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Development of Working Day Weather Charts for Transportation Construction in South Dakota

Study SD97-07

Final Report

Prepared by
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DISCLAIMER

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16. Abstract

Seasonal and daily weather events impact grading, surfacing and structure construction projects in various ways across the different climate regions of the state. When weather conditions prevent timely completion of major sequential components of a construction project, it often requires additional construction time leading to delays and subsequent requests for contract time extensions. Past experience has shown that significant time and effort are spent on settling disputes between what the contractor and the Department (SDDOT) consider to be a reasonable number of weather related non-working days during the contracting period. In addition, SDDOT plans to implement innovative contracting methods designed to reduce the time of highway construction projects. Before the Department and contractors can fully implement innovative contracting procedures such as incentive-disincentive contracts, A+B bidding, and lane rental, they need guidance on the number of construction working days available in the different climate regions of South Dakota for grading, surfacing and structural projects. The overall goals of the this project are: 1) reduce contractors' risks related to bidding innovative contracting, calendar-day, working-day and completion-date projects; 2) reduce the magnitude and number of disputes, claims, time extension requests and costs due to weather delays; and 3) provide the Department of Transportation with tools that will enable a more accurate determination of contract completion requirements. This study produced various charts defining the expected adverse weather days and expected working days for six zones and two construction type categories. Procedures for using this information to calculate contract time and determine time extensions for adverse weather are presented.

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EXECUTIVE SUMMARY

Seasonal and daily weather events impact grading, surfacing and structural construction projects in various ways across the different climate regions of South Dakota. When weather conditions prevent timely completion of major sequential components of a construction project, it often requires additional construction time, leading to delays and subsequent requests for contract time extensions. Past experience has shown that significant time and effort are spent on settling disputes between what the contractor and the South Dakota Department of Transportation (SDDOT) consider to be a reasonable number of adverse weather days during the contracting period.

Based on this, the overall goals of the project were: 1) reduce contractors' risks related to bidding innovative contracting, calendar-day, working-day and completion-date projects;
2) reduce the magnitude and number of disputes, claims, time extension requests and costs due to weather delays; and 3) provide the Department of Transportation with tools that will enable a more accurate estimation of contract time. The objectives to meet these goals were:

1. Develop criteria and guidelines to establish the number of monthly construction working days available for grading, surfacing and structural construction projects in South Dakota.

2. Develop regional classification maps based on significant geographical factors and climate regions that can be used to determine weather-related construction working days.

3. Develop working-day weather charts that can be used for grading, surfacing and structure construction projects in the various regions of South Dakota.

4. Recommend how best to use working-day weather charts for the contract administration of projects with working-day, calendar-day or completion-date contracts.

Initially it is important to define specific terms used within this research project. An *adverse weather day* refers to a day when the magnitude of a weather parameter (precipitation or temperature) is such that it creates conditions that inhibit the ability of the contractor to work. Although there are other conditions that can cause a non-working day, in this study *a non-working day* is synonymous with an adverse weather day. Adverse weather days and non-working days can be quantified in terms of calendar days or working days. A *calendar day* is based on all available days including weekends and holidays. *Working days* are based on a five-day work week and exclude weekends and holidays.

Literature Review and Project Interviews

This study began with a literature review process where 49 state transportation departments, the Army Corp of Engineers and the Indian Health Service were contacted for information. Thirty-five of the transportation agencies and the Corps of Engineers responded with various types of information, and the Indian Health Service responded, but had no information. The information received identified different weather parameter criteria used to calculate the number of working or non-working days, how non-working days are categorized based upon geographical zones and project types and multiple definitions of a non-working day.

Two primary applications of working-day weather charts are determining contract time and contract time extensions due to adverse weather. Expected adverse weather is taken into consideration by setting the contract completion date based on the number of calendar days or working days available. The primary elements for contract administration of weather delay time extensions are defining expected adverse weather conditions, time extension criteria, documentation of weather, and verification of the occurrence of unexpected adverse weather conditions.

A representative sample of construction contractors and SDDOT engineers were interviewed to assess the impacts of weather conditions on construction activities and determine temperature and precipitation ranges appropriate for grading, surfacing and structural construction in the various geographical regions of South Dakota. Fifty-four projects from different areas around the state were selected for review. The primary result of the interviews conducted was the understanding of how weather affects different project types and locations based upon the experience of the engineers and contractors.

Validation Process

Each project was evaluated to determine precipitation thresholds that create an adverse weather day. It became apparent during the evaluation process that temperature thresholds could not be determined due to lack of non-working days associated with temperature. The validation was accomplished by comparing bi-weekly progress reports, diary comments and historical precipitation data.

After evaluation of all projects, the precipitation amo unts causing a non-working day generally ranged from 6.35 to 12.7 mm (0.25 to 0.50 in) and the mean ranged from 8.64 to 9.65 mm (0.34 to 0.38 in) for all construction types. Based on the literature review, interview process and sensitivity analysis, a threshold of 7.62 mm (0.30 in) was selected for all construction types. A difference between grading projects and surfacing or structural projects was that 19.05 mm (0.75 in) of rain or greater generally caused a non-working day the following day for grading, but not for surfacing or structural projects. This lead to the division of the construction types into two construction classes, one for grading and another for surfacing and structural projects.

Expected Adverse Weather Days

The objective of the research was to use weather parameter thresholds based on the interviews, validation process and climate data to calculate the expected number of days that exceed the thresholds developed for the different construction types (i.e., expected adverse weather days). A total of 103 climate stations with 30 years of records each were used for the analysis. Based on the literature review, validation results and sensitivity analysis, the following criteria were approved:

- All scenarios were run based on the 80th percentile.
- A single precipitation threshold of greater than 7.62 mm (0.30 in) was used to determine the number of adverse weather days. This threshold was applied uniformly across the state for all construction types.
- A single daily maximum temperature threshold of less than 0^{o} C (32° F) was applied uniformly across the state.
- A precipitation threshold of 19.05 mm (0.75 in) was used for adding additional non-working days to grading projects only.
- A combination of daily maximum temperature less than 0^{o} C (32° F) and precipitation greater than 7.62 mm (0.30 in) to define the joint probability that both occur. This chance of both occurring is

subtracted from the chance that precipitation greater than 7.62 mm (0.30 in) occurs and that temperature less than 0^{o} C (32° F) occurs. This accounts for the probability of both 7.62 mm (0.30 in) precipitation and temperature less than 0^{o} C (32° F) occurring on the same day and ensures that no double accounting of days occurs.

The results of this analysis are the number of monthly expected adverse weather days at each climate station based on a calendar day. Thus, the data includes weekends and holidays and must be adjusted by multiplying by 5/7ths to determine the number of monthly expected adverse weather days reflecting working days. This analysis provides the basis for developing the working-day weather charts.

Calculation and Development of Zones and Maps

The objective of this task was to use the estimated number of monthly expected adverse weather days to develop working-day weather zones, maps and charts for the two project classifications: 1) grading and 2) surfacing and structures.

The calculated number of expected adverse weather days (non-working days due to weather) at each climate station were used to generate a spatial distribution for both the construction season (April 1 to November 30) and the off-season (December 1 to March 31) across the state. The spatial distribution of the two seasons varied greatly. The construction season spatial distribution was used to create zones, since this is the only time when working days are counted. The zones were modified to follow county lines to make it easy to distinguish which zone a project is in.

The average number of expected adverse weather days were calculated for each zone, month and construction type based on the climate stations within each zone. Figure A shows the resulting zones and monthly expected adverse weather days for each zone and construction type (based on calendar days).

There are two primary applications for working-day information: 1) estimation of the contract time necessary for completion of a specific construction project; and 2) to determine time extensions due to unexpected adverse weather. Additionally, it will be beneficial to have a field chart available to engineers and contractors that will provide them information on expected adverse weather days over each month. Based on the desired applications, three chart types were developed (in addition to the chart shown in Figure A) for implementation of the expected adverse weather days. Each chart type is described as follows:

1. The cumulative count of expected number of calendar days available for construction (Table A); one chart is generated for each zone and each type of construction. These charts reflect the total number of monthly calendar days (includes weekends and holidays) less the estimated number of expected adverse weather days.

2. The estimated percentage of expected calendar days available per month for each zone and construction type (Table B). This chart reflects the total number of monthly calendar days (includes weekends and holidays) less the estimated number of expected adverse weather days.

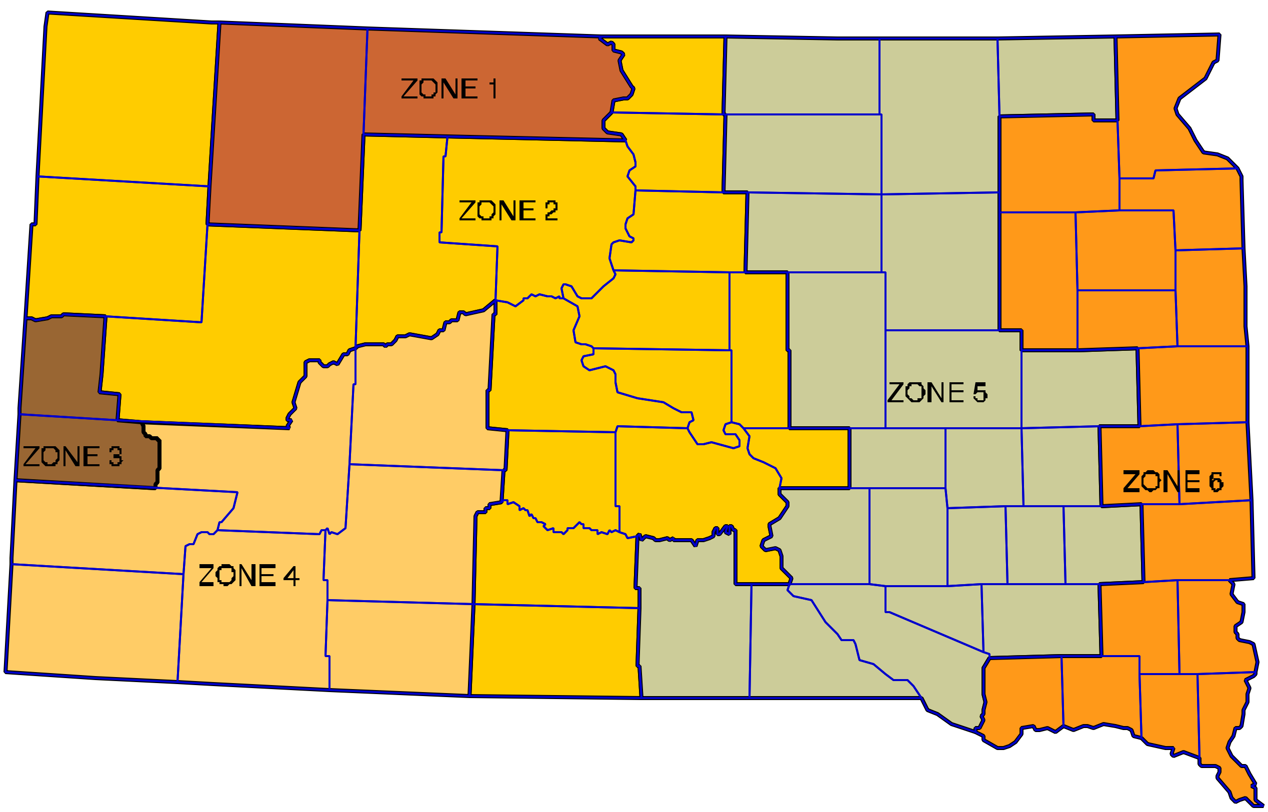
3. The expected number of adverse weather days remaining in a month in calendar days (Table C) and the expected number of calendar days remaining in any month (Table D). One chart like this is generated for each zone and construction type.

Estimation of Contract Time

One of the objectives of this project is to develop working-day weather charts for implementation of innovative contracting methods. Although there are several innovative contracting methods including Incentive/Disincentive, A + B Bidding and Lane Rental, it is assumed that all contracting methods fall under either a calendar-day or working-day category. The common conversion used to convert calendar days into working days is to multiply the calendar days by 5/7ths and then subtract holidays. This is based upon the assumption of a five-day workweek. Conversely, to convert from working days to calendar days, holidays are added to the working days and then multiplied by 1.4 (i.e., seven divided by five).

Initially the number of working days required to complete a construction project are estimated based on the type of work, production rates and other logistical factors. Using the developed charts, a procedure is followed to determine the number of calendar days required to complete the project and, with a known starting date, the ending date can be determined. Subsequently, given a fixed calendar-day time period, the number of working days available within that time period can be determined. The procedure and example calculations are described in the final research report.

Figure A. Expected Adverse Weather Days for South Dakota



	Grading Projects						Surfacing and Structural Projects					
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Jan	18	18	16	16	22	24	18	18	15	16	21	23
Feb	19	18	12	14	19	21	19	18	12	14	19	21
Mar	12	10	9	8	11	13	12	10	9	8	10	12
Apr	6	5	8	5	6	6	5	4	6	4	4	4
May	6	6	8	6	6	6	5	5	6	4	4	5
Jun	7	6	7	6	7	8	5	5	5	4	5	6
Jul	5	5	6	5	6	7	4	4	5	3	4	5
Aug	4	4	5	4	5	6	3	3	4	3	4	4
Sep	3	3	4	3	4	5	2	2	3	2	3	4
Oct	4	3	5	3	4	4	3	3	4	2	3	3
Nov	11	9	8	7	10	12	11	9	8	7	10	11
Dec	21	19	15	14	20	22	21	19	15	14	20	22

NOTE: Includes Holidays and Weekends.

Table A. Cumulative Count of Expected Number of Calendar Days Available Over a Three Year Period.[2,3]

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
6	24	Apr	24							
6	25	May	49	25						
7	23	Jun	72	48	23					
5	26	Jul	98	74	49	26				
4	27	Aug	125	101	76	53	27			
3	27	Sep	152	128	103	80	54	27		
4	27	Oct	179	155	130	107	81	54	27	
11	19	Nov	198	174	149	126	100	73	46	19
6	24	Apr	222	198	173	150	124	97	70	43
6	25	May	247	223	198	175	149	122	95	68
7	23	Jun	270	246	221	198	172	145	118	91
5	26	Jul	296	272	247	224	198	171	144	117
4	27	Aug	323	299	274	251	225	198	171	144
3	27	Sep	350	326	301	278	252	225	198	171
4	27	Oct	377	353	328	305	279	252	225	198
11	19	Nov	396	372	347	324	298	271	244	217
6	24	Apr	420	396	371	348	322	295	268	241
6	25	May	445	421	396	373	347	320	293	266
7	23	Jun	468	444	419	396	370	343	316	289
5	26	Jul	494	470	445	422	396	369	342	315
4	27	Aug	521	497	472	449	423	396	369	342
3	27	Sep	548	524	499	476	450	423	396	369
4	27	Oct	575	551	526	503	477	450	423	396

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.

[2]The cumulative count reflects the total number of days available through the last day of each month.

[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure A.

Table B. Estimated Percentage of Calendar Days Available Per Month.

	Grading Projects						Surfacing and Structural Projects					
	Zone	Zone	Zone	Zone	Zone	Zone	Zone	Zone	Zone	Zone	Zone	Zone
Jan	42%	39%	48%	48%	29%	23%	42%	42%	52%	48%	32%	26%
Feb	32%	36%	57%	50%	32%	25%	32%	36%	57%	50%	32%	25%
Mar	61%	68%	71%	74%	65%	58%	61%	68%	71%	74%	68%	61%
Apr	80%	83%	73%	83%	80%	80%	83%	87%	80%	87%	87%	87%
May	81%	81%	74%	81%	81%	81%	84%	87%	81%	87%	87%	84%
Jun	77%	80%	77%	80%	77%	73%	83%	83%	83%	87%	83%	80%
Jul	84%	84%	81%	84%	81%	77%	87%	87%	84%	90%	87%	84%
Aug	87%	87%	84%	87%	84%	81%	90%	90%	87%	90%	87%	87%
Sep	90%	90%	87%	90%	87%	83%	93%	93%	90%	93%	90%	87%
Oct	87%	90%	84%	90%	87%	87%	90%	90%	87%	94%	90%	90%
Nov	63%	70%	73%	77%	67%	60%	63%	70%	73%	77%	70%	63%
Dec	32%	39%	52%	55%	39%	29%	32%	39%	52%	55%	39%	29%

NOTE: Percentages represent the total number of calendar days available in the month (includes holidays and weekends) less the number of expected adverse weather days.

Time Extensions Due to Adverse Weather

Determination of time extensions is an element vital to this study. Time extensions are justified if the number of actual adverse weather days exceeds the expected number of adverse weather days over the life of a project. The number of days that exceed the expected number of adverse weather days are defined as unexpected adverse weather days. Assessing time extensions for adverse weather requires:

- determining and keeping track of the number of non-working days caused by adverse weather; and
  - calculation of the difference between the actual adverse weather days and expected adverse weather days.

The recommended procedure for determining whether or not a day is an adverse weather day is based upon weather data gathered and decisions made in the field. The ability to work during varying weather conditions is based on many factors. Thus, the procedures recommended here for determination of an adverse weather day (non-working day due to weather) are guidelines.

The recommended approach is presented below and should be initiated as soon as adverse weather takes place.

1. Initially the contractor and field engineer should get together and discuss whether the conditions warrant working or not working. If the contractor and field engineer both agree that the conditions are such that working is impossible, then the day or partial day is a non-working day due to weather.

2. If the contractor believes that work cannot be performed in the weather conditions due to low efficiency or other reasons and the field engineer believes that the contractor could work without major hindrance, then the decision will be based upon the weather data for that site for the day in question. If the precipitation over the full day of work in question before the time of shutting down is greater than or equal to 7.62 mm (0.30 in) of precipitation (snow or rain equivalent), then it is an adverse weather day. If the precipitation value is less than 7.62 mm (0.30 in) of precipitation (snow or rain equivalent), then it is a working day. If it rained greater than 19.05 mm (0.75 in) the previous day, then it is an adverse weather day for grading projects only. If the maximum temperature during the day is less than 0°C (32°F), then it is an adverse weather day. Otherwise, if the maximum temperature is greater than or equal to 0°C (32°F), then it is not an adverse weather day.

This will allow the contractor and field engineer to work together to decide whether or not a day is workable or not, and if they disagree, then the precipitation and temperature information shall provide a clear and concise answer that neither can dispute, thus reducing claims. Then each month, the total number of actual adverse weather days can be compared to the expected number of adverse weather days as shown in Figure A. If the number of actual adverse weather days exceeds the expected amount, then the difference is the potential days for contract time extensions due to weather. A running total will be kept for all of the months over the entire project. Once the project completion date is reached or the number of working days is completed, the contractor may request that any net positive adverse weather days from the running total be awarded as a time extension in terms of calendar days.

Findings and Conclusions

The results reflect an understanding of the effects of weather on different construction types in different geographical and climate areas. Specific precipitation and temperature thresholds were established in order to calculate expected adverse weather days. However, the actual amount of precipitation that will cause a non-working day will vary depending on several factors.

The calculations at each climate station, presented in the final report, are specific based on the assumptions and methodology and represent the expected number of adverse weather days at that location. The adverse weather day charts developed for each zone represent an average based on all climate stations in that zone. Thus, specific locations at the edges of the zones will tend to be slightly higher or lower than the mean. The expected number of adverse weather days and associated working-day charts developed in this study, provide a definitive basis for the estimation of contract time and determination of adverse weather. The question as to whether or not an adverse weather day has occurred resulting in a non-working day is defined.

Implementation Recommendations

The following recommendations are based on the information and results presented in this study and the actions necessary to achieve the desired goals.

1) The following additions, deletions and changes should be made to the 1998 South Dakota Department of Transportation Standard Specifications for Roads and Section 8.6 Determination and Extension of Contract Time to incorporate the estimated expected adverse weather days. This action is necessary to fully achieve the objectives of this study.

1.1 Item 8.6.A.2 on page 43 and 8.6.B.2 on page 45 be deleted.

1.2 Items 8.6.A.3 - 8.6.A.7 on page 43 and 8.6.B.3 - 8.6.B.7 on page 45 be decreased by one.

1.3 Item 8.6.A.1 on page 43 and 8.6.B.1 on page 45 be replaced with the following:

The occurrence of unexpected adverse weather during the life of the Contract will be considered a basis for extending contract time when work is not already suspended for other reasons. Unexpected adverse weather means weather which, at the time of year it occurs, is unusual for the place in which it occurs.

Extension of time for extreme adverse weather will be determined on a monthly basis and will include only those actual adverse weather days in excess of the normal adverse weather days included in the Contract Time. Adverse weather means adverse weather which, regardless of its severity, is to be reasonably expected for that particular place at that time of year. The adverse weather days included in the Contract Time are based on historical records of temperature and precipitation for the six zones and two project classifications as shown in Figure A.

Actual Adverse weather days are those days meeting one or more of the criteria in "a", "b", "c" and "d" below. Time extensions for days meeting more than one criterion will take into consideration only that criterion having the greatest impact. Actual adverse weather days covered by criterion "a", "b", "c" or "d" will be counted without regard to when they occur or their impact on contract completion. Adverse weather days which exceed the number of expected adverse weather days as shown in Table 1 will be considered for time extensions if they occur on a working day or in the case of criterion "c", they occur on a Sunday or holiday preceding a scheduled working day in which case one full day will be allowed.

a. Days with maximum temperature of 0° C (32° F) or less - one full day allowed.
b. Days when 7.62 mm (0.30 in) or more precipitation (rain or snow equivalent) occurs - one full day allowed.
c. Days when 19.05 mm (0.75 in) or more precipitation (rain or snow equivalent) occurs on a grading project - two full days allowed.
d. Days when weather-related conditions exist which prohibit proper performance of work as specified - one full day allowed, subject to the agreement of both the contractor and the project engineer. If no agreement is reached, then the criteria "a", "b" and "c" supercede. Allowance of such days will be subject to the work which is delayed being critical to timely contract completion and the contractor making every reasonable effort to minimize the adverse impact of the conditions. Also, if the contractor chooses or decides to work on the controlling item, a working day will be counted.

1.4 The following definitions should be added to Division 1, Section 1, Definitions and Terms.

(1) Adverse weather day: A day when the magnitude of a weather parameter (precipitation or temperature) is such that it creates conditions that inhibit the ability of the contractor to work productively on the critical construction item.

(2) Expected adverse weather days: The number of adverse weather days expected to occur on a monthly basis and defined for six zones and two different construction types (1. grading and 2. surfacing and structures) within each zone.

(3) Unexpected adverse weather days: The number of adverse weather days that exceed the expected number of adverse weather days determined on a monthly basis.

(4) Actual adverse weather days: The actual number of adverse weather days that occur during a single month.

2) Develop and adopt a standard procedure policy for calculation of contract completion time that takes into consideration available working days or calendar days. A defined procedure will promote consistent use of the working-day weather charts. Additionally, a standard policy will help contractors in understanding the expectations of SDDOT and how the expected adverse weather days have been used to estimate the contract time. This action is necessary to fully achieve the objectives of this study.

3) Specific weather information: precipitation (hourly and daily total), temperature (hourly, minimum and maximum), wind (direction, hourly and maximum) and soil temperature -- should be collected in the field for determination of adverse weather days. This information should be added to the biweekly progress reports and field diaries. This information will prove beneficial to validation and updating of the working-day weather charts developed in this study. This action is necessary to fully achieve the objectives of this study.

4) Portable climate stations are needed to collect the weather parameter data specified in Recommendation 3.

5) It is recommended that the development and application of the working-day weather charts be presented in a training format to SDDOT engineers at each area office. Understanding the development of the working-day weather charts will be beneficial in their application. This will also enable a question and discussion session regarding field procedures for defining adverse weather. This could be conducted by the appropriate SDDOT representative and/or a representative from the research team.

6) Following a two- or three-year period, it is recommended that construction and climate data gathered in the field be used to validate and possibly update the working-day weather charts developed in this study. To facilitate this evaluation, it is recommended that a common working-day weather database be developed to store this information and that it be made accessible to both SDDOT and interested contractors. This could be delegated to the appropriate SDDOT department or developed as follow-up research.

7) Future research is recommended for defining the flows and associated risk used for sizing control structures in drainages associated with structure construction. High flows in drainage channels and streams cause significant construction problems and potential delays and are directly related to weather. However, working-day weather charts do not deal directly with high flows in drainage channels and streams. A defined flow and associated risk would provide for consistent design and sizing of control structures needed during construction. Additionally, the defined risk would provide a clear definition when severe flow conditions occur.

1.0 INTRODUCTION

1.1 Problem Statement

Seasonal and daily weather events impact grading, surfacing and structural construction projects in various ways across the different climate regions of South Dakota. Standard Specifications for Roads and Bridges (SDDOT 1998) establishes seasonal limitations and weather conditions that must be met for work to proceed on various types of construction. These specifications take the form of both narrative and numerical values. For example, Section 320.3.A "Asphalt Concrete," states that asphalt concrete shall not be placed when the underlying surface is wet or frozen and when weather conditions prevent proper handling, compaction or finish. Section 320.3.A also establishes numerical values for a minimum air temperature of 7.22°C (45° F) and 4.44°C (40° F) for compacted thickness of 25.4 mm (1 in) or less and over 25.4 mm (1 in), respectively. Thus, weather conditions can affect the ability of a contractor to perform various types of construction.

Weather conditions that do not allow the contractor to continue normal construction results in what is called an adverse weather day which simply means that the contractor is not able to work or work efficiently on the controlling item of work that day due to weather conditions. The specific weather parameter (rain, temperature, wind, etc.) and its magnitude that result in an adverse weather day will depend on the geophysical conditions at the construction site and the type of construction being conducted (grading, surfacing and structural construction). Construction site geophysical conditions relate primarily to the type of soils and the ability of the soils to drain. A well-drained soil will require more rain than a poorly-drained soil to create poor working conditions.

When weather conditions prevent timely completion of major sequential components of a construction project, it often requires additional construction time, leading to delays and subsequent requests for contract time extensions. Past experience has shown that significant time and effort are spent on settling disputes between what the contractor and the South Dakota Department of Transportation (SDDOT) consider to be a reasonable number of weather-related non-working days during the contracting period. In addition to the concern of weather-related time delays for current contracting methods, SDDOT along with other state highway agencies are implementing innovative contracting methods designed to reduce the time of highway construction projects (Trauner Consulting Services, 1996). Before the Department and contractors can fully implement innovative contracting procedures such as incentive-disincentive contracts, A+B bidding and lane rental, they need guidance on the number of construction working days available in the different climate regions of South Dakota for grading, surfacing and structural projects.

Thus, there is a need to determine the number of expected weather-related non-working days during a contract period that is clearly understood by both the contractor and the South Dakota Department of Transportation. This will enable better estimation of the average number of construction working days available over a contract period. Development of the expected weather-related non-working days must incorporate the geophysical location of the project, the type of construction (grading, surfacing or structures) and the magnitude of the weather parameter that would cause a non-working day. This information is intended to be used for estimation of contract time (as defined in SDDOT Standard Specifications for Roads and Bridges) and determination of contract time extensions due to unexpected adverse weather.

Initially it is important to define specific terms used within this research project. An adverse weather day refers to a day when the magnitude of a weather parameter (precipitation or temperature) is such that it creates conditions that inhibit the ability of the contractor to work. Although there are other conditions that can cause a non-working day, in this study a non-working day is synonymous with an adverse weather day. Adverse weather days and non-working days can be quantified in terms of calendar days or working days. For the charts developed and presented in the research report, a calendar day is based on all available days including weekends and holidays. Working days are based on a five-day workweek and exclude weekends and holidays.

1.2 Research Objectives

As stated above, the overall goals of the project are : 1) reduce contractors' risks related to bidding innovative contracting, calendar-day, working-day and completion-date projects; 2) reduce the magnitude and number of disputes, claims, time extension requests and costs due to weather delays; and 3) provide the Department of Transportation with tools that will enable a more accurate estimation of contract time. The objectives to meet these goals were:

1) Develop regional classification maps based on significant geographical factors and climate regions that can be used to determine weather-related construction working days.

2) Develop criteria and guidelines to establish the number of monthly construction working days available for grading, surfacing and structural construction projects in South Dakota.

3) Develop working-day weather charts that can be used for grading, surfacing and structural construction projects in various regions of South Dakota.

4) Recommend how best to use working-day weather charts for the contract administration of projects with working-day, calendar-day or completion-date contracts.

1.3 Research Tasks

The specific research tasks carried out to achieve the established objectives are listed below as stated in the project proposal.

1) Meet with the project's technical panel to review the project scope and work plan.

2) Review and summarize literature pertinent to working-day weather charts and the innovative contracting procedures which utilize them.

3) Research and compile a summary of other agencies (Army Corps of Engineers, Bureau of Indian Affairs and State Highway Administrations) that use working-day weather charts, identify how the data is compiled and used in calendar-day or other types of contracts, and provide documentation on contractual successes and failures.

4) Interview a representative sample of construction contractors and SDDOT engineers to assess the impacts of weather conditions on construction activities and determine temperature and precipitation ranges appropriate for grading, surfacing and structural construction in the various geographical regions of South Dakota.

5) Validate the ranges established in Task 4 by comparing past SDDOT transportation construction project records to observed weather data (1990-1996 with emphasis on 1994-1996).

6) Based on information obtained in Research Tasks 4 and 5 and a minimum of thirty years of National Oceanic and Atmospheric Administration (NOAA) daily climate data, develop regional maps that identify monthly temperature and precipitation ranges appropriate for grading, surfacing and structural construction.

7) Using the data established in Research Tasks 3, 4, 5 and 6, develop and recommend criteria and guidelines for preparing and using working-day weather charts.

8) Prepare regional working-day weather charts and tables that can be used in SDDOT contracting documents for grading, surfacing and structural projects.

9) Document how the US Army Corps of Engineers working-day weather charts, which have been utilized for construction activities at Ellsworth Air Force Base, South Dakota, compare with the working-day weather charts developed in Task 8.

10) Provide sample contract clauses which utilize the working-day weather charts and recommend changes in SDDOT policies and procedures necessary to effectively use the weather data.

11) Prepare a final report and executive summary of the literature review, interviews, research methodology, findings, conclusions and recommendations.

12) Make an executive presentation to the SDDOT Research Review Board and the Associated General Contractors of South Dakota (AGC) at the conclusion of the project.

1.4 Initial Project Meeting

A project kickoff meeting was held Tuesday, May 6, 1997, at the SDDOT offices in Pierre. Table 1.1 below gives the name, agency and phone number of those present at the meeting.

Table 1.1 Kickoff Meeting Attendees

NAME	AGENCY	PHONE
Hal Rumpca	SDDOT	773-3852
John Salmen	SDSM&T	394-2291
Shane Matt	SDSM&T	394-2513
Scott Kenner	SDSM&T	394-2513
Ron Johnson	SDSM&T	394-2291
Milton Morris	Morris Inc.	223-2585
John Forman	SDDOT	773-3184
Alan Bender	SDSU	688-5678
Blair Lunde	SDDOT	773-5961
Mike Wever	SDDOT	773-3571
Gary Engel	SDDOT	394-2248

Additionally, a meeting was held on May 13, 1997, at the AGC offices to discuss the objectives of the project with area contractors. Those attending the meeting are listed in Table 1.2. The objectives of this meeting were: 1) inform the contracting community about the project and its objectives; 2) obtain input on the objectives and specific tasks; and 3) make them aware of the upcoming interview contacts. This was a very successful meeting, and the contractors provided insight on the project objectives and tasks. Several issues were raised during the discussion with more emphasis on the implementation and procedures regarding the use of working-day weather charts.

Table 1.2 Contractors' Meeting Attendees

NAME	***COMPANY/AGENCY***	***PHONE***
Terry Humer	Irving F Jensen Co.	712-252-1891
	Sioux City, IA.	
Dennis Wipf	Myrl & Roy's Paving Inc	605-334-3204
Bill Keller	Hills Materials Co.	605-394-3300
Lynn Kading	Hills Materials Co.	605-394-3300
Tim Ericksrud	Border States Paving, Inc	701-237-4860
Dan Thompson	Border States Paving, Inc	701-237-4860
Blair Lunde	SDDOT-Research	773-5961
Hal Rumpca	SDDOT-Research	773-3852
Mark Knight	Foothills Contracting, Inc.	345-3795
Kari Karst	Buskerud Construction Inc	428-5483
Harold Skatvold	Buskerud Construction Inc	428-5483
Wayne Gustafson	Heavy Constructors Inc	342-3152
Milton Morris	Morris Inc.	223-2585
Scott Kenner	SDSM&T	394-2513

2.0 EXISTING LITERATURE REVIEW AND SUMMARY

The objective of Tasks 2 and 3 were to review and summarize available literature pertinent to working-day weather charts; research and compile a summary of other agencies that use working-day weather charts; identify how the data is compiled and used in calendar-day or other types of contracts; and provide documentation on contractual successes and failures. The search for literature and information from various agencies was accomplished using the following primary search methods:

1) Library search of existing material related to weather and construction;
2) Internet search;
3) Contacting other state DOTs via phone, fax, email and mail; and
4) Search for material through other agencies.

2.1 Literature

Several references document the effects of weather on various types of construction (Havers and Morgan, 1972; Hinze and Coleman, 1991; Mills, 1968; Transportation Research Board, 1978; and Russo, 1965). Hinze and Coleman (1991) conducted an extensive survey of several state and federal agencies to evaluate how adverse weather is used in construction contracts. They found that most agencies do not use the seasonal weighting of days, and in those cases when it is used, it is rarely applied in a consistent or traditional manner. Hinze and Coleman (1991) concluded that if normally anticipated weather is to be included in the contract duration, it is imperative that this be clearly defined.

The Transportation Research Board (1978) documented the impact of precipitation, temperature and wind on highway construction in terms of severe, moderate and little. Although this study did define climate criteria for different materials used in construction (i.e., concrete, asphalt, etc.) they did not define thresholds for general construction activities such as grading, surfacing and structures. Russo (1965) completed a study evaluating the economic impact of weather on the construction industry. Similarly, this study (Russo 1965) also defined the impacts of weather on various construction operations in terms of light or moderate and based the analysis on the ability to work in terms of a wind chill factor.

A primary objective of this study was to evaluate available weather information that can be used to reduce potential losses to the construction industry. Although these references clearly establish the impact of weather on construction practices, there is limited information regarding the development and application of working-day weather charts.

2.2 State and Federal Agencies

Other state transportation agencies were contacted for information via faxes, e-mail and telephone calls. Table 2.1 shows the transportation agencies that were contacted and which ones responded to our request for specified information. The initial contact with each transportation agency requested answers to the following questions:

1) What kind of contract types do you use? (i.e., calendar-day, working-day, completion-date and/or innovative contracts)

2) What criteria are required in determining a weather-related non-working day and how is a non-working day defined?
3) Identify any written documentation on how non-working days are determined and incorporated into contracts. (Obtain contract examples and methods to determine non-working days)
4) What documentation is required by contractors in the field?

Thirty-five of the forty-nine transportation agencies contacted responded in one form or another, with responses varying in quantity and quality. The information received identified different weather parameter criteria used to calculate the number of working or non-working days, how non-working days are categorized based upon geographical zones and project types and multiple definitions of a non-working day. Although the information obtained has been invaluable to this project, we were unable to obtain any formal documentation of methodologies used to establish non-working day or working-day weather charts. Essentially, it is our understanding that the information obtained was based on in-house studies or historical project data gathered by the agency and analyzed to estimate available working days.

The Army Corps of Engineers and Indian Health Service were also contacted. The Army Corps of Engineers sent documentation on how the "anticipated number of working days" are calculated and their criteria for awarding contract time extensions. The Army Corps of Engineers was to update their working-day data during the summer of 1997; however, this project was not implemented. The Indian Health Service currently does not estimate working days, but commented that they had just started a study concerning the estimation of working days.

The following summary provides a description of the different types and ranges of information obtained. It is not intended to be a complete documentation of every transportation agency's methodology for developing and using working-day weather information.

2.3 Criteria

Several states have used climate history for the calculation of non-working days due to weather. Delaware uses 6.35 mm (0.25 in) and/or a maximum daily temperature not exceeding 0°C (32°F) as reported by National Climatic Data Center at Wilmington Airport. New Jersey based their working days on "seasonal patterns." Oklahoma uses three criteria to define a non-working weather day:

- Maximum temperature less than 0°C (32°F) -- one full day.
- Minimum temperature of 0°C (32°F) or less but whose maximum temperature is greater than 0°C (32°F) -- one-half of a working day.
- 12.7 mm (0.5 in) or more precipitation (snow or rain equivalent) -- one full day.
- Days when weather-related conditions exist which prohibit proper performance of work -- one full day.

Georgia used weather data from 1951 to 1980 to develop their working-day weather charts. Several other states have used past projects as a basis for the calculation of non-working days. Arkansas based their charts on project diaries over a three-year period. Indiana determined non-working days from the average amount of non-working days from past projects. Maryland based its working days upon 150 contracted projects. Virginia uses an "in-house planning tool." South Carolina's are based upon days historically available. Tennessee based theirs on history and past experience.

Working days are divided into different construction types but not geographical zones in Mississippi, Indiana, New Jersey and South Carolina. Mississippi contains four construction types: grading and drainage projects (160 days), base and paving projects (170 days), bridge or specialized projects (180 days) and widening or overlay projects (170 days). Indiana has three construction types: Medium and Heavy Grading (100 days), Light Grading and Urban (110 days) and Bridge (135 days). New Jersey has two construction types: roadwork and road and bridgework. South Carolina contains two construction types, the first being grading, drainage, base and surfacing projects and the second being resurfacing projects.

Several states divide their state into different geographical working-day zones, but do not consider project type. Arkansas has three zones: Zone A has 125 working days, Zone B has 126 working days and Zone C has 120 working days. Oklahoma has eight geographical locations. Georgia has three geographical zones. Maryland has three regional zones and two project types (bridges and roads). Pennsylvania uses a combination of geographical zones and project types with a total of nine different classifications which can be modified individually for each project.

Several states only have one set of working days for the entire state and all project types. Delaware, Nebraska, Virginia and Wyoming have only one set of working days that cover the entire state and all project types. Kansas has only one broad "rule of thumb" for working days per month that was "derived long ago from experienced construction engineers" basing their approach on past experiences and knowledge about the state's weather.

It should be noted that there are several types of charts used to represent working days. The specific types of charts are discussed and presented later during the development of charts for South Dakota. This provides for a better comparison of the different types.

Two primary applications of working-day weather charts are for determining contract time and determination of contract time extensions due to adverse weather. Wisconsin, Florida and West Virginia provided detailed procedures for estimation of contract time. In general production rates, road user costs, logistics and other considerations are used to estimate the number of working days needed to construct the project. Subsequently, the number of working days can be converted to calendar days. This is typically done by using a simple conversion of seven calendar days for every five working days (based on a five-day workweek). Expected adverse weather is then taken into consideration by setting the contract completion date based on the number of calendar days or working days available.

Specifications determining contract time extensions for the states researched (Oklahoma, Wisconsin, Florida, Delaware, South Carolina, North Dakota and Georgia) have one or more of the following items stated in their Determination and Extension of Contract Time specification.

- A working day is usually defined as a day during the working season which is not a Saturday, Sunday or holiday.
- The state's policy and procedures for working on Saturdays and holidays.
- The method for determination of a working day or a partial non-working day.
- The definition of conditions under which no working days will be charged.
- Definition of extreme adverse weather.
- Furnishing the contractor a report of workdays charged on some repeat time basis.
- Time allowed for contractor to file a written protest against the working days charged. Otherwise, the report shall be deemed accepted by the contractor.
- Methodology for requesting a time extension including justification for the extension and the fact that insufficient time is not a valid justification.
- The process for awarding a time extension.
- If a time extension is granted, the extended time for completion shall then be in full force and effect the same as though it was the original time.
- If Area Engineer and Contractor fail to reach an agreement on the amount of non-working days, the report shall be submitted to the Region Engineer for review and a final decision.
- Definition of "substantially complete."

Not all of these items deal with time extensions due to weather delays. As identified by Isom (1985) the primary elements for contract administration of weather delay time extensions are weather classification, time extension criteria, documentation of weather and verification of the occurrence of unusual weather conditions. The objective of weather classification is to differentiate between usual weather conditions and unusual weather conditions. Typical terms that are used include normal, other than normal and unusually severe. At a minimum, two fundamental criteria must be met to receive a time extension: 1) the weather condition must delay the critical item of work; and 2) the weather causing the delay must be "other than normal" or "unusually severe." Documentation of weather is necessary to define "unusually severe" weather and justify that it has occurred.

3.0 PROJECT INTERVIEWS

To accomplish Task 4 a representative sample of construction contractors and SDDOT engineers were interviewed to assess the impacts of weather conditions on construction activities and determine temperature and precipitation ranges appropriate for grading, surfacing and structural construction in the various geographical regions of South Dakota.

The interview process was carried out by first identifying past construction projects to be used for the interviews. Initially a list of approximately 115 projects covering the period 1992 to 1996 was compiled based on project information from the area offices and the Pierre office. A conference call meeting was then held to narrow the list down to a set of priority projects that would be used in the interview process. Selection of the priority projects was made according to the following objectives: provide a cross section covering a range of geophysical locations and construction types, identify projects that had no delays due to weather as well as those that did, and represent the different climate regions across the state. This resulted in selecting 54 priority construction projects, 18 surfacing, 14 grading, 15 structural and 7 multi-task.

The priority projects provide a good representation of the various geophysical locations, climate types and construction types. Figure 3.1 shows the spatial distribution of the priority projects overlaying a spatial distribution of annual rainfall. Table 3.1 gives various characteristics regarding each selected project by area office. Table 3.2 shows the number and type of construction projects by year. More projects were selected from the period 1994 to 1996 which represents a wet period. Table 3.3 shows the number of projects in the different soil classes across the state. No projects occur in areas with soil class C or F. Soil class C is found in the south-southwest area of the state. No projects were done in this area during the period 1992 to 1996. Soil class F represents a small part of the state consisting of portions of Faulk, Hyde and Hand Counties. Although no projects occurred in this area, the soil classes adjacent to this area are very similar and provide a good representation. Table 3.4 gives the distribution of contractors represented by the selected projects. Of the 25 different contractors represented, 11 are located out-of-state.

A standard form was used to ensure the desired information was obtained for each interview/project. An example of the form can be found in Appendix A. Interviews with SDDOT engineers or a project representative were completed for all but one project. Table 3.4 shows the number of interviews completed with contractors. Over all project types, interviews

Figure 3.1 Spatial Distribution of Priority Projects Over the Average Annual Precipitation for South Dakota.

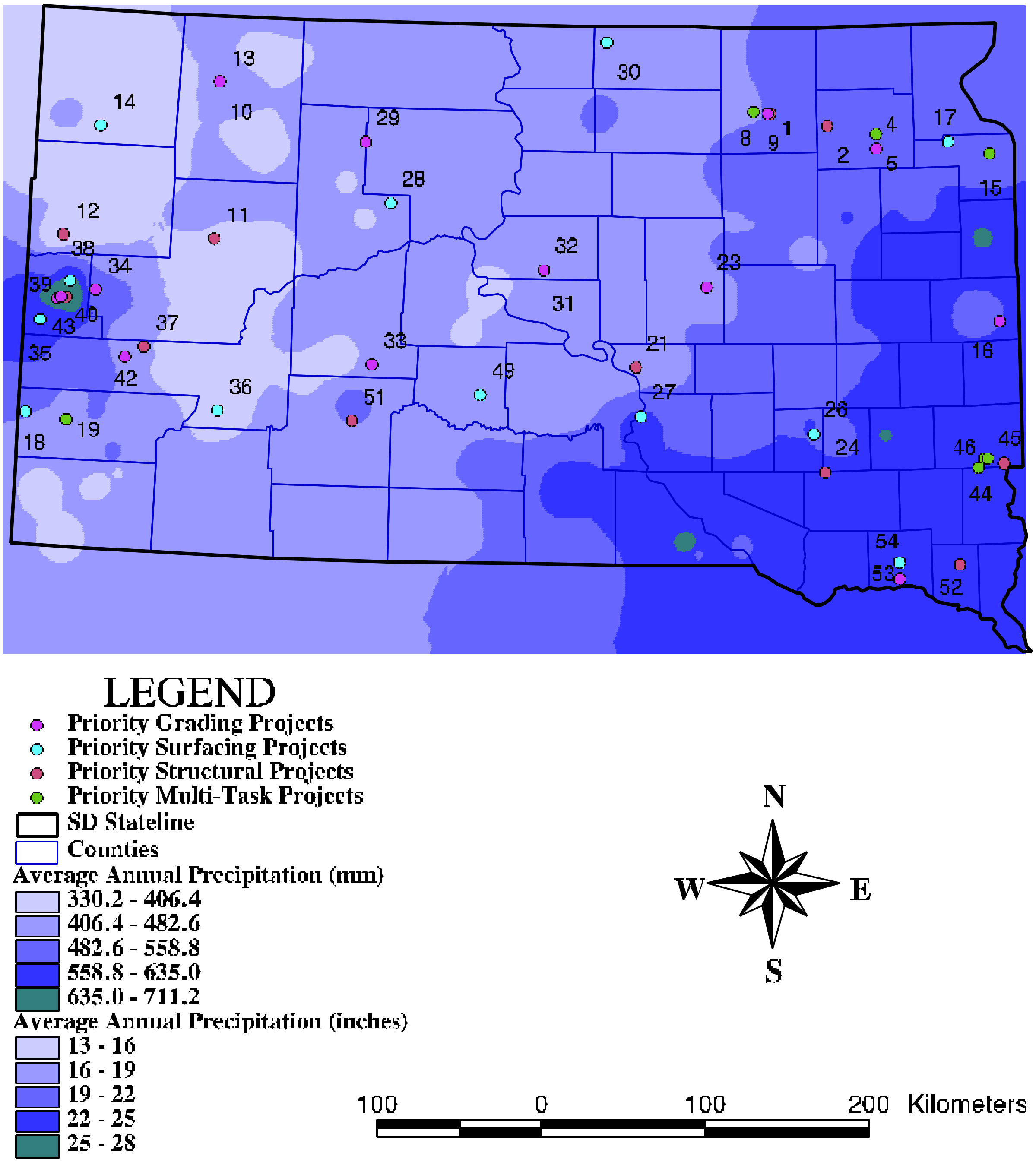

LEGEND
Priority Grading Projects
Priority Surfacing Projects
Priority Structural Projects
Priority Multi-Task Projects
SD Stateline
Counties
Average Annual Precipitation (mm)
330.2 - 406.4
406.4 - 482.6
482.6 - 558.8
558.8 - 635.0
635.0 - 711.2
Average Annual Precipitation (inches)
13 - 16
16 - 19
19 - 22
22 - 25
25 - 28
N
W
E
S
100
0
100
200
Kilometers

Table 3.2 Distribution of Starting Dates for Priority Projects

Year	Project Types				TOTAL
	Surfacing	Grading	Structural	Multi-Task	
92	0	0	0	1	**1**
93	2	3	1	1	**7**
94	3	3	2	1	**9**
95	7	2	10	2	**21**
96	6	6	2	2	**16**
TOTAL	**18**	**14**	**15**	**7**	**54**

Table 3.3 Distribution of Soil Classes for Priority Projects

Soil Classes	Project Types				TOTAL
	Surfacing	Grading	Structural	Multi-Task	
A	3	2	1	0	**6**
B	3	2	6	0	**11**
C	0	0	0	0	**0**
D	3	4	3	1	**11**
E	2	1	0	0	**3**
F	0	0	0	0	**0**
G	1	0	1	0	**2**
H	0	1	1	1	**3**
I	1	0	2	0	**3**
J	2	0	0	0	**2**
K	2	2	0	1	**5**
L	1	0	1	1	**3**
M	0	1	0	3	**4**
N	0	1	0	0	**1**
TOTAL	**18**	**14**	**15**	**7**	**54**

A - Northwest Loamy and Sandy Tableland
B – Clay Plain
C – Southwest Silty and Sandy Tableland
D – Black Hills
E – Agar Silty Plain
F – Glenham Loamy Plain
G – Williams Loamy Plain

H – Lake Dakota Plain
I – Houdek Loamy Plain
J – Clarno Loamy Prairie
K – Poinsett-Kranzburg Silty Prairie
L – Northeast Lowland
M – Moody Silty Prairie
N – Missouri Lowland

Table 3.4 Distribution of Priority Projects Among Contractors

	Project Types					
Contractors	**Surfacing**	**Grading**	**Structural**	**Multi-Task**	**TOTAL**	**Interview**
Stanley Johnsen Concrete Contractor, Inc.	4	2	1	1	**8**	**Y**
Swingen Construction Co.	0	0	5	0	**5**	**N**
A.G.E. Corporation	0	3	0	0	**3**	**Y**
Border States Paving, Inc.	3	0	0	0	**3**	**Y**
Castle Rock Construction Co.	2	0	0	1	**3**	**O**
Graves Construction Co., Inc.	0	1	2	0	**3**	**Y**
Heavy Constructors, Inc.	0	1	2	0	**3**	**Y**
Loiseau Construction, Inc.	0	3	0	0	**3**	**Y**
Anderson Western, Inc.	2	0	0	0	**2**	**O**
Dakota Const.	0	0	1	1	**2**	**Y**
McLaughlin & Schulz, Inc.	2	0	0	0	**2**	**N**
Progressive Construction	1	0	1	0	**2**	**N**
Sioux Falls Construction	0	0	2	0	**2**	**Y**
W. Hodgman & Sons, Inc.	2	0	0	0	**2**	**Y**
D & G Concrete Const., Inc.	0	1	0	0	**1**	**Y**
Duininck Bros., Inc.	1	0	0	0	**1**	**N**
E.H. Oftedal & Sons, Inc.	0	1	0	0	**1**	**N**
Foothills Contracting, Inc.	0	1	0	0	**1**	**Y**
J.H. Hilt Engineering, Inc.	0	0	1	0	**1**	**Y**
Lakeview Construction (Minn)	0	0	0	1	**1**	**N**
RG Construction	0	1	0	0	**1**	**N**
Riley Brothers	0	0	0	1	**1**	**N**
Triple R Paving, Inc.	1	0	0	0	**1**	**O**
Upper Plains Contracting, Inc.	0	0	0	1	**1**	**Y**
Zandstra	0	0	0	1	**1**	**N**
TOTAL	**18**	**14**	**15**	**7**	**54**	
INTERVIEWED	**9**	**12**	**9**	**3**	**33**	
	50.0%	**85.7%**	**60.0%**	**42.9%**	**61.1%**	

Y = Interviewed
N = Not Interviewed
O = Contacted, but not interviewed.

were completed for 33 out of 54 projects. Thirteen of the 25 different contractors were interviewed. This represents 52% of the priority projects and the contractors. The projects where contractors were interviewed represent an even distribution across project types.

The interview process did not provide information to quantitatively determine temperature and precipitation ranges appropriate for grading, surfacing and structural construction. The primary result of the interviews conducted provided a good understanding of how weather affects the different project types and locations differently based upon the experience of the engineers and contractors. This understanding proved invaluable for interpretation of biweekly progress reports and diary comments during the validation (presented in the next section).

In general, it was evident that adverse weather conditions can cause delays in construction. One question asked all contractors was, "How soon after a precipitation event can you return to the project?" In general, both paving and structural contractors felt they could return to the project the next day. However, depending upon the conditions, grading contractors will often require an additional day for conditions to dry out or to recover working conditions. Spring and fall weather conditions tended to be more critical as projects are just beginning or in the end stages.

It would appear that the entire grading construction process is subject to adverse weather, and maintaining adequate drainage during construction is critical to grading projects. After heavy or prolonged precipitation grading projects often require additional days to return to productive progress.

One of the most critical components for structure construction is the substructure. High flows in the drainage or stream channel can result in significant delays. Additionally, there did not appear to be any consistent approach to determining the degree of flow control necessary for construction of the substructure.

Critical components for paving construction are items that require work with the base or subgrade. On grading projects that were completed the previous year, the condition of the grading surface is critical to startup of the paving project. Another critical item for paving is the haul road and paving material stockpiles. Although the weather may be adequate to allow paving to take place, wet conditions can cause problems for the haul road, especially when drainage is poor. When paving material stockpiles become wet, it requires more effort to dry the material, reducing the production rate significantly.

The interview results were compiled and compared with the SDDOT engineer interview results. Other issues that were addressed in the interviews and beyond the scope of this project are summarized in Appendix A.

4.0 VALIDATION PROCESS

Initially, the objective was to validate ranges established by the interviews. Though, the interview process did not produce quantitative precipitation or temperature ranges, it did provide qualitative information on the addition of an adverse weather day for unexpected precipitation events. A review of weather comments from each project's bi-weekly progress Report (WPR) and field engineer diary was made for references to non-working days in order to establish precipitation ranges. To validate these non-working days with actual weather data, a climate database of weather data was set up using the National Climatic Data Center's (NCDC) CD-ROM. Weather parameter ranges were selected based on both the WPR and diary commented non-working days and the corresponding weather data from the climate database. Thresholds were established based on these precipitation ranges and subsequently used for development of the weather charts and maps.

4.1 Approach

One objective of the study was to take into consideration geophysical characteristics (i.e. soil characteristics). Although, weather parameter thresholds were not directly related to soil types, the projects used for validation represent almost all the different soil types within the state. The parameter thresholds established on a project by project basis inherently reflect the type of soils for that project. Thus, soil characteristics are indirectly related to the established weather parameter thresholds through the project validation process.

WPRs were requested for all projects identified in the interview process. These WPRs were reviewed to identify any weather-related days that occurred during the course of a project. Specific dates for all weather-related days were noted in data tables for each project.

To validate these weather days, the project diaries or pages for the pertinent dates were requested from each Department of Transportation area office. WPRs and diaries were analyzed for both weather-related comments and type of work being done on days when adverse weather occurred and these were noted in data tables. Inspection of diary pages revealed days that were weather-related but not noted in the WPRs. These days were included in the data tables and the corresponding weather data was gathered from the weather database. Based on comments in the diaries, a need was seen to include the day before and the day after a noted weather event to capture days when rain that occurred on a weekend or overnight was affecting the current weather day.

The weather-related days as noted in both the WPRs and project diaries were validated by looking at weather data from the climate stations closest to each project.

The weather database was created using the EarthInfo Summary of the Day CD-ROM which contains all the primary and cooperative climate stations in South Dakota including both active and inactive stations. The data set covers complete historical records up to 1995 for the active stations with daily observations of precipitation, snowfall, maximum and minimum temperatures and evaporation. Other pertinent data recovered from the CD-ROM were the station’s latitude, longitude, period of record and amount of coverage. All the available data was downloaded except for the evaporation data. This data is the current weather database that is used throughout the study.

Initially, 293 climate stations were referenced from the EarthInfo CD-ROM. After applying certain criteria, 103 climate stations remained. An interpolation method, Inverse Distance Weighted (IDW), was used for spatial distribution of these climate stations. IDW assumes that each input point (i.e., climate stations) has a local influence that diminishes with distance. It weights points closer to the processing cell greater than those farther away. In this method, there were two parameters specified. The first is the number of nearest neighbors using a default of 12 neighbors. This was chosen for the study as it best represents the surface. The second parameter specified was the power. This is the exponent of distance and controls the significance of surrounding points upon the interpolated value. The most reasonable results were obtained with a power of 3 because it gave larger influence to closer stations and smaller influence to stations farther away. As with all interpolation methods, this method works best with a greater number of input points and a sampling that is sufficiently dense. The 103 climate stations chosen for this study were spatially distributed such that most areas of the state were sufficiently represented.

Criteria were then applied to the climate stations to meet the objectives of the study. The criteria used were as follows:

1) <u>Only active stations were used</u>. This criteria was used to represent the most recent climatology data across the state and for continued updating of the weather database. As of 12/31/94, the number of active stations was 141.

2) <u>Only stations with at least 30 years of record were used as defined in the project scope</u>. This criteria resulted in 115 qualifying stations.

3) <u>The percent coverage of the period of record was to be at least 90 percent</u>. When the criteria was raised to 95 percent, an additional loss of 21 stations was encountered. The 90 percent criterion was chosen to create a database with sufficient density and as complete coverage as possible. After placing this restriction, 106 climate stations remained.

4) <u>Climate stations must have both precipitation and temperature data</u>. To account for joint probabilities, only stations that had both precipitation and temperature data were used. An additional 3 stations were lost resulting in 103 climate stations.

After all criteria were met, 103 climate stations remained for this study. The spatial distribution of these 103 climate stations is shown in Figure 4.1. The climate stations and their corresponding map IDs, station IDs, latitudes and longitudes are listed in Table 4.1.

The development of project data tables resulted from the need to compare the weather-related diary comments with the corresponding climate station data.

The actual construction projects were spatially distributed and overlaid with the climate stations, and the closest (usually less than 10 miles) climate station(s) were selected around each project to validate the weather comments. For each weather day noted in the WPRs, the corresponding climate data for each specific date was taken from the weather database. The climate information was transferred to the project data table.

The resulting data tables for each project include project latitude and longitude, the surrounding climate station(s) and their corresponding latitudes and longitudes, the climate station data including maximum temperature, minimum temperature, precipitation and snowfall, the WPR weather comments and the diary weather-related comments. Table 4.2 gives an example of a project data table.

Table 4.1 Climate Station Data

Map ID	Climate Station	Lat	Lon	Station ID
1	ABERDEEN REGIONAL AP	45.45	-98.43	20
2	ACADEMY 2NE	43.50	-99.07	43
3	ALEXANDRIA	43.65	-97.78	128
4	ARDMORE 2N	43.05	-103.65	236
5	ARMOUR	43.32	-98.35	296
6	BELLE FOURCHE	44.67	-103.85	559
7	BISON	45.52	-102.47	701
8	BONESTEEL	43.08	-98.95	778
9	BRIDGEWATER	43.55	-97.50	1032
10	BRITTON	45.78	-97.75	1049
11	BROOKINGS 2NE	44.32	-96.77	1076
12	CAMP CROOK	45.55	-103.98	1294
13	CANTON 4WNW	43.30	-96.67	1392
14	CASTLEWOOD	44.72	-97.03	1519
15	CEDAR BUTTE	43.58	-101.02	1539
16	CENTERVILLE 6SE	43.05	-96.90	1579
17	CLARK	44.88	-97.73	1739
18	CLEAR LAKE	44.75	-96.68	1777
19	COLUMBIA 8N	45.73	-98.30	1873
20	COTTONWOOD 2E	43.97	-101.87	1972
21	CUSTER	43.78	-103.60	2087
22	DEADWOOD	44.38	-97.55	2207
23	DESMET	44.38	-103.73	2302
24	DUPREE	45.05	-101.60	2429
25	DUPREE 15SSE	44.85	-101.45	2446
26	EUREKA	45.78	-99.63	2797
27	FAITH	45.03	-102.03	2852
28	FAULKTON	45.03	-99.13	2927
29	FLANDREAU	44.05	-96.60	2984
30	FORESTBURG 3NE	44.03	-98.07	3029
31	FORT MEADE	44.40	-103.47	3069
32	GANN VALLEY 4NW	44.07	-99.07	3217
33	GETTYSBURG	45.02	-99.95	3294
34	GLAD VALLEY 2W	45.40	-101.82	3316
35	GREGORY	43.23	-99.43	3452
36	HARRINGTON	43.17	-101.27	3574
37	HARROLD 12SSW	44.37	-99.80	3608
38	HIGHMORE 1W	44.52	-99.47	3832
39	HIGHMORE 23N	44.85	-99.48	3838
40	HILLAND 2NW	44.32	-101.87	3857
41	HOT SPRINGS	43.43	-103.47	4007
42	HOWARD	44.02	-97.52	4037
43	HURON REGIONAL AP	44.38	-98.22	4127
44	INTERIOR 3NE	43.75	-101.95	4184
45	IPSWICH	45.45	-99.03	4206
46	KENNEBEC	43.92	-99.87	4516
47	LEAD	44.35	-103.77	4834
48	LEMMON	45.93	-102.17	4864
49	LEOLA	45.72	-98.93	4891
50	LONG VALLEY	43.47	-101.50	4983
51	LUDLOW	45.85	-103.38	5048
52	MADISON 2E	44.00	-97.07	5090

Table 4.1 Climate Station Data (cont.)

Map ID	Climate Station	Lat	Lon	Station ID
53	MARION	43.42	-97.25	5228
54	MARTIN 1S	43.17	-101.73	5281
55	MCINTOSH 6SE	45.88	-101.30	5381
56	MELLETTE	45.15	-98.50	5456
57	MENNO	43.23	-97.58	5481
58	MIDLAND	44.07	-101.15	5506
59	MILBANK 2SSW	45.20	-96.63	5536
60	MILESVILLE 8NE	44.53	-101.57	5544
61	MILLER	44.52	-98.98	5561
62	MISSION	43.30	-100.67	5620
63	MISSION 14S	43.12	-100.62	5638
64	MITCHELL 2N	43.73	-98.02	5671
65	MOBRIDGE 2NNW	45.57	-100.45	5691
66	MT RUSHMORE NATL MEM	43.88	-103.45	5870
67	MURDO	43.88	-100.70	5891
68	NEWELL	44.72	-103.42	6054
69	OAHE DAM	44.45	-100.42	6170
70	OELRICHS	43.18	-103.23	6212
71	ONIDA 4NW	44.73	-100.15	6292
72	PACTOLA DAM	44.07	-103.48	6427
73	PHILIP 2N	44.07	-101.65	6552
74	PICKSTOWN	43.07	-98.53	6574
75	PIERRE MUNICIPAL AP	44.38	-100.28	6597
76	POLLOCK	45.90	-100.28	6712
77	PORCUPINE 11N	43.38	-102.38	6736
78	RALPH 1N	45.78	-103.07	6907
79	RAPIDCITY	44.12	-103.28	6947
80	RAPIDCITY REGINL AP	44.05	-103.07	6937
81	REDFIELD 2NE	44.90	-98.50	7052
82	REDIG 11NE	45.38	-103.38	7062
83	SELBY	45.50	-100.03	7545
84	SIOUX FALLS FOSS FLD	43.57	-96.73	7667
85	SISSETON 2E	45.67	-97.05	7742
86	SPEARFISH	44.50	-103.87	7882
87	STEPHAN 1ENE	44.25	-99.45	7890
88	SUMMIT 1W	45.30	-97.07	8116
89	TIMBER LAKE	45.43	-101.07	8307
90	TYNDALL	43.00	-97.87	8472
91	VERMILLION 2SE	42.75	-96.92	8622
92	WAGNER	43.08	-98.30	8767
93	WASTA	44.07	-102.43	8911
94	WATERTOWN MUNI AP	44.92	-97.15	8932
95	WAUBAY NWR	45.43	-97.33	8980
96	WEBSTER	45.33	-97.53	9004
97	WENTWORTH 2WNW	44.02	-97.00	9042
98	WESSINGTON SPRINGS	44.08	-98.57	9070
99	WHITE LAKE	43.73	-98.72	9232
100	WINNER	43.38	-99.87	9367
101	WOOD	43.50	-100.48	9442
102	YANKTON 2E	42.88	-97.35	9502
103	ZEONA 10SSW	45.07	-103.00	9537

Each project data table was evaluated to determine precipitation and temperature thresholds. It became apparent during the evaluation process that temperature thresholds would not be found this way due to the lack of data or insufficient data.

The evaluation process was accomplished in the following steps:

1) Days were selected based on WPR and/or diary comments noting a day as a non-working day.
2) The magnitude of the precipitation was noted from the surrounding climate stations for these days.
3) A range of threshold values were selected based on the precipitation magnitudes that caused a non-working day.

An example of the evaluation process using Table 4.2 follows.

Project Number IM090-1(59)30 was a grading project that started on April 16th of 1995 and ended on September 7th of 1996. For brevity, only two pages of the data table example are shown. The project was located at the intersection of I-90 and Highway 34. Ft. Meade was chosen as the only surrounding climate station due to its close proximity to the project site. This climate station is located about three miles east of the project location and is fairly representative of the weather occurring near the project. Each day that was noted as a non-working day in the project data table has corresponding weather data from Ft. Meade.

From Table 4.2, April 25, 28, May 1-3, 6, 8-10, 13, 24, 26, June 28, September 19, 20 and October 4, 5 and 30th are commented as non-working days or construction days affected by precipitation. The precipitation ranges from 6.10 mm (0.24 in) on October 4th to 97.3 mm (3.83 in) on May 8th. May 7th and 8th were not used for determining ranges due to the extreme rainfall. The final range then becomes 6.10 to 14.48 mm (0.24 to 0.57 in). On May 6th the climate data shows there was 9.14 mm (0.36 in) of precipitation and work was called off at 10 a.m., and on May 12th 9. 40 mm (0.37 in) of rain occurred and they still worked. This may be due either to most of the rain falling later in the day or not actually falling on the project site.

Most every day that was noted as a non-working day had rain amounts greater than 7.62 mm (0.30 in) and most days where they worked had no rain or rain amounts less then 7.62 mm (0.30 in). The threshold range identified for this project was 6.35 mm (0.25 in) to 12.70 mm (0.50 in). Another factor is cumulative rain that caused a non-working day the next day due to wet conditions. This can be seen on April 30th and May 1st where there was cumulative rain of more than an in that caused a non-working day on May 2nd. Note that May 3rd was also a non-working day due to wet conditions when little precipitation fell the day before. For the majority of the projects, extreme precipitation in excess of 19.05 mm (0.75 in) usually added only one additional day. In this case, the addition of two days is possibly the result of other factors in addition to the extreme precipitation amount.

After evaluation of all projects, the precipitation amounts generally ranged from 6.35 mm (0.25 in) to 12.70 mm (0.50 in) for all construction types. A difference between grading projects and surfacing or structural projects was that extreme precipitation of 19.05 mm (0.75 in) of rain or greater seemed to cause a non-working day the following day for grading projects but not for surfacing or structural projects.

Table 4.3 shows the statistics for the various construction types after all projects were evaluated. From the statistics it can be seen that the mean ranges from 8.64 mm (0.34 in) to 9.65 mm (0.38 in). A conservative value of 7.62 mm (0.30 in) was selected for the threshold.

Table 4.3 Statistics of Estimated Thresholds Based on Construction Type

	Surfacing		Grading		Structural		Muti-task	
	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)
Max	11.43	0.45	11.43	0.45	12.70	0.50	10.16	0.40
Min	7.62	0.30	6.35	0.30	7.62	0.30	7.62	0.30
Median	10.16	0.40	8.89	0.35	8.89	0.35	10.16	0.40
Mean	9.65	0.38	8.64	0.34	9.40	0.37	9.65	0.38

The interview process and evaluation of project data tables lead to observations that grading projects were affected by rains from previous days that caused an additional non-working day resulting in a division of the construction types into two construction classes, one for grading and another for surfacing and structural projects.

Temperature thresholds could not be determined from the WPRs or the diaries due to limited data, limited documentation and work performed in large temperature variations. A temperature threshold of 0° C (32° F) was selected based on the literature review where it is used by the Wisconsin DOT, the Army Corps of Engineers and other state DOTs. In Section 5.0, results of an analysis to compare the number of adverse weather days due to temperatures below both 0° C (32° F) and 4.4° C (40° F) is shown.

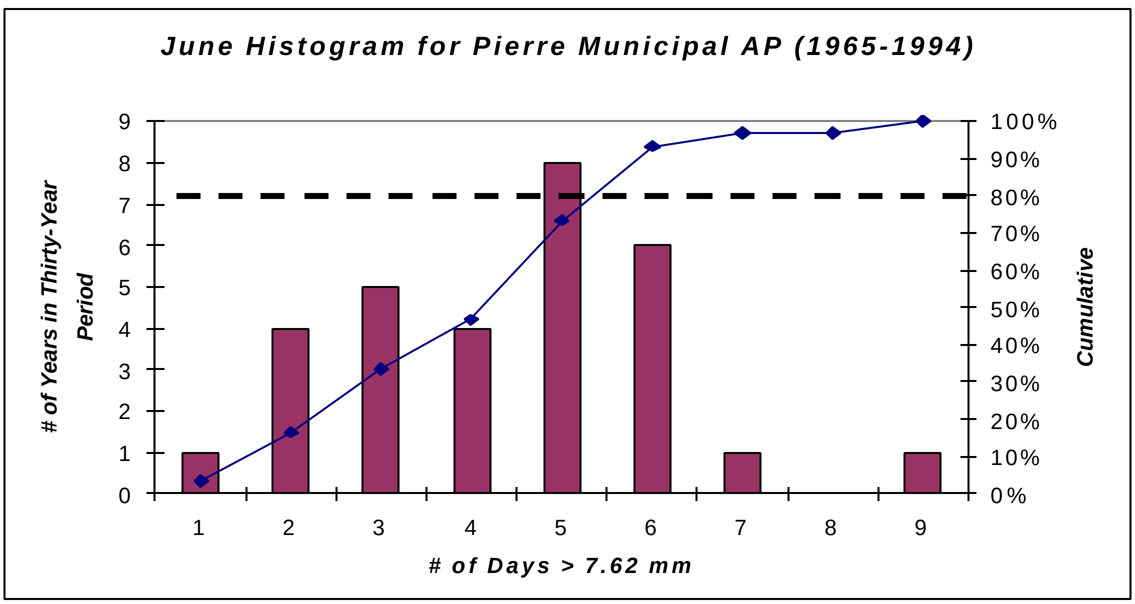
5.0 USE OF CRITERIA TO ANALYZE HISTORICAL DATA

The objective of this analysis was to apply the weather parameter thresholds based on the interviews, validation process and climate data to calculate the number of days that exceed the thresholds. A day when the weather parameter threshold is exceeded results in an adverse weather day. A statistical approach is then used to establish the expected number of adverse weather days for each month. This analysis included using a precipitation threshold of greater than 7.62 mm (0.30 in), a maximum daily temperature threshold of less than 0° C (32° F) and 4.4° C (40° F). Additionally, an analysis was done on the sensitivity of the estimated monthly expected adverse weather days to the precipitation threshold.

5.1 80th Percentile

It was decided to run all scenarios based on the 80th percentile. The 80th percentile represents that only 20 percent of the time will the number of adverse weather days for any given month be exceeded. In Figure 5.1, Pierre is used as an example showing the number of days that exceeded the 7.62 mm (0.30 in) precipitation threshold in June against the frequency of occurrences (number of years over the thirty-year period) based on the 80th percentile.

Figure 5.1 Histogram of Adverse Weather Days for June at Pierre Municipal Airport



The figure shows that over a thirty-year period, the number of days that exceeded 7.62 mm (0.30 in) of precipitation is five days or less 80 percent of the time.

5.2 Sensitivity

Initially a sensitivity analysis was performed on precipitation threshold values based on the 80th percentile to test the sensitivity of the number of days exceeding a specific threshold. The thresholds define the amount of precipitation or temperature necessary to cause a non-working day.

The general approach to the statistical analysis involved the following steps:

1. Complete monthly records over the period of record for the selected stations were queried. (i.e., a month has a complete record when there is a measurement recorded for each day of the month.) When a month didn't have a complete record, it was not included in the analysis.
2. For each month in each year of record, a count was made of the number of days a specified weather threshold was exceeded.
3. A count was made of the number of times (frequency) that each possible number of exceedances had occurred for each month over all years of record.
4. A count was done of the number of days the precipitation threshold was equaled or exceeded 20% of the time (i.e., is less than or equal to 80 percent of the time).

As an example, the sensitivity analysis is shown for Pierre Municipal Airport using precipitation thresholds of 2.54, 5.08, 7.62, 10.16, 12.70 and 15.24 mm (0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 in).

Figure 5.2 graphically displays the change in annual number of adverse weather days as a function of precipitation threshold. This figure indicates that there is a higher change (slope of line) initially between thresholds of 2.54 mm (0.1 in) to 5.08 mm (0.2 in) and then is fairly constant. Figure 5.3 shows the number of days in each month averaged over the thirty-year period that exceeded the threshold 20 percent of the time.

Figure 5.2 Annual Number of Exceedances for Various Thresholds

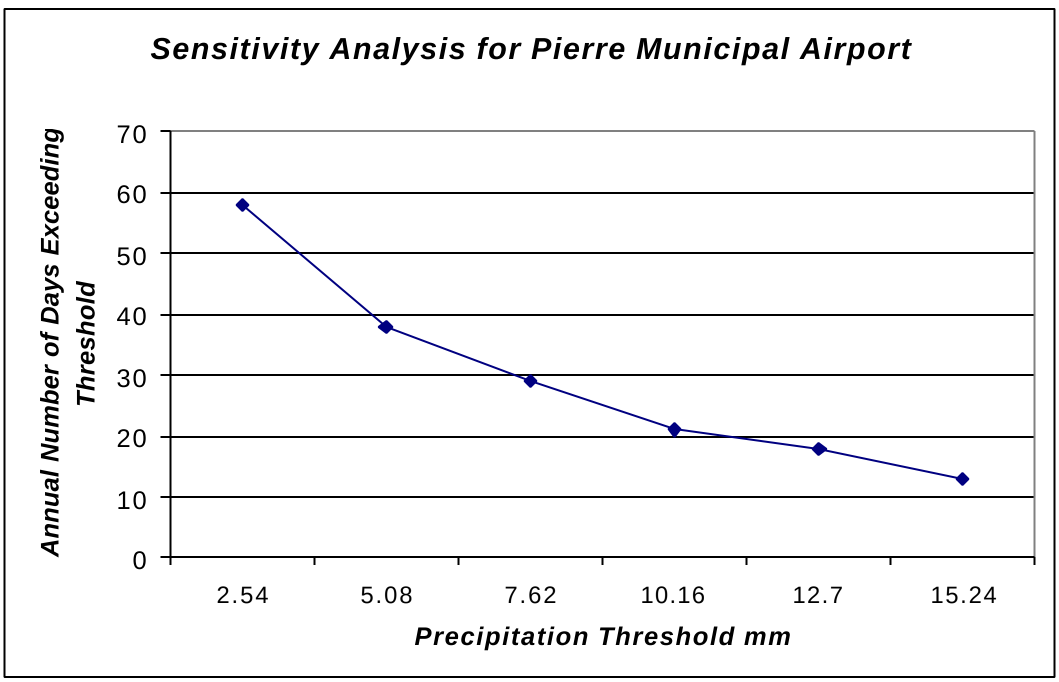
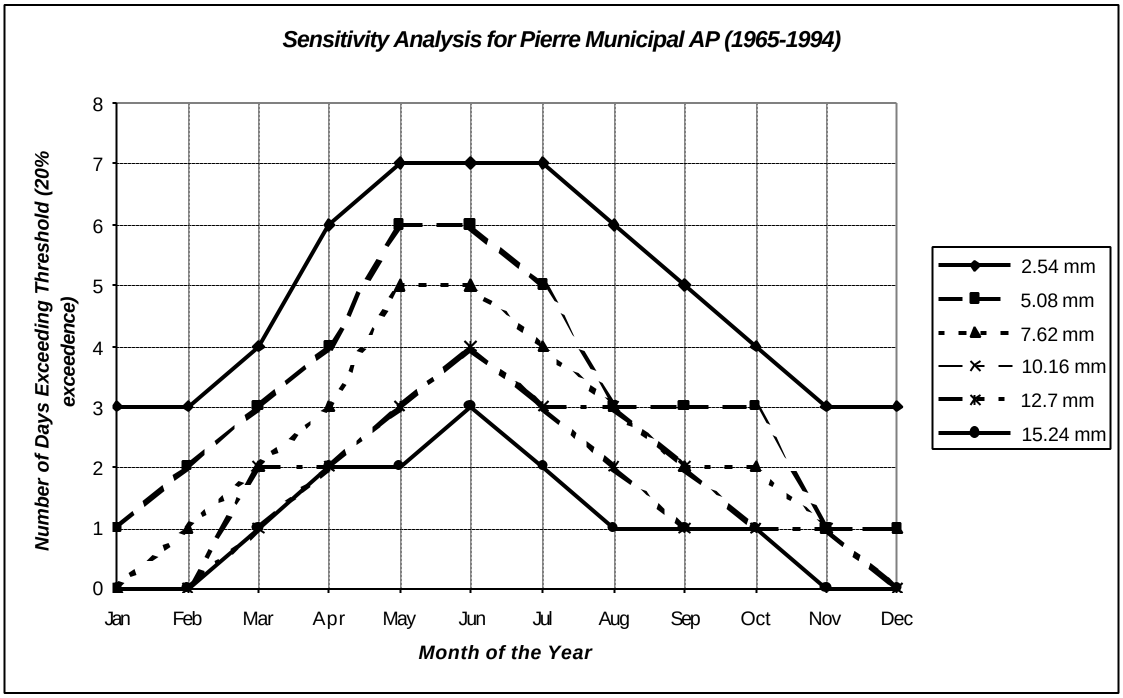


Figure 5.3 Monthly Number of Exceedances for Various Thresholds



Reviewing Figures 5.2 and 5.3, shows that the sensitivity of the annual number of days decreases non-linearly as the threshold increases. The biggest change occurs between a threshold of 2.54 mm (0.1 in) and 5.08 mm (0.2 in). Figure 5.2 shows this as a steeper slope between 2.54 mm (0.1 in) and 5.08 mm (0.2 in). This change is verified in Figure 5.3 where the number of days that exceeds each threshold is a difference of two or three days. The slope flattens out after 5.08 mm (0.2 in), and as can be seen in Figure 5.2, the number of non-working days either doesn't change or only changes by a day or two in any given month. Here it should be noted that the biggest differences do occur between the months of April and September.

Table 5.1 shows the number of days exceeding the specified precipitation threshold for each month and the total number of days on an annual basis.

Table 5.1 Sensitivity Analysis of Thresholds for Pierre Municipal AP

Month	Threshold 2.54 mm (0.10 in)	5.08 mm (0.2 in)	7.62 mm (0.30 in)	10.16 mm (0.40 in)	12.7 mm (0.50 in)	15.24 mm (0.60 in)
Jan	3	1	0	0	0	0
Feb	3	2	1	0	0	0
Mar	4	3	2	2	1	1
Apr	6	4	3	2	2	2
May	7	6	5	3	3	2
Jun	7	6	5	4	4	3
Jul	7	5	4	3	3	2
Aug	6	3	3	3	2	1
Sep	5	3	2	2	1	1
Oct	4	3	2	1	1	1
Nov	3	1	1	1	1	0
Dec	3	1	1	0	0	0
TOTAL	58	38	29	21	18	13

It should also be pointed out that the total number of days at the 2.54 mm (0.1 in) threshold may initially appear unrealistically high. For Pierre, it is 58 days or nearly two calendar months.

Table 5.2 gives the change in the annual number of adverse weather days for each 2.54 mm (0.1 in) incremental change in the precipitation threshold.

Table 5.2. Annual Number of Days and Percentage Change between Thresholds.

	Pierre		Bison		Lead		Sioux Falls	
Threshold	Days	Percent	Days	Percent	Days	Percent	Days	Percent
2.54 - 5.08 mm (0.10 - 0.20 in)	20	34.48%	22	36.67%	29	32.58%	18	26.87%
5.08 - 7.62 mm (0.20 - 0.30 in)	9	15.52%	7	11.67%	20	22.47%	13	19.40%
7.62 - 10.16 mm (0.30 - 0.40 in)	8	13.79%	8	13.33%	10	11.24%	7	10.45%
10.16 - 12.7 mm (0.40 - 0.50 in)	3	5.17%	5	8.33%	5	5.62%	5	7.46%
12.7 - 15.24 mm (0.50 - 0.60 in)	5	8.62%	6	10.00%	8	8.99%	6	8.96%

It can be seen that by changing the threshold value, the annual change in the number of days for Pierre decreases 20 days from 2.54 to 5.08 mm (0.1 to 0.2 in), 9 days from 5.08 to 7.62 mm (0.2 to 0.3 in) and 8 days from 7.62 to 10.16 mm (0.3 to 0.4 in). At the 5.08 mm (0.2 in) threshold, the annual number of days drops an average of 34.48 percent. For 7.62 mm (0.3 in) the average drop is 15.52 percent and 10.16 mm (0.4 in) is 13.79 percent.

The sensitivity analysis was also done for three other climate stations: Bison, Lead and Sioux Falls Foss Field. The results are also found in Table 5.2.

5.2 Scenarios

Based on the literature review, validation results and sensitivity analysis, the following criteria were used for the 80th percentile:

1) A single precipitation threshold of 7.62 mm (0.3 in) was used to determine the number of adverse weather days. This threshold was applied uniformly across the state for all construction types.

2) Two temperature thresholds of 0° C (32° F) and 4.4° C (40° F) were applied uniformly across the state. The 0° C (32° F) threshold was applied for all construction types and the 4.4° C (40° F) scenario was applied for surfacing and structural projects only. A comparison was made between these thresholds and is shown in the results.

3) A precipitation threshold of 19.05 mm (0.75 in) was used for adding additional adverse weather days to grading projects only.

4) A combination of temperature less than 0° C (32° F) and precipitation greater than 7.62 mm (0.3 in) was used to calculate the joint probability that both occur on the same day. This avoids double accounting when the temperature threshold is not exceeded and the precipitation threshold is exceeded in the same day. This combination was also run for temperature less than 4.4° C (40° F) and precipitation greater than 7.62 mm (0.3 in) for surfacing and structural projects only.

Extraction of weather data from the climate station database for use in running the above scenarios was accomplished with a combination of a database script and a computer program. The climate station database was queried for 1965 to 1994 precipitation and temperature records for each qualifying station as described in the last section. These records were queried for days that exceeded 7.62 mm (0.3 in) of precipitation, 19.05 mm (0.75 in) of precipitation, temperature less than 0° C (32° F) or temperature less than 4.4° C (40° F). These remaining records qualified as meeting all criteria, and statistics were then calculated for each climate station.

5.3 Results

An example of one scenario output for Aberdeen Regional Airport for all months from precipitation greater then 7.62 mm (0.3 in) is shown in Table 5.3.

Table 5.3. Output From 0.30 inch Precipitation Scenario

Climate Station	Long	Lat	Month	Mean	Std Dev	# of Days	Range		# of Months
ABERDEEN REGIONAL AP	-98.43	45.45	Jan	0.172	0.378	0	0	1	29
ABERDEEN REGIONAL AP	-98.43	45.45	Feb	0.233	0.423	1	0	1	30
ABERDEEN REGIONAL AP	-98.43	45.45	Mar	1	0.91	2	0	3	29
ABERDEEN REGIONAL AP	-98.43	45.45	Apr	2.133	1.996	3	0	10	30
ABERDEEN REGIONAL AP	-98.43	45.45	May	2.433	1.978	4	0	8	30
ABERDEEN REGIONAL AP	-98.43	45.45	Jun	2.933	1.965	4	0	8	30
ABERDEEN REGIONAL AP	-98.43	45.45	Jul	2.867	1.857	4	0	8	30
ABERDEEN REGIONAL AP	-98.43	45.45	Aug	1.933	1.315	2	0	5	30
ABERDEEN REGIONAL AP	-98.43	45.45	Sep	1.7	1.32	2	0	5	30
ABERDEEN REGIONAL AP	-98.43	45.45	Oct	1.267	1.459	2	0	5	30
ABERDEEN REGIONAL AP	-98.43	45.45	Nov	0.533	0.67	1	0	2	30
ABERDEEN REGIONAL AP	-98.43	45.45	Dec	0.107	0.409	0	0	2	28

This example shows that for the period 1965 to 1994 in January for the Aberdeen Regional Airport, 29 months were used in the calculations and one was not due to missing data. The mean January precipitation was 4.37 mm (0.172 in) with a standard deviation of 0.378, the number of adverse weather days due to precipitation greater than 7.62 mm (0.30 in) for the 80^{th} percentile was zero, the minimum number of times that precipitation exceeded 7.62 mm (0.30 in) was zero and the maximum number of times precipitation exceeded 7.62 mm (0.30 in) in the 29 months of January, was one. All additional outputs read the same.

A comparison between temperature thresholds for surfacing and structural projects was made due to Section 320.3 of the South Dakota Standard Specifications for Roads and Bridges where it is stated that 4.4° C (40° F) is the low cutoff for asphalt projects with a seasonal limitation from May 1^{st} to October 15^{th}, inclusive. Previously, a run was made using 0° C (32° F) as the maximum temperature threshold. A new run using a maximum temperature threshold of 4.4° C (40° F) was run for comparison. The output was used to calculate adverse weather days due to temperatures less than 4.4° C (40° F) and precipitation greater than 7.62 mm (0.3 in).

Table 5.4 lists mean adverse weather days for all months for each zone based on the 80th percentile over the thirty-year period. To retain consistency between runs, joint probabilities were accounted for, but extreme precipitation greater than 19.05 mm (0.75 in) was not.

Table 5.4 Temperature Comparison of Number of Adverse Weather Days

	Zone 1			***Zone 2***			***Zone 3***		
	0 Celsius 32 Fahrenheit	4.4 Celsius 40 Fahrenheit	Days Change	0 Celsius 32 Fahrenheit	4.4 Celsius 40 Fahrenheit	Days Change	0 Celsius 32 Fahrenheit	4.4 Celsius 40 Fahrenheit	Days Change
January	18	24	6	18	26	8	15	23	8
February	19	24	5	18	24	6	12	18	6
March	12	19	7	10	17	7	9	15	6
April	5	8	3	4	6	2	6	9	3
May	5	5	0	4	5	1	6	6	0
June	5	5	0	5	5	0	5	5	0
July	4	4	0	4	4	0	5	5	0
August	3	3	0	3	3	0	4	4	0
September	2	2	0	2	2	0	3	3	0
October	3	6	3	3	5	2	4	6	2
November	11	17	6	9	16	7	8	15	7
December	21	27	6	19	26	7	15	22	7
Annual	9	12	3	8	12	4	8	11	3

	Zone 4			***Zone 5***			***Zone 6***		
	0 Celsius 32 Fahrenheit	4.4 Celsius 40 Fahrenheit	Days Change	0 Celsius 32 Fahrenheit	4.4 Celsius 40 Fahrenheit	Days Change	0 Celsius 32 Fahrenheit	4.4 Celsius 40 Fahrenheit	Days Change
January	16	21	5	21	27	6	23	29	6
February	14	19	5	19	24	5	21	26	5
March	8	13	5	10	17	7	12	21	9
April	4	6	2	4	6	2	4	7	3
May	4	4	0	4	4	0	5	5	0
June	4	4	0	5	5	0	6	6	0
July	3	3	0	4	4	0	5	5	0
August	3	3	0	4	4	0	4	4	0
September	2	2	0	3	3	0	4	4	0
October	2	4	2	3	4	1	3	5	2
November	7	12	5	9	16	7	11	18	7
December	14	20	6	19	26	7	22	28	6
Annual	7	9	2	9	12	3	10	13	3

Table 5.4 shows the greatest variability in the number of adverse weather days for the months of January, February, March, November and December. Notable changes in the number of days are also evident in April and October. May through September show almost no variability whatsoever. The 4.4° C (40° F) threshold does explicitly show the division from non-construction to construction season, verifying the need for asphalt projects to start later and shut down earlier in the year than other project types. The change in the number of expected adverse weather days across zones for both April and October is rather small and does support the possibility of expanding the surfacing and structural construction season.

Separate runs were made for each scenario using three separate programs. These three programs were the temperature, precipitation and combination programs.

1) The temperature program allows for five missing days (i.e., days with missing data) per month for each month over the thirty-year period. The process to generate the statistics follows:

    a) The geographical locations of the climate stations were converted into decimal degrees.
    b) A check for missing data was made throwing out any month with more than 5 missing days. A calculation using zero missing days was initially made and resulted in a large loss of temperature data.
    c) Statistics were generated for each climate station. An example based on precipitation greater than 7.62 mm (0.30 in) is shown in Table 5.3.
    d) The results were put in an output file and imported into ArcView for spatial distribution.

2) The precipitation program ran exactly the same way as the temperature program, but values were calculated for precipitation that exceeded 7.62 mm (0.3 in). Missing days were not allowed in this program since the precipitation data had excellent coverage and including missing days didn't improve results a great deal.

3) The combination program was run for days when the temperature threshold was not exceeded and the precipitation threshold was exceeded. This eliminated double accounting when both occurred on the same day.

6.0 DEVELOPMENT OF ZONES, MAPS AND CHARTS

The objective of this task was to use the number of monthly adverse weather days estimated in Task 6 to develop working-day weather zones, maps and charts for the two project classifications of grading, surfacing and structures.

The number of adverse weather days was added as an attribute to the spatial representation of the climate stations. Using this information, a spatial distribution of the estimated number of expected adverse weather days (non-working days due to weather) was created for two seasons. Figure 6.1 shows the construction season (April 1 to November 30) and Figure 6.2 shows the off-season (December 1 to March 31). Since the spatial distribution of the two seasons varied greatly, the construction season spatial distribution was used to create zones, since this is the only time when working days are counted. Figure 6.3 shows the distribution of expected adverse weather days and the established zones. The zones were modified to follow county lines to make it easy to distinguish which zone a project is in. The zone number and the counties that are included in each zone are listed below.

Zone 1: Perkins and Corson

Zone 2 : Campbell, Harding, McPherson, Walworth, Edmunds, Ziebach, Dewey, Potter, Butte, Sully, Hyde, Stanley, Hughes, Lyman, Buffalo, Jones, Mellette, Todd and Meade

Zone 3: Lawrence, Western Pennington (West of Highway 79)

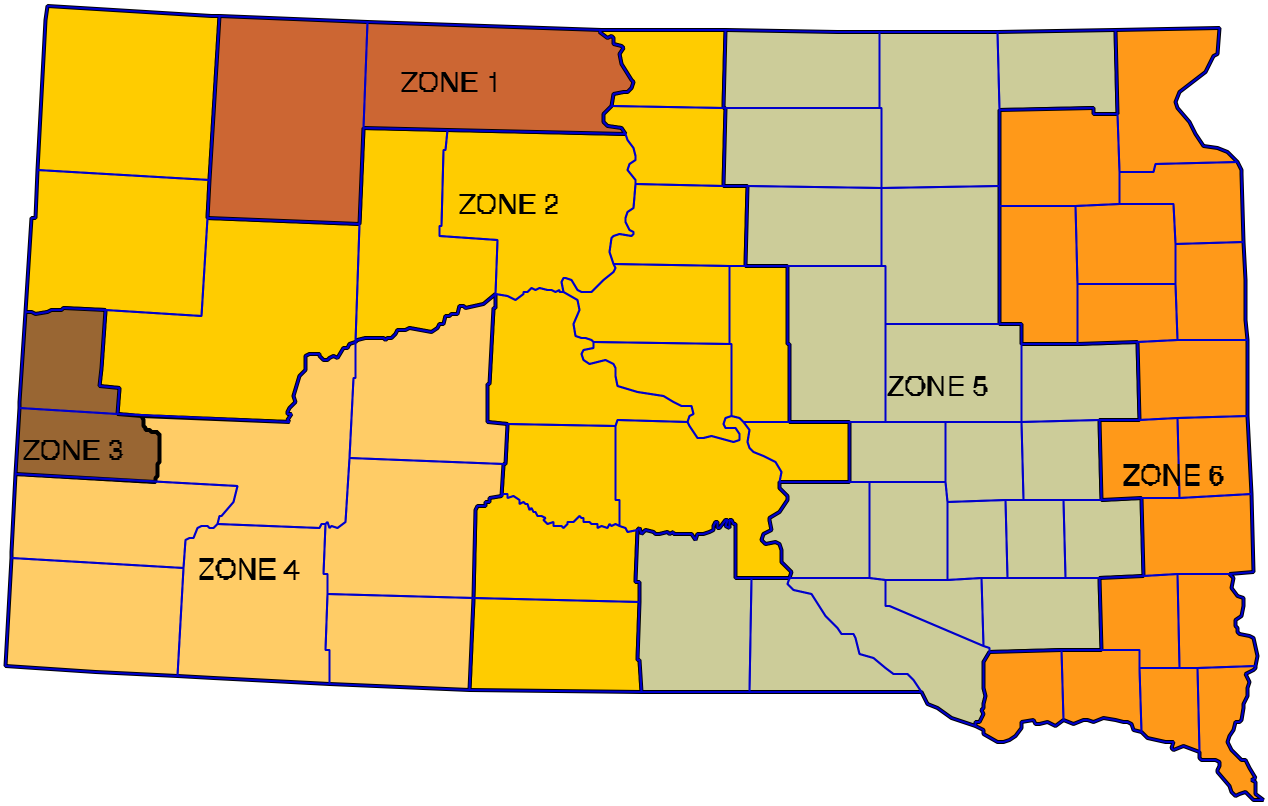
Zone 4: Haakon, Jackson, Fall River, Bennett, Custer, Shannon and Eastern Pennington (East of Highway 79)

Zone 5: Hutchinson, Douglas, Charles Mix, Gregory, Tripp, McCook, Hanson, Davison, Brule, Aurora, Miner, Sanborn, Jerauld, Kingsbury, Beadle, Hand, Spink, Faulk, Marshall and Brown.

Zone 6: Roberts, Day, Grant, Clark, Codington, Deuel, Hamlin, Brookings, Moody, Lake, Minnehaha, Turner, Lincoln, Yankton, Bon Homme, Union and Clay.

The climate stations were then grouped into the zones in which they were located. The maximum, minimum, mean and standard deviation of the expected adverse weather days were calculated for each zone and type of construction. Tables 6.1 and 6.2 give the summary data for each zone and construction category.

Figure 6.3 Expected Adverse Weather Days for South Dakota



	Grading Projects						Surfacing and Structural Projects					
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Jan	18	18	16	16	22	24	18	18	15	16	21	23
Feb	19	18	12	14	19	21	19	18	12	14	19	21
Mar	12	10	9	8	11	13	12	10	9	8	10	12
Apr	6	5	8	5	6	6	5	4	6	4	4	4
May	6	6	8	6	6	6	5	5	6	4	4	5
Jun	7	6	7	6	7	8	5	5	5	4	5	6
Jul	5	5	6	5	6	7	4	4	5	3	4	5
Aug	4	4	5	4	5	6	3	3	4	3	4	4
Sep	3	3	4	3	4	5	2	2	3	2	3	4
Oct	4	3	5	3	4	4	3	3	4	2	3	3
Nov	11	9	8	7	10	12	11	9	8	7	10	11
Dec	21	19	15	14	20	22	21	19	15	14	20	22

NOTE: Includes Holidays and Weekends.

Table 6.1 Statistics of the Expected Number of Adverse Weather Days for Grading Projects.

	ZONE 1				ZONE 2				ZONE 3			
	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min
Jan	18	1	19	16	18	2	24	15	16	2	18	14
Feb	19	1	20	18	18	2	20	13	12	1	13	10
Mar	12	1	13	11	10	2	14	7	9	1	10	8
Apr	6	0	6	6	5	1	8	4	8	1	8	7
May	6	1	7	5	6	1	9	4	8	1	9	6
Jun	7	0	7	7	6	1	9	5	7	1	9	6
Jul	5	1	6	4	5	1	8	4	6	2	9	4
Aug	4	1	4	3	4	1	7	2	5	1	6	4
Sep	3	1	4	2	3	1	6	2	4	1	5	3
Oct	4	1	5	4	3	1	7	1	5	1	6	3
Nov	11	1	12	11	9	1	12	6	8	1	10	7
Dec	21	1	23	20	19	3	24	13	15	1	16	13
TOTAL	116				106				103			

	ZONE 4				ZONE 5				ZONE 6			
	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min
Jan	16	2	19	12	22	2	26	18	24	2	28	19
Feb	14	3	20	9	19	2	23	15	21	3	25	15
Mar	8	2	10	4	11	2	15	8	13	2	16	10
Apr	5	1	6	4	6	1	8	4	6	1	6	4
May	6	1	8	4	6	1	8	4	6	1	9	5
Jun	6	1	7	4	7	1	9	6	8	1	10	7
Jul	5	1	7	3	6	1	7	4	7	1	10	4
Aug	4	1	4	3	5	1	6	3	6	1	7	4
Sep	3	1	5	2	4	1	6	3	5	1	7	4
Oct	3	1	4	1	4	1	5	2	4	1	6	3
Nov	7	1	9	5	10	1	13	7	12	1	15	9
Dec	14	2	18	9	20	3	24	14	22	3	26	15
TOTAL	91				120				134			

NOTE: Includes Weekends and Holidays.

Table 6.2 Statistics of Expected Adverse Weather Days for Surfacing and Structural Projects.

	ZONE 1				ZONE 2				ZONE 3			
	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min
Jan	18	1	19	16	18	2	23	15	15	1	16	14
Feb	19	1	20	18	18	2	20	13	12	1	13	10
Mar	12	1	13	11	10	2	14	7	9	1	10	8
Apr	5	1	5	4	4	1	6	3	6	1	7	5
May	5	1	5	4	5	1	7	3	6	1	7	5
Jun	5	0	5	5	5	1	7	3	5	1	6	4
Jul	4	1	4	3	4	1	6	3	5	2	7	3
Aug	3	1	3	2	3	1	6	2	4	1	5	3
Sep	2	1	3	2	2	1	5	1	3	1	4	2
Oct	3	1	4	3	3	1	6	1	4	1	5	3
Nov	11	1	12	11	9	1	12	6	8	1	9	7
Dec	21	1	23	20	19	3	24	13	15	1	16	13
TOTAL	108				100				92			

	ZONE 4				ZONE 5				ZONE 6			
	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min	Mean	Std Dev	Max	Min
Jan	16	2	19	12	21	2	25	17	23	2	27	18
Feb	14	3	20	9	19	2	23	15	21	3	25	15
Mar	8	2	10	4	10	2	14	7	12	2	15	9
Apr	4	1	5	3	4	1	6	3	4	1	5	3
May	4	1	6	3	4	1	6	3	5	1	7	4
Jun	4	1	5	3	5	1	6	4	6	1	7	5
Jul	3	1	5	2	4	1	5	3	5	1	6	3
Aug	3	1	3	2	4	1	5	2	4	1	5	3
Sep	2	1	4	2	3	1	4	2	4	1	5	3
Oct	2	1	3	1	3	1	4	1	3	1	4	2
Nov	7	1	9	5	10	2	13	7	11	2	15	8
Dec	14	2	18	9	20	3	24	14	22	3	26	15
TOTAL	81				107				120			

NOTE: Includes Holidays and Weekends

From the data in Tables 6.1 and 6.2, it can be seen that the standard deviations during the construction season range from 0-2 with a large majority having a standard deviation of 1. This indicates that approximately 67 percent of the data are within one day or less of the mean. Therefore, the monthly mean of each zone was used to represent the zone during that month, and the annual total (sum of the monthly totals) is shown in Table 6.3. Table 6.3 shows that there was a change of 6 to 14 days between the Grading Class and the Structural and Surfacing Class.

Figure 6.3 shows the resulting zones and expected adverse weather days for each construction category. This information is used to develop estimated adverse weather day charts.

6.1 Background on Charts

The literature review of other state transportation agencies identified, in general, four different types of working-day charts.

The Wisconsin Department of Transportation uses a table format in which the probable working days are represented by a percentage factor. (This percentage factor is the percent of time available of possible days available each month.) This representation is beneficial as it can be applied to time periods that are not complete months. This representation can also be applied to both working-day or calendar-day projects, if the possible number of working days or calendar days is available. An example of Wisconsin's table format is shown in Table 6.4.

Several states use a cumulative day chart where the expected number of adverse weather days available for each month are given along with cumulative days starting at the beginning of any month and ending on the last day of any subsequent month. The disadvantage is that the number of days available for a partial month is not readily determined. An example of this type can be seen in Table 6.5.

Another type of table used by states to show the amount of expected adverse weather days on a monthly basis can be as simple as the one in Figure 6.3.

Table 6.3 Comparison of Annual Expected Adverse Weather Days in Each Zone.

	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
Grading	116	106	103	91	120	134
Surfacing & Structural	108	100	92	81	107	120

Note: Includes Holidays and Weekends

Table 6.4 Percentage Table Used by the Wisconsin Department of Transportation.

MONTH	Grading %	Bridge %	Base Course %	P.C.C. Pavement %	Asphaltic Concrete Pavement %	Painting %
January	58	61				
February	43	65				
March	58	65				
April	58	77	58			
May	80	80	80	80	68	64
June	80	80	80	80	81	69
July	85	85	85	85	85	69
August	85	85	85	85	85	77
September	76	80	72	72	70	60
October	77	73	73	72	27	
November	70	70	74	43		
December	58	58	58			

Table 6.5 Cumulative Count of Expected Number of Calendar Days Available Over a Three Year Period.[2,3]

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
6	24	Apr	24							
6	25	May	49	25						
7	23	Jun	72	48	23					
5	26	Jul	98	74	49	26				
4	27	Aug	125	101	76	53	27			
3	27	Sep	152	128	103	80	54	27		
4	27	Oct	179	155	130	107	81	54	27	
11	19	Nov	198	174	149	126	100	73	46	19
6	24	Apr	222	198	173	150	124	97	70	43
6	25	May	247	223	198	175	149	122	95	68
7	23	Jun	270	246	221	198	172	145	118	91
5	26	Jul	296	272	247	224	198	171	144	117
4	27	Aug	323	299	274	251	225	198	171	144
3	27	Sep	350	326	301	278	252	225	198	171
4	27	Oct	377	353	328	305	279	252	225	198
11	19	Nov	396	372	347	324	298	271	244	217
6	24	Apr	420	396	371	348	322	295	268	241
6	25	May	445	421	396	373	347	320	293	266
7	23	Jun	468	444	419	396	370	343	316	289
5	26	Jul	494	470	445	422	396	369	342	315
4	27	Aug	521	497	472	449	423	396	369	342
3	27	Sep	548	524	499	476	450	423	396	369
4	27	Oct	575	551	526	503	477	450	423	396
11	19	Nov	594	570	545	522	496	469	442	415

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

The Wyoming DOT uses an incremental decreasing estimated adverse weather days table. This can be seen as Table 6.6 below.

Table 6.6. Incremental Decreasing Estimated Adverse Weather Days for the Month of January.

DATE		ADVERSE WEATHER DAYS
Jan.	1-4	8
	5-8	7
	9-12	6
	13-16	5
	17-20	4
	21-24	3
	25-28	2
	29-31	1

In choosing a type of chart to represent available working days or expected adverse weather days, it is important to take into consideration how the charts will be used. Initially there are two primary applications of the working-day information: 1) it will be used to estimate the contract time necessary for completion of the project; and 2) it will be used to determine time extensions due to unexpected adverse weather. Additionally, it will be beneficial to have a field chart available to engineers and contractors that will provide them information on expected adverse weather days over the next month. This chart is to be used only as a "planning tool" since it is based on a linear distribution of the expected adverse weather days over each month. This chart is shown as Table 6.7. With this understanding, all of the basic chart types, except the table used by Wyoming, will be used for implementation of the expected adverse weather days. These chart types are shown in Appendix B.

6.2 Estimation of Contract Time

Initially it is important to have a clear definition of a calendar day and a working day. For the charts developed and presented here, a calendar day is based on all available days including weekends and holidays. Working days are based on a five-day workweek and excludes weekends and holidays.

Table 6.7. Number of Expected Adverse Weather Days (in Calendar Days) Remaining to the End of the Month from a Specified Day in the Month.[1]

	Day of the Month																														
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
Jan	18	17	17	16	16	15	15	14	13	13	12	12	11	10	10	9	9	8	8	7	6	6	5	5	4	3	3	2	2	1	1
Feb	19	18	18	17	16	16	15	14	14	13	12	12	11	10	10	9	8	7	7	6	5	5	4	3	3	2	1	1			
Mar	12	12	11	11	11	10	10	9	9	9	8	8	7	7	7	6	6	5	5	5	4	4	4	3	3	2	2	2	1	1	0
Apr	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	0	0	
May	5	5	5	4	4	4	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	0	0	0
Jun	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	0	0	
Jul	4	4	4	4	4	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	0	0	0
Aug	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Sep	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	
Oct	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Nov	11	11	10	10	10	9	9	9	8	8	7	7	7	6	6	6	5	5	4	4	4	3	3	3	2	2	1	1	1	0	
Dec	21	20	20	19	18	18	17	16	16	15	14	14	13	12	12	11	10	10	9	8	7	7	6	5	5	4	3	3	2	1	1

[1]The distribution of expected adverse weather days in each month is linear and is intended for "planning purposes" only.

It is commonly found in the literature of the other state transportation agencies that a common equation to convert calendar days into working days is to multiply the calendar days by 5/7. This is based upon the assumption of a five-day workweek. If using a six-day workweek, multiply by 6/7. Conversely, to convert from working days to calendar days, the working days are multiplied by 1.4 (i.e., seven divided by five). How holidays are incorporated into this conversion was not discussed. However this project does incorporate holidays in Section 6.2.1 Procedures for Project Time Estimation.

One of the objectives of this project is to develop working-day weather charts for implementation of innovative contracting methods. Although there are several innovative contracting methods including Incentive/Disincentive, A + B Bidding and lane rental, it is assumed that all contracting methods fall under either a calendar-day or working-day category. Thus, examples for implementing the working-day weather data are developed for both calendar and working-day contracts.

The steps and examples below show how the charts can be used in the estimation of contract time for working-day and calendar-day contracts.

6.2.1 Procedures for Project Time Estimation.

Conversion of Expected Number of Working-Days to Total Estimated Contract Time in Calendar Days.

1) Calculate the number of days required to complete the construction project from production rates and other logistical factors; let this be the Estimated Required Construction Time (ERCT).

   - For example, a working-day contract is expected to be completed in 60 days according to production rates and other logistical factors. The project is located in Zone 1 and is a grading project that is set to start on May 1, 1998.

$$\mathrm{ERCT} = 60$$

2) Multiply the estimated required time for construction by 1.4 to transform into calendar days; let this be the Calendar Day Estimated Construction Time (CDECT).

$$CDECT = 1.4 \times ERCT = 84$$

3) Select the "Cumulative Expected Number of Calendar Days Chart" based upon project construction type and zone.

   - Use Zone 1 - Grading Projects
     Cumulative Count of Expected Number of Calendar Days (See Table 6.5)

4) Starting at the month of your starting date, work your way down the column until you reach the largest number that is less than the Calendar Day Estimated Construction Time (CDECT). This value will be called the Last Full Month Value (LFMV). The project will last fully through the month that corresponds with the LFMV. Let this month be the Last Full Month (LFM).

   - Using a starting day of May 1,

$$LFMV = 74$$

- Therefore,

$$LFM = JULY$$

5) Subtract the Last Full Month Value (LFMV) from the Calendar Day Estimated Construction Time (CDECT). This value will become the Remainder Value (RV).

$$RV = CDECT - LFMV = 84 - 74 = 10$$

6) Select the corresponding Percentage Factor (PF) for the Last Month (LM), the month following the Last Full Month (LFM), from the "Estimated Percentage of Calendar Days Per Month" table based on zone and project type (See Table 6.8)

$$LM = AUGUST$$

$$PF = .87 = 87\%$$

Table 6.8. Estimated Percentage of Calendar Days Available Per Month

	Grading Projects						Surfacing and Structural Projects					
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Jan	42%	39%	48%	48%	29%	23%	42%	42%	52%	48%	32%	26%
Feb	32%	36%	57%	50%	32%	25%	32%	36%	57%	50%	32%	25%
Mar	61%	68%	71%	74%	65%	58%	61%	68%	71%	74%	68%	61%
Apr	80%	83%	73%	83%	80%	80%	83%	87%	80%	87%	87%	87%
May	81%	81%	74%	81%	81%	81%	84%	87%	81%	87%	87%	84%
Jun	77%	80%	77%	80%	77%	73%	83%	83%	83%	87%	83%	80%
Jul	84%	84%	81%	84%	81%	77%	87%	87%	84%	90%	87%	84%
Aug	87%	87%	84%	87%	84%	81%	90%	90%	87%	90%	87%	87%
Sep	90%	90%	87%	90%	87%	83%	93%	93%	90%	93%	90%	87%
Oct	87%	90%	84%	90%	87%	87%	90%	90%	87%	94%	90%	90%
Nov	63%	70%	73%	77%	67%	60%	63%	70%	73%	77%	70%	63%
Dec	32%	39%	52%	55%	39%	29%	32%	39%	52%	55%	39%	29%

Note: Percentages represent the total number of calendar days available in the month (includes holidays and weekends) less the number of expected adverse weather days.

7) Divide the Remainder Value (RV) by the Percentage Factor (PF) from the table. This is the Overflow Days (OD) that extend into the month following the Last Full Month (LFM).

$$OD = \frac{RV}{PF} = \frac{10}{.87} = 11.49$$

8) Round the Overflow Days (OD) to the next highest integer.

$$OD = 12$$

9) Calculate the number of Holidays (HOL) that occur during the time frame of the project.

10) There are two holidays from May 1, 1998 to August 12, 1998 (See Table 6.9)
   - Therefore,

$$HOL = 2$$

11) Add Holidays (HOL) to the Overflow Days (OD) to get the Total Overflow Days (TOD).

$$TOD = HOL + OD = 2 + 12 = 14$$

12) This is the number of days that are allowed for the Month Following (MF).

- Therefore, the Estimated Ending Date (EED) for this project would be the 14th of August. For this example, the Total Estimated Contract Time in calendar days is 106 days for the time period May 1 to August 14 and represents 60 working days.

$$TECT = 106$$

Table 6.9. Holidays Recognized by the State of South Dakota

Month	Holidays
January	New Year's Day (Jan.1)
January	Martin Luther King Day (3rd Monday)
February	Presidents' Day (3rd Monday)
May	Memorial Day (Last Monday)
July	Independence Day (July 4)
September	Labor Day (1st Monday)
October	Native American Day (2nd Monday)*
November	Veterans' Day (Nov. 11)
November	Thanksgiving Day (4th Thursday)
December	Christmas Day (Dec. 25)

*Native American Day is an observed holiday according to the 1998 South Dakota Standard Specifications for Roads and Bridges, but written permission from the region engineer is not necessary to work.

This procedure provides the means to determine calendar days from working days. To determine the number of working days within a calendar day time period, the procedure is simply reversed as shown below.

Conversion of Total Estimated Contract Time in Calendar Days to Expected Number of Working Days

1) The following information must be available: The Total Expected Contract Time (TECT), the type of project, the zone in which it is located and the starting date of the project.

- For example, the Total Expected Contract Time (TECT) for a working day project is 106 calendar days (includes holidays and weekends). The project is located in Zone 1 and is a grading project that is set to start on May 1, 1998.

$$TECT = 106$$

2) Calculate the Expected Ending Date (EED) (by counting the number of TECT days from your starting date.

- Therefore, for this project August 14th would be the Expected Ending Date (EED).

$$TECT = 31 + 30 + 31 + 14 = 106$$

$$EED = AUG\ 14$$

3) Determine the Last Month (LM) and the Total Overflow Days (TOD).

- Let August be the Last Month (LM) and the Total Overflow Days (TOD) equal the days in the Last Month.

$$LM = AUGUST$$

$$TOD = 14$$

4) Calculate the number of Overflow Days (OD) by subtracting the number of Holidays (HOL) during the Total Estimated Contract Time (TECT).

- There are two holidays from May 1, 1998, to August 14, 1998 (See Table 6.9).

$$HOL = 2$$

$$OD = TOD - HOL = 14 - 2 = 12$$

5) Multiply the Overflow Days (OD) by the Percentage Factor (PF) for the appropriate month (LM), zone and project type from Table 6.8 to get the Remainder Value (RV). The Remainder Value is the actual amount of calendar days that are available when considering estimated adverse weather. Round the Remainder Value (RV) to the nearest whole number.

- Select the Percentage Factor (PF) for August, Zone 1 and grading projects.

$$PF = .87$$

$$RV = PF \times RV = .87 \times 12 = 10.44 = 10$$

6) Select the appropriate "Cumulative Expected Number of Calendar Days Chart" based upon construction zone and type. Starting at the month of the starting date, read the expected amount of calendar days for the Last Full Month (LFM), the month before the Last Month (LM). This amount is the Last Full Month Value (LFMV).

$$LFMV = 74$$

7) Add the Last Full Month Value (LFMV) and the Remainder Value (RV) to calculate the Calendar Day Estimated Construction Time (CDECT).

$$CDECT = RV + LFMV = 10 + 74 = 84$$

8) Divide the Calendar Day Estimated Construction Time (CDECT) by 1.4 to get the Estimated Required Construction Time (ERCT).

$$ERCT = CDECT / 1.4 = 84 / 1.4 = 60$$

- Therefore, there are 60 estimated working days available to complete this project.

6.3 Time Extensions Due to Adverse Weather

Determination of time extensions is an element vital to this study. Time extensions are justified if the number of actual adverse weather days exceeds the expected number of adverse weather days over the life of a project. Assessing time extensions for adverse weather requires:

- Determining and keeping track of the number of non-working days caused by adverse weather.
- Calculating the difference between the actual adverse weather days and expected adverse weather days.

6.4 Procedures for Determining Adverse Weather Days.

The recommended procedure for determining whether or not a day is an adverse weather day is based upon decisions made and weather data gathered in the field. The information gathered and results of this study show that there is not a clear definitive way to quantify the occurrence of a non-working day due to adverse weather. The ability to work during varying weather conditions is based on many factors. Thus, the procedure recommended here for determination of an adverse weather day are guidelines. The recommended approach on deciding whether an adverse weather day is occurring is as follows and should be initiated as soon as adverse weather takes place.

1) Initially the contractor and field engineer should get together and discuss whether the conditions warrant working or not working. If the contractor and field engineer both agree that the conditions are such that working is impossible, then the day or partial day is a non-working day due to weather.

2) If the contractor believes that work cannot be performed in the weather conditions due to low efficiency or other reasons and the field engineer believes that the contractor could work without major hindrance, then the decision will be based upon the weather data for that site for the day in question. If the precipitation over the full day of work in question before the time of shutting down is greater than or equal to 7.62 mm (0.30 in) of precipitation (snow or rain equivalent), then it is an adverse weather day. If the precipitation value is less than 7.62 mm (0.30 in) of precipitation (snow or rain equivalent), then it is a working day. If it rained greater than 19.05 mm (0.75 in) the previous day, then it is an adverse weather day for grading projects only. If the maximum temperature during the day is less than 0°C (32°F), then it is an adverse weather day. Otherwise, if the maximum temperature is greater than or equal to 0°C (32°F), then it is not an adverse weather day.

This will allow the contractor and field engineer to work together to decide whether or not a day is workable or not, and if they disagree, then the precipitation and temperature information provide a clear and concise answer that neither can dispute, thus reducing claims. Then for each month the total number of actual adverse weather days can be compared to the expected number of adverse weather days as shown in Figure 6.3. If the number of actual adverse weather days exceeds the expected amount, then the difference is the potential days for contract time extensions due to weather. A running total will be kept for all of the months over the entire project. Once the project completion date is reached or the number of working days is completed, the contractor may request that any net positive adverse weather days from the running total be awarded as a time extension.

Thorough and complete documentation in the field is necessary for determination of adverse weather days. This documented project information will also be valuable for verifying and updating the results of this study. Therefore, it is recommended that the following data needs to be documented on either a new form or a modification made to the current WPRs.

- The controlling item of work
- Total precipitation for the day
- Time that the precipitation started
- Duration of the precipitation
- Maximum and minimum temperature for the working hours
- Decision made on whether or not it was an adverse weather day

This data should be sent to the contractor at the end of the week for his review. Within 7 days the contractor can sign it in agreement with the information stated or return it unsigned with a written explanation of what was not in agreement.

It is recommended that a portable weather station be set up on every project site where work is performed for more than 30 days. This will be beneficial in several ways. First, it would measure the parameters necessary for use in making on-site decisions and for determining time extensions due to adverse weather. Also, it would measure the necessary parameters to update this study in two to three years. The following are the recommended parameters and measurement intervals for the portable weather stations:

1. Precipitation
   - Measured on an hourly basis at a minimum.
   - When precipitation begins, ends and duration.
   - Daily total.

2. Temperature
   - Measured on an hourly basis at a minimum.
   - Maximum and minimum daily temperature.

3. Wind
   - Wind speed measured on a five-minute basis.
   - Hourly maximum wind speed.
   - Direction.

4. Soil Temperature

It is recommended that hourly temperature data be collected in order for the on-site climate stations to be of maximum value. The time when the temperature falls below the established threshold is essential to the decision making process for the current working day and for future analysis in updating the study.

Ideally, the collection and recording of precipitation would consist of when the rain or snowfall event began, when it ended, the amount collected and the duration. For example, the event begins when the first 0.25 mm (.01 in) of water equivalent precipitation is collected and ends when the precipitation has quit for a certain amount of time. The precipitation bucket would then dump, record the amount, record the duration and then reset for the next precipitation event. At a minimum it is recommended that precipitation is collected each hour as it occurs, the amount and duration is recorded and then the bucket dumps. Additionally, the water content of snowfall could be measured using a heater with the precipitation bucket to melt any snowfall.

Wind and soil temperature are recommended parameters to be measured. Collection of these two parameters would aide in establishing wind thresholds and soil temperature profiles. Established wind thresholds could help determine adverse weather days for days with extremely high winds or when temperatures are low enough to cause wind chill effects. A soil temperature profile would aide in determining when the frost depth is low enough to allow construction activities to resume. These two parameters could then be included in any update of this study. For the present study, neither wind or soil temperature were used as there was insufficient data reported in the diaries and WPRs to substantiate any decisions making on these parameters. Wind collection components are standard on most of the portable weather stations and a soil temperature component would add an additional cost.

Portable weather stations come in different price ranges depending on their instrumentation, data collection complexity and ease of installation. For each level of complexity the price of the systems increase with low range models collecting mainly daily weather values and high-range models using smaller collection time intervals. The smaller time intervals provides the best information for both decision making and analysis. The low-range models are not recommended without a computer interface for collecting smaller time interval weather data. The high-range models are recommended and can be used with or without a PC to collect the recommended data.

Below are two climate stations that fit into each price category. These were found on the World Wide Web where current prices and additional information can be found on all the various weather parameter collection components.

<u>Low Range (less than $1500).</u>

♦ Weather Monitor II Combination Kit by Davis Instruments

Includes:

- Temperature and humidity sensor for measuring maximum and minimum temperature.
- Rainfall collecting bucket for measuring daily and accumulated rainfall.
- Anemometer for measuring wind speed and direction.
- Total price with no options: about $500.00 plus shipping.

Options:

- Solar power kit ($295.00).
- Battery for running solar power kit during darkness ($30.00).
- WeatherLink datalogger for storing data from 1 to 120 minute increments. ($165.00).
- Modem ($250.00).
- Heater for rain bucket for melting snow ($120.00).
- Total price including recommended options: about $1400.00 plus shipping.
- Total price does not include price of PC (286 or better) for interfacing with datalogger or a shelter to protect data logger.

<u>High Range (greater than $1500.00).</u>

This is a build your own weather station with a datalogger that stores information onsite without the aide of a computer. Additional considerations include a 286 PC or better for interfacing with the datalogger for analysis purposes.

♦ MetData1 by Campbell Scientific

Includes:

- Datalogger ($1090.00).
- Weather proof shelter for datalogger ($200.00).
- Solar power kit and power supply ($410.00)
- Air temperature probe ($71.50).
- Rain gage ($301.25).
- Total Price around $2100.00 plus shipping for collection of temperature and precipitation parameters without computer interface.
- Anemometer ($550.50).
- Soil temperature probe ($72.75).
- Total cost for measuring all recommended parameters without computer interface is currently around $2700.00 plus shipping.

7.0 COMPARISON WITH US ARMY CORPS OF ENGINEERS WORKING-DAY WEATHER CHARTS

The objective of this task (task 9) is to document how the US Army Corps of Engineers working-day weather charts, which have been utilized for construction activities at Ellsworth Air Force Base, South Dakota, compare with the working-day weather charts developed in this study. The COE methodology is taken directly from the US Army Corps of Engineers Construction Bulletin (June, 1996).

Development of the anticipated normal weather delay schedules, by month, for each geographic location are based on data published by the National Oceanic and Atmospheric Administration (NOAA). NOAA provides a count of the number of days of precipitation exceeding 0.10 in and the number of days with a temperature less than 32° F. These day counts are based on a ten-year period of record. Calculation of the monthly normal anticipated weather delay days utilizes an 80 percent concurrence; that is, of the days listed for each activity (precipitation and temperature), two or more will be occurring simultaneously, 80 percent of the time. The procedure is outlined below for the month of January.

NOAA data (this data is always in calendar day) for the month of January.

1) Days of Precipitation $\geq$ 2.54 mm (0.10 in) = 9 days
2) Days of Temperature below 0°C (32° F) = 3 days

- The days of precipitation over 2.54 mm (0.1 in) is the maximum delayer; therefore, that number is used as the base line. Other weather (temperature) is used to calculate the "nonconcurrence" days.

3) Nonconcurrence = 0.20 x 3 = 0.6 calendar days = 1 calendar day
   (all fractions are rounded to whole numbers)

4) Total Normal Anticipated Weather Delay for the Month = 9 + 1 = 10 calendar days

It should be noted that the COE recommends that the result should be evaluated against practical experience at the particular site.

Table 7.1 gives the "Anticipated Normal Weather Delay Days" for Ellsworth Air Force Base and the Adverse Weather Days in zone 4 for both grading and paving and structure construction.

Table 7.1 Comparison of Normal Weather Delay Days (COE) to Adverse Weather Days (SDDOT) for Ellsworth Air Force Base.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
COE	10	9	9	8	7	7	7	5	6	5	7	8	**88**
Grading	16	14	8	5	6	6	5	4	3	3	7	14	**91**
Surfacing & Structures	16	14	8	4	4	4	3	3	2	2	7	14	**81**

Difference in the annual totals is 3 days or 3.4 percent between grading and COE, and 7 days or 8 percent between paving and structures and COE. Based on the variability inherent in the data these differences are not considered large. However, the differences that occur on a monthly basis could be considered significant. The seasonal transition months of March and November are almost equal. For the months of April through October the results of this study estimate fewer adverse weather days than the COE. This difference is likely due to the use of a 2.54 mm (0.1 in) threshold for precipitation by the COE verses a 7.62 mm (0.3 in) threshold used in this study. For the months of December through February the results of this study show significantly more adverse weather days than the COE method. Although both methods use the same temperature threshold of 0° C (32° F), the COE assumes an 80 percent concurrence factor. This assumes that 80 percent of the days with a temperature less than 0° C (32° F) occur simultaneously with a precipitation event greater than 2.54 mm (0.1 in). In this study we calculated the actual joint occurrences of precipitation greater than 7.62 mm (0.3 in) and temperature less than 0° C (32° F) on a monthly basis. For the months of December through February, the number of joint occurrences ranged from 0 to 1 on a monthly basis. Thus, the assumption of 80 percent concurrence would appear to be high. However, the number of joint occurrences would likely increase as the precipitation threshold is lowered.

Although, there are differences in the weather days estimated using the COE method when compared to the results of this study. These differences are explained by the differences in the thresholds and the methodology. The results of this study do reflect the information gathered and used to determine the expected number of adverse weather days.

8.0 FINDINGS AND CONCLUSIONS

The results reflect an understanding of the effects of weather on different construction types in different geographical and climate areas. Specific thresholds were established in order to calculate expected adverse weather days. However, the actual amount of precipitation that will cause a non-working day will vary depending on several factors.

The calculations at each climate station are specific based on the assumptions and methodology and represent the expected number of adverse weather days at that location. The adverse weather day charts developed for each zone represent an average based on all climate stations in that zone. Thus, specific locations at the edges of the zones will tend to be slightly higher or lower than the mean. The zones were developed to represent variability across the state while at the same time limiting the development of excessive information. Variability within zones can be reduced by increasing the number of zones, moving to a county by county basis, or developing charts for individual stations.

The expected number of adverse weather days and associated working day charts developed in this study do provide a definitive basis for the estimation of contract time and determination of contract time extensions. The question as to whether or not an adverse weather day has occurred resulting in a non-working day is defined.

9.0 IMPLEMENTATION RECOMMENDATIONS

The following recommendations are based on the information and results presented in this study and the actions necessary to achieve the desired goals.

1) The following additions, deletions and changes should be made to Section 8.6 "Determination and Extension of Contract Time" of the 1998 South Dakota Department of Transportation Standard Specifications for Roads when the next revision is completed to incorporate the estimated expected adverse weather days. In the interim , it is recommended that the following be included as a special provision of all contracts as soon as possible. An example special provision is provided in Appendix C. These actions are necessary to fully achieve the objectives of this study.

1-1) Item 8.6.A.2 on page 43 and 8.6.B.2 on page 45 be deleted.

1-2) Items 8.6.A.3 - 8.6.A.7 on page 43 and 8.6.B.3 - 8.6.B.7 on page 45 be decreased by one.

1-3) Item 8.6.A.1 on page 43 and 8.6.B.1 on page 45 be replaced with the following:

The occurrence of unexpected adverse weather during the life of the Contract will be considered a basis for extending contract time when work is not already suspended for other reasons. Unexpected adverse weather means weather which at the time of year it occurs is unusual for the place in which it occurs (i.e. adverse weather beyond the expected amount.)

Extension of time for unexpected adverse weather will be determined on a monthly basis and will include only those actual adverse weather days in excess of the normal adverse weather days included in the Contract Time. Expected adverse weather means adverse weather which, regardless of its severity, is to be reasonably expected for that particular place at that time of year. The expected adverse weather days included in the Contract Time are based on historical records of temperature and precipitation for the six zones and two project classifications as shown in Figure 6.3.

Actual Adverse weather days are those days meeting one or more of the criteria in "a", "b", "c" and "d" below. Time extensions for days meeting more than one criterion will take into consideration only that criterion having the greatest impact. Actual adverse weather days covered by criterion "a", "b", "c", or "d" will be counted without regard to when they occur or their impact on contract completion. Adverse weather days which exceed the number of expected adverse weather days as shown in Figure 6.3 will be considered for time extensions if they occur on a working day or in the case of criterion “c”, occur on a Sunday or holiday preceding a scheduled working day in which case one full day will be allowed

e. Days with maximum temperature of 0°C (32°F) or less - one full day allowed.
f. Days when 7.62 mm (0.30 inch) or more precipitation (rain or snow equivalent) occurs - one full day allowed.
g. Days when 19.05 mm (0.75 inch) or more precipitation (rain or snow equivalent) occurs on a grading project - two full days allowed.
h. Days when weather-related conditions exist which prohibit proper performance of work as specified - one full day allowed, subject to the agreement of both the contractor and the project engineer. If no agreement is reached, then the criteria "a", "b" and "c" supercede. Allowance of such days will be subject to the work which is delayed being critical to timely contract completion and the contractor making every reasonable effort to minimize the adverse impact of the conditions. Also, if the contractor chooses or decides to work on the controlling item, a working day will be counted.

1-4) The following definitions should be added to Division 1, Section 1 Definitions and Terms.

(1) <u>Adverse weather day</u>: A day when the magnitude of a weather parameter (precipitation or temperature) is such that it creates conditions that inhibit the ability of the contractor to work productively on the critical construction item.

(2) Expected adverse weather days: The number of adverse weather days expected to occur on a monthly basis and defined for six zones and two different construction types (1. grading and 2. surfacing and structures) within each zone.

(5) Unexpected adverse weather days: The number of adverse weather days that exceed the expected number of adverse weather days determined on a monthly basis.

(6) Actual adverse weather days: The actual number of adverse weather days that occur during a single month.

2) Develop and adopt a standard procedure policy for calculation of contract completion time that takes into consideration available working days or calendar days. A defined procedure will promote consistent use of the working day weather charts. Additionally, a standard policy will help contractors in understanding the expectations of SDDOT and how the expected adverse weather days have been used to estimate the contract time. This action is necessary to fully achieve the objectives of this study.

3) Specific weather information; precipitation (hourly and daily total), temperature (hourly, minimum and maximum), wind (direction, hourly and maximum) should be collected in the field for determination of adverse weather days. This information should be added to the biweekly progress reports and field diaries. This information will prove beneficial to validation and updating of the working day weather charts developed in this study. This action is necessary to fully achieve the objectives of this study.

4) A small climate station should be operated at each construction site for projects lasting more than 30 days. The climate data will provide recommended field information needed to define adverse weather days and again provide for validation and updating of the working day weather charts developed in this study.

5) It is recommend that the development and application of the working day weather charts be presented in a training format to SDDOT engineers at each area office. Understanding the development of the working day weather charts will be beneficial in their application. This will also enable a question and discussion session regarding field procedures for defining adverse weather. This could be conducted by the appropriate SDDOT representative and/or a
representative from the research team.

6) Following a two or three year period it is recommended that construction and weather data gathered in the field be used to validate and possibly update the working day weather charts developed in this study. To facilitate this evaluation, it is recommended that a common working day weather database be developed to store this information and that it be made accessible to both SDDOT and interested contractors. This could be delegated to the appropriate SDDOT department or developed as follow-up research.

7) Future research is recommended for defining the flows, and associated risk, used for sizing control structures in drainages associated with structure construction. High flows in drainage channels and streams cause significant construction problems and potential delays and are directly related to weather. However, working day weather charts do not deal directly with high flows in drainage channels and streams. A defined flow and associated risk would provide for consistent design and sizing of control structures needed during construction. Additionally the defined risk would provide a clear definition when severe flow conditions occur.

10.0 BIBLIOGRAPHY

Albro, A. S. Jr., Major General, “Construction Contract Time Extensions for Weather,” U.S. Army Corps of Engineers Memorandum and Attachments (April 1984).

Bunkers, Matt, “A Climatological Evaluation of the Northern Plains from the Late 19th Century to 1990.” Masters Thesis 1993.

Feyerherm, A.M, L. Dean Berk and W.C. Burrows, “Probabilities of sequences of wet and dry days in SD” North Central Research Publication 161. Agricultural Experiment Station, K. State University of Agriculture and Applied Science. Manhattan Kansas. 1965.

Genetti, A.J., Colonel, “Construction Time Extensions for Weather Regulation ER 415-1-15” US Army Corps of Engineers. October 31, 1989.

Havers, J. A. and R. M. Morgan, “Literature Survey of Cold Weather Construction Practices,” Purdue Research Foundation, Hanover (May 1972).

Hinze, J. and B. Coleman, “Time Provisions in State Highway Construction Contracts,” Transportation Research Record 1310, Transportation Research Board, National Research Council, Washington D.C. (1991) pp. 34-43

Hinze, Jimmie and James Couey, “Weather in Construction Contracts,” Journal of Construction Engineering and Management, Vol. 115, No. 2, June 1989.

Isom, Sam, “Weather Delay Time Extensions: Contract Administration for Contractors.” Highway and Heavy Construction. V128, p41, July 1985.

Li, Shirong, “New Approach for Optimization of Overall Construction Schedule.” Journal of Construction Engineering and Management. March 1996. 7-13

Mills, D. Q., “Seasonality: Scope and Extent,” AGC Seasonality in Construction Conference, Washington D.C. (1968) pp. 10-19.

Russo, J. A. Jr., “The Complete Money Saving Guide to Weather for Contractors,” Environmental Information Services Newington Connecticut (September 1971).

Russo, J. A. Jr., “The Operational and Economic Impact of Weather on the Construction Industry of the United States,” The Travelers Research Center Inc., Hartford (March 1965).

Schroer, C. R. “Developing and Analyzing Adverse Weather Data,” U.S. Army Corps of Engineers Construction Bulletin (June 1996).

South Dakota Department of Transportation, “Standard Specifications for Roads and Bridges.” 1990 Edition.

Spuhler, Walter, W.F. Lytle and Dr. Dennis Moe, “Climate of South Dakota” Agriculture Experiment Station, SD State University, Brookings. Bulletin 582. Nov. 1971.

Transportation Research Board, “NCHRP Synthesis of Highway Practice 47: Effect of Weather on Highway Construction,” National Research Council, Washington D.C. (1978).

Transportation Research Board, “NCHRP Synthesis of Highway Practice 79: Contract Time Determination,” National Research Council, Washington D.C. (Oct. 1981).

Transportation Research Board, “NCHRP Synthesis of Highway Practice 215: Determination of Contract Time for Highway Construction Projects,” National Research Council, Washington D.C. (1995).

Trauner Consulting Services, Inc., “Criteria and Guidelines for Innovative Contracting” South Dakota Department of Transportation, Pierre, S.D. (February 1996)

Westin, Fred C., Leo F. Puhr and George J. Buntley, “Soils of South Dakota.” Agronomy Department Agriculture Experiment Station, SD State University, Brookings SD. July 1967.

APPENDICES

APPENDIX A: Interviews

The following represent *general comments made by contractors* during the interviews based on their overall experience.

1. Drainage:

- High water tables are a problem.
- Less problem west of the river due to gradient.
- Grading flattened out. Erosion. Temporary diversion or range.
- Sloughs and wetlands --- A couple of the dry years have been ok.
- Urban is more difficult and more critical.

2. Start - Up Time:

- Depends, earlier in the west.
- Frost. 30 day variability - snow cover. April 1. Utility work - March 1.
- To Thanksgiving, Mainline Oct. 15 joint sealing
- Urban work March 15

3. Shut - Down:

- November 1 is a good date for asphalt.
- Freezing - 20% moisture, 4" frost. Overnight (0 degrees F) - 10% moisture, 1" frost.
- Sealing - Nov. 1 is a better date, but only on days above 45 degrees.
- When temperatures are below freezing or frost is on the ground.
- Shoot for December 1. Can work with enclosures and cold temperature as it affects workers.
- Thanksgiving is the target. Freezing --- when the ground freezes stop. Concrete temperature specifications: 1) if ground freezes, remove the frost, 2) cover concrete.

4. Unusual Circumstances:

- Rock and swamps must be calculated.
- The difference between the actual site condition subsurface and the plans. The DOT does not show soil boring in plans, they leave it up to contractor to know the site.

5. Critical Path Method:

- Good on more complicated projects.
- Not good, too many changes.
- Manipulation is finer in identifying the critical item controlling the progress of the project and is good on bigger projects.
- Most North Dakota projects require a CPM.

6. Weekly meetings:

- Good, even when it is just between the supervisor and the project engineer.

7. Bidding Process:

- Shabby, the past performances of the contractors should be reviewed.
- Prequalification process should be stricter.
- Prime contractor should be present at the pre-bid meetings.

8. Lettings:

- Earlier lettings.

9. Specifications:

- They should be flexible.
- Common sense should be used.
- The specs on gravel are too narrow.
- The specs on asphalt are too tight.

10. Partnering:

- Good idea.
- Not needed, as a good contractor does partnering every day.

- This is already done on every project. The approach is important and takes a level of outside involvement.

11. Traffic:
- Where do you put traffic when base is wet, especially in the east?

12. Planning and Organization.
- Scheduling: Continuous projects - one delay, subsequent delays.
- Estimating time is a formal process that requires spreadsheets and is based on good weather conditions.
- Estimating the project time depends on the size (0 - 1,000,000 - 50 hrs). Having own spreadsheets including the time spent with contractors and match with quotes.

13. Contractors (contract stakers):
- Contract stakers - a new thing with lots of problems.
- If the project has a good contractor, there will be no problems.
- Inexperience is bad.

14. Other:
- Time: State is usually tight, especially on large projects and less on small projects. Fleet construction and cost.
- Take soil samples before the project and make completion date dependent on the moisture on the dirt.
- 5 yr plan does not happen.
- Hiring consultants is a bad idea because they do not know their highway work, they are not competent inspectors, and they do not have testing facilities.
- Make Contractors guarantee their work for 10 years.
- Constructablilty is a good idea on large projects.
- Variables that should determine completion date - Size of project (cut), land slope (topography), and soil conditions.
- Designers do not have enough field experience.
- Consistency problem over all area offices.
- Completion date is getting tougher and tougher to achieve.

The following represent *general comments made by SDDOT engineers* based on their overall experience:

1. Drainage:
- Too flat
- High Water Table
- Urbanization causing Runoff.
- Flooding
- Springs and Wet Areas Cause Delays
- Low Areas
- Sloughs
- Creeks can cramp work space.

2. Start - Up Time:
- Whenever the ground thaws.
- 15-Mar
- Varies form year to year - temperature.
- Look to when farmers are in the field.
- Late April
- Depends on the quality of the work.
- Depend on the type of work being done.
- Early April
- Following specs is good.

3. Shut - Down Time:
- Contractors are allowed to go for too long.
- Depends on the timing and the depth of the ground freezing.
- Depends on the type of winter - mild (do not shut-down), cold (shut-down when necessary).

- Nov. 1, Nov. 15 at the latest.
- Depends on the condition of the road or structure.
- Asphalt - Oct. 1
- Concrete - Oct. 1
- Structures can be built throughout the year.
- Paving - when the ground freezes.

4. Unusual Circumstances.
- Working around utilities.
- Type of project should determine work day/ non-work day.
- Landslides.
- Coordination with public and private developers.
- Contractors: capability and quality of work.
- Isolated areas - tough to get materials to.

5. Critical path Method:
- Paid for by the state.
- Good idea.
- Is a joke - the way that it is used. Schedules change daily and it is difficult with many subs.
- Mixed feelings.
- Updates must be made quickly or it is not worth the time.
- Expert monitoring system.
- Too expensive.
- Fairly new concept.
- Contractor should ultimately pay for CPM.

6. Weekly meetings:
- Good idea.
- Promotes communication.
- Communication is a must!
- Follow-up meeting necessary.

7. Penalties:
- New special provision has helped.
- Not substantial enough.
- Are substantial enough.
- Make the consultants responsible for their actions - if they screw up, make them pay for it.
- Should depend on size of project, public inconvenience, repairs, expenses, and whether it is rural or urban.
- Incentive/disincentive idea is good.
- Fines are good. Costs DOT indirectly.

8. Lettings:
- Grading - before May 1
- Letting time is crucial.
- Push into fall too often.
- Let projects earlier.

9. Specifications:
- Thrown out the window in October.
- Often rough interpretation and clarification.
- A lot of "gray" areas.
- If a spec is necessary keep it, otherwise get rid of it.
- Poorly organized.
- Should be strictly followed.
- Open to different interpretations.

10. Partnering:

- Very applicable in urban work. Less so in rural work.
- Good idea on bigger projects.
- Use the "concept", but without all the effort.

11. Traffic:

- Detour around projects, not through them.
- Makes urban jobs more difficult.
- Causes the worst problems.
- Different interpretation of specs.

12. Planning and Organization.

- Contractors are spread too thin.
- Not much effort is put into estimating times required to do specific jobs.
- Completion date is set more based on seasonal limits.
- Planning is key.

13. Other:

- Fully complete project. Do not leave loose ends.
- Do not allow the contractor to go over the field engineer's head.
- Consistency is a problem. With reference to specs, daycounts, and WPRs.
- Contractors need more help.
- DOT does not have the time to inspect properly.

The following represent *comments made regarding specific structure construction* projects by contractors and engineers.

1. Weather Delays:

Precipitation Problems:

- Yes and high flows.
- Snow, but not abnormal. Spring thaw caused small delays.
- Snow, but not abnormal
- Spring thaw was as high as the road.
- Spring rains that last more than one day
- Wet snows early in fall and late spring (heavy)
- No, some minor delays
- Yes, 8 inches from Sept 19-26.
- Drainage:
- High flow all through summer which was abnormal.
- Flow caused problems for two days and also some extra construction due to 3 springs.
- topography & soils can allow grading all winter because it does not hold moisture
- rain, work causes rutting, next day had to re-work

Temperature:

- A couple of days of extreme temperature, but not abnormal.
- Some extreme cold, but not abnormal.

Other:

- Hindsight is 20/20--could have started earlier, but could not have foreseen it.
- Should have been let with the grading project one year prior.
- Structures projects should be let in early fall or late summer.
- Some preparation and research about the James river could have prevented claim.
- Samples cannot be taken in bed, therefore only estimates can be made from samples near abutments.
- Contractor should be expected to comply with environmental standards in plans, and the state should back them up.
- Talk to contractor about calculating project length.
- Great project. Contractor organized things well. (NH0212(49)15)
- Problem with removing asphalt due to road being soft underneath.

The following represent *comments made regarding specific grading construction* projects by contractors and engineers.

1. Weather Delays:
- Not much.
- Lot of problems with rain.
- Flooding across other county and township roads in addition to this one being close allowed no way for local people to get out.

2. Drainage:
- Some high standing water caused problems
- High water table and poorly drained soils

3. Frost:
- Early Frost cause grading problems starting approx. Nov. 11.

4. Other:
- Contractor started late and there was an early frost
- The only reason for a problem with non-working days due to weather, was due to the contractor's late start. Contractor could have finished in 1996 season if he had moved in on time, this disagrees with the contractor.
- They gave the contractor a lot of days that they shouldn't have.
- They used CPM, but it didn't help much, Didn't like it for road construction.

The following represent *comments made regarding specific surfacing construction* projects by contractors and engineers.

1. Weather Delays:

Precipitation:

- No, one day was rained out

Temperature:

- Shutdown for winter, temperatures required by specifications were limiting factors.

Winds:

- High winds - has/can cause blowing and a reason to shut down.

2. Other:

- The Processing and laying of material was not done properly.
- Construction techniques can affect how precipitation affects the project.
- Scheduling of the job.
- The contractor wanted an extension on the job before it was even begun.
- The grading contractor got done late.
- The state let the job too soon.
- Late start due to prior conditions, grading contractor. Added time to stabilize and dig out grading.

- According to specifications. Contractor responded promptly. Discussed with contractor to try to settle right away. If conflict remains, document what happened.
- WPR's are used to document payroll
- Day count sheets are prepared weekly
    - copy submitted to contractor
    - contractor currently does not have immediate recourse
    - happens toward the end of the project contractor
    - includes why and what information must be submitted

- Contractor got started late due to finishing up a previous project
- Contract duration is duration of actual construction based on contractor start
- Bi-weekly progress reports.
- General comments: Dry, extra water used (hot)
- Grading: safety issue
- Diaries will pick up on how much re-work occurs to get back to where the project was.

<u>Objectives of the Project Interviews and Reviews</u>

This effort consists of interviewing a representative sample of construction contractors and Department engineers to assess the impacts of weather conditions on construction activities and determine temperature and precipitation ranges appropriate for grading, surfacing, and structure construction in the various geographical regions of South Dakota. The interview results will be compiled and used to compare with available construction records from project diaries. We will take comprehensive notes during each interview and have identified below the general type of information we will be compiling. Some of this information has already been obtained through the Pierre and regional offices. However, we will want to verify all information and obtain additional information when appropriate.

Field Engineer ____

Project ID ____

The following are to be asked in specific reference to the project.

Construction Site Location: (highway, mile post, county(s), city etc.) ____
____

Type of project contract:	working-day	______
	calendar day	______
	completion date	______
Type(s) of construction:	grading	_____
	paving	_____
	structures	_____

Award Date: month__________, day __________, year __________

Work Starting date: month__________, day __________, year __________

Contract Completion Date: month__________, day __________, year __________

Actual Completion Date: month__________, day __________, year __________

Fall Shut Down (if applicable) month__________, day __________, year __________

Spring Start-up (if applicable) month__________, day __________, year __________

Type of conditions that individually or in combination caused the non-working days and the magnitude of the weather causing the delay (i.e. inches of rain, low temperature etc.)

precipitation _______________ (inches)
(in general) ____

temperature _______________ (this could be low or high temperatures)
(in general) ____

geophysical characteristics (a general description of the soil characteristics, i.e. sandy, sandy/clayey, clayey, rock, cobble/boulder etc.) ____
____

drainage characteristics (minor and major drainage, steep slopes, high water table, poorly drained soils, etc.)________
____
____

cumulative/extenuating conditions (any combination of unusual conditions that relate to weather delays)__________
____
____

Was a contract time extension requested; yes _____ no _____

If so how many days were requested _______________
How many days actually awarded _______________
Number of weather related non-working days: _______________
the date of the day(s) when bad weather occurred _______________

How was the request processed? (i.e. the procedure for documenting and requesting non-working weather days) ____
____
____
____

APPENDIX B: Charts

Cumulative Charts

TABLE B.1.1

CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(GRADING PROJECT, ZONE 1, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
6	24	Apr	24							
6	25	May	49	25						
7	23	Jun	72	48	23					
5	26	Jul	98	74	49	26				
4	27	Aug	125	101	76	53	27			
3	27	Sep	152	128	103	80	54	27		
4	27	Oct	179	155	130	107	81	54	27	
11	19	Nov	198	174	149	126	100	73	46	19
6	24	Apr	222	198	173	150	124	97	70	43
6	25	May	247	223	198	175	149	122	95	68
7	23	Jun	270	246	221	198	172	145	118	91
5	26	Jul	296	272	247	224	198	171	144	117
4	27	Aug	323	299	274	251	225	198	171	144
3	27	Sep	350	326	301	278	252	225	198	171
4	27	Oct	377	353	328	305	279	252	225	198
11	19	Nov	396	372	347	324	298	271	244	217
6	24	Apr	420	396	371	348	322	295	268	241
6	25	May	445	421	396	373	347	320	293	266
7	23	Jun	468	444	419	396	370	343	316	289
5	26	Jul	494	470	445	422	396	369	342	315
4	27	Aug	521	497	472	449	423	396	369	342
3	27	Sep	548	524	499	476	450	423	396	369
4	27	Oct	575	551	526	503	477	450	423	396
11	19	Nov	594	570	545	522	496	469	442	415

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.2
CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(GRADING PROJECT, ZONE 2, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
5	25	Apr	25							
6	25	May	50	25						
6	24	Jun	74	49	24					
5	26	Jul	100	75	50	26				
4	27	Aug	127	102	77	53	27			
3	27	Sep	154	129	104	80	54	27		
3	28	Oct	182	157	132	108	82	55	28	
9	21	Nov	203	178	153	129	103	76	49	21
5	25	Apr	228	203	178	154	128	101	74	46
6	25	May	253	228	203	179	153	126	99	71
6	24	Jun	277	252	227	203	177	150	123	95
5	26	Jul	303	278	253	229	203	176	149	121
4	27	Aug	330	305	280	256	230	203	176	148
3	27	Sep	357	332	307	283	257	230	203	175
3	28	Oct	385	360	335	311	285	258	231	203
9	21	Nov	406	381	356	332	306	279	252	224
5	25	Apr	431	406	381	357	331	304	277	249
6	25	May	456	431	406	382	356	329	302	274
6	24	Jun	480	455	430	406	380	353	326	298
5	26	Jul	506	481	456	432	406	379	352	324
4	27	Aug	533	508	483	459	433	406	379	351
3	27	Sep	560	535	510	486	460	433	406	378
3	28	Oct	588	563	538	514	488	461	434	406
9	21	Nov	609	584	559	535	509	482	455	427

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.3
CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(GRADING PROJECT, ZONE 3, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
8	22	Apr	22							
8	23	May	45	23						
7	23	Jun	68	46	23					
6	25	Jul	93	71	48	25				
5	26	Aug	119	97	74	51	26			
4	26	Sep	145	123	100	77	52	26		
5	26	Oct	171	149	126	103	78	52	26	
8	22	Nov	193	171	148	125	100	74	48	22
8	22	Apr	215	193	170	147	122	96	70	44
8	23	May	238	216	193	170	145	119	93	67
7	23	Jun	261	239	216	193	168	142	116	90
6	25	Jul	286	264	241	218	193	167	141	115
5	26	Aug	312	290	267	244	219	193	167	141
4	26	Sep	338	316	293	270	245	219	193	167
5	26	Oct	364	342	319	296	271	245	219	193
8	22	Nov	386	364	341	318	293	267	241	215
8	22	Apr	408	386	363	340	315	289	263	237
8	23	May	431	409	386	363	338	312	286	260
7	23	Jun	454	432	409	386	361	335	309	283
6	25	Jul	479	457	434	411	386	360	334	308
5	26	Aug	505	483	460	437	412	386	360	334
4	26	Sep	531	509	486	463	438	412	386	360
5	26	Oct	557	535	512	489	464	438	412	386
8	22	Nov	579	557	534	511	486	460	434	408

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.4
CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(GRADING PROJECT, ZONE 4, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
5	25	Apr	25							
6	25	May	50	25						
6	24	Jun	74	49	24					
5	26	Jul	100	75	50	26				
4	27	Aug	127	102	77	53	27			
3	27	Sep	154	129	104	80	54	27		
3	28	Oct	182	157	132	108	82	55	28	
7	23	Nov	205	180	155	131	105	78	51	23
5	25	Apr	230	205	180	156	130	103	76	48
6	25	May	255	230	205	181	155	128	101	73
6	24	Jun	279	254	229	205	179	152	125	97
5	26	Jul	305	280	255	231	205	178	151	123
4	27	Aug	332	307	282	258	232	205	178	150
3	27	Sep	359	334	309	285	259	232	205	177
3	28	Oct	387	362	337	313	287	260	233	205
7	23	Nov	410	385	360	336	310	283	256	228
5	25	Apr	435	410	385	361	335	308	281	253
6	25	May	460	435	410	386	360	333	306	278
6	24	Jun	484	459	434	410	384	357	330	302
5	26	Jul	510	485	460	436	410	383	356	328
4	27	Aug	537	512	487	463	437	410	383	355
3	27	Sep	564	539	514	490	464	437	410	382
3	28	Oct	592	567	542	518	492	465	438	410
7	23	Nov	615	590	565	541	515	488	461	433

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.5
CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(GRADING PROJECT, ZONE 5, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
6	24	Apr	24							
6	25	May	49	25						
7	23	Jun	72	48	23					
6	25	Jul	97	73	48	25				
5	26	Aug	123	99	74	51	26			
4	26	Sep	149	125	100	77	52	26		
4	27	Oct	176	152	127	104	79	53	27	
10	20	Nov	196	172	147	124	99	73	47	20
6	24	Apr	220	196	171	148	123	97	71	44
6	25	May	245	221	196	173	148	122	96	69
7	23	Jun	268	244	219	196	171	145	119	92
6	25	Jul	293	269	244	221	196	170	144	117
5	26	Aug	319	295	270	247	222	196	170	143
4	26	Sep	345	321	296	273	248	222	196	169
4	27	Oct	372	348	323	300	275	249	223	196
10	20	Nov	392	368	343	320	295	269	243	216
6	24	Apr	416	392	367	344	319	293	267	240
6	25	May	441	417	392	369	344	318	292	265
7	23	Jun	464	440	415	392	367	341	315	288
6	25	Jul	489	465	440	417	392	366	340	313
5	26	Aug	515	491	466	443	418	392	366	339
4	26	Sep	541	517	492	469	444	418	392	365
4	27	Oct	568	544	519	496	471	445	419	392
10	20	Nov	588	564	539	516	491	465	439	412

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.6
CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(GRADING PROJECT, ZONE 6, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
6	24	Apr	24							
6	25	May	49	25						
8	22	Jun	71	47	22					
7	24	Jul	95	71	46	24				
6	25	Aug	120	96	71	49	25			
5	25	Sep	145	121	96	74	50	25		
4	27	Oct	172	148	123	101	77	52	27	
12	18	Nov	190	166	141	119	95	70	45	18
6	24	Apr	214	190	165	143	119	94	69	42
6	25	May	239	215	190	168	144	119	94	67
8	22	Jun	261	237	212	190	166	141	116	89
7	24	Jul	285	261	236	214	190	165	140	113
6	25	Aug	310	286	261	239	215	190	165	138
5	25	Sep	335	311	286	264	240	215	190	163
4	27	Oct	362	338	313	291	267	242	217	190
12	18	Nov	380	356	331	309	285	260	235	208
6	24	Apr	404	380	355	333	309	284	259	232
6	25	May	429	405	380	358	334	309	284	257
8	22	Jun	451	427	402	380	356	331	306	279
7	24	Jul	475	451	426	404	380	355	330	303
6	25	Aug	500	476	451	429	405	380	355	328
5	25	Sep	525	501	476	454	430	405	380	353
4	27	Oct	552	528	503	481	457	432	407	380
12	18	Nov	570	546	521	499	475	450	425	398

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.7

CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(STRUCTURAL & SURFACING PROJECTS, ZONE 1, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
5	25	Apr	25							
5	26	May	51	26						
5	25	Jun	76	51	25					
4	27	Jul	103	78	52	27				
3	28	Aug	131	106	80	55	28			
2	28	Sep	159	134	108	83	56	28		
3	28	Oct	187	162	136	111	84	56	28	
11	19	Nov	206	181	155	130	103	75	47	19
5	25	Apr	231	206	180	155	128	100	72	44
5	26	May	257	232	206	181	154	126	98	70
5	25	Jun	282	257	231	206	179	151	123	95
4	27	Jul	309	284	258	233	206	178	150	122
3	28	Aug	337	312	286	261	234	206	178	150
2	28	Sep	365	340	314	289	262	234	206	178
3	28	Oct	393	368	342	317	290	262	234	206
11	19	Nov	412	387	361	336	309	281	253	225
5	25	Apr	437	412	386	361	334	306	278	250
5	26	May	463	438	412	387	360	332	304	276
5	25	Jun	488	463	437	412	385	357	329	301
4	27	Jul	515	490	464	439	412	384	356	328
3	28	Aug	543	518	492	467	440	412	384	356
2	28	Sep	571	546	520	495	468	440	412	384
3	28	Oct	599	574	548	523	496	468	440	412
11	19	Nov	618	593	567	542	515	487	459	431

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.8
CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(STRUCTURAL & SURFACING, ZONE 2, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
4	26	Apr	26							
5	26	May	52	26						
5	25	Jun	77	51	25					
4	27	Jul	104	78	52	27				
3	28	Aug	132	106	80	55	28			
2	28	Sep	160	134	108	83	56	28		
3	28	Oct	188	162	136	111	84	56	28	
9	21	Nov	209	183	157	132	105	77	49	21
4	26	Apr	235	209	183	158	131	103	75	47
5	26	May	261	235	209	184	157	129	101	73
5	25	Jun	286	260	234	209	182	154	126	98
4	27	Jul	313	287	261	236	209	181	153	125
3	28	Aug	341	315	289	264	237	209	181	153
2	28	Sep	369	343	317	292	265	237	209	181
3	28	Oct	397	371	345	320	293	265	237	209
9	21	Nov	418	392	366	341	314	286	258	230
4	26	Apr	444	418	392	367	340	312	284	256
5	26	May	470	444	418	393	366	338	310	282
5	25	Jun	495	469	443	418	391	363	335	307
4	27	Jul	522	496	470	445	418	390	362	334
3	28	Aug	550	524	498	473	446	418	390	362
2	28	Sep	578	552	526	501	474	446	418	390
3	28	Oct	606	580	554	529	502	474	446	418
9	21	Nov	627	601	575	550	523	495	467	439

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.9
CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(STRUCTURAL & SURFACING, ZONE 3, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
6	24	Apr	24							
6	25	May	49	25						
5	25	Jun	74	50	25					
5	26	Jul	100	76	51	26				
4	27	Aug	127	103	78	53	27			
3	27	Sep	154	130	105	80	54	27		
4	27	Oct	181	157	132	107	81	54	27	
8	22	Nov	203	179	154	129	103	76	49	22
6	24	Apr	227	203	178	153	127	100	73	46
6	25	May	252	228	203	178	152	125	98	71
5	25	Jun	277	253	228	203	177	150	123	96
5	26	Jul	303	279	254	229	203	176	149	122
4	27	Aug	330	306	281	256	230	203	176	149
3	27	Sep	357	333	308	283	257	230	203	176
4	27	Oct	384	360	335	310	284	257	230	203
8	22	Nov	406	382	357	332	306	279	252	225
6	24	Apr	430	406	381	356	330	303	276	249
6	25	May	455	431	406	381	355	328	301	274
5	25	Jun	480	456	431	406	380	353	326	299
5	26	Jul	506	482	457	432	406	379	352	325
4	27	Aug	533	509	484	459	433	406	379	352
3	27	Sep	560	536	511	486	460	433	406	379
4	27	Oct	587	563	538	513	487	460	433	406
8	22	Nov	609	585	560	535	509	482	455	428

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.10

CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(STRUCTURAL & SURFACING, ZONE 4, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
4	26	Apr	26							
4	27	May	53	27						
4	26	Jun	79	53	26					
3	28	Jul	107	81	54	28				
3	28	Aug	135	109	82	56	28			
2	28	Sep	163	137	110	84	56	28		
2	29	Oct	192	166	139	113	85	57	29	
7	23	Nov	215	189	162	136	108	80	52	23
4	26	Apr	241	215	188	162	134	106	78	49
4	27	May	268	242	215	189	161	133	105	76
4	26	Jun	294	268	241	215	187	159	131	102
3	28	Jul	322	296	269	243	215	187	159	130
3	28	Aug	350	324	297	271	243	215	187	158
2	28	Sep	378	352	325	299	271	243	215	186
2	29	Oct	407	381	354	328	300	272	244	215
7	23	Nov	430	404	377	351	323	295	267	238
4	26	Apr	456	430	403	377	349	321	293	264
4	27	May	483	457	430	404	376	348	320	291
4	26	Jun	509	483	456	430	402	374	346	317
3	28	Jul	537	511	484	458	430	402	374	345
3	28	Aug	565	539	512	486	458	430	402	373
2	28	Sep	593	567	540	514	486	458	430	401
2	29	Oct	622	596	569	543	515	487	459	430
7	23	Nov	645	619	592	566	538	510	482	453

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.11

CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS AVAILABLE OVER A THREE YEAR PERIOD (STRUCTURAL & SURFACING, ZONE 5, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
4	26	Apr	26							
4	27	May	53	27						
5	25	Jun	78	52	25					
4	27	Jul	105	79	52	27				
4	27	Aug	132	106	79	54	27			
3	27	Sep	159	133	106	81	54	27		
3	28	Oct	187	161	134	109	82	55	28	
10	20	Nov	207	181	154	129	102	75	48	20
4	26	Apr	233	207	180	155	128	101	74	46
4	27	May	260	234	207	182	155	128	101	73
5	25	Jun	285	259	232	207	180	153	126	98
4	27	Jul	312	286	259	234	207	180	153	125
4	27	Aug	339	313	286	261	234	207	180	152
3	27	Sep	366	340	313	288	261	234	207	179
3	28	Oct	394	368	341	316	289	262	235	207
10	20	Nov	414	388	361	336	309	282	255	227
4	26	Apr	440	414	387	362	335	308	281	253
4	27	May	467	441	414	389	362	335	308	280
5	25	Jun	492	466	439	414	387	360	333	305
4	27	Jul	519	493	466	441	414	387	360	332
4	27	Aug	546	520	493	468	441	414	387	359
3	27	Sep	573	547	520	495	468	441	414	386
3	28	Oct	601	575	548	523	496	469	442	414
10	20	Nov	621	595	568	543	516	489	462	434

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.

[2]The cumulative count reflects the total number of days available through the last day of each month.

[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

TABLE B.1.12

CUMMULATIVE COUNT OF EXPECTED NUMBER OF CALENDAR DAYS
AVAILABLE OVER A THREE YEAR PERIOD
(STRUCTURAL & SURFACING, ZONE 6, SOUTH DAKOTA)

Estimated Adverse Weather Days	Available Calendar Days[1]	Month	Starting Date (First of Month)							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
4	26	Apr	26							
5	26	May	52	26						
6	24	Jun	76	50	24					
5	26	Jul	102	76	50	26				
4	27	Aug	129	103	77	53	27			
4	26	Sep	155	129	103	79	53	26		
3	28	Oct	183	157	131	107	81	54	28	
11	19	Nov	202	176	150	126	100	73	47	19
4	26	Apr	228	202	176	152	126	99	73	45
5	26	May	254	228	202	178	152	125	99	71
6	24	Jun	278	252	226	202	176	149	123	95
5	26	Jul	304	278	252	228	202	175	149	121
4	27	Aug	331	305	279	255	229	202	176	148
4	26	Sep	357	331	305	281	255	228	202	174
3	28	Oct	385	359	333	309	283	256	230	202
11	19	Nov	404	378	352	328	302	275	249	221
4	26	Apr	430	404	378	354	328	301	275	247
5	26	May	456	430	404	380	354	327	301	273
6	24	Jun	480	454	428	404	378	351	325	297
5	26	Jul	506	480	454	430	404	377	351	323
4	27	Aug	533	507	481	457	431	404	378	350
4	26	Sep	559	533	507	483	457	430	404	376
3	28	Oct	587	561	535	511	485	458	432	404
11	19	Nov	606	580	554	530	504	477	451	423

[1]Total number of days available in the month minus the expected adverse weather days which includes holidays and weekends.
[2]The cumulative count reflects the total number of days available through the last day of each month.
[3]The months included in the cumulative count, April - November, reflect the standard construction period. For working days available during December through March, refer to Figure 6.3.

Percentage Chart

TABLE A.2.1

ESTIMATED PERCENTAGE OF CALENDAR DAYS AVAILABLE PER MONTH

	Grading Projects						Surfacing and Structural Projects					
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Jan	42%	39%	48%	48%	29%	23%	42%	42%	52%	48%	32%	26%
Feb	32%	36%	57%	50%	32%	25%	32%	36%	57%	50%	32%	25%
Mar	61%	68%	71%	74%	65%	58%	61%	68%	71%	74%	68%	61%
Apr	80%	83%	73%	83%	80%	80%	83%	87%	80%	87%	87%	87%
May	81%	81%	74%	81%	81%	81%	84%	87%	81%	87%	87%	84%
Jun	77%	80%	77%	80%	77%	73%	83%	83%	83%	87%	83%	80%
Jul	84%	84%	81%	84%	81%	77%	87%	87%	84%	90%	87%	84%
Aug	87%	87%	84%	87%	84%	81%	90%	90%	87%	90%	87%	87%
Sep	90%	90%	87%	90%	87%	83%	93%	93%	90%	93%	90%	87%
Oct	87%	90%	84%	90%	87%	87%	90%	90%	87%	94%	90%	90%
Nov	63%	70%	73%	77%	67%	60%	63%	70%	73%	77%	70%	63%
Dec	32%	39%	52%	55%	39%	29%	32%	39%	52%	55%	39%	29%

Remaining Days Charts

APPENDIX C: Special Provision

STATE OF SOUTH DAKOTA
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION FOR

TIME EXTENSION DUE TO UNEXPECTED ADVERSE WEATHER

PROJECT NO. ______________

A. General

This provision specifies the procedure for determination of time extensions due to unexpected adverse weather in accordance with the Standard Specifications For Roads and Bridges, South Dakota Department of Transportation, 1998.

B. Definitions and Terms

For the purpose of these Special Provisions the following definitions apply:

(3) Adverse weather day: A day when the magnitude of a weather parameter (precipitation or temperature) is such that it creates conditions that inhibit the ability of the contractor to work productively on the critical construction item.

(4) Expected adverse weather days: The number of adverse weather days expected to occur on a monthly basis and defined for six zones and two different construction types (1. grading and 2. surfacing and structures) within each zone.

(7) Unexpected adverse weather days: The number of adverse weather days that exceed the expected number of adverse weather days determined on a monthly basis.

(8) Actual adverse weather days: The actual number of adverse weather days that occur during a single month.

C. Project Type and Working Day Weather Zone

Project Number _________ [*Insert Project Title*], is defined as a [*insert project type, either grading, surfacing or structure*] and is located in working day weather zone [*insert correct zone 1 through 6*]. Based on the project type and working day weather zones the expected adverse weather days are defined in Figure A.

D. Determination of Time Extensions Due to Unexpected Adverse Weather

The following modifications modify, change, delete from or add to Section 8.6 DETERMINATION AND EXTENSION OF CONTRACT TIME. When a conflict between Section 8.6 and this Special Provision exists this Special Provision shall take precedence.

1. DELETE item 8.6.A.2 on page 43 and 8.6.B.2 on page 45.

2. DELETE items 8.6.A.1 on page 43 and 8.6.B.1 on page 45, and SUBSTITUTE the following:

The occurrence of unexpected adverse weather during the life of the Contract will be considered a basis for extending contract time when work is not already suspended for other reasons. Unexpected adverse weather means weather which at the time of year it occurs is unusual for the place in which it occurs.

Extension of time for unexpected adverse weather will be determined on a monthly basis and will include only those actual adverse weather days in excess of the expected adverse weather days included in the Contract Time. Expected adverse weather means adverse weather which, regardless of its severity, is to be reasonably expected for that particular place at that time of year. The expected adverse weather days included in the Contract Time are based on historical records of temperature and precipitation for the six zones and two project classifications as shown in Table 1 below.

Table 1. Expected Adverse Weather Days for South Dakota

	Grading Projects						Surfacing and Structural Projects					
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Jan	18	18	16	16	22	24	18	18	15	16	21	23
Feb	19	18	12	14	19	21	19	18	12	14	19	21
Mar	12	10	9	8	11	13	12	10	9	8	10	12
Apr	6	5	8	5	6	6	5	4	6	4	4	4
May	6	6	8	6	6	6	5	5	6	4	4	5
Jun	7	6	7	6	7	8	5	5	5	4	5	6
Jul	5	5	6	5	6	7	4	4	5	3	4	5
Aug	4	4	5	4	5	6	3	3	4	3	4	4
Sep	3	3	4	3	4	5	2	2	3	2	3	4
Oct	4	3	5	3	4	4	3	3	4	2	3	3
Nov	11	9	8	7	10	12	11	9	8	7	10	11
Dec	21	19	15	14	20	22	21	19	15	14	20	22

NOTE: Includes Holidays and Weekends.

Actual Adverse weather days are those days meeting one or more of the criteria in "a", "b", "c" and "d" below. Time extensions for days meeting more than one criterion will take into consideration only that criterion having the greatest impact. Actual adverse weather days covered by criterion "a", "b", "c" or "d" will be counted without regard to when they occur or their impact on contract completion. Adverse weather days which exceed the number of expected adverse weather days as shown in Table 1 will be considered for time extensions if they occur on a working day or in the case of criterion "c", they occur on a Sunday or holiday preceding a scheduled working day in which case one full day will be allowed.

i. Days with maximum temperature of 0°C (32°F) or less - one full day allowed.
j. Days when 7.62 mm (0.30 inch) or more precipitation (rain or snow equivalent) occurs - one full day allowed.
k. Days when 19.05 mm (0.75 inch) or more precipitation (rain or snow equivalent) occurs on a grading project - two full days allowed.
l. Days when weather-related conditions exist which prohibit proper performance of work as specified - one full day allowed, subject to the agreement of both the contractor and the project engineer. If no agreement is reached, then the criteria "a", "b" and "c" supercede. Allowance of such days will be subject to the work, which is delayed being critical to timely contract completion and the contractor making every reasonable effort to minimize the adverse impact of the conditions. Also, if the contractor chooses or decides to work on the controlling item, a working day will be counted.

The schedule of expected adverse weather days will constitute the base line for monthly weather time evaluations. Upon acknowledgement of the notice to proceed and continuing throughout the contract (on a monthly basis), actual adverse weather days will be recorded on a calendar day basis (including weekends and holidays) and compared to the monthly expected adverse weather days in Table 1.

The number of actual adverse weather days shall be calculated chronologically from the first to the last day in each month. Once the number of actual adverse weather days expected in figure A. have been incurred, the Engineer will examine any subsequent occurring adverse weather days to determine whether the contractor is entitled to a time extension. The Engineer will convert any delays meeting the above requirements to calendar days and issue a modification in accordance with standard specification Section 8.6 DETERMINATION AND EXTENSION OF CONTRACT TIME.