Minnesota Asphalt
Pavement Association
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Comprehensive Guide to PG Asphalt Binder Selection in Minnesota

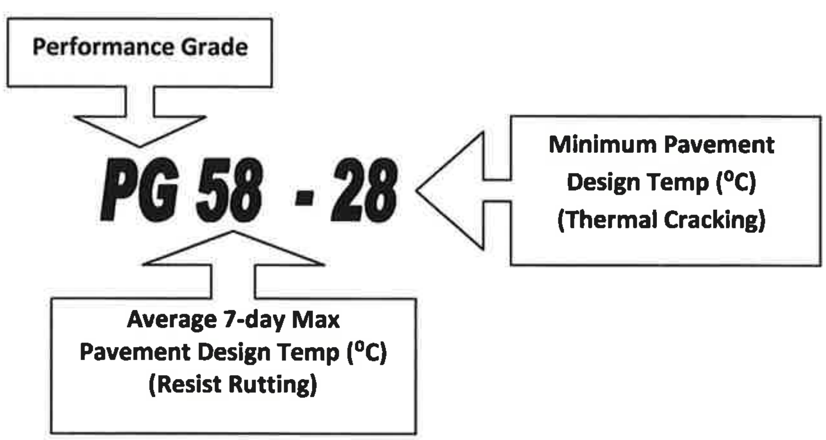
PG Binders

The Performance Grade (PG) system is the method of categorizing an asphalt cement binder used in Hot Mix Asphalt (HMA) relative to its rated performance at different temperatures. It was originally developed during the Strategic Highway Research Program (SHRP) in the early 1990's and was called "SuperPave™." Performance grading is based on the concept that asphalt binder properties should be related to the conditions under which the binder is used including air and pavement temperatures, and specific application for that specific facility.

The physical properties of asphalt cement change with temperature, i.e. asphalt cement is stiffer at lower temperatures and relatively softer at higher temperatures. PG asphalt binders are categorized and selected to meet performance criteria at expected high and low temperature extremes with a certain level of reliability. This increases the resistance to permanent deformation or rutting at high temperatures and increases the resistance to transverse thermal cracking at low temperatures.

What Do the Numbers Mean?

An example of a performance graded binder is PG 58-28. PG indicates that it is a performance graded binder. The first two numbers (58) indicate that the binder meets high temperature physical properties up to 58 degrees Celsius (58°C = 136°F). The last two numbers (-28) indicate the binder meets low temperature physical properties down to -28 degrees Celsius (-28°C = -19°F). A level of reliability can be determined for a binder selected for use in a particular area using temperature data. The level of reliability deemed necessary will need to be determined by the specifying agency for each particular facility designed with HMA.



The SuperPave™ PG specification classifies asphalt binders into grades that change at 6°C intervals. Examples of typical PG grades include PG 58-28, PG 52-34, PG 58-34, PG 64-28, and PG 64-22. Based on economics and engineering risk comfort, the Canadian refiner/suppliers also have provided PG grading that changes at 3°C intervals such as PG 58-31, PG 58-37, PG 58-40, PG 64-25, and PG 64-31.

Although more expensive than unmodified binder, using a modified asphalt binder in HMA is another consideration for performance, durability, and traffic (usage) conditions. When selecting the PG type, the engineering group representing the specifier should weigh the importance of the performance characteristics of the facility (such as resistance to rutting, thermal cracking, fatigue damage, stripping, temperature susceptibility, the intrinsic value for customer satisfaction) with the economics of the project. Below are a few considerations on these performance characteristics.

Rutting
HMA technologists are in agreement that rutting is best controlled by selecting proper aggregate requirements such as fractured faces for the proposed mixture and an acceptable level of uniform compaction (in-place voids) prior to traffic usage. Permanent deformation (or rutting) of asphalt pavements has been virtually eliminated in Minnesota through the Quality Management (QM) program that controls the field produced mixture volumetrics. Selecting the proper mix and monitoring mixture volumetric properties are critical factors for a rut-resistant HMA mixture. The proper selection of mix gyrations, stringent criteria for aggregate, and other proven mixture requirements can compensate for using an unmodified asphalt binder rather than a modified asphalt to prevent rutting.

Transverse Thermal Cracking
Proper structural pavement design, drainage, and construction practices are critical to withstand low temperature (thermal) cracking. The PG asphalt binder can assist as a mix component. Due to seasonal movement in the subgrade, one can anticipate some transverse thermal cracking to occur in any pavement, especially in a relatively thin structural section, an overlay, or a mill and fill overlay on jointed pcc, or an overlay over an already cracked pavement.

Fatigue Damage
The proper structural pavement design section for the designed loads is imperative to prevent fatigue cracking (cracking due to pavement strength deficiency). This should be the first priority and materials selection would be the next consideration. In other words, if a pavement is under-designed, PG asphalt type alone, modified or unmodified, will not prevent fatigue cracking. No matter what the goal is, it is very important for the designer to understand what the needs are for a facility and the importance of a cost-effective balance for achieving a long-term performing pavement.

Currently, the PG system does not adequately describe asphalt binders that are modified. Research is underway to address this shortcoming and most likely will be available as a tool in the near future. Asphalt modification is available in a number of forms and additives can range from chemical materials to mineral fillers. In general, if the performance of the HMA is not significantly improved, the use of the modifier additive must be re-evaluated.

Stripping
The current Minnesota Department of Transportation (Mn/DOT) 2360 bituminous mixture specification requires HMA to pass a stripping test called Tensile Strength Ratio (TSR). A minimum percent is required to obtain an approved Materials Design Report (Job Mix Formula) and can be verified in the field produced mixture at the time of mixture production, thus stripping is not a concern for 2360 specification HMA mixtures.

Engineering Judgment
What are the right applications for the use of the various PG asphalt grades? It would be unusual to see modified binders used for low-volume roads, golf cart paths, bike paths, driveways, shoulders, porous pavement, temporary construction, or in most non-wearing courses. The structural design, quality of the materials specified, location of the pavement layer due to an insulation effect, temperature gradient, and uniqueness of the facility are all valid considerations for selecting between PG asphalts. In general, the rule of thumb is no more than two PG types should be specified per project. Tonnage of mix per PG type should also be considered. Regardless of the PG type specified for the particular mix, the key objective must be to make the most life-cycle cost-efficient choice of HMA for taxpayers, owners, and users.

Initial work performed on PG selection was based on air temperature distribution (Attachment 1). Later, data became available regarding the temperature within asphalt pavements, and thus a relationship between air temperature and pavement temperature was developed from heat flow models for HMA.

MAPA contracted with a consultant (Braun Intertec and ERES) to refine the heat flow models to more accurately predict the extreme temperatures that are needed for the selection of the appropriate PG asphalt. To further help illustrate the distribution of these reliabilities throughout the Midwest, the contour maps were generated by the consultant for several PG binders at various depths for new construction and rehabilitation in Minnesota, North Dakota and South Dakota . In this research, regression equations were developed that relate the maximum 7-day air temperature to the pavement temperature, and the minimum air temperature to the minimum pavement temperature. To better understand how climatic variations affect reliability, calculations were made to determine the reliability of a specific maximum or minimum temperature at all of the weather stations which resulted in probability/reliability charts for the surface and 2" below surface (see attachments). The data format shown is similar to a contour map for interpretation.

It is acknowledged that traffic type, speed, and type of construction has some bearing on PG asphalt selection, but meeting expected climatic conditions for the pavement is a key priority for performance and cost considerations.

Hot mix asphalt recycling and PG asphalt selection is a way of controlling project costs. Changes in material prices will also depend on crude oil pricing in the futures market and the stability of the U.S. Dollar in the global market. However, PG asphalt cement will remain as a byproduct from the production of gasoline and other fuels from crude oil. The nature of the crude oils being processed will continue to affect this on a local basis.

Examples

To illustrate designer decision, the following example assumes that the exact same HMA roadway is in northern Minnesota (i.e. Warroad) and southern Minnesota (i.e. Albert Lea) and is subject to the same 20 year projected traffic loads. The following can be seen from the PG probability/reliability contours (Attachments 2 through 9) considering <u>air</u> and <u>pavement</u> temperature.

Table 1. Example of PG Reliability Data from Attachments 2 through 9.

Distress Type	PG Type	Depth in Structure	Probability	
			Warroad	Albert Lea
Rutting	52	At Surface (Attachment 2)	96%	71%
	52	2" Below Surface (Att. 3)	100%	98%
	58	At Surface (Att. 4)	100%	97%
	58	2" Below Surface (Att. 5)	100%	100%
Thermal Cracking	-28	At Surface (Att. 6)	39%	93%
	-28	2" Below Surface (Att. 7)	68%	100%
	-34	At Surface (Att. 8)	84%	100%
	-34	2" Below Surface (Att. 9)	100%	100%

<u>Guidelines for new PG selection (designing construction/rehabilitation projects to prevent rutting and thermal cracking due to the asphalt binder)</u>:

- The reliability against rutting at the surface for PG 52 (Att. 2) and PG 58 (Att. 4) are:
  - For Warroad
    - PG 52 at the surface is 96%
    - PG 58 at the surface is 100 %
  - For Albert Lea
    - PG 52 at the surface is 71%
    - PG 58 at the surface is 97%
  - Therefore:
    a. Both PG 52 & PG 58 are well suited for Warroad with 96% and 100% reliability against surface rutting, respectively.
    b. PG 58 is more applicable for Albert Lea with a reliability of 97% against rutting.
- The reliability against thermal cracking at the surface and 2" below the surface for PG -28 vs. PG -34 is:
  - For Warroad
    - At the surface, the PG -28 (Att. 6) is 39%
    - At 2" below the surface, the PG -34 (Att. 9) is 100%.
  - For Albert Lea
    - At the surface, the PG -28 (Att. 6) is 93%.
    - At 2" below the surface, the PG -28 (Att. 7) and PG -34 (Att. 9) are 100%.
  - Thus, PG -34 would be appropriate for northern Minnesota (Warroad) and PG -28 for southern Minnesota (Albert Lea).
- The above guidelines indicate that PG 52-34, 58-28, and perhaps even PG 58-31 (Canadian System currently supplies half grades) are a consideration for Warroad (Northern MN).

- The above guidelines indicate that PG 58-28 is sufficient for Albert Lea/Southern Minnesota.
- Generally, the PG binder highest temperature property for rutting can be met when choosing a PG binder, and a more serious consideration will be warranted for low temperature cracking property.
- In reviewing the attached probability/reliability contour maps for Minnesota (Attachments 2-9) consideration for PG selection vary depending on the general location of the project either basically north or south of I-94.
- Designers should be aware of cost/ton of liquid (PG 52 vs. PG 58 and -28 vs. -34, etc.), quantity, intended use for the facility, number of warranted mix designs, and construction sequencing for traffic control.

In 2001, ERES Consultants continued the contour line concept for Minnesota at the 95th and 98th percentile for low temperatures at the surface and at a 2-inch (50 mm) depth. A series of Minnesota maps (Attachments 10 – 13) were created with a line label (contour line) representing the northern boundary for that particular PG rating. For example, Attachment #10 shows the contours for low temperature at the pavement surface for 95 percent reliability. PG -28 meets the climatic conditions from the southern border of Minnesota to the -28 contour (at approximately I-94). PG -31 meets the climatic conditions between the -28 contour line (about I-94) to the -31 line. PG -34 could be used for the extremely cold northern areas of Minnesota. Note: there are some exceptions based on the PG -28 contour such as northeast of Minneapolis/St. Paul and along the shore of Lake Superior.

It should be realized that the low temperature designation specified for a binder, when tested in the laboratory for compliance is typically about 3^{o} more. As an example, a -28 binder is actually refined and supplied at about a -31 to ensure it will be within the binder specification. In conclusion, PG -28 at 2" below the surface encompasses approximately the southern two-thirds of Minnesota.

Other considerations for PG

Q1. What are the risks in placing HMA using a binder that has a low temperature number different than recommended?

A1. The risks depend on the facility type and design. There can be higher costs to the specifier due to binder cost or they may be minimal. Materials and mix design requirements must also be considered when making decisions about the use of binders. A critical risk would be if the structure was left without its warranted pavement structural need for the traffic type and volume for an extended period of time which could allow for fatigue of the under-designed pavement layers.

Q2. How does an engineer design a HMA pavement for oxidation, weathering, or raveling?

A2. Surface durability is primarily a function of proper mix selection, mix design, specifications, and compaction (in-place voids) as compared to just the PG selection. SuperPave^{TM} technology has improved the ability of HMA to withstand surface deterioration related to oxidation, weathering, and raveling.

Q3. What about mix tenderness, power steering/scuffing movement, or commercial facilities?

A3. Tender mixes may pose concern at the construction stage or the in-service performance stage or both. Currently, MAPA's suggested alternatives to alleviate the tenderness issue for HMA pavements exposed to standing traffic and/or low speed turning motion are:

1. Use recycle asphalt pavement (RAP) in the HMA to enhance the strength of the HMA pavement layer matrix.
2. Utilize PG 58-28 only for non-wear or wear HMA with RAP.
3. If above options are not feasible, use PG 64-22 for all virgin aggregate wear mix.

Q4. What about data regarding asphalt mixtures with RAP or all virgin aggregate mix?

A4. Experimental results indicate that the asphalt mixtures containing RAP have higher dynamic modulus values than the control mixtures containing no RAP.

Q5. What if recycled asphalt pavement (RAP) and/or recycled asphalt shingles (RAS) are incorporated into the HMA?

A5. These items are addressed in the Mn/DOT 2360 Specification. Recycle materials are required to meet the same stringent quality criteria as a virgin mix. The Mn/DOT 2360 Specification is often updated and can be found at:
http://www.dot.state.mn.us/materials/bituminous.html

Q6. What is the recycling policy of the Federal Highway Administration (FHWA)?

A6. The FHWA has established agency goals for enhancing the human and natural environment, increasing mobility, raising productivity, improving safety throughout the highway industry, and preserving national security. See www.fhwa.dot.gov/legsregs/directives/policy/recmatpolicy.htm for the FHWA recycling policy and recycling programs. They state that restrictions that prohibit the use of recycled materials without technical basis should be removed from specifications.

Conclusions

HMA remains the most cost-efficient paving material because it is a renewable material that does not need to be completely removed or replaced, it increases in equity, and it is an environmentally sustainable transportation solution for today and tomorrow.

The information in this publication was authored by Richard O. Wolters, P.E., Executive Director, and Jill M. Thomas, P.E., Associate Director, Minnesota Asphalt Pavement Association. It was compiled from several sources including the FHWA, Mn/DOT, Transportation Research Board, Asphalt Institute, MAPA, and consultant services.

ATTACHMENT #1

From the Asphalt Institute's SuperPave^{TM} Series No. 1 (SP-1) "Performance Graded Asphalt Binder Specification and Testing"

A Point of Discussion Regarding Superpave Asphalt Binder Selection

This information is provided to clarify the procedures for determining the low pavement design temperature for performance graded (PG) asphalt binders in the Superpave asphalt mix design system.

In the development of the Superpave binder specification, researchers used the low air temperature as the low pavement design temperature for performance graded (PG) binders. However, this extreme requirement is not consistent with the history of binder performance from many Canadian pavements, and it results in binders that can be difficult and expensive to produce.

The Asphalt Institute's *Superpave Binder* and *Superpave Level Mix Design* manuals, Superpave Series Nos. 1 and 2 (SP-1 and SP-2), provide this equation for determining the low pavement design temperature:

$$T_{min} = 0.859T_{air} + 1.7^{\circ}$$

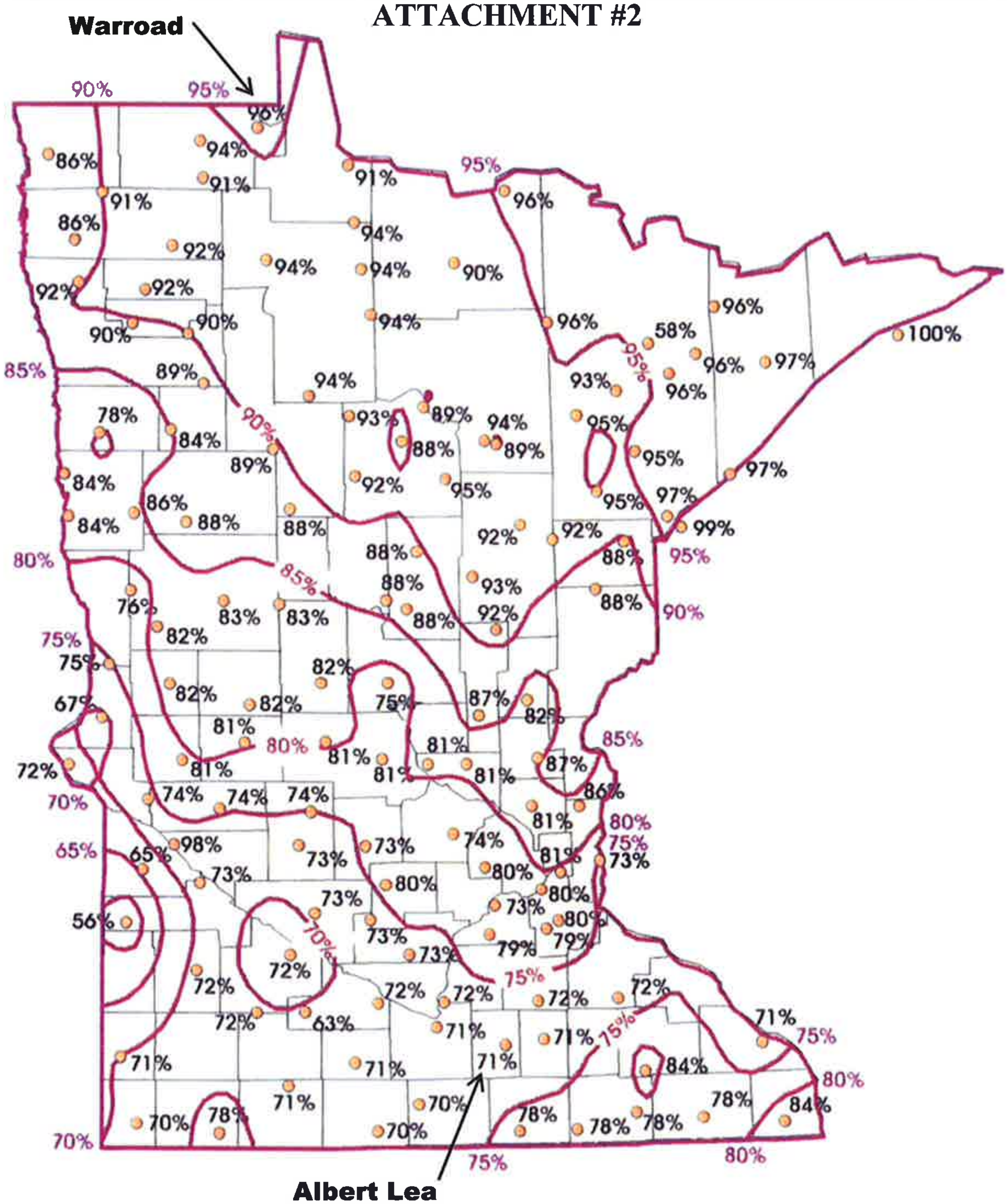
where T_{min} = minimum pavement design temperature in °C,
T_{air} = minimum air temperature in average year in °C.

This equation was developed by Canadian SHRP researchers, and more closely matches Canadian experience with asphalt binder performance. This equation's use is gaining acceptance by North American asphalt technologists and is used in Asphalt Institute publications when illustrating low temperature PG binder selection.

The issue of how to determine the low pavement design temperature is still unresolved within the asphalt industry, and this equation is one method being proposed. It is hoped that this issue will be resolved soon to facilitate consistent implementation of the Superpave asphalt mix design system.

August 1995
Asphalt Institute
Lexington, Kentucky

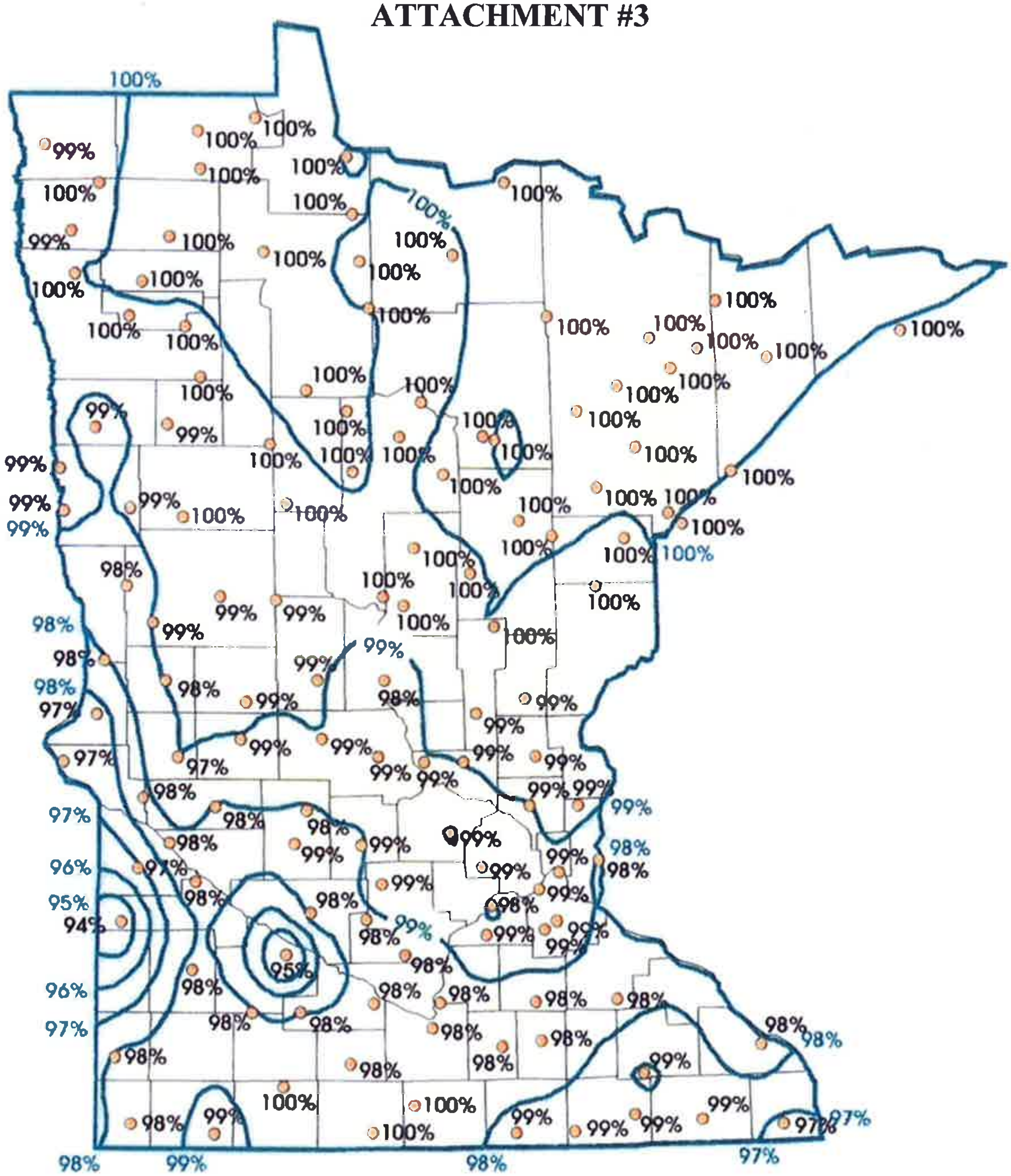
ATTACHMENT #2



PG 52 Reliability Contours

BRAUN INTERTEC

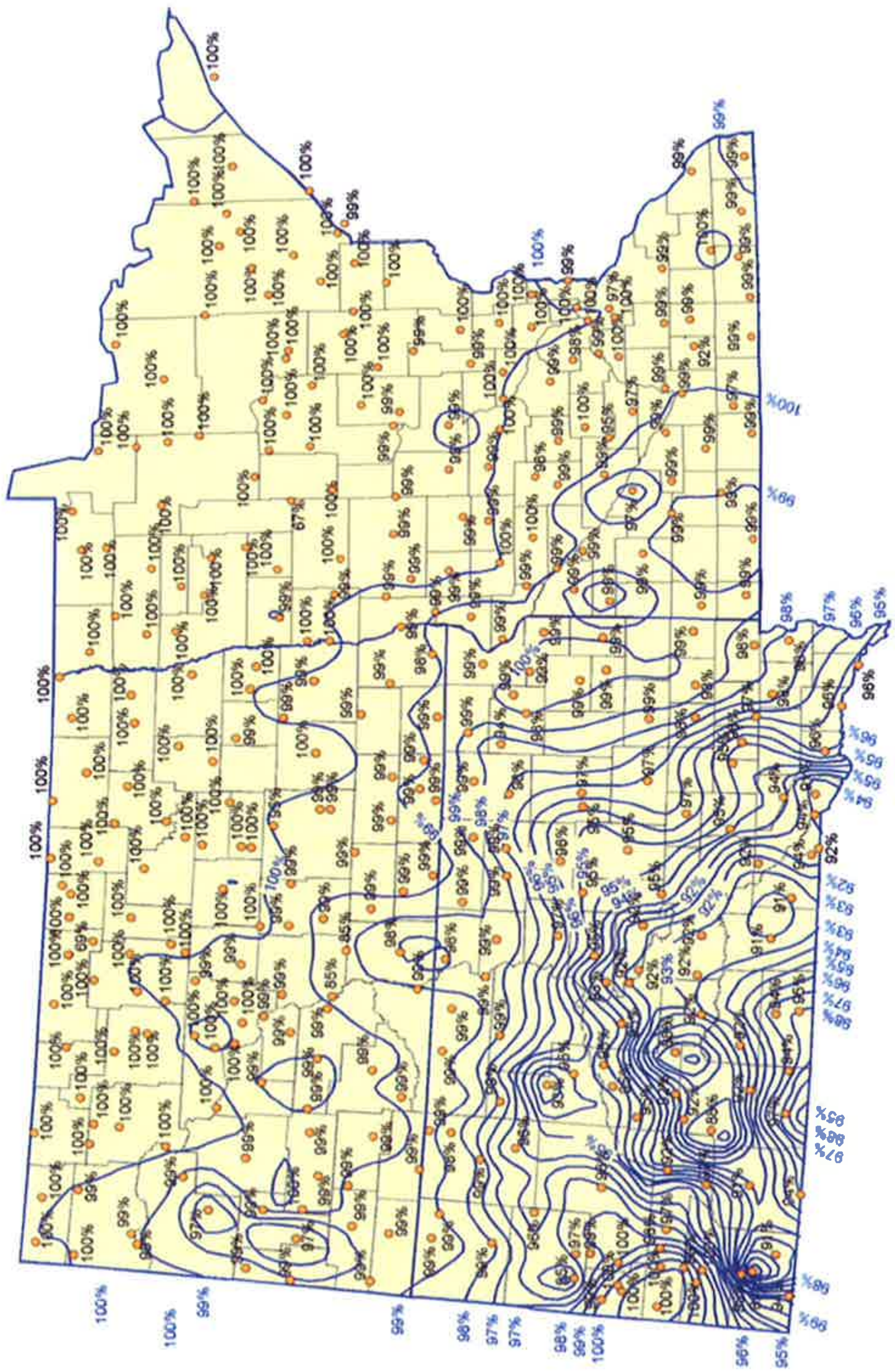
ATTACHMENT #3



PG 52 Reliability Contours at 50mm Depth

BRAUN INTERTEC

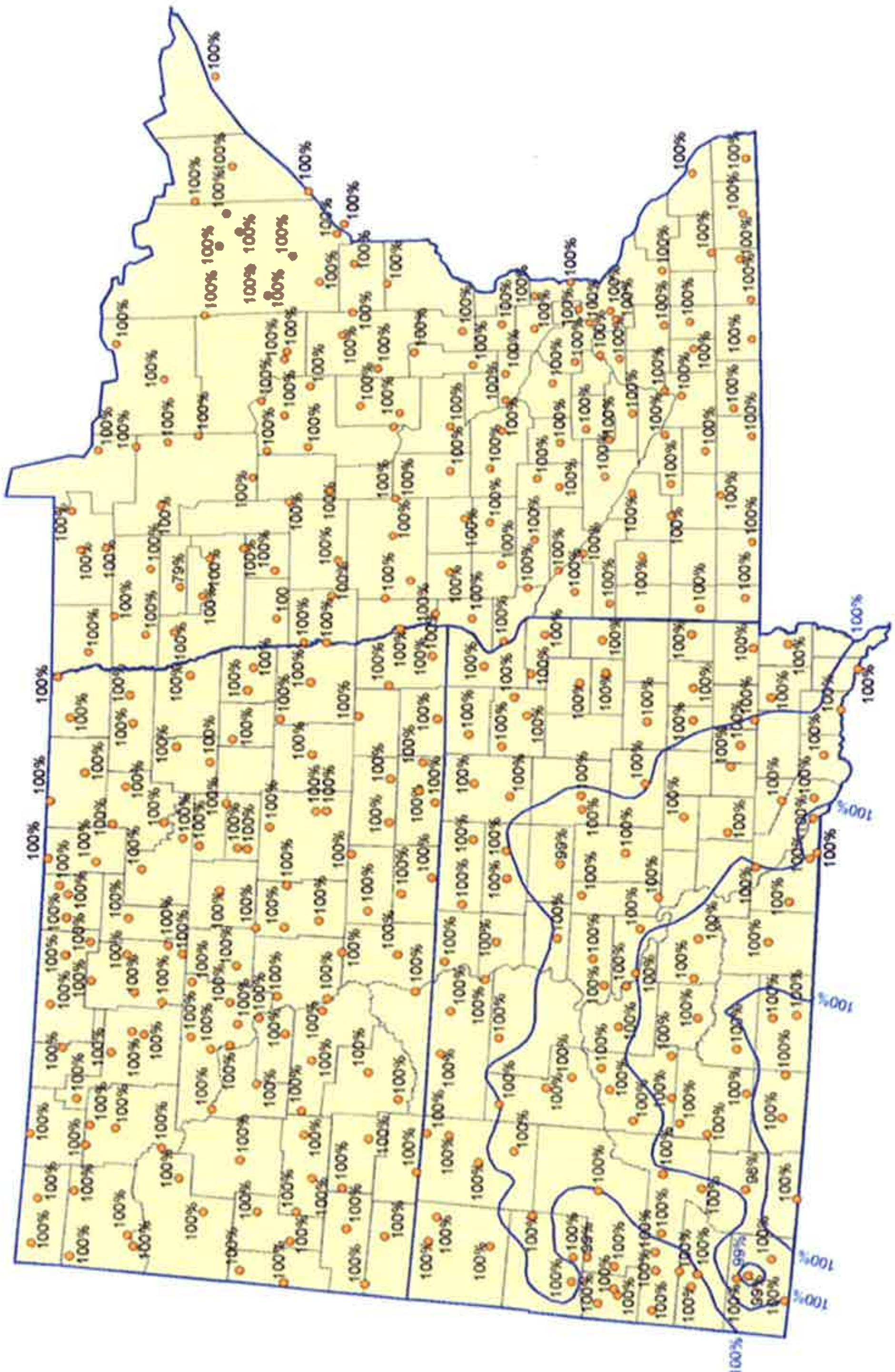
ATTACHMENT #4



Probability for PG 58 at the Surface

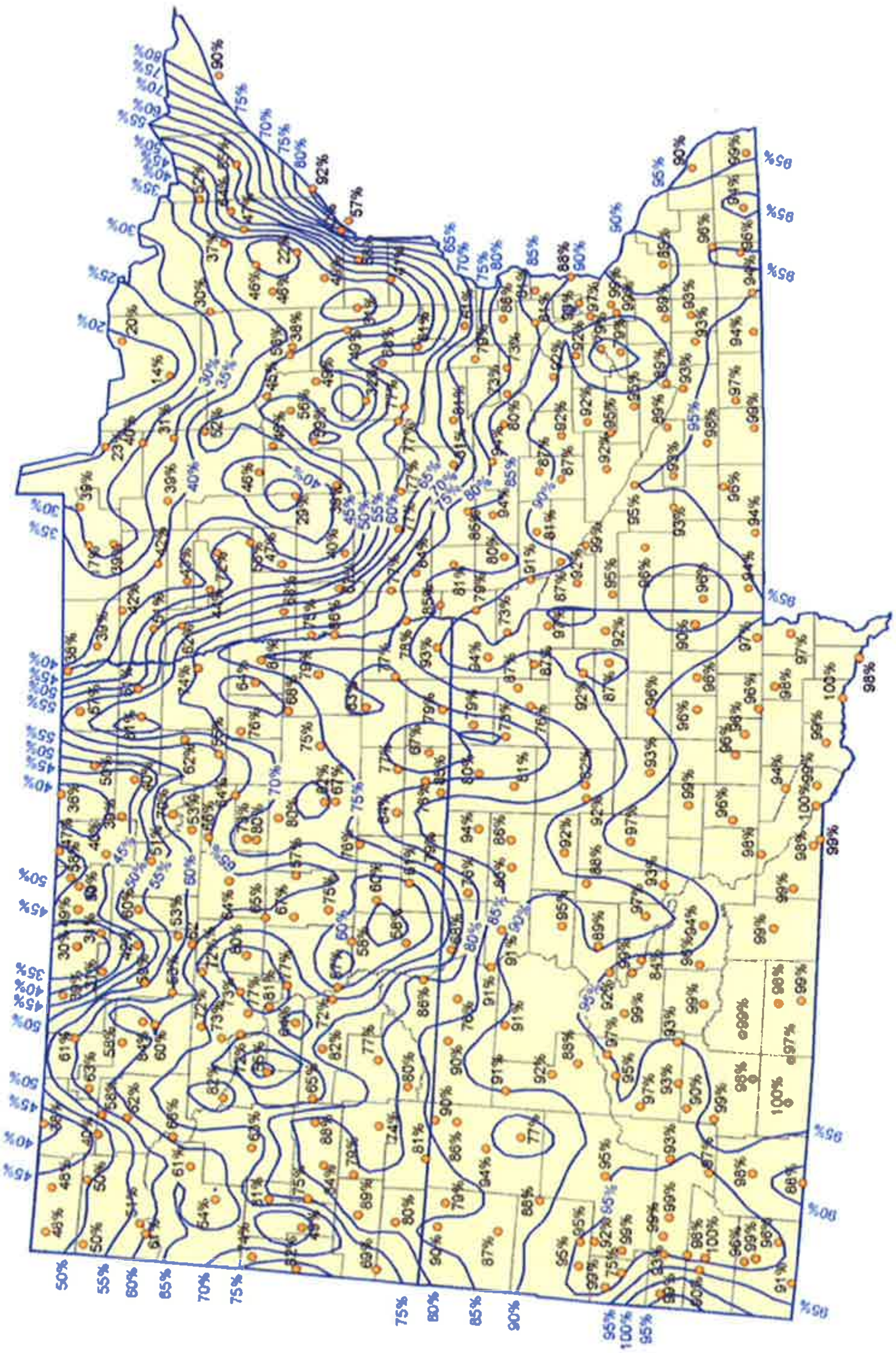
BRAUN INTERTEC

ATTACHMENT #5



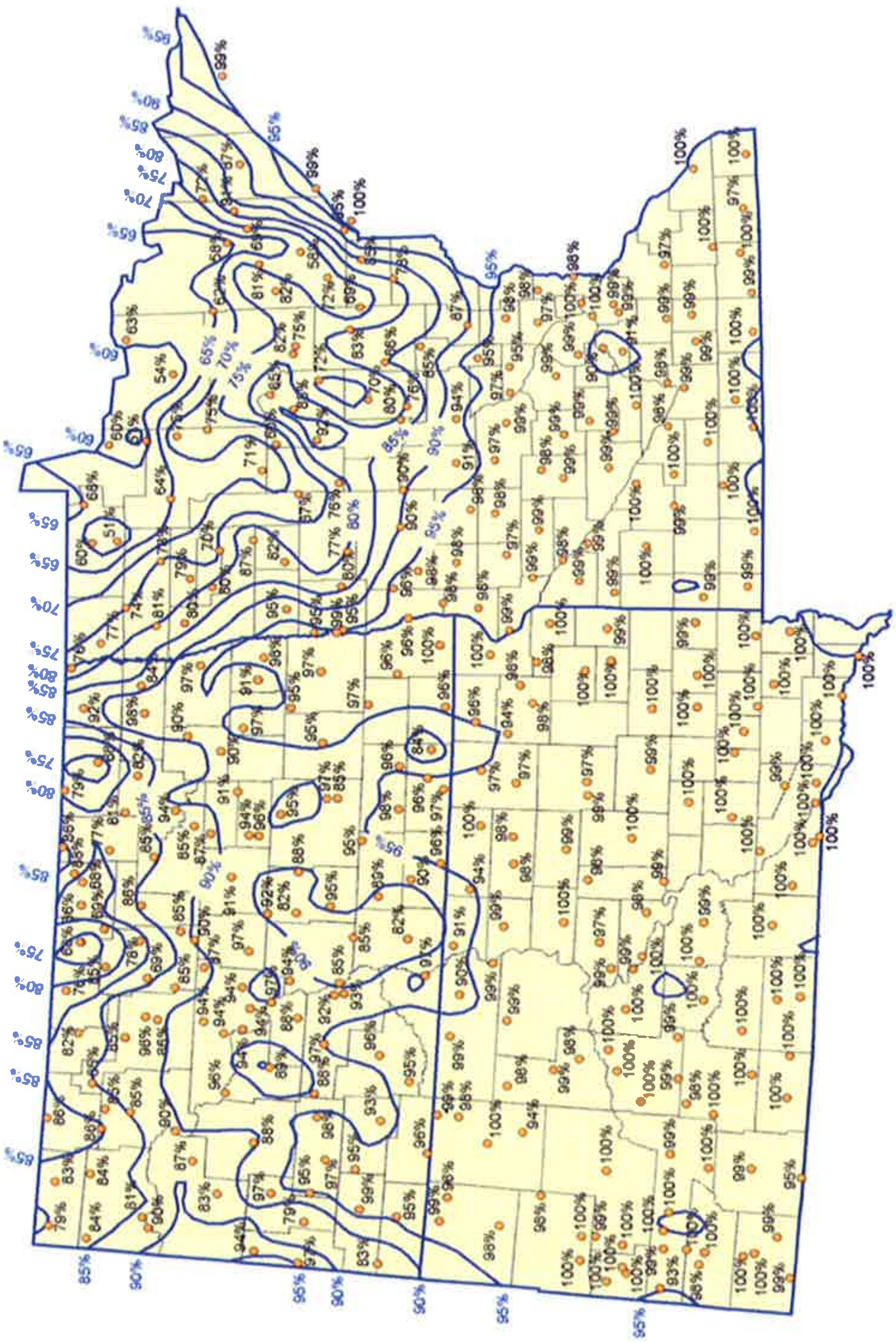
Probability for PG 58 at 2 inches Below Surface

ATTACHMENT #6



Probability for PG -28 at the Surface

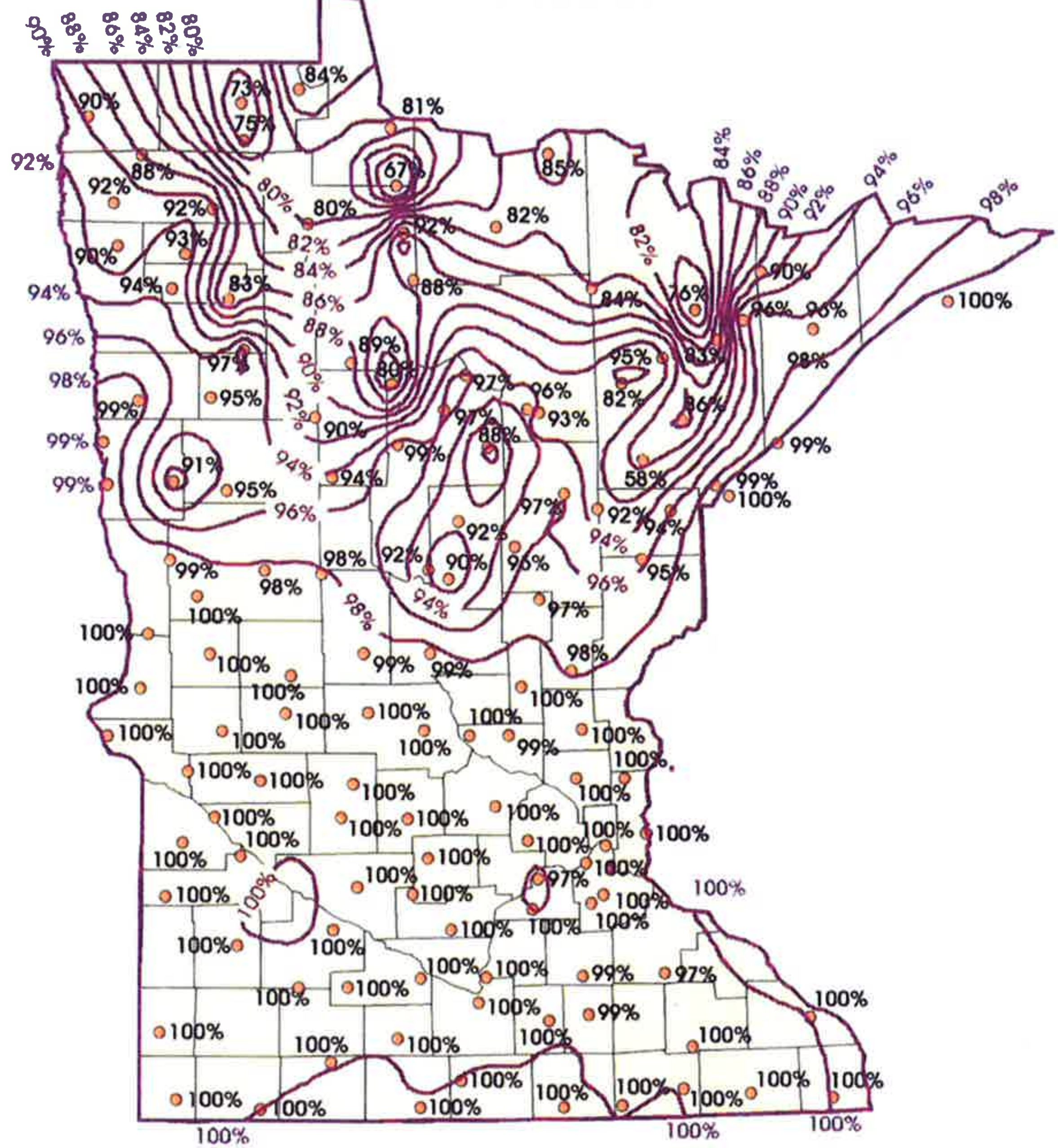
ATTACHMENT #7



Probability for PG -28 at 2 inches Below Surface

BRAUN INTERTEC

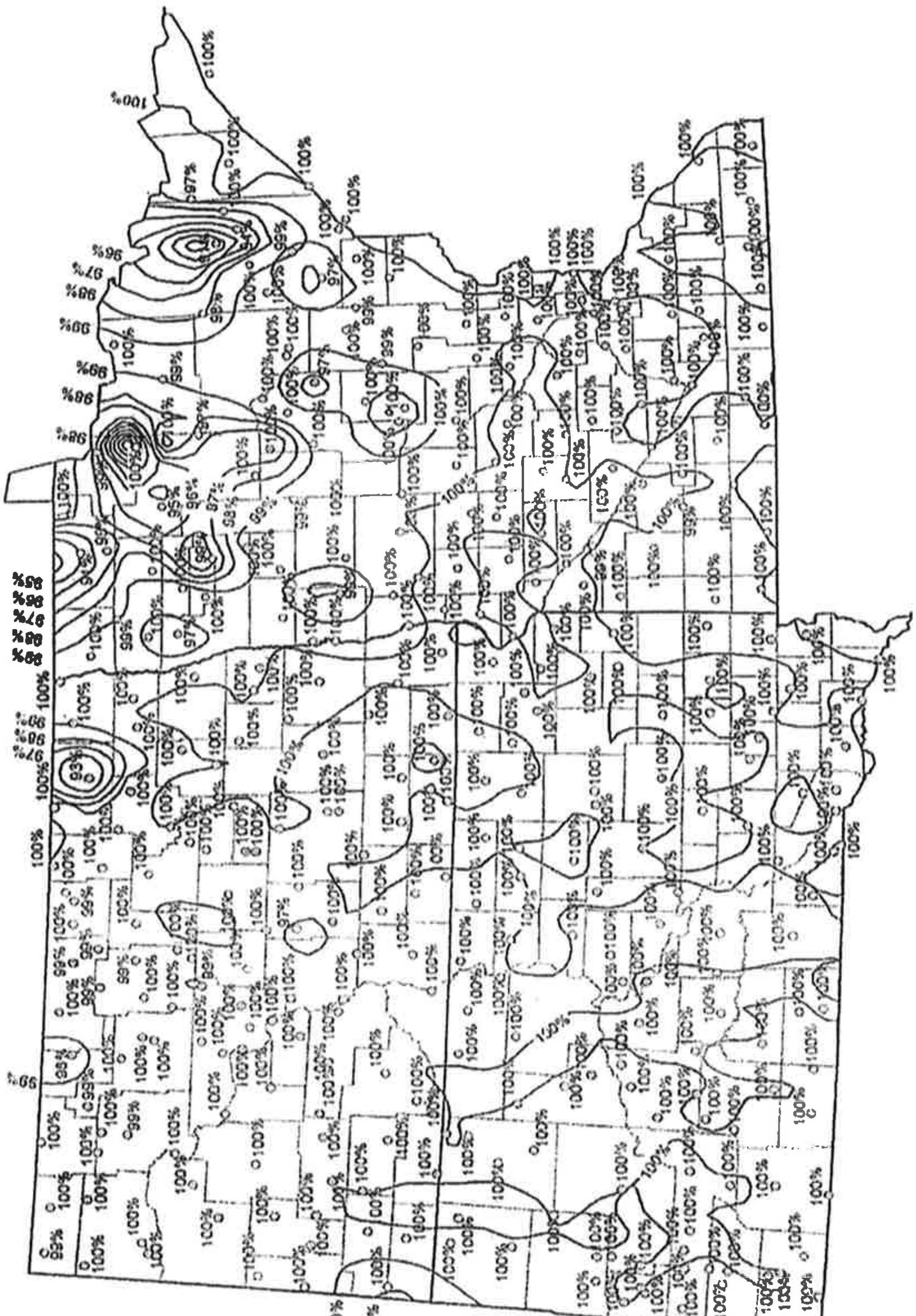
ATTACHMENT #8



PG -34 Reliability Contours

BRAUN INTERTEC

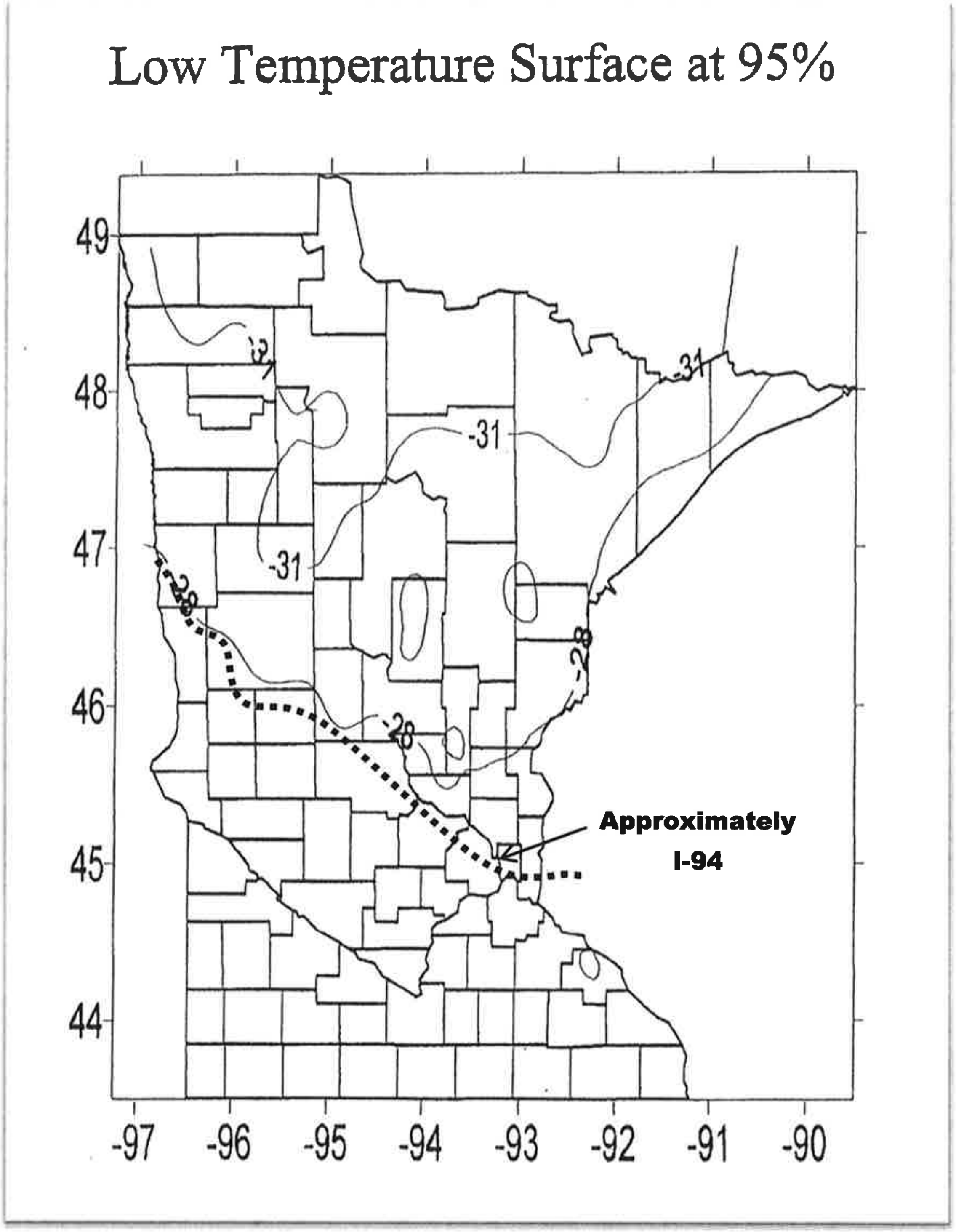
ATTACHMENT #9



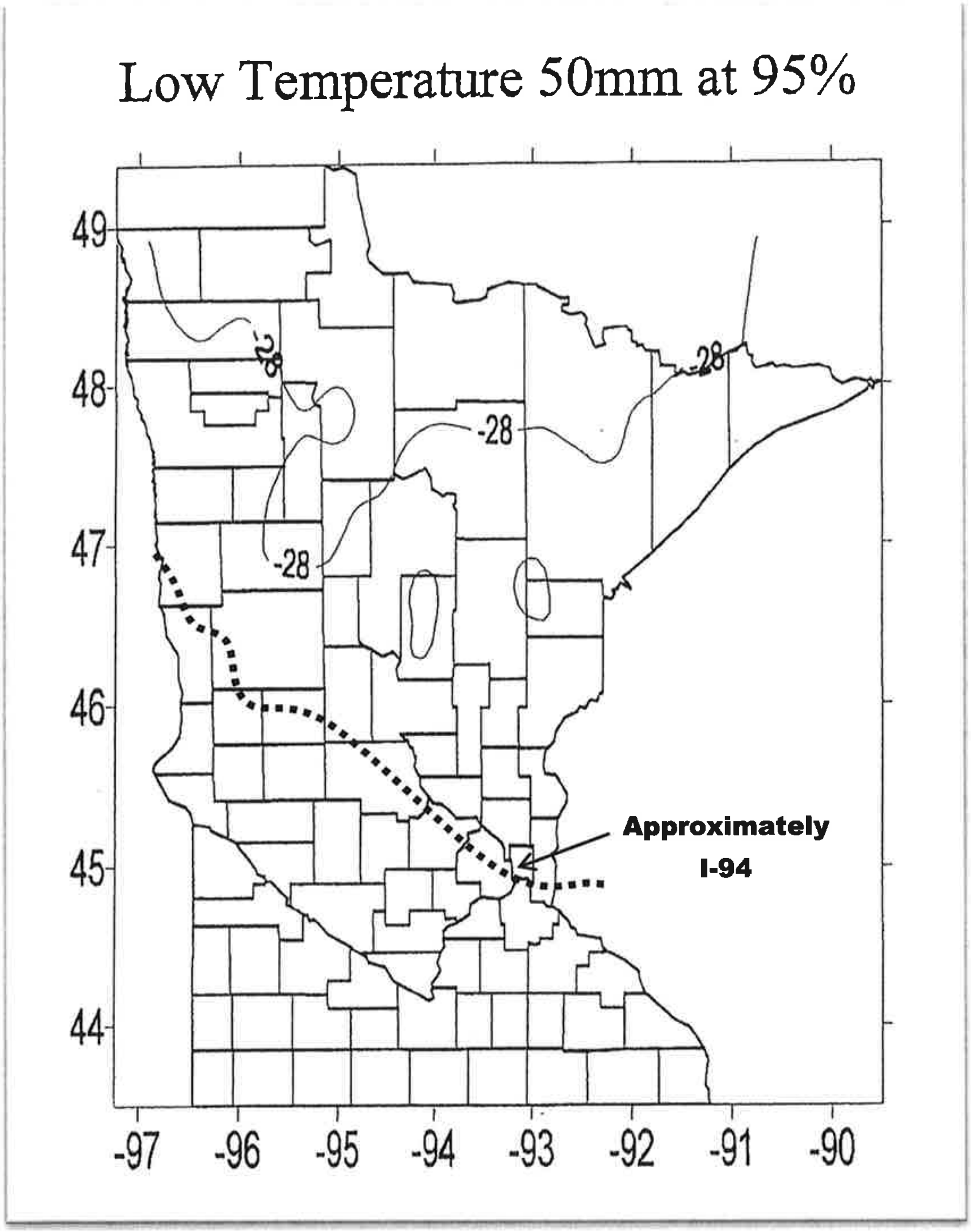
Probability for PG -34 at 2 inches Below Surface

BRAUN INTERTEC

ATTACHMENT #10

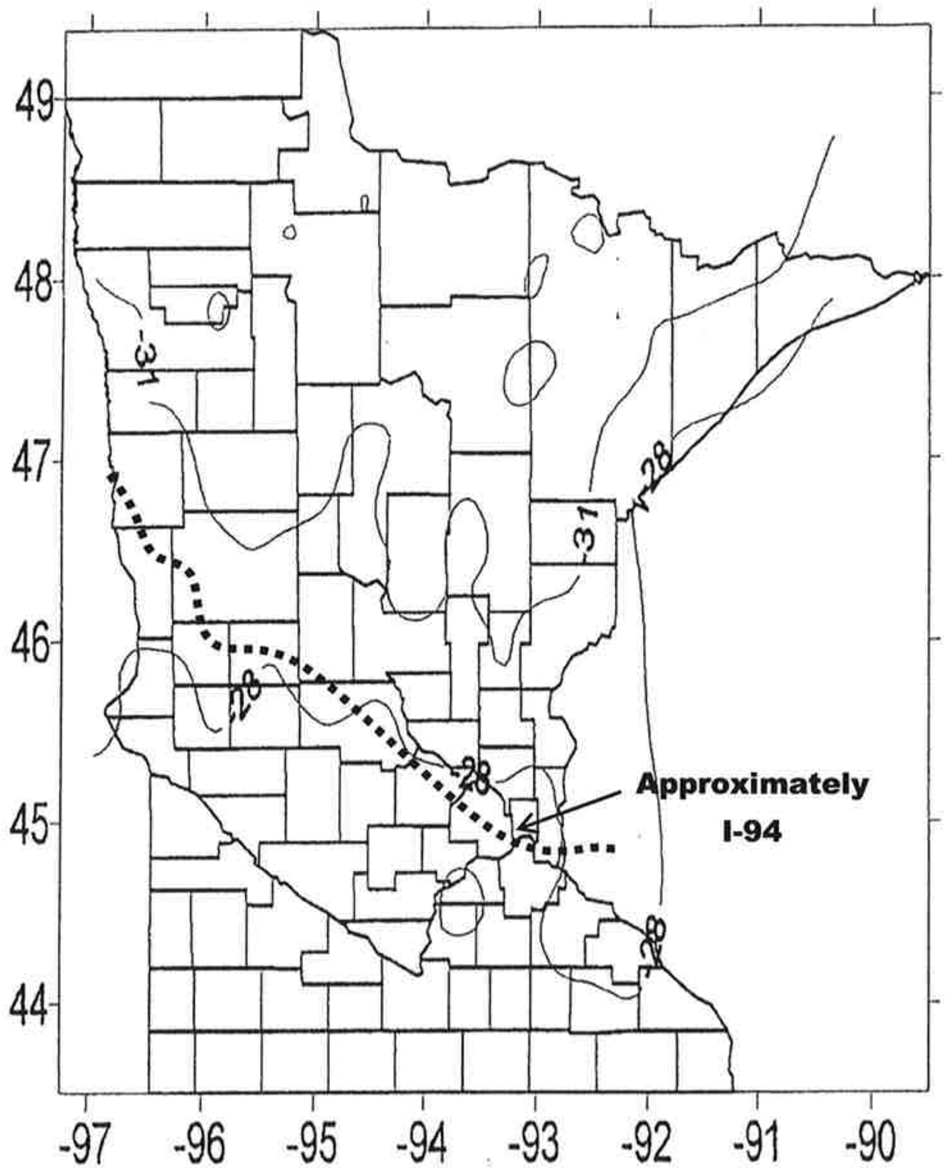


ATTACHMENT #11



ATTACHMENT #12

Low Temperature Surface at 98%



ATTACHMENT #13

Low Temperature 50mm at 98%