Probability of Detection for Search Dogs or How Long is Your Shadow?

by Hatch Graham

Background

Foot searchers have developed methods of controlling their probability of detection (PoD) with techniques like critical separation. Usually, dog handlers who work alone or with a single observer have not employed techniques to ensure their coverage will result in a predictable PoD.

In 1980, I wrote a short paper, "Probability of Detection for Air-Scenting Dogs in Wilderness Searches," that proposed a method based on research in air pollution science and micrometeorology. I suggested to the handful of search dog units across the country that they try it out. I received little response from dog handlers, but over the years I've presented the material at NASAR conferences and workshops; to the United States Police Canine Association; to national search dog schools; at SAR City, USA; at the Second International Disaster Dog Symposium in Mexico City; and at informal meetings of search dog handlers. At these meetings, I've never had anyone challenge the basic premises.

My wife, Judy, and I, who are active dog handlers, have informally tested these ideas over the past 13 years. We are active in evaluating candidates for mission-ready status in our own search dog unit and have observed the validity of the system. I don't hesitate to add that the system has never undergone rigorous, scientific field trials. Nevertheless, I am confident that it can assist the dog handler and, perhaps what is more important, the Planning Section chief and the incident commander in evaluating PoD of the dog team in the field.

Air Pollution Research

In the early 1970s, a British physicist, F. Pasquill, studied the industrial smokestacks in England to determine if there were ways to diminish the pollution by timing the operations of the plants. He carefully measured the concentration of gases and particulate matter in smoke plumes at the source (the mouth of the stack) and simultaneously at 100 meters from the source under all weather variations.

The concentration of the smoke proved to be highly predictable if one knew the weather. He published a textbook on the subject in 1975, entitled Atmospheric Diffusion, which revealed these findings. Air stability is a key factor in the concentration or diffusion of the discharged matter. Stability is influenced by solar insolation which in turn is affected by daylight and dark, cloud cover, wind shear and the angle of the sun. The sun's angle is altered by latitude, time of year, slope and aspect.

The various combinations of conditions resulted in clearly separable and verifiable changes in smoke concentrations. At 100 meters from the source, the greatest convectional turbulence (instability) resulted in 40 times greater dispersion of smoke than under the most stable conditions when the smoke would hang like a pall over the countryside. The concentrations could be rather easily sorted into six categories (Table 1).

Table 1

Relative Concentration by Stability Category at 100 Meters from the Source		
A	0.025	1/40
B	0.050	1/20
C	0.100	1/10

D	0.250	1/4
E	0.400	2/5
F	1.000	1/1

Researchers in the U.S. Department of Agriculture-Forest Service were seeking ways to burn slash from timber sales and conduct prescribed burns for silvicultural improvements without creating a blanket of smog over major metropolitan areas. Pasquill's work offered a solution. If the burning were confined to days of high instability, the smoke would be quickly dispersed into the atmosphere with little visible or other environmental effects.

The problem was how to calculate the air stability without measurement of the sun's angle under field conditions. The slash crew foreman could be counted on to recognize day from night, to be trained to estimate the cloud cover and whether or not the clouds were low, medium or high. Simple handheld wind gauges are available to measure the wind, or it can be estimated by application of rules of thumb like the Beaufort Wind Scale (Table 2).

Table 2

Estimating Wind Speed Based on the Wind Scale Developed by Admiral Beaufort, HMN	
Less than 4 mph	Direction of wind (if any) shown by smoke but not by wind vane.
4 to 7 mph	Wind felt on face; leaves rustle; wind vane moved.
8 to 10 mph	Leaves and small twigs in motion; wind extends surveyor's tape.
11 to 14 mph	Wind raises dust and loose paper.
15 to 25 mph	Small branches and small trees in leaf begin to sway; crested wavelets form on inland waters.

The Naval Observatory's huge book showing the sun's angle for every day of the year at each minute of latitude could not easily be put in a handheld computer. Leonidas C. Lavdas, at the Forest Service's Southern Forestry Experiment Station, came up with the solution. In a paper, "A Groundhog's Approach to Estimating Insolation," he showed how measuring the shadow of a 6-foot vertical could solve the spherical trigonometry involved. A shadow of less than 3.5 feet would equate to high insolation, high convection, high instability and high dispersion. The shadow length takes into account slope, aspect and the sun's elevation above the horizon. No tools are needed since the foreman can be shown where 6 feet is in relationship to his or her own height.

A shadow length of 3.5 to 8.5 feet indicates moderate convection and a shadow length over 8.5 feet indicates low convection. These three value ranges result in valid significant differences. Lavdas modified Pasquill's data to come up with a chart showing the stability category under these three conditions (Table 3).

Table 3

Probability of Detection[1] Based on Stability Estimating Method[2]

How to use the table:

1. Locate main column head for day or night. Night applies from 1 hour before sunset to 1 hour after sunrise.
2. Locate subcolumn head for cloud cover.
3. If for day situation, locate sub-subcolumn head for 6 foot vertical standard shadow length.
4. Locate row for surface windspeed.
5. In row and tinder column, read probability of detection based on grid sweeps spaced at 100 meter intervals

Surface Windspeed (mph)	DAY									NIGHT	
	Clear OR 50% or less cloud cover with low and mid clouds OR any high clouds			More than 50% low and mid clouds			More than 50% low clouds				
	6-foot vertical standard shadow length (in feet)									50% or more cloud cover w/low and mid clouds or high overcast	Clear or less than 50% cloud cover w/low and middle clouds
	Less than 3.5	3.5 to 8.5	Greater than 8.5	Less than 3.5	3.5 to 8.5	Greater than 8.5	Less than 3.5	3.5 to 8.5	Greater than 8.5		
Less than 4	A 5-25	A-B 7-27	B 10-30	A-B 7-27	B 10-30	D 80-85	B 10-30	D 80-85	D 80-85	Insufficient data	Insufficient data
4-7	A-B 7-27	B 10-30	C 35-45	B 10-30	C 35-45	D 80-85	C 35-45	D 80-85	D 80-85	E 90-92	F 95-96
8-10	B 10-30	B-C 20-40	C 35-45	B-C 20-40	C 35-45	D 80-85	C 35-45	D 80-85	D 80-85	D 80-85	E 90-92
11-14	C 35-45	C-D 55-65	D 80-85	C-D 55-65	D 80-85	D 80-85	D 80-85	D 80-85	D 80-85	D 80-85	D 80-85
More than 14	C 35-45	D 80-85	D 80-85	D 80-85	D 80-85	D 80-85	D 80-85	D 80-85	D 80-85	D 80-85	D 80-85

[1]Based on Graham, Hatch, *Probability of Detection for Air-Scenting Dogs in Wilderness Searches*, 1980.
[2]After Pasquill, F., *Atmospheric Diffusion*, 1975; as modified by Lavdas, Leonidas C., *A Groundhog's Approach to Estimating Insolation*, 1976.

Application to Air Scenting

The missing victim is essentially a scent generator. Scent can be thought of as a pollutant just like smoke. The often microscopic particles of human scurf (rafts, dandruff) and their passengers of bacteria (which are converting the human protein into gaseous byproducts through digestion) behave as smoke does. The initial concentrations are much smaller and thus invisible; nonetheless, they act the same way.

The dog is capable of detecting concentrations as small as one part in 10 quadrillion (10-15 molar). Even so, reducing the concentration to 1/40th (.025) of that at the source (the victim) presents problems for most dogs. Fortunately, the highest rates of dispersion do not occur all the time. They are most apt to occur in the middle of a clear day around the summer solstice (June 22) when there is little wind. They also often occur on south-facing slopes for a greater period of the day (always when the shadow length is less than 3.5 feet long and the wind is less than 8 mph).

A realistic strategy for overcoming this shortfall is to schedule the dog teams' shifts for night, early mornings and late afternoons, at least from mid-April to mid-August. By avoiding midday (1000-1400 standard time), most of the difficult periods are avoided.

Probability of Detection

The 100-meter distance used by Pasquill is fortunate in that it approximates the length of a football field, which is fairly easy to visualize. It is a common distance a dog team uses when grid-searching a search segment. In searching a football field at a distance from one goal post to the other, dogs almost invariably can detect the victim at night with a light breeze. Broken terrain and vegetation can reduce the PoD by 5 or 10 percent. We use the 90 and 95 percent figures based on observations of dogs under those conditions. We also observe that dogs miss victims at very close range under the conditions described as "A." Handlers are more likely to see victims under "A" conditions than the dog is to scent them.

The scent concentration from the source is essentially a straight line relationship. PoD can be increased by gridding at a closer separation (Table 4). However, an advantage of using a dog team is the speed with which a segment can be cleared. To use a dog at 12.5 meter spacing to achieve a higher PoD is not much more effective than using foot searchers.

Table 4

Probability of Detection Based on Air Stability Class and Distance from the Source by the Dog Alone				
Air Stability Class	100 Meters	50 Meters	25 Meters	12.5 Meters
A	5%	50%	75%	87%
B	10%	55%	77%	89%
C	35%	67%	86%	93%
D	80%	90%	95%	97%
E	90%	95%	97%	99%
F	95%	97%	99%	99%

Table 4 is applicable to night searches. For daylight, we consider the handler and the dog as two search resources. The handler is a visual searcher in daylight and performs about half as well as a member of a grid team. The 50 percent reduction is based on the greater speed of travel and the handler's necessary concentration on watching the dog. Using figures from Jon Wartes, we can ascribe an average PoD for the handler alone (Table 5). Table 6 shows the cumulative PoD for the dog and the handler.

Table 5

Probability of Detection Based on a Visual Search by a Dog Handler Working a Dog			
100 Meters	50 Meters	25 Meters	12.5 Meters
8%	12%	31%	40%

Table 6

Cumulative Probability of Detection by Air Stability Class and Distance from the Source for a Dog/Handler Team				
Air Stability Class	100 Meters	50 Meters	25 Meters	12.5 Meters
A	13%	56%	82%	92%
B	22%	60%	84%	93%
C	40%	71%	91%	96%
D	82%	91%	97%	98%
E	91%	96%	98%	99%
F	95%	97%	99%	99%

Probability of Detection as a Planning Tool

Modern search theory uses PoD to predict outcomes of alternative proposed search actions. It also uses cumulative PoD to represent how effective a search effort has been.
Some valuable uses are to:

- Decide whether to re-search a segment.
- Decide whether to expand the total search area.
- Decide whether to use additional or different resources.
- Defend search actions to higher authorities, the media, relatives or in court.[1]

While effort has been made to train dog handlers to derive a PoD using the stability estimating method, it has not become a universal practice. There are several reasons for this. Foremost is that the dog handler is busy keeping track of his dog, his location and watching where he steps, so that constant monitoring of shadow length and wind speed fall by the wayside. Also the method is not widely taught, and the table is not readily available. New handlers are coming into the fold almost daily and PoD has not been a requirement in their training. Some doubtless believe that their empirical estimate is good enough. If you average a dog's PoD under all conditions it will work out to about 50 percent so why not use that figure? Obviously, the latter answer is not

satisfactory to the search planners, especially when the truth may be 13 or 95 percent.
One answer to the dilemma is to put the responsibility on the Planning Section. The dog handler can be questioned during the search on a regular (hourly) basis, and a simple questionnaire can be filled out by the radio operator at search base. Cloud cover can be determined from the search base. The necessary information needed from the handler is simple:

- What is your location?
- How far apart are your grid sweeps?
- How much wind are you getting at ground level?
- Can you feel it on your face?
- Are leaves in motion?
- Is the wind raising dust or blowing leaves around?
- Are small branches or small trees swaying?
- How long is your shadow?

Armed with Table 3 and this information, the planners can easily plot PoDs on the map. They will vary by terrain (from south slope to north slope to the flat), but the information will be far more specific and valuable than anything the handlers are likely to provide after their assignments.
This approach may irritate some conscientious dog handlers who can provide this information themselves. However, the Planning Section has the resources, the time to think about it and the need. Experience has shown that the likelihood of accurate PoDs being derived from the handlers' reports is not as high as it would be if this system were used.
We are not suggesting that the handler not even be questioned on PoD at debriefing. On the contrary, cover, terrain and other variables may result in changes from the PoDs estimated by the air stability method. However, lacking other reasons, the Planning Section will have a more valuable tool, as well as more insight into air-scenting conditions, by using this method.

Summary

Scent behaves like smoke and is transported and diffused according to laws of thermodynamics and kinetic energy in a gaseous state. Air stability affects convection and diffusion, which have an impact on the ability of the dog to detect the scent of the missing person. Daylight and dark, cloud cover and the character of the clouds, windspeed and the angle of sun in relationship to the slope of the ground influence air stability. Air stability, and consequently the probability of the dog to detect the missing person's scent, can be predicted accurately with some simple meteorological observations. The Planning Section on a search incident can derive acceptable PoDs by periodically obtaining field data from the dog handler by way of radio. This method requires no specialized equipment except for the table of values provided here. It was obtained from scientific research on atmospheric diffusion and 15 years of field observation of air-scenting dogs

[1]NASAR, *Managing the Search Function* and ERI, *Search is an Emergency: A text for Managing Search Operations*.

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