.71040 | 34.45350 | | **North Region** | **15** | **37** | **Nor** | |
| 25 | Nor | 99999963896 | -85.99980 | 34.69410 | | **Southeast Region** | **38** | **61** | **SE** | |
| 26 | Nor | USC00010063 | -87.17838 | 34.21096 | | **Southwest Region** | **62** | **69** | **SW** | |
| 27 | Nor | USC00010260 | -87.37195 | 34.96285 | | **West Central Region** | **70** | **88** | **WC** | |
| 28 | Nor | USC00010390 | -86.95080 | 34.77520 | | | | | | |

Main | Holidays

**Figure B.3 The worksheet “Main” for Results_Analysis_ByRegion.xlsm spreadsheet.**

The "AAWDs-Update" sub-folder includes the derived results of monthly available workdays or AWDs for 72 GHCN weather stations: 38 GHCN stations were used to derive the study results and 34 new GHCN stations are the corresponding GSOD stations used in this study. How to extend the weather data in a future year for updating AAWDs and for a project planning or negotiation with a contractor, ALDOT can use AAWDs_GHCN_ALDOT.xlsm spreadsheet to perform the necessary updates. Detailed steps and functions of the spreadsheet are described in section 4.7.

Both AAWDs_GHCN_ALDOT.xlsm and AAWDs_ALDOT.xlsm spreadsheets have a worksheet "AAWDs" to show AWDs and AAWDs results as given in Figure B.4 below in addition to plots in Figure B.2. The first part shows monthly AAWDs results determined from all available years or specified years under the selected threshold parameter for adverse weather. The second part shows monthly AWDs during the project period (up to 20 years). Annual total AAWDs or AWDs and percent of 365 days are automatically updated for each year.

| A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Threshold for Adverse Weather:** | | | **WDayR2T40** | **>0.2"** | **<40oF** | **P13** | | | | **FirstYear** | **last year** | **NoYears** |
| Station | Months | N-Years | AAWDs | StdEV | MiniAWD | MaxAWD | Median | 80PerTile | Skewness | **1959** | **2022** | **64** |
| USW00003856 | 1 | 64/64 | 8 | 3 | 1 | 15 | 8 | 11 | -0.016 | **(Data Period for AAWDs)** | | |
| USW00003856 | 2 | 64/64 | 10 | 3 | 1 | 17 | 10 | 12 | -0.025 | **StdEV = Standard Deviation** | | |
| USW00003856 | 3 | 64/64 | 16 | 3 | 6 | 21 | 16 | 18 | -0.578 | **80PerT = 80 percentile of AWDs** | | |
| USW00003856 | 4 | 64/64 | 17 | 2 | 12 | 21 | 17 | 18 | -0.181 | | | |
| USW00003856 | 5 | 64/64 | 18 | 2 | 14 | 22 | 18 | 19 | -0.032 | | | |
| USW00003856 | 6 | 64/64 | 17 | 2 | 12 | 21 | 17 | 19 | -0.423 | | | |
| USW00003856 | 7 | 64/64 | 18 | 2 | 11 | 21 | 18 | 19 | -0.727 | | | |
| USW00003856 | 8 | 64/64 | 19 | 2 | 14 | 22 | 19 | 20 | -0.305 | | | |
| USW00003856 | 9 | 64/64 | 18 | 2 | 12 | 21 | 18 | 19 | -0.434 | | | |
| USW00003856 | 10 | 64/64 | 18 | 2 | 12 | 22 | 18 | 20 | -0.535 | | | |
| USW00003856 | 11 | 64/64 | 14 | 3 | 9 | 20 | 14 | 17 | 0.218 | | | |
| USW00003856 | 12 | 64/64 | 10 | 3 | 4 | 18 | 10.5 | 12.4 | -0.033 | | | |
| | | **Annual Total** | **183** | | | | | | | | | |
| | | **Percent of 365 days** | **50.1%** | | | | | | | | | |

| N | O | P | Q | R | S | T | U | V | W | X | Y | Z | AA | AB | AC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **AWDs** | **Project** | **Years** | | | | | | | | | | | | | |
| **Monthly** | **Months** | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| **Avaiable** | **1** | 12 | 15 | 9 | 6 | 8 | 6 | 7 | 11 | 10 | 3 | 8 | 8 | 14 | 11 |
| **Workdays** | **2** | 15 | 11 | 9 | 11 | 9 | 4 | 9 | 17 | 13 | 5 | 3 | 11 | 16 | 12 |
| **by Year** | **3** | 16 | 21 | 21 | 17 | 17 | 17 | 18 | 17 | 12 | 16 | 14 | 18 | 15 | 19 |
| | **4** | 16 | 16 | 16 | 17 | 18 | 19 | 14 | 17 | 17 | 15 | 13 | 17 | 17 | 17 |
| | **5** | 20 | 18 | 21 | 17 | 17 | 18 | 19 | 19 | 18 | 18 | 17 | 19 | 17 | 16 |
| | **6** | 18 | 20 | 16 | 19 | 19 | 16 | 15 | 19 | 16 | 13 | 19 | 19 | 16 | 15 |
| | **7** | 17 | 18 | 16 | 20 | 21 | 18 | 17 | 14 | 17 | 18 | 18 | 16 | 15 | 18 |
| | **8** | 19 | 20 | 21 | 17 | 19 | 22 | 19 | 18 | 19 | 20 | 16 | 17 | 18 | 20 |
| | **9** | 20 | 17 | 18 | 20 | 17 | 20 | 19 | 18 | 18 | 19 | 20 | 21 | 17 | 13 |
| | **10** | 20 | 16 | 17 | 19 | 12 | 16 | 18 | 19 | 21 | 19 | 18 | 19 | 18 | 20 |
| | **11** | 12 | 14 | 16 | 12 | 17 | 13 | 15 | 19 | 12 | 12 | 15 | 17 | 20 | 11 |
| | **12** | 5 | 13 | 16 | 9 | 11 | 7 | 13 | 14 | 11 | 13 | 16 | 10 | 11 | 11 |
| | **Annual Total** | **190** | **199** | **196** | **184** | **185** | **176** | **183** | **202** | **184** | **171** | **177** | **192** | **194** | **183** |
| | **Percent of 365 days** | **52.1%** | **54.5%** | **53.7%** | **50.4%** | **50.7%** | **48.2%** | **50.1%** | **55.3%** | **50.4%** | **46.8%** | **48.5%** | **52.6%** | **53.2%** | **50.1%** |

**Figure B.4 The worksheet "AAWDs" for spreadsheets AAWDs_GHCN_ALDOT.xlsm and AAWDs_ALDOT.xlsm to show AAWDs (top) and AWDs (bottom) results.**