STRUCTURAL ENGINEERS ASSOCIATION OF OREGON
P.O. Box 3285 • PORTLAND, OR 97208
503.753.3075
www.seao.org • E-mail: jane@seao.org

2010 OREGON SNOW LOAD MAP UPDATE AND INTERIM GUIDELINES FOR SNOW LOAD DETERMINATION FOR THE STATE OF OREGON

SEAO Snow Load Committee
January, 2011

1. ABSTRACT

Based on additional new snow data and improved analysis methods, an update to the 2007 Snow Load Analysis for Oregon is being created. This data will replace the previous 2007 ground snow load map data and will ultimately be made available for site-specific lookup on a website being created through a joint effort of the Prism Climate Group at Oregon State University, the Oregon Building Codes Division and SEAO.

The scope of the current project, methodology, analysis procedures and interim guidelines for snow load determination are discussed. It should be noted that many of the anticipated design snow loads, particularly at mid and high elevations, have increased from those shown in the 2007 mapping, and it is recommended that the interim guidelines in this report be used for snow load determination in the state of Oregon until new electronic mapping is made available.

2. BACKGROUND

The *Snow Load Analysis for Oregon* was first published in 1971 and updated in 1978. Based on a 33-year mean recurrence interval, the snow load data was presented in graphical form with county areas with similar ground snow load versus elevation relationships grouped together.

With the help of the Oregon Climate Services at Oregon State University, the Structural Engineers Association of Oregon (SEAO) created a new ground snow load map for the State of Oregon based on a 50-year mean recurrence interval (MRI), making the load probability consistent with the ASCE Standard. The new map loads are the result of 36 years of additional data and were generated using the latest climate modeling technology, PRISM. Along with the map, the SEAO Snow Load Committee updated the *Snow Load Analysis for Oregon* and published this third edition with the new map in December 2007.

In May of 2008, the State of Oregon Building Codes Division issued an Alternate Method Ruling No. 08-01 in which the following sections of the *2007 Snow Load Analysis for Oregon* were adopted: the 50-Year Ground Snow Load Map for Oregon included with the book, Part 1 Section “Use of Map”, Part II Section “Minimum Roof Snow Load”, and Part II Section “Rain-On-Snow Surcharge”. The remaining portions of the book were not adopted as they were intended to serve as a reference for current snow load design procedures and were not to be considered mandatory code requirements.

Shortly after publication of the book and map, areas of northwestern Oregon experienced record setting snowfall in the winter of 2007-2008. The SEAO Snow Load Committee began reviewing the data in early 2009 to see if it would affect of the 50-year snow load at certain sites. After researching the snowfall from that winter we found that the 50-year predicted snowfall for a number of mid-elevation sites exceeded those predicted on our map. We also realized that the 50-year station values for some locations on the map were much lower than the surrounding snow load contour lines.

To better understand these anomalies and to see if the 2007-2008 storm was a more severe storm than our 50-year mean recurrence interval (MRI) map would predict, the snow load committee performed a thorough review of the methods used to develop the 2007 published map. Based on this review, we concluded that snowfalls did exceed the predicted values in a number of locations. An effort was then undertaken to determine the reasons for the deviations. It was found that there were several factors used in developing the map that are contributing to these discrepancies. The first was the snow density used to convert snow depths to snow loads. The density used to convert COOP site data for the 2007 map was 8.32 pounds per cubic foot (pcf) for Eastern Oregon and 11.34 pcf for Western Oregon. This was consistent with the conversion used in development of ASCE 7-05 for 12 inches of snow depth which gives 8.19 pcf as noted on page 3 of the snow load manual. This density conversion was proposed by the Oregon Climate Services group and agreed to by the SEAO Snow Load Committee. Based on further research of the densities used in the development of other studies, the committee later concluded that the density conversion models that relate an increase in density with an increase in snow depth provide more realistic snow load values. Density conversion models are discussed in greater detail later in this paper.

Another contributing factor found by the committee was that the statistical model used to develop the 50-year MRI station input data for the 2007 Map was a normal (or Gaussian) distribution. However, additional research has shown that the lognormal distribution statistical model is a better fit for determining the 50-year MRI ground snow load.

The dependent variable used in the original map development was also reviewed. It was found that average annual snowfall was used as the dependent variable, rather than elevation as incorrectly noted in the 2007 manual. Though initially thought to be a possible contributing factor, further study has shown that average annual snowfall is the best fit as the dependent variable.

3. SCOPE OF PROJECT

Based on these findings, the Snow Load Committee concluded that some of the snow data needed to be revised and incorporated into an updated map. An enormous volunteer effort has been under way (and is near completion) to revise the snow load data and determine new station values for 50-year MRI ground snow loads to input into Prism to develop the new map. The methodology for these revisions is described in more detail in the sections below. In addition to updating some of the snow data, the current project consists of an effort to develop an electronic version of the snow load map. The SEAO Snow Load Committee is working with the Prism Climate Group at Oregon State University to develop the new map and upon completion will be hosted for public access similar to the U.S.G.S. seismic maps now available to determine the Ss and S1 values. We are finalizing an agreement for the project to be partially funded by the State of Oregon Building Codes Division.

3.1. METHODOLOGY

The method used to create the snow load map is described at length in the 2007 manual. A brief description follows to highlight the differences in the current analysis.

Station Data: Snow load and snow depth data were obtained from two types of weather stations: the National Weather Service Cooperative Observing Network (COOP) stations which manually record snow depth daily and the National Resources Conservation Service SNOTEL stations which automatically record snow weight hourly. The snow weight is recorded as Snow Water Equivalent (SWE) in inches to be compatible with precipitation records. The SNOTEL data was converted directly to snow load by multiplying the SWE by the density of water. The COOP data was converted to snow load by multiplying the snow depth by an assumed density of snow. There are a number of snow density models in use which will be discussed further in the next section.

Station 50 year return ground snow load: Once the daily data is compiled, the maximum reading for each year is noted, and a statistical analysis is made using these maximum values. Extreme value statistics are used to calculate the value with a predicted 50-year return period. Several extreme value statistical models were investigated for use to predict snow load return periods. The *normal* distribution was used in the creation of the 2007 map, while the *lognormal* distribution is being used for this project. The differences between these methods are discussed further in the next section.

Map creation with PRISM: After the single 50-year snow load value is determined for each station, the values are interpolated across the state using the PRISM program. The program calculates a regression curve and a load value for each of a set of grid points spaced at approximately 4 km. The calculation includes many topographical and meteorological relationships between the grid point and the nearby stations. For the map published in 2007, the set of grid values was smoothed to create contours. Smoothing the calculated grid values is not planned for the current project.

3.2. ANALYSIS PROCEDURES

There are four important differences between the analysis procedures used to develop the 2007 map and the current project.

1) A majority of the historical weather data available is snow depth measured in inches. To be useful for load determination, the historical depth data has to be converted to load data using an assumed snow density. A number of density models have been developed for other snow load estimation projects. In most models, the density typically increases as the snow depth increases. Figure 1 compares several of the models, including the one used for the creation of the 2007 map. Also included is the density data from several SNOTEL stations which record both snow depth and snow weight. It can be observed that for larger snow depths, the constant density values used for the 2007 map become unconservative. A much better fit is the model used by ASCE to create the snow load map published in the ASCE-7, *Minimum Design Loads for Buildings and Other Structures*. As part of the current project, the calculated 50-year return maximum ground snow depths for each station were converted to snow loads using the ASCE-7 model. The resulting snow load estimates for some stations increased significantly. Generally, areas with lower snow depths were unaffected by this change, and areas in the high mountains and passes were also largely unaffected because they relied more heavily on SNOTEL data which measure the snow load directly.

2) Statistical analysis of the annual maximum snow depth and load data was used to estimate snow load corresponding to a 50-year return period for each station. This type of statistical analysis falls into the category of extreme value statistics. Essentially, the *normal* probability distribution is replaced with an alternate extreme value distribution that is skewed toward the extreme values (maxima or minima). There are a number of extreme value distributions commonly used to model random phenomena. ASCE used the lognormal distribution to create the ASCE7 snow load map. Figure 2 compares the normal distribution to the lognormal distribution. The 50-year return period value is equivalent to the value that has a 2% probability of being exceeded in any one year, or the 98th percentile value of the cumulative probability distribution. Figures 3 and 4 illustrate these relationships and also compare the normal distribution to the lognormal and exponential types of extreme value distributions. It can be observed that the extreme value distributions show higher probabilities of occurrence for high load values. In this way the extreme value distributions more

conservatively and more accurately predict the occurrence of the extreme load values. For example, on Figure 4, the extreme value distributions predict that a 305 psf load has a 50-year return period, while the normal distribution predicts that a 305 psf load would only occur once in 250 years. It can also be observed that the lognormal distribution is slightly more conservative than the exponential distribution.

The relative accuracy of the calculations was also investigated by considering a large set of station snow load values. The definition of a 50-year return period is the maximum value which, *on average*, is expected to occur once every 50 years. Another way to consider the definition is that the maximum value in a 50-year data set should have a calculated return period of 50 years, on average. Some data sets will have a maximum with a longer calculated return period, and some will have a shorter calculated return period. But to meet the definition, a large number of data sets for a large number of stations should have an average return period that matches the number of years of the record. This calculation was made for the SNOTEL stations, most of which have roughly 30 recording periods. The calculated return period of the maximum value at each station using the lognormal distribution is illustrated in Figure 5, and averaged out to 39.8 years. By comparison, the average using the normal distribution is 255 years, and again supports the use of the lognormal distribution.

Based on this information, and the precedent of using the lognormal distribution for the ASCE-7 map, the lognormal distribution was selected for this project. The resulting recalculated 50-year return station snow load values are consistently higher and more conservative than the values calculated for the 2007 map using the normal distribution.

3) Most of Northern Oregon saw record setting snowfall in the winter of 2007-2008. The station snow load and snow depth values were obtained for the years of 2005 through 2009 so that this potentially important information could be included in the recalculation effort. The station values used for the current project include the data from these recent years, where it was still being recorded. Generally, for stations where the 2007-2008 winter snowfall was an all time record, the calculated 50-year snow load increased. For other stations, the added years increased the size of the data set, which reduced the calculated 50-year snow load.

4) The description of the PRISM analysis used to create the 2007 map, as presented in the snow load manual, states that the basis for interpolation of the snow loads (the independent variable in the regression) was elevation. It was later learned that a two step process was used to create the map. The first step was to use PRISM to create a data set of average annual snowfall grid points with elevation as the basis for interpolation. The second step was to use the resulting grid of average annual snowfall values as the basis for interpolation for the 50-year snow loads. The result of the second step was the map of 50-year snow loads. A similar method is being used for the current project. While this is not a change of methodology, the documentation of this procedure was inaccurate and required clarification.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. CONCLUSIONS

This paper is being distributed to provide an interim guideline for snow load determination in the State of Oregon. After the record snow fall in the winter of 2007-2008, it was determined that the predicted snowfall for a number of mid-level sites exceeded those predicted in the map issued in 2007 by SEAO. The SEAO snow load committee is continuing to work on the development of an updated electronic version of the State of Oregon Snow Load Map in cooperation with OSU and BCD. This map will be made available on the web by OSU's Prism Climate Group. Until the completion of that project, this paper and accompanying tables will provide guidelines for determining ground snow loads for the State of Oregon. The 50-year return ground snow loads for each COOP station used in the creation of the 2007 ground snow load map have been updated for the current project. Information showing the revised 50-year MRI COOP snow station values is included in Table 1 below. The loads have been updated to account for a change in the snow density model, a change in the statistical model, and the new snow data available since the 2007 map was published. The loads at a majority of the stations had some increase, though about 30% of the stations experienced a load increase of more than 20%. Most of the stations with significant load increases are at mid to higher elevations, where the effects of the modeling changes and the new data are more significant and where the affects of all three changes become additive. The updating mapping will be created by PRISM using the updated 50-year MRI values for the COOP stations and the SNOTEL station data. A timeline for completing this mapping is still uncertain, but we intend to provide notice of completion and any future updates on the SEAO website at www.seao.org.

4.2. RECOMMENDATIONS

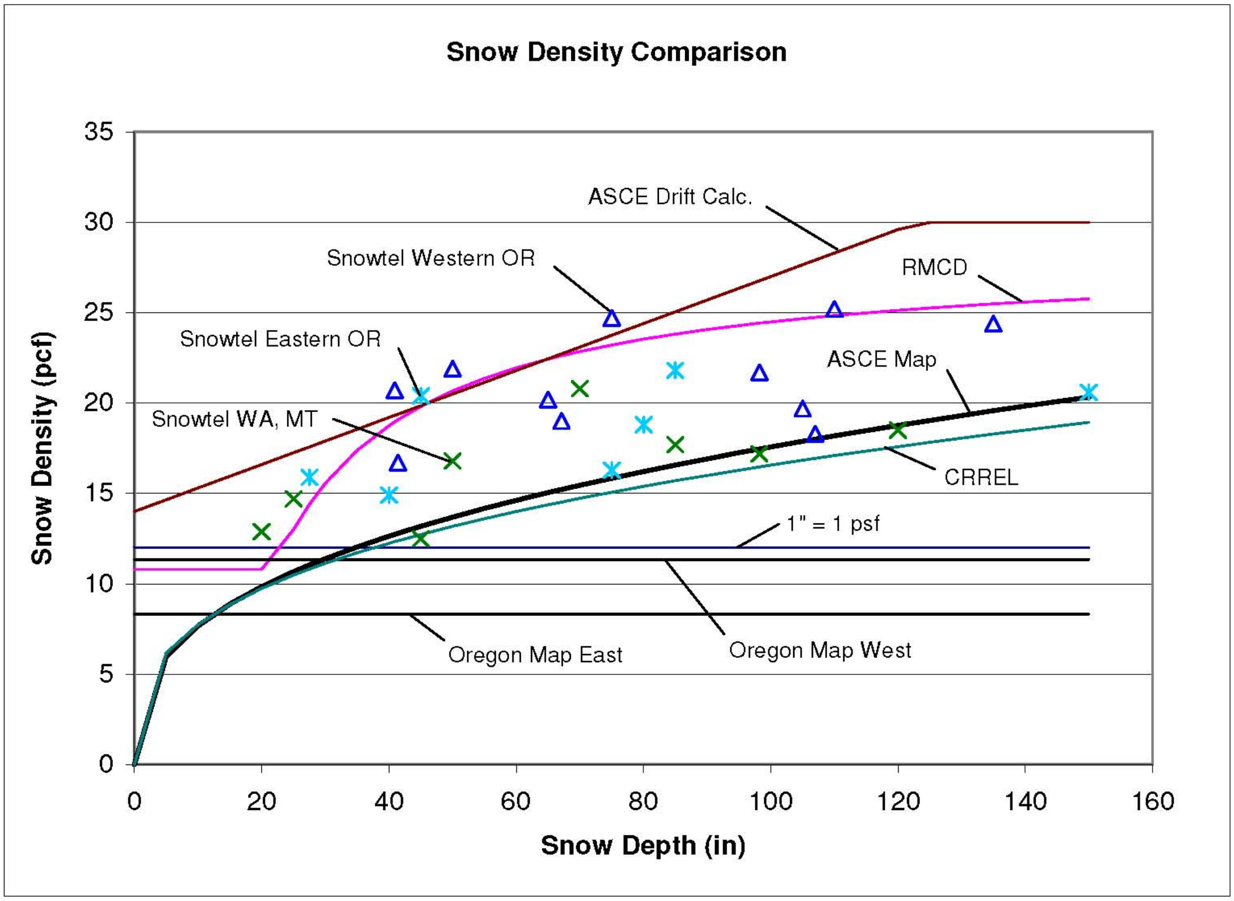
SEAO recommends that users of the 2007 ground snow load map use caution when determining ground snow loads, particularly for mid and high elevation projects. Updated tables are attached and can be used as described below to determine snow loads. However, the procedures require some care and design snow loads should also be confirmed with the local building official having jurisdiction, particularly during this interim period.

The attached table lists the updated calculated 50-year MRI values for each COOP station. Factors such as distance to, and elevation of, the adjoining stations must be weighted to determine their contribution to the project site. When the user intends to establish the appropriate snow load for a given site, one must compare the project site elevation and proximity to available historical data from COOP and SNOTEL sites. Generally, areas shown on the 2007 map having a 30 psf or less snow load value did not show a significant increase, with a few notable exceptions. These exceptions are noted with an asterisk (*) in the table, and indicate those sites which were previously shown in the 2007 manual to have a 30 psf or less snow load, but now have an increased design load. For map areas that previously showed ground snow loads greater than 30 psf, values may have increased 20% or more at some sites. Although the new 50-year loads listed in the attached table should serve as the primary reference, data from the *1978 Snow Load Analysis of Oregon* snow load graphs could be viewed as an additional resource. As noted before, the mid and higher elevation sites are the ones most impacted by these updated guidelines, and therefore are the projects sites that require greater caution in determining the ground snow loads for this interim period. In no case should a value be used that is less than what is shown on the 2007 map.

Attachments:

Figure 1, Snow Density Comparison
Figure 2, Normal vs. Lognormal Distributions, Mud Ridge Snotel Site
Figure 3, Extreme value Distributions
Figure 4, Comparison of Predicted Return Periods
Figure 5, Accuracy of Return Period Estimation for 30 yr. Snotel Records

Table 1, National Weather Service COOP Stations
Table 2, National Resources Conservation Service SNOTEL Stations



Snow Density Comparison
ASCE Drift Calc.
Snowtel Western OR
RMCD
Snowtel Eastern OR
ASCE Map
Snowtel WA, MT
CRREL
1" = 1 psf
Oregon Map East
Oregon Map West
Snow Density (pcf)
Snow Depth (in)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
120
140
160

Figure 1

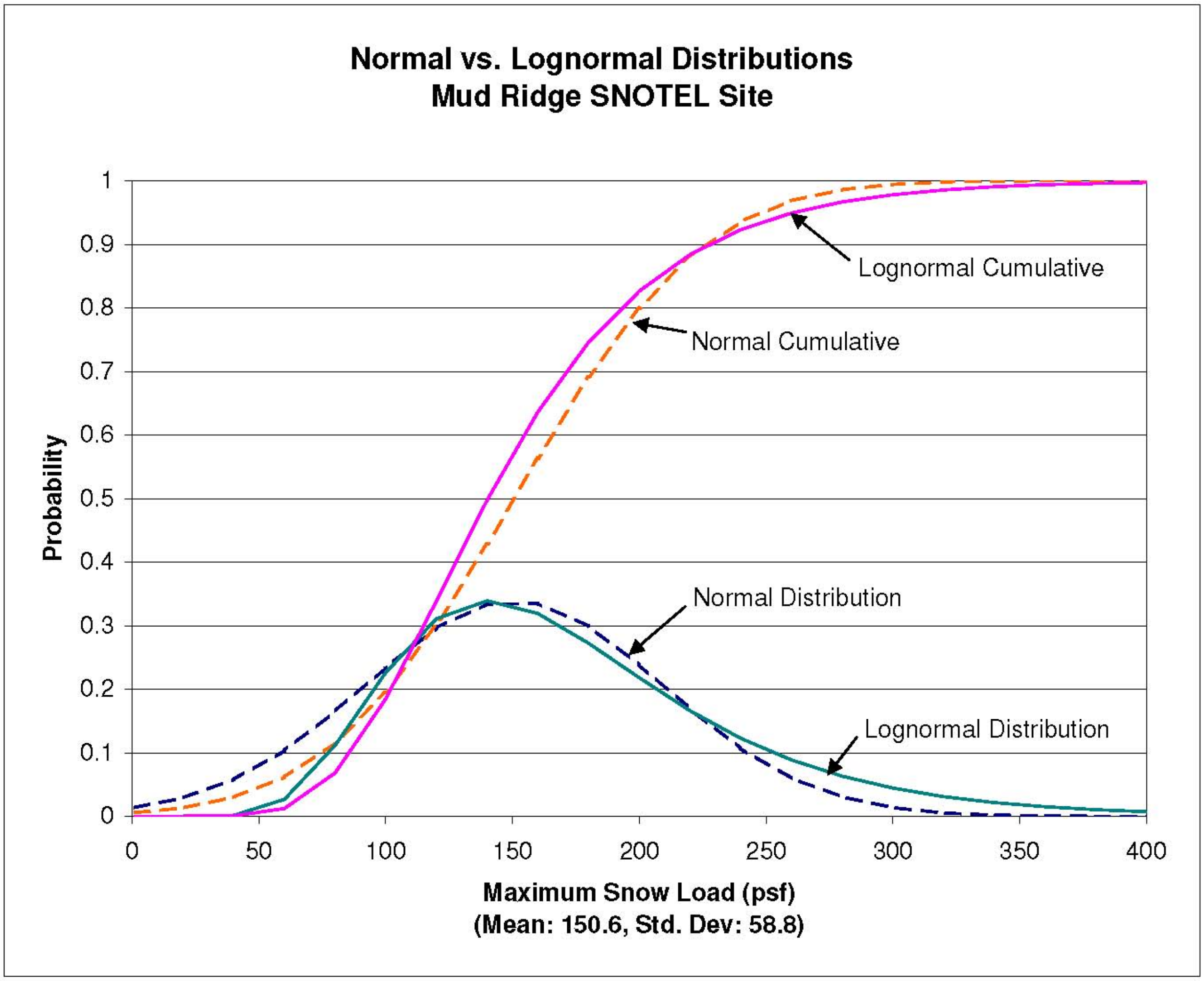

Normal vs. Lognormal Distributions
Mud Ridge SNOTEL Site
Probability
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
Lognormal Cumulative
Normal Cumulative
Normal Distribution
Lognormal Distribution
Maximum Snow Load (psf)
(Mean: 150.6, Std. Dev: 58.8)

Figure 2

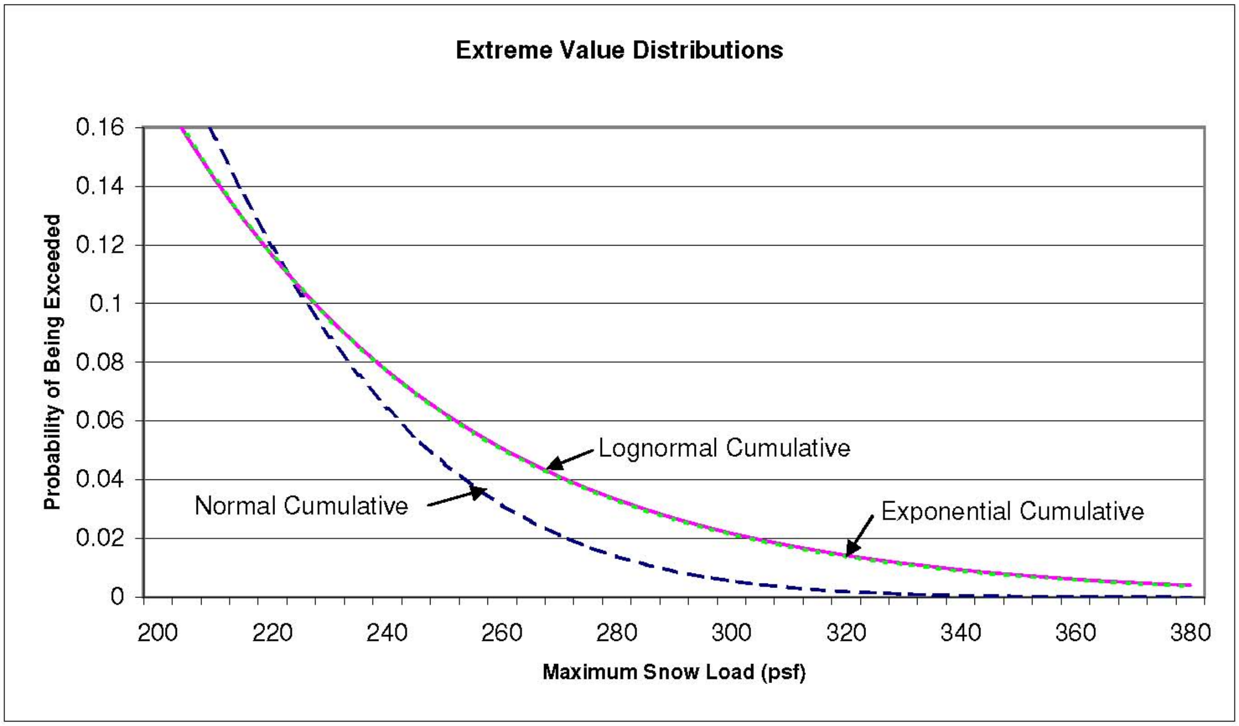


Figure 3

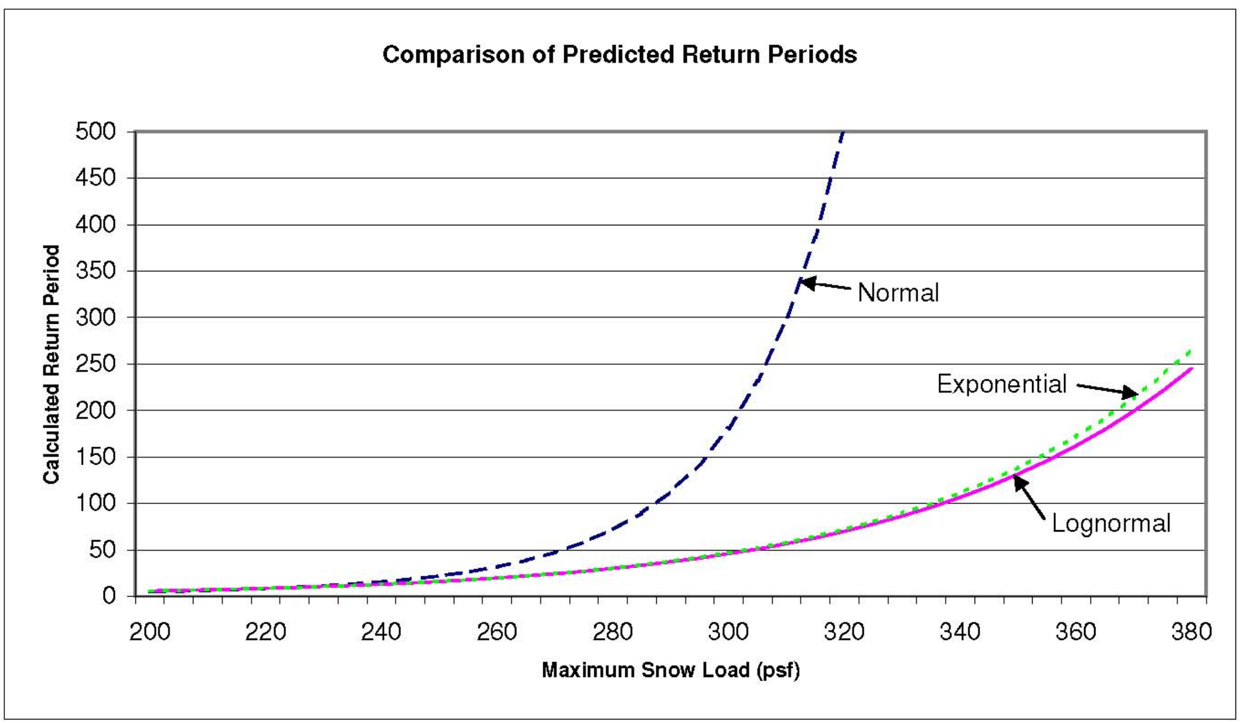
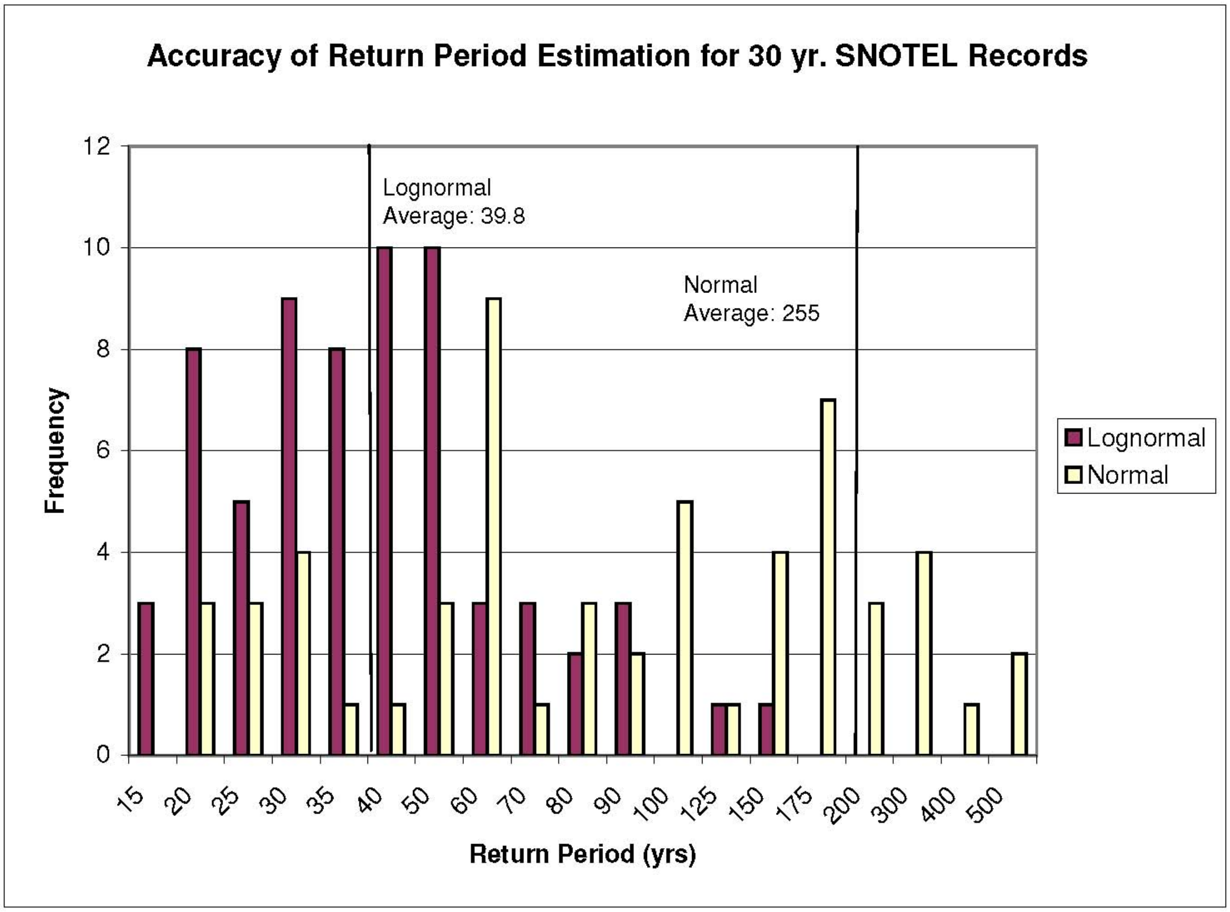


Figure 4



Accuracy of Return Period Estimation for 30 yr. SNOTEL Records
Frequency
12
10
8
6
4
2
0
Lognormal
Average: 39.8
Normal
Average: 255
Lognormal
Normal
15
20
25
30
35
40
50
60
70
80
90
100
125
150
175
200
300
400
500
Return Period (yrs)

Figure 5