PREDICTING PROFILES OF SNOWDRIFTS IN TOPOGRAPHIC CATCHMENTS [1]

By

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Introduction

It is common knowledge that snowdrifts form behind certain terrain features, and yet we continue to build highways, railways, canals, spillways, and even buildings that are choked or buried by snowdrifts. Incongruous as it may seem, this oversight is partly due to the advanced technology that gives us powerful snow removal equipment and comfortable offices for design engineers. But in defense of the engineer, a strong case can be made for a real deficiency in knowledge concerning the quantitative relationship between terrain and snow accumulation. The only substantive work of which the author is aware is the wind tunnel studies conducted by Finney (1939) more than 35 years ago.

The imperative for information on this sadly neglected subject is rapidly developing. Costs are spiralling for "brute force" snow removal, and fuel shortages further argue for better approaches to snowdrift control. Attention is also turning to the hydrologic significance of snowdrifts, in response to a growing need for increased water yields. Efforts to rehabilitate strip-mined land in the "snow belt" will soon lead to realization of the importance for managing blowing snow to achieve desired levels of revegetation.

The author's work on snow fences for drift control along Wyoming's highways has led to the observation that the slope of snow drifts in road cuts does not agree with the few results in the literature. This paper reports the development and testing of a regression model to predict the configuration of drift deposits based entirely on topographic data. Although there is little doubt that approaches incorporating more fundamental fluid physics will be developed in the future, it is hoped that early presentation of this rudimentary regression model will stimulate further research and provide a useful design tool for immediate application. The success of the model to date has spurred the Wyoming Highway Department to interface the prediction technique described here with their earthwork computer program as a first step in designing drift-free roads.

The Equilibrium Profile

Definition.--It is reasonable to assume that any given topographic accumulation area has a maximum snow retention capacity which can not be exceeded regardless of the amount of blowing snow entering the trap. The snow surface corresponding to this maximum drift is here defined as the equilibrium profile or slope.

If the development of a snowdrift follows the so-called law of natural growth, so that any given time growth rate is inversely proportional to the total snow accumulation up to that time, then it might be expected that the trapping efficiency of the catchment declines in some manner as the topographic feature fills with snow. If so, the true equilibrium profile may be approached as a limit, but may not be attained with a finite amount of snow transport. Because there is no way to be certain that a true equilibrium has indeed been attained for any given trap observed in the field (since the amount of blowing snow is always limited in nature), we will refer to observed profiles as exhibiting "apparent equilibrium." Obviously, the larger the capacity of a trap, the greater the potential disparity between the apparent and true equilibrium profiles.

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The pattern of incremental drift growth behind a snow fence or in a topographic catchment is such that the ultimate drift depth is approached more rapidly than is the ultimate drift length (Fig. 1). The apparent equilibrium drift should exhibit a smooth profile, without abrupt slope changes indicating an obvious snow transport deficiency. But it deserves emphasizing that a smooth snow profile is not in itself sufficient evidence that a terrain feature has filled to capacity. Although the true equilibrium profile must by definition be independent of snow transport, the apparent equilibrium slope need not be.

Factors affecting deposition.--An intuition for the relationship between terrain and snow deposition can be developed by viewing the problem in terms of the surface wind shear stress. For laminar flow, shear stress is defined as the product of the fluid viscosity and the vertical velocity gradient. Snow transport is associated with fully turbulent flow, however, for which an analogous shear stress may be approximated as the product of eddy viscosity (a manifestation of the turbulent momentum transport across the flow) and the gradient of the temporal mean velocity.

The stability of a snow surface depends upon the surface wind shear in relation to the "tractive force" or critical shear (τ_c) required to initiate movement of surface particles. The critical shear stress depends upon the size, shape, and density of the snow particles, as well as the intergranular bonding in the surface layer.

Any factor that changes the velocity gradient will affect the surface shear stress (τ_o); thus, in an area of flow divergence (such as on the lee side of a hill), τ_o will decrease and if it becomes less than τ_c, deposition will result. It can also be reasoned that the presence of transported snow particles in the air layer near the snow surface will tend to reduce the velocity gradient and decrease τ_o compared to that prevailing in the absence of transport (Odar, 1965). Although this hypothesis remains to be substantiated (Budd, Dingle, and Radok, 1966), it could explain why snow accumulations in road cuts protected by large-capacity snow fences do not follow the same slope as deposits in similar but unfenced cuts--an effect analogous to that caused by the increased eroding power of sediment-free water released below a dam. Although surface shear stress is obviously a function of free-stream wind speed, implying that snow profiles will be steeper with strong winds than with light ones, this effect may be offset by the reduced surface shear stress as transport increases with wind speed.

The deposition slope will be such as to just compensate for the deposition rate; as the snow slope becomes less and less steep, the rate of deposition must decrease, explaining the rapidly diminishing depth growth as the snow profile builds in an accumulation zone (Fig. 1). The apparent equilibrium slope tends to reflect the maximum transport rate (or mass flux) which characterizes a site. This is because the above reasoning leads us to suspect that the flattest snow slopes are formed during such conditions, and wind-drifted snow can become quite resistant to subsequent erosion as a result of surface melting or the intergranular bonding of particles (sintering) that takes place despite subfreezing temperatures.

The approach described below assumes that the relationship between terrain and flow divergence allows snow profiles to be predicted on the basis of terrain slopes, at least regionally.

The Regression Model

Field measurements.--To determine what ground slope parameters might be used to predict the snow profile at apparent equilibrium, the terrain and snow slopes were determined for 17 different sites in Wyoming and Colorado 3/ (Table 1). These sites comprised about half of the data usable for this purpose that we had accumulated over the past 15 years. The remainder was reserved for an independent test of the final model. Sites were selected for this analysis so as to provide the widest range of upwind and downwind terrain; only those sites were used where snow accumulation appeared representative of equilibrium conditions. Elevations were between 2380 and 3350 m (7800 to 11,000 ft), winter precipitation ranged from 200 to 500 mm (8 to 20 inches), and fetch distances varied from 600 m (2000 ft) to more than 6000 m (20,000 ft).

3/ The author gratefully acknowledges the use of data from mountainous terrain in Colorado provided by Drs. M. Martinelli and R. A. Schmidt of the Alpine Snow and Avalance Research Project of the Rocky Mountain Forest & Range Experiment Station at Fort Collins, Colorado.

The apparent equilibrium slope was taken to be that portion of the drift profile having a smooth uniform slope, usually beginning near the upwind end of the accumulation and extending to the beginning of the concavity where the profile was influenced by the ground's proximity at the foot of the catchment. In the case of very large traps which were not completely filled, the snow slope selected for analysis was terminated about 20 m (60 ft) upwind of the cornice. The length of the slope segment selected under these criteria varied from 12 m (40 ft) in the case of the smallest traps, to 69 m (225 ft) for the largest catchment.

Terrain profiles were measured during the summer by differential levelling, with the transects oriented parallel to the prevailing wind direction as observed at the time of snow measurement. Snow depths were measured near the time of peak accumulation by probing the shallow drifts, and by rod and level surveys where drifts were too deep to probe.

Analysis.--Multiple linear regression was used to determine the combination of approach and exhaust slopes having the best predictive value for the snow slopes, as indicated by the smallest residual variance plus other considerations as noted later. All distances used in the analyses (Table 1) are in relation to the upwind limit of the snow accumulation, regardless of the location of that part of the snow deposition used for the apparent equilibrium slope.

In considering the possibility of using terrain slopes to estimate the slope of uniform shear stress, the need for specifying some maximum limit for the exhaust slopes becomes immediately apparent since, simplistically, the wind cannot "see" below the separation streamline. The best value for this exhaust slope limit was determined as part of the regression analysis.

Results.--A number of different slope combinations were found to have about equal predictive capability, which is hardly surprising since the various terrain slope variables are correlated with one another. The following regression was selected as the final predictor on the basis of its small residual variance (m.s. regr. = 69.74; m.s. resid. = 3.40; $R^2 = 0.87$) and because the weighting coefficients were intuitively logical, their sum was equal to 1.00, and the regression constant (A_o) was approximately zero:

$$Y = 0.25X_1 + 0.55X_2 + 0.15X_3 + 0.05X_4, \quad \text{if measured } X_2, X_3, X_4 < -20, \text{ set } X_2, X_3, X_4 = -20 \tag{1}$$

where Y is the snow slope (%) over the main portion of the drift, X_1 is the average ground slope (%) over a distance of 45 m (150 ft) upwind of the catchment, and X_2, X_3, and X_4 are the ground slopes (%) over distances of 0-15 m (0-50 ft), 15-30 m (50-100 ft), and 30-45 m (100-150 ft) downwind of the trap lip. Slopes upward in the direction of the wind are taken as positive, and downward slopes as negative.

Dynamic extension.--For many applications, the utility of a method for predicting snow drifts would be enhanced if all portions of the profile, including the concave tail slope, could be predicted. If Eq. (1) is generally applicable to any trap, regardless of its size, then it should also predict the snow slope at any point on the drift's profile. This possibility arises from the tendency, alluded to previously, for the upwind part of the drift to approach equilibrium even while the downwind portion remains to be filled in, so that each increment of growth takes place as though the snow profile up to the cornice defined in itself a topographic trap. With this reasoning, Eq. (1) is also assumed to estimate the slope of successive increments of the profile (arbitrarily taken as 10 ft or 3.0 m) allowing a drift to be constructed in segments by beginning calculations at the upwind end of the trap and continuing to intersection with the ground. In these calculations, X_2 is taken as the slope from the snow surface to the ground at a horizontal distance of 15 m (50 ft). Using the case in Figure 2 as an example, the slope (Y) predicted for the next 3.0 m segment beyond point A would be calculated as

$$Y = 0.25\ (-8) + 0.55\ (-20) + 0.15\ (+2) + 0.05\ (-3) = -12.8\%$$

This dynamic application of the prediction equation has been found to provide close agreement with whole measured profiles for all of our data from the plains and mountains of Wyoming and Colorado. Figures 3-5 compare predicted and measured values for sites selected

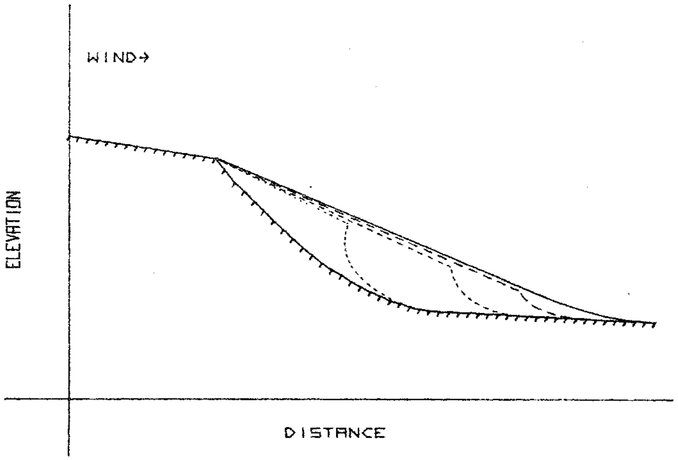

Figure 1. Idealized stages in the growth of a snowdrift.

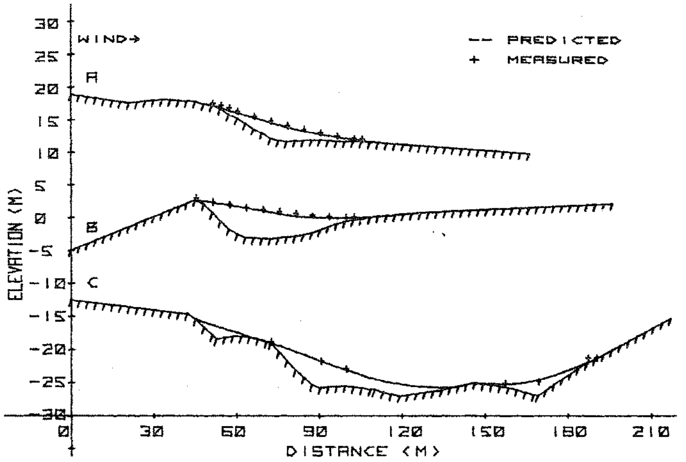

Figure 3. Snow profile predicted from Eq. (1) compared with measured values at three sites. (A) Lee side of fill at milepost 252.5, I-80, Wyoming; (B) Straight Creek Pass, Colorado; (C) Milepost 271.4, I-80, Wyoming. (B) and (C) not used in regression analyses.

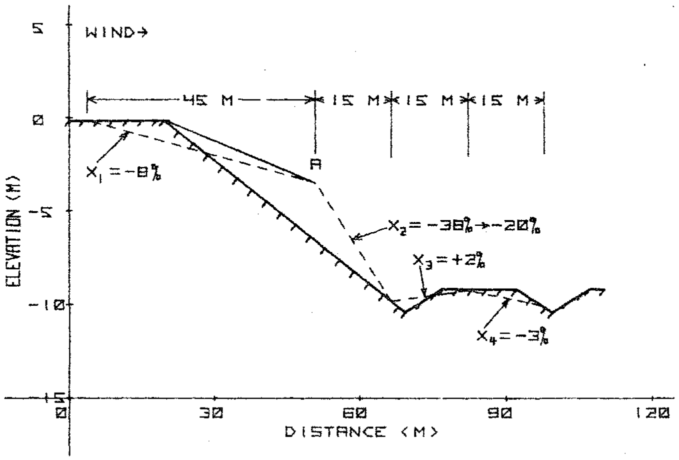

Figure 2. Example demonstrating the terrain slopes used in Eq. (1) to calculate slope of the next increment of snow profile beyond point A. Note vertical and horizontal scales not equal.

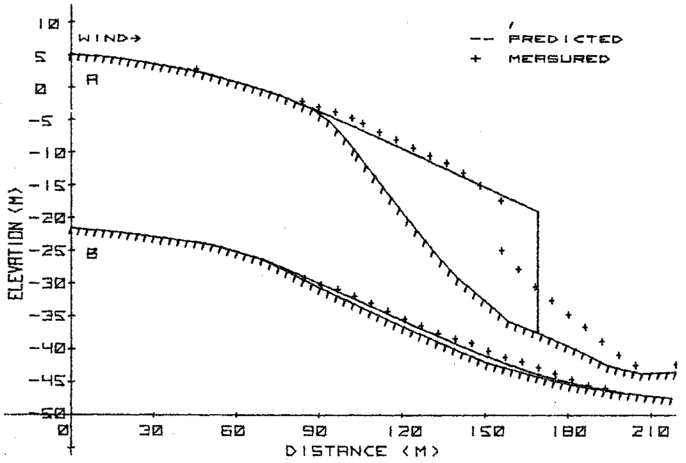

Figure 4. Snow profiles predicted from Eq. (1) compared with measured values at two sites. (A) Middlewood Hill, Wyoming (profile truncated where predicted storage volume equals estimated snow transport); (B) hill west of milepost 276, I-80, Wyoming (not used in regression analyses).

to represent the entire range of our data. Those sites not used in the regression analysis are so identified in the figure titles.

One interesting verification of the model is to be found in the case of the "upslope" drift, which forms in response to a divergence of flow as it approaches the windward side of an abrupt hill or embankment (Fig. 3,c). Although no upslope case was used in the regression analyses, the dynamic application of Eq. (1) can be seen to give reasonable agreement with observed upslope profiles.

Iterative analysis.--An interesting question is what happens when the model is run several times in succession, using the previous snow surface as the terrain. An example of such an experiment (Fig. 6) shows that an iterative application causes successively thinner depths to be added to the previously predicted profile. This is consistent with our earlier discussion which pointed out the possibility of an equilibrium slope that was approached only as a limit in the presence of unlimited snow transport. The incrementation predicted here may very well take place as the amount of blowing snow increases to levels well in excess of those typical of the climate where our measurements have been made.

The possibility of using this iterative analysis to adjust the model for other geographic areas is intriguing, should this seem necessary.

Range of applicability.--Equation (1) must be considered appropriate only for the conditions of our study sites, and should not be extrapolated without testing. Most of our profile observations have been made in gentle to moderately rolling terrain. The greater turbulence expected in rugged mountainous country could cause slopes steeper than those predicted by Eq. (1) although our data do not show any such tendency.

Approach slopes encountered in the model's development and testing range from -20 to +30% , and exhaust slopes from -60 to +40%. This range is probably adequate for most practical purposes. Because the trapping efficiency of a catchment declines rapidly for steeper (upward) approach slopes (presumably due to particle trajectories) the equilibrium slope for these cases has little meaning because the bulk of the deposition is rather uniformly distributed over a longwind distance in response to the gradual falling out of lofted particles.

It is hoped that other investigators will extend the testing of this approach over a wider range of topography and climate.

Comparison with Finney's results.--The prediction technique developed here can be further evaluated by briefly comparing results with those from Finney's (1939) wind tunnel experiments which employed flake mica and balsa dust. For vertical embankments (downwind-facing steps), Finney found drift length to equal 6.5 times the embankment height, over heights of 2 to 10 ft (0.61 to 3.05 m). The dynamic application of Eq. (1) shows drift length to vary exponentially with height (drift length equalling 52H for a 1.22 m embankment), but to converge on a value close to 6.5H for embankments of great height ($\geq$ 60 m) (Fig. 7). One explanation for this disparity might be found in the likelihood that the boundary layer was poorly developed in Finney's tunnel, so that his geometrically scaled embankment heights (1 inch = 2 ft) were actually very great in relation to the boundary layer thickness.

Another result of Finney's that deserves comparison is his finding that there is no accumulation on an embankment downslope of 1:6 (about -17%). Dynamic application of Eq. (1) to an embankment height of 15 m (Fig. 8) also predicts very shallow drifts on downslopes of 17% or less. For abrupt slopes, our model yields drifts that are noticeably less "whale-backed" than those described by Finney.

Applications

Highway design.--Although the length of this paper does not permit developing engineering criteria, the application of this technique to highway design is obvious and straightforward. The Wyoming Highway Department is presently in process of making this snow accumulation analysis part of their earthwork computer program; cross-sections exhibiting accumulation on the shoulder of the earth grade are automatically flagged so that the section can be redesigned to eliminate drift encroachment. Figure 9 gives an example of how

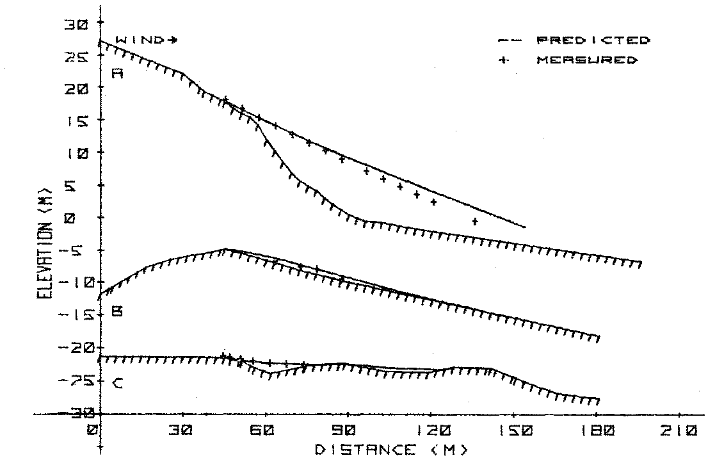

Figure 5. Snow profiles predicted from Eq. (1) compared with measured values at three sites. (A) Mount Evans, Colorado; (B) ridge west of milepost 284, I-80, Wyoming (not used in regression analyses); (C) milepost 288.8, I-80, Wyoming.

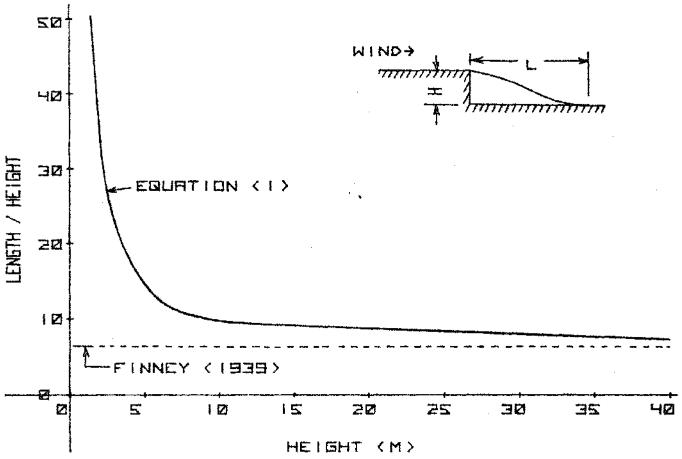

Figure 7. Relationship between height (H) of vertical embankment and drift length (L/H), comparing results from Eq. (1) with those of Finney (1939).

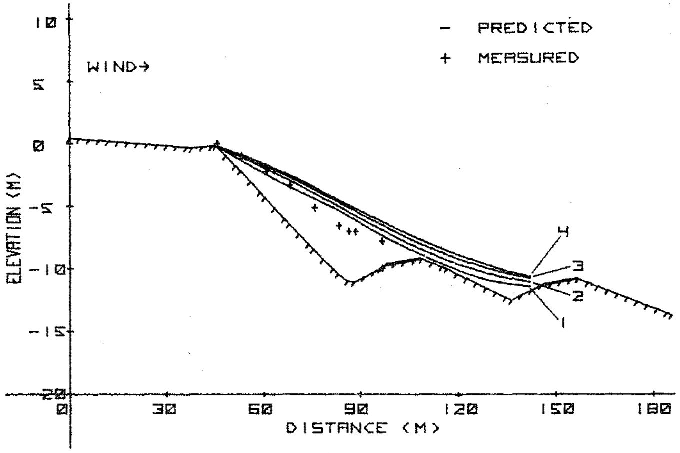

Figure 6. Iterative application of Eq. (1), using the previous snow profile (1,2,3) as the terrain for successive runs (2,3,4). Actual terrain case at milepost 269.5, I-80, Wyoming.

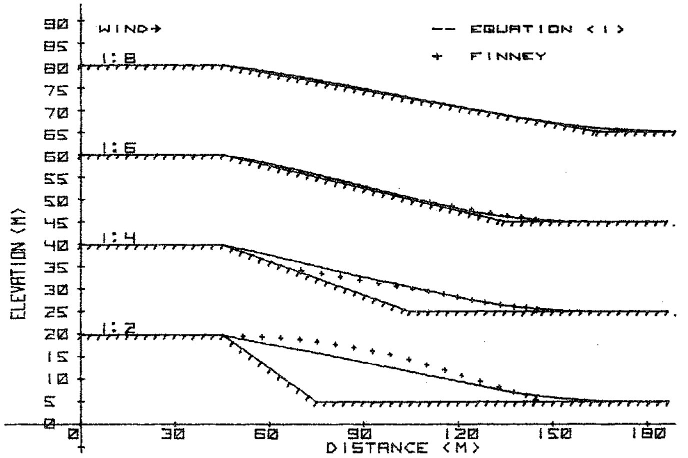

Figure 8. Effect of slope on snow profile behind a 15-m (50-ft) embankment, comparing results from Eq. (1) with those of Finney (1939).

a cut section was redesigned to eliminate drift accumulation without changing the grade of the highway, by rounding off the upwind cut shoulder and widening the ditch on the downwind side. This example demonstrates how downwind terrain can affect snow accumulations--a factor not considered in previously published criteria for highway design.

Shaping terrain for rehabilitating mined areas.--One objective of reshaping mined terrain might well be to maximize the on-site retention of snow to conserve moisture necessary for revegetation. The prediction technique described here could be used to determine an amplitude and wavelength for rolling terrain that would result in the most uniform snow cover, and having adequate storage for the winter's snowfall (Fig. 10). Alternative configurations could be developed that would reduce or even eliminate the bare areas on the tops and windward side slopes.

Calculator/Plotter Program

To facilitate application of this method to problems like those defined above, a program listing for the Hewlett-Packard [4] 9820A calculator and 9826A X-Y plotter are given below. Hardware requirements include the Mathematics and Peripheral control "ROM's" and the 429 register option. The program may be run without the plotter and associated ROM if only a tape output is required.

Features of this program include: storage capacity for a maximum of 47 stations with no limit to the length of the cross-section, an option for terminating the drift profile at the point where drift volume equals the annual snow transport, a return loop allowing sequential trials for purposes of highway redesign, and a printer output consisting of station, snow elevation, snow depth, and accumulated cross-sectional area of the drift. The calculation of snow slope proceeds at 10-ft (3.05 m) distance increments, beginning 150 ft (45.7 m) downwind of the first (upwind-most) station. All units are in feet to more readily accomodate existing engineering data. A detailed explanation of the program is available upon request.

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[4] The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

Procedure.--

A. Enter maximum transport expected at site ($ft^3 H_2O/ft$); if unknown or truncation of the drift is not desired, push "RUN PROGRAM."

B. Enter 1 if plot is desired, 0 if not; "RUN PROGRAM."

C. If plot, enter transect length (ft) for "X MAX," maximum elevation (even 10 ft) for "Y MAX," minimum elevation (even 10 ft) for "Y MIN."

D. Enter first (upwind) station (ft), elevation (ft) of first station, etc.

E. After last station has been entered, push "RUN PROGRAM."

F. Ground profile will be plotted at this point, followed by snow profile.

G. If new section is to be analyzed on same plot, enter 1, then "RUN PROGRAM." Resume at D.

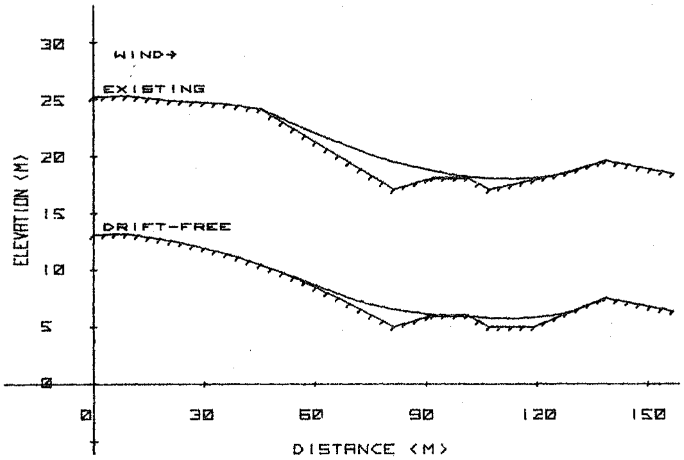

Figure 9. Predicted snow accumulation before and after redesign. East-bound lane off-ramp, Walcott Junction, I-80 (Wyoming).

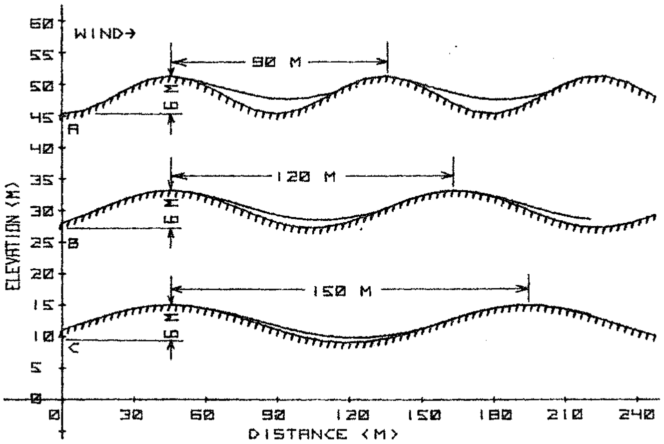

Figure 10. Example of how Eq. (1) might be used to develop criteria for reshaping strip-mined terrain to maximize on-site retention of snowfall and regulate its areal distribution. Snow storage capacity in these examples would be adequate for winter precipitation amounts of (A) 430, (B) 240, (C) 150 mm (17, 9, and 6 inches). A simple sinusoidal undulation is given only as an example--asymmetric or complex configurations could be developed so as to minimize or eliminate bare areas on windward slopes and ridgetops.

```
0:
PRT "   USGS DRI
FT","    PROFILE
";SPC 1⊢
1:
SPC 2;0→A→R4;
CFG 0;CFG 2;SFG
3;CFG 5;CFG 13⊢
2:
ENT "MAX TRANSPO
RT?",R4;IF FLG 1
3;CFG 13;CFG 3⊢
3:
ENT "ENT 1 FOR P
LOT",A;IF A=1;
SFG 0;GTO "PLOT"
⊢
4:
"DATA";0→A;PRT "
STATION","ELEV";
FXD 1;-1→B⊢
5:
ENT "STN.?",R(11
+A)→X;IF FLG 13;
A→R3;0→A;JMP 4⊢
6:
ENT "ELEV.?",R(6
0+A)→Y;PRT X,Y;A
+1→A;SPC 1⊢
7:
IF A=47;ENT "NO
MORE DATA",Z;A→R
3;0→A;JMP 2⊢
8:
JMP -3⊢
9:
R(60+A)→R(11+R3+
A);JMP (A+1→A)=R
3⊢
10:
CFG 13;IF FLG 0;
B+1→B;PLT R(11+B
),R(11+R3+B);
JMP R(10+R3)≤R(1
1+B)⊢
11:
PEN ;-10→B⊢
12:
B+10→B;GSB "ELEV
"⊢
13:
Y→R(11+2R3+B/10)
;IF B≤140;JMP -1
⊢
14:
0→R(37+2R3)→R(38
+2R3);150→X→B;0→
A⊢
15:
SPC 2;PRT "STN."
,"SNOW ELEV","SN
OW DEPTH","CUM A
REA"⊢
16:
FXD 0;SPC 2;PRT
X;FXD 1;PRT R(26
+2R3),0,0⊢
17:
SPC 1;IF FLG 0;
PLT 150,R(26+2R3
)⊢
18:
GTO "SNOW"⊢
19:
"PLOT";ENT "X MA
X ?",R1,"YMAX ?"
,R5,"Y MIN ?",R6
⊢
20:
R1/20→R9;(R5-R6)
/10→R10⊢
21:
.0064R1→R0;.0064
(R5-R6)→R2;SCL 0
,R1+.5R0,R6-.5R2
,R5+.5R2⊢
22:
AXE 0,R6,(20)1.0
1,(10)1.01;1→B;
FXD 0⊢
23:
LTR 100B+R0,R6+1
,212;PLT 100B;
JMP (1+B→B)>R1/1
00⊢
24:
0→B⊢
25:
LTR 0+10,R5-B-R2
,211;PLT R5-B;
JMP (B+20→B)>R5-
R6⊢
26:
LTR 150,R5-10,22
1;PLT "WIND*";
GTO "DATA"⊢
27:
"ELEV";-1→A⊢
28:
A+1→A;JMP B≤R(11
+A)⊢
29:
IF B=R(11+A);R(1
1+R3+A)→Y;RET ⊢
30:
(B-R(10+A))/(R(1
1+A)-R(10+A))→C;
C(R(11+R3+A)-R(1
0+R3+A))+R(10+R3
+A)→Y;RET ⊢
31:
"SNOW";0→R2⊢
32:
R2+50→R2;X+R2→B;
GSB "ELEV"⊢
33:
Y→R(27+2R3+R2/50
);IF R2≤100;JMP
-1⊢
34:
(R(28+2R3)-R(26+
2R3))/50→R(32+2R
3)⊢
35:
-1→A⊢
36:
A+1→A;(R(29+2R3+
A)-R(28+2R3+A))/
50→R(33+2R3+A);
JMP A=1⊢
37:
-1→A⊢
38:
A+1→A;IF R(32+2R
3+A)≤-0.20;-0.20
→R(32+2R3+A)⊢
39:
IF A≤1;JMP -1⊢
40:
(R(26+2R3)-R(11+
2R3))/150→R(31+2
R3+Z)⊢
41:
.25RZ+.55R(Z+1)+
.15R(Z+2)+.05R(Z
+3)→R(35+2R3)⊢
42:
-1→A⊢
43:
A+1→A;R(12+2R3+A
)→R(11+2R3+A);
JMP A=14⊢
44:
R(26+2R3)+10R(35
+2R3)→R(26+2R3)⊢
45:
X+10→X→B;GSB "EL
EV"⊢
46:
Y→R(27+2R3);IF R
(26+2R3)≤Y;Y→R(2
6+2R3)⊢
47:
R(26+2R3)-R(27+2
R3)→R(36+2R3)⊢
48:
FXD 0;PRT X;FXD
1;PRT R(26+2R3),
R(36+2R3)⊢
49:
IF FLG 0=1;PLT X
,R(26+2R3)⊢
50:
5(R(36+2R3)+R(37
+2R3))+R(38+2R3)
→R(38+2R3)⊢
51:
FXD 0;PRT R(38+2
R3);SPC 1;R(36+2
R3)→R(37+2R3)⊢
52:
IF X+150>R(10+R3
);PRT "END/END/E
ND";PEN ;SPC 4;
GTO "OBS"⊢
53:
IF FLG 3;IF R4≤.
5R(38+2R3);PRT "
MAX ACCUM";SPC 4
;SFG 5⊢
54:
IF FLG 5;IF FLG
0;PLT X,R(27+2R3
);PEN ;GTO "OBS"
⊢
55:
IF FLG 5;GTO "OB
S"⊢
56:
GTO "SNOW"⊢
57:
"OBS";CFG 4;0→A;
ENT "1 FOR NEW S
ECT.",A;IF A=1;
SFG 4;CFG 13⊢
58:
IF FLG 4;SPC 1;
PRT "ALT. SECT."
;PEN ;GTO "DATA"
⊢
59:
END ⊢
R145
```

Figure 11. Program listing for Hewlett-Packard 9820A calculator and plotter.

Table 1.--Terrain and snow slopes (%) for sites used in regression analysis. All distances are measured from the upwind end of the snow drift. Negative slopes are downward in the direction of the wind.

	Approach slope			Exhaust slope					
	Distance upwind (m)			Distance downwind (m)				Snow profile	
Site number	0-15	15-30	30-45	0-15	15-30	30-45	45-60	Slope	Location (m)
1	-15.8	-10.0	-6.0	-49.0	-45.0	-33.0	-23.0	-15.0	5-75
2	-17.0	-11.4	-9.0	-27.4	-53.7	-52.6	-46.0	-20.0	10-55
3	-7.0	-3.8	-2.8	-11.6	-38.0	-23.8	-23.0	-11.6	45-115
4	-28.0	-17.0	-17.0	-38.0	-48.0	-28.0	-10.0	-20.0	5-60
5	+0.5	0.0	0.0	-14.0	-2.0	0.0	+10.0	-6.7	2-12
6	+9.0	+6.0	0.0	-14.0	-17.0	+1.0	+2.0	-7.0	10-35
7	-1.0	-1.0	-1.0	-20.4	-2.0	0.0	0.0	-12.0	0-10
8	-2.5	-2.5	-3.0	-32.0	+2.8	+3.4	-6.0	-9.0	0-30
9	0.0	-2.0	-2.0	-27.0	-27.4	-16.0	+10.0	-18.0	5-35
10	-4.8	-3.0	-3.0	-34.0	-3.4	-2.4	0.0	-15.5	5-20
11	-1.0	-1.0	-1.0	-14.0	+5.4	+2.0	-7.0	-7.0	0-15
12	-1.9	-1.9	-1.9	-25.5	-26.0	-24.0	+8.0	-16.0	5-40
13	-5.6	+4.0	-6.0	-24.0	-12.6	-2.0	-2.0	-13.0	5-30
14	-9.2	0.0	+3.2	-24.0	-15.0	-13.0	+2.5	-14.0	10-30
15	+1.2	+1.2	+1.2	-19.0	-1.0	0.0	0.0	-11.0	0-12
16	-1.5	-1.5	-1.5	-7.4	-10.4	+13.4	-2.0	-6.5	0-15
17	+3.0	+1.0	0.0	-26.0	+2.0	-3.6	-1.0	-11.3	0-25

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