Summary of Limitations and Value of Slide-Based Visual Range Measurements

Executive Summary

1) Slide-based VR measurements have a high uncertainty associated with them.
2) Cumulative frequency values are biased by the high uncertainty such that:
   a) The "clean" values are too clean. They can be used as conservative (from the federal land manager standpoint) value when estimating clean visibility values for a Class I area.
   b) The "dirty" values are too dirty. No one's really protecting their dirty days anyway.
   c) The median (50%) values are reasonably accurate.

Purpose

Recent detailed examination of the uncertainties associated with slide-based visual range (VR) measurements has led to general confusion as to the worth, or lack thereof, of such measurements. The purpose of this report is to summarize the limitations and value of slide-based VR measurements in a brief format without rigorous statistical derivations. Such derivations are performed in a report by Air Resource Specialists (ARS), Inc. in Fort Collins. The report is not yet available for general distribution.

Error In VR Measurements From A Single Scanned Slide

The error in a single measurement of B_{ext} can be computed directly from the formula for B_{ext},

$$B_{ext} = (1/r)\ln\left[\frac{R_n C_o}{C_r}\right]$$

if the uncertainty in each of the variables, r, R_n, C_o, C_r, is known. ARS has provided estimates of these uncertainties based on their extensive experience with this measurement technique. The provided uncertainties themselves are subject to some uncertainty, so that this analysis should be understood to be a best available estimate.

Figure 1 below shows the 68% confidence interval, corresponding to +/- 1 standard deviation about a given VR measurement for a site with a good ("dark") target. The squares represent the 1:1 line. For a given measured visual range, for example 200 km, the actual ambient visual range at the time of the measurement was 68% likely to be within the range 115km <VR <391 km. The upper bound would be substantially higher, but 391 km represents the Rayleigh limit for clean atmosphere VR. VR values above 391 km are truncated to 391 km. It can be seen from Figure 1 that both the absolute and relative errors associated with individual VR measurements are large. Data from sites with brighter (lower contrast) targets will have even higher uncertainties. Daily VR values computed from three-slides-per-day averages will be subject to somewhat lower uncertainties.

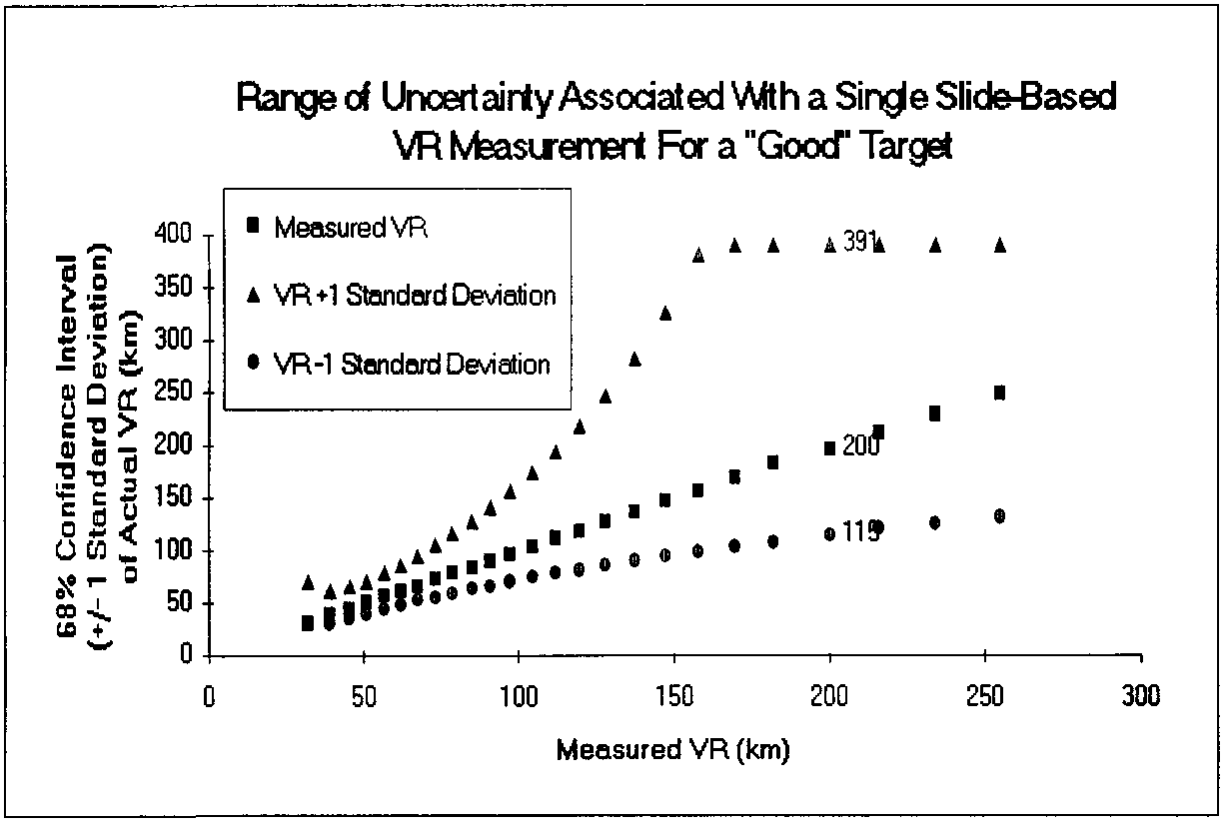

Figure 1

Bias in Cumulative Frequency Values of Slide Based VR

The large uncertainty in slide based VR estimates introduces a statistical bias in a cumulative frequency plot of the VR measurements. This is a direct result of the fact that high VR values will sometimes be overestimated, and those overestimated values will bias the "clean" numbers, causing them to be too clean. Additionally, low VR values will sometimes be underestimated, and those underestimated values will bias the "dirty" numbers, causing them to be too dirty. The average VR could be substantially affected by this, however the median or 50% value will be not be significantly affected.

Figure 2 is a diagram of the bias introduced into a typical cumulative frequency plot. The error bars are not precisely calculated for a specific data set, but are intended to represent the direction and approximate magnitude of the bias. Calculating a confidence interval for this type of information would be extremely difficult.

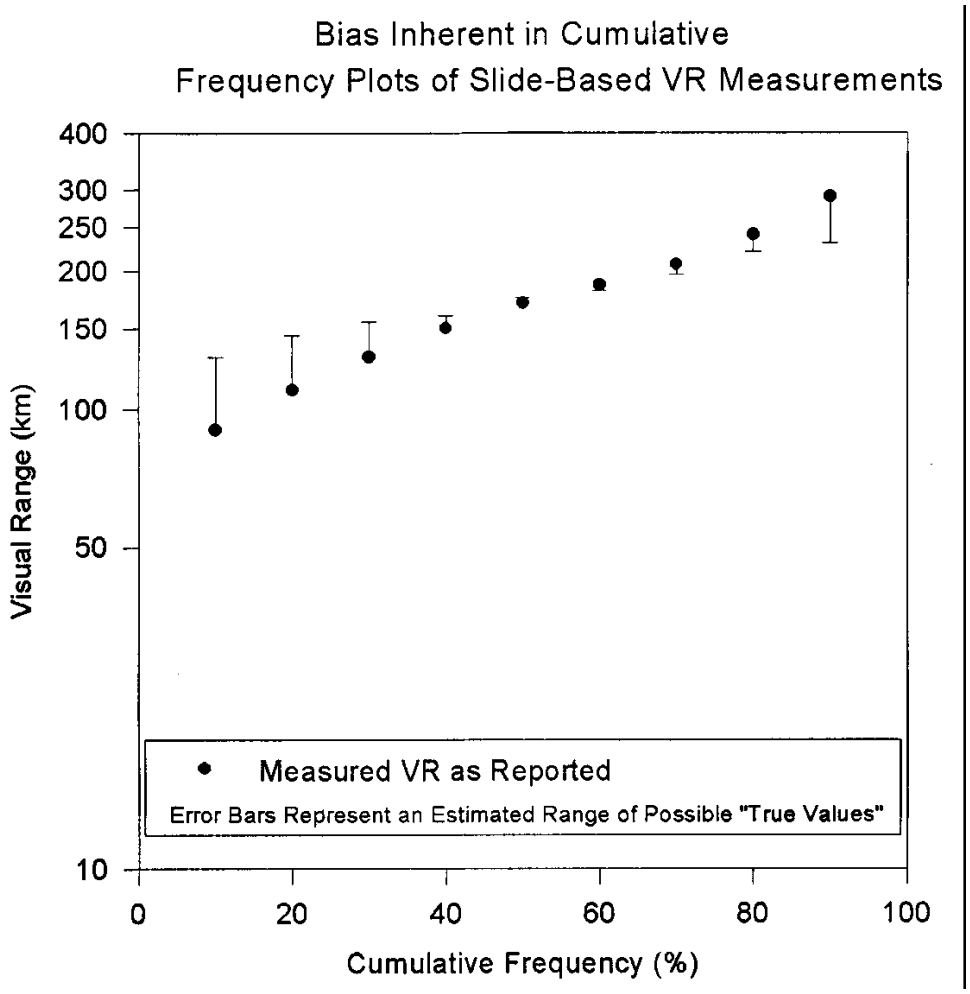

Figure 2.

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