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Avalanche Final

NORMAN A. WILSON
SNOW CONSULTANT SERVICES • P.O. BOX 8010 • TRUCKEE, CA 95737 • (916) 587-1593

AVALANCHE CONTROL
SITE PLANNING
AVALANCHE ZONING
OPERATIONS PLANNING, TRAINING
EXPLOSIVES TRAINING
TECHNICAL WITNESS

Snowcreek

Avalanche Hazard Studies and Avalanche Control Plan 1985

Prepared for O'Connor Design Group, Inc.
Mammoth Lakes California

O'CONNOR DESIGN GROUP, INC.
P. O. Box 1717
MAMMOTH LAKES, CALIFORNIA 93546

(619) 934-4192

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NORMAN A. WILSON
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Addendum to Avalanche Hazard Studies
Sherwin Ski Area (Snowcreek)
March 1986

During the week of 16-22 February 1986 a series of intense rain and snow storms spawned a cycle of very large snow avalanches throughout the Sierra Nevada.

At Sherwin Ski Area the most notable avalanches were at North Face, where two adjacent avalanche paths released, apparently simultaneously, on the 18th and ran from ridgetop to valley floor, a vertical relief of some 2200', destroying many hundreds of mature conifers enroute. The westerly of the two slidepaths was significantly enlarged by the tree removal; in the easterly path, a giant swath, some 500-700' wide, was cleared through what had been mature forest. These avalanches ran to within some 600' of predicted maximum runout distance. Debris was distributed across some 50-60% of the width of the predicted runout zone.

Other notable avalanches were: (1) at Moto Cross Base area, where avalanches ran to approximately the predicted runout distance, but exceeded the predicted width in the starting zones; (2) at lower Horn (Division) Ridge, where avalanches ran into Solitude Flat, possibly slightly in excess of predicted limits, but not as far as proposed facilities sites; (3) at Canyon Lodge area, where earth, snow and rock avalanches from Horn Ridge affirmed predicted widths of avalanches and attained some 80% of predicted lengths; (4) at Solitude West Bowl, where a massive avalanche covered an estimated 90% of predicted limits; (5) below Sherwin Station, where avalanche tracks were significantly widened by destruction of large amounts of timber; and (6) at the Three Fingers (Sisters)-Moraines areas, where nearly 100% of the predicted avalanche zone was affected by avalanching.

These avalanches generally affirmed the conclusions of the avalanche studies previously described herein, i.e.: a clear requirement for careful selection of facilities sites, structural protection systems at selected sites, and a carefully conceived and executed avalanche control plan. No significant changes in the current development plan are indicated; but the avalanches do emphasize:

1. The need for very careful positioning of the lower terminal of Fingers Base Station, along with special design features noted in the earlier text. Regarding the risk factor at this terminal: the loss of the great amount of timber that occurred on 18 February constitutes removal of a significant barrier that provided a large measure of security for the terminal site. Large avalanches in this path can now be expected to run more frequently and to reach maximum runout distance more frequently. The terrain features will still tend to divert flowing snow away from the terminal site; but if future avalanches or any other cause further decimates the remaining timber above and to the west and south of the terminal site, the avalanche threat will increase significantly. With this in mind, it appears appropriate that Fingers Base Station be installed not less than 500' from the new avalanche trimline.

When the ski area commences operations, the operations plan will include regular and intensive active avalanche control along with regular and intensive compaction of these slopes. These measures will reduce the incidence of large avalanches on these slopes, but cannot eliminate the possibility of their occurrence.

2. Careful positioning of lift terminals at Moto Cross area, along with an earth barrier system as recommended in my letter of 28 August 1985.

3. The need to consider unstable rock where it exists. The avalanches at Canyon Lodge area clearly illustrate this need.

4. A clear need to carefully position all lift line towers, to minimise their number to the extent practical, and to provide structural protection where needed.

5. The occurrences of 2-86 also suggest reconsideration of location of upper terminal of lift #5. I recommend this terminal be placed on high ground -- on the crest of a subdued ridge some 600' down-line from the current proposed terminal site, at circa elevation 8450'.

In recognition of the difficulties of precise positioning on available maps, I recommend that final siting of all facilities be accomplished on the ground at the individual sites.

Respectfully submitted,

Norman A Wilson

NORMAN A. WILSON
SNOW CONSULTANT SERVICES • P.O. BOX 8010 • TRUCKEE, CA 95737 • (916) 587-1593

AVALANCHE CONTROL
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Snowcreek

Avalanche Hazard Studies
and
Avalanche Control Plan

1985

This report completes work described in Standard Contract Agreement initiated 21 April 1985 between O'Connor Design Group, Inc., and the writer.

Contained herewith are:

I Narrative description of the Avalanche Control Plan
- Objectives
- Area description
- Control methods recommended
  - Applicability
  - Limitations
- Preliminary Avalanche Control Plans
- Estimated manpower, equipment, facilities, explosives, and other special avalancne control materials requirements

II Avalanche Zone Map

III Avalanche Plan Maps, each Alternative

Respectfully submitted,

Norman A Wilson

I The Avalanche Control Plan

This primary plan provides for necessary control measures discerned as a result of development of the Avalanche Zone Map (AZM). The AZM was developed during the spring and summer months of 1985 by various studies: 1. Aerial reconnaiscance and oblique aerial photography; 2. On-snow and on-the-ground study of the terrain, vegetation, avalanche damage patterns and debris distribution and snow distribution patterns; 3. Study of winter photos taken in prior winters; 4. Aerial photo interpretation (stereo pairs); 5. Estimation of snowfall and other weather events at the area based on the above studies along with extrapolation from known events and observations at Mammoth Ski Area and at Mammoth Lakes Ranger Station and on limited data available from the Resources Agency of the State of California.

The primary plan is intended to serve as an initial guideline that will be refined and upgraded with time and experience in the actual operation.

The objectives of the plan are to provide maximum operation and utilization of the area facilities and ski terrain along with maintenance of as high a degree of safety as can be attained within the limits of the avalanche art. This degree of safety cannot be considered absolute at all times in the mountains during the snow season; but compares favorably with risks commonly accepted on a daily basis in various other aspects of daily life.

Snowcreek Ski Area contains numerous large and small avalanche paths and avalanche zones where skiers may be buried by large or small avalanches. Major avalanche paths that carry great destructive potential are scattered throughout the area; most notably, these are: North Face avalanches that fall from North Ridge to Hidden Lake Meadow; the Three Sisters-Moraines slopes; Division Ridge -- both the northwest and the southeast sides; Solitude east and west bowls; and slopes that fall from Pyramid North Face into Solitude Canyon.

Lift-served minimum and medium hazard zones include:

<u>Minimum Hazard</u>: slopes that require little or no control measures or that can be controlled quickly and easily

slope (s)	served by lift
the Glades and adjacent lower slopes	1, 2, 4a, 6, 12
Moto-Cross slope, Division North Face	2a
Solitude Flat, beginner & intermediate slopes	7
slopes below Canyon Lodge	7, 2a, 2b

<u>Medium Hazard</u>: slopes that require a greater degree of control and effort to control, but that are specially favored by timber cover or terrain configurations and/or by location

slope (s)	served by lift
Lower Judge's Bench slopes (east and northwest slopes)	4a
Sherwin Bowl (above Judge's Bench)	4b, 5

In further refinement and upgrading of this preliminary avalanche control plan, it is important to note that the AZM is a broad mapping of the study area; therefore, small slide zones capable of release of small avalanches that may bury skiers may exist within areas not shown within the avalanche zones. Such small avalanche sites must be searched out and provided for during final development of the avalanche control plan.

Recommended Control Methods

Methods available include:

1. Planning - The AZM allows planners to place facilities in safe zones where such zones are appropriately located that will allow creation of a logical and practical ski area. Thoughtful use of the AZM allows planners to design lift systems that will make minimum hazard ski slopes available; and that will enhance an efficient active avalanche control program, while minimizing the need for, and maximizing the efficiency of, structural protection of facilities. In development of the Snowcreek lift system, primary emphasis must be placed on achievement of avalanche-free lift terminals and other public facilities sites, and on development of lift lines where a minimum of structural protection for line towers would be required.

In no instance should active avalanche control methods be relied on to provide protection for fixed facilities.

2. Structural Defenses - It is important to note that each structural defense system, whether for protection of a lift line tower or of a lift terminal or any other facility, must be designed and tailored for each individual site. In this report, certain structural types are recommended for two specific sites: a. lower terminal of lift #4a; and b. Canyon Lodge lift terminals/public facility building.

Where line tower protection is required, the danger areas are indicated on the AZM; in these areas the protective design must be determined after the precise tower sites are determined by the lift designer. A general recommendation for these areas is: Design the lifts so that the smallest practicable number of towers will lie within the avalanche zones. Examples of protective structures are illustrated in the attached Planning Guide.

a. Structural defense for lower terminal of lift #4a:
This system will protect against the remote possibility of lateral spread of avalanches that fall from North Ridge, and which might overrun the presumed lateral limits of avalanches here.
An earthen guidewall, consisting of an earth berm, 200' in length, 19' in height (assume a 10' snowpack, with 9' clear height of berm above the snowpack). Earth fill in the berm should be installed at angle of repose on the northwest side of the berm, may be at a lower angle on the southeast side if desired. Snowfall should be allowed to accumulate on top of the berm during the winter to increase the effective height of the berm as the winter progresses.

b. Structural defense for Canyon Ldg facilities:
This system will protect against avalanches from Division Ridge.
A concrete shell/earthfill deflection barrier, designed to deflect avalanches to the west and away from the western-most end of the facility. The concrete shell would serve to retain the earth fill, which would provide the mass required to resist expected snow pressures. The shell could further serve as support for a sundeck or other portion of the facility. The barrier should intercept the flowing snow at as low an angle as is practicable, but at an angle not greater than 20°. The shell must be vertical. Earth fill retained within the shell must lie at a slope not greater than angle of repose. Height of the barrier must be not less than 33' above level ground west of the facility (assume 20' snowpack, with 13' clear height of barrier above the maximum snowpack).

The two defense structures described in general terms above must receive final design at-site, concurrent with final design and precise location of the protected facilities. The reader should note that neither facility will actually lie within a discerned avalanche path; but because they will be installed immediately alongside discerned avalanche runout zones, the defense structures are recommended to provide for the remote possibility of overrun of the assumed avalanche limits. Assuming no unprecedented or cataclysmic natural events, the recommended structures can be considered reliable.

In design of the lift system, avoidance of those portions of very steep, untimbered avalanche paths, where very high-velocity avalanches are expected, will allow design of reliable defenses for the line towers.

3. Active Avalanche Control Methods

These methods include standard methods widely employed in the ski industry:

a. Stabilization by compaction
(skier traffic)
b. Control with explosives
c. Temporary and permanent closures and warnings

Principles of these techniques are described in depth in USDA #489 Avalanche Handbook. The Handbook should be considered a guideline to be followed during development of specific on-site criteria and procedures that will render the avalanche control program for Snowcreek's own physical character and weather environment as efficient and effective as possible.

At Snowcreek, special consideration must be given th following:

a. The ski development lies very close to heavily used public roads and a population center. Further, the area has historically been used by ski tourers, ski mountaineers, and cross country skiers.

b. The Old Mammoth-Mammoth Lakes Basin road (currently not plowed in winter) and the terrain through which the road passes, appears to be a logical winter route for the groups mentioned in a., above. Avalanches fall into portions of this logical route from steep slopes immediately outside of the ski development boundary. Downhill skiers will have easy access to these out-of-area avalanche slopes. Avalanche control work just inside the boundary could conceivably trigger avalanche releases on the out-of-area slopes.

a., and b., above suggest that a procedure and warning system be developed to prevent accidents that may occur if the hazard zone were entered at the wrong time. Snowcreek management may wish to control the out-of-area slopes mentioned as a practical matter; but this action may entail assumption of undesirable liabilities, should thus be considered carefully. In any case, the area boundaries must be carefully and appropriately marked at logical points, along with appropriate warning signs where persons may enter the hazard zones within and immediately adjacent to the boundaries.

Preliminary Avalanche Control Plan

Alternatives II, III, V, or VI

Note: This preliminary plan is an initial plan, intended to be refined and upgraded with experience in performance of the plan.

Plan A - ridgetop lifts operable, moderate use of avalaunchers

/Step 1 team 1 ascend lift 1 to avalauncher position, fire on all targets
teams 2 & 3 ascend lifts 2 (or 2a & b) & 8 to ridge,
then control routes 1, 2, & mid 3,
team 4 fire Moto Cross launcher, while
teams 5, 6 ascend lift 2 or 2a, then
team 5 descend to Solitude Flat launcher & fires same, while
team 6 descends to and controls route 9, while
team 4 ascend lifts to Canyon Lodge & fires launcher on all
except Solitude West Bowl targets

opens lifts 1, 2, 2a, 2b, 4b, 5, 6, 7, 8, 12

Step 2 team 1 ascend lifts 4a & 5, control route lower 3,
teams 4, 5, 6 ascend lifts 3 & 8, control routes
5, 6, 7, & upper 3

Step 3 all teams perform follow-up work as required -- ski checking,
additional handcharges, set appropriate signs, control
route 10 if required.

Step 4 one team ascend lift 3, control route 8 & 11
one team ascend lifts 4a & 5, or 10, control routes 4, 4a

opens balance of lifts

Plan C Assumes several teams overnight at facility on ridge (recommend at Solitude Ldg) -- If weather allows, these teams would commence handcharging of critical high routes to speed operations and render them more efficient.

Critical high routes: 3, 5, 6, 7, 1

Routes not controlled by the overnighting teams would be controlled in order as in Plan A, also, avalaunchers would be fired as needed in Plan A. Firing of the avalaunchers on any of the target zones may not be required during a given control mission, depending on results achieved by control of routes 3, 5, 6, 7, 10.

Various permutations of the above plans are possible. For example: If an overnight facility is established at Solitude Ldg, five teams could commence operations at that point, negating the need for a significant amount of avalauncher use, and speeding the various phases of the process.

Avalanche Control Operations - the various Alternatives

Alternatives II, III, V, & VI each make the entire ski terrain available to skiers; therefore, the objectives and requirements are essentially the same for each Alternative.

The intent of Alternative I is to make the area north of Solitude Lodge and Division Ridge available to skiers, plus occasional availability of the area south of Solitude Lodge and Division Ridge. Regular explosive control will be conducted north of Solitude Lodge and Division Ridge, with the areas to the south temporarily or permanently closed to skiers.

The intent of Alternative IV is to make the area south of Solitude Lodge and Division Ridge available to skiers, plus occasional availability of the area north of Solitude Lodge and Division Ridge. Regular explosive control will be conducted south of Solitude Lodge and Division Ridge, with the areas to the north temporarily or permanently closed to skiers.

In both Alternatives I and IV, the option exists to open the additional terrain to the north or south of the closure lines mentioned above after execution of control measures in the outer areas. Intensive and careful control measures will be necessary to open these outer areas; because the outer areas will receive relatively little ski compaction; and thus the snow in these areas will be more prone to the weakening effects of the Temperature-Gradient metamorphic process. Higher incidences of Temperature-gradient metamorphism are seen during the winter months where the snow lies undisturbed and uncompacted for long periods.

Preliminary Avalanche Control Plan

Alternative I

Plan A - ridgetop lifts operable

opens all lifts

Step 1 team 1 ascend lift 1, fire avalauncher on all targets, teams 2, 3, & 4 ascend lift 4a, fire avalauncher on all targets, control routes mid 3, lower 3, 1, 2, & upper part of 4, team 1 follows up lift 4a, controls balance of routes 4 & 4a, all teams perform follow-up work, set signs closing Solitude Canyon, the upper ridge, other areas as appropriate.

opens outer areas

Step 2 if Solitude Canyon will be opened: two teams ascend lift 4b, control routes 5, 6, 9, and set signs closing uncontrolled avalanche zones.

Plan B - ridgetop lifts inoperable

opens lifts 1, 4a

Step 1 team 1 ascend lift 1, fire avalauncher on all targets, teams 2, 3, & 4 ascend lift 4a, fire avalauncher on all targets, control routes lower 3, 10, and set signs closing uncontrolled avalanche zones.

NOTE: An essential element of the control plan for this Alternative is an overnight facility at Sherwin Station (Judge's Bench). This facility will be required during major storm/high hazard periods when approaches to lower terminal of lift 4a may be dangerous prior to control of North Face avalanches.

Preliminary Avalanche Control Plan

Alternative IV

Plan A - ridgetop lift operable

Step 1 team 1 fire Moto Cross avalauncher,
teams 2, 3, & 4 ascend to Canyon Lodge,
team 2 fires Canyon Lodge avalauncher,
team 3 descend to Solitude Flat avalauncher, fire same,
team 4 descend to and control route 9,

opens all lifts

Step 2 all teams ascend to Pyramid Lodge,
control routes 11, upper 3, 5, 7, & 6,
all teams ascend to Pyramid Lodge, controlroutes 8,
perform follow-up work above upper terminal lift 6, and
set signs closing areas north of controlled areas, and
other uncontrolled areas.

opens outer areas

Step 3 If areas to north will be opened, all teams proceed to
Pyramid Lodge, perform control on balance of routes.

Plan B - ridgetop lift inoperable

Step 1 team 1 fire Moto Cross avalauncher
teams 2, 3, & 4 ascend to Canyon Lodge,
team 2 fires Canyon Lodge avalauncher,
team 3 descend to Solitude Flat avalauncher, fire same,
team 4 descend to and control route 9,

opens lifts 2 & 11

Step 2 teams 1 & 2 ascend lift 11, control routes 7 & 8,
all teams perform follow-up work, set signs closing
uncontrolled areas.

Manpower and Equipment, and Facilities Requirements

Avalanche control personnel usually consist of one Director-Avalanche Technician assisted by Professional Ski Patrol personnel, who normally receive overtime pay for that portion of the control work performed during overtime hours.

Estimated overtime requirements (averages):

- 4 hours per man per maximum control day - estimate 45 days per season
- 2 hours per man per minimum control day - estimate 15 days per season

In addition to the above personnel, a number of lift operations personnel and oversnow vehicle operators would be required on the estimated time basis indicated above.

Estimated personnel requirements for each Alternative are shown in Table I.

Facilities and major equipment requirements will vary in number with the various Alternatives; but each will include, as major features:

- explosives and explosives magazines, explosives materials, and explosives preparation facility
- on-the mountain overnight facility for control crews
- avalaunchers and fixed firing positions, projectiles, and propellant
- avalanche rescue caches and storage space
- avalanche rescue beacons for control and support personnel
- radio communications system
- ski area boundary signs
- special avalanche warning and closure signs
- rope for use at selected segments of sign lines
- miscellaneous small tools and equipment
- central office space and storage facility
- snow study plot and related weather observation instruments

Estimated requirements of the above are shown in Table I.

Table I

requirement	Alternative I	II	III	IV	V	VI
control personnel	8	12	12	8	12	12
lift operators	3	7	7	3	7	7
vehicle operators	0	1	2	0	1	2
explosives charges (complete)	4125	9000	9000	4125	9000	9000
expl. prep. facility	1	1	1	1	1	1
overnight facility	1*	1**	1**	0	1**	1**
avalaunchers	2	5	5	3	5	5
firing positions	2	5	5	3	5	5
projectiles (complete w/propellant)	540	1500	1500	800	1500	1500
rescue caches	6	11	13	6	12	13
rescue beacons	15	20	20	15	20	20
radio system	1	1	1	1	1	1
base station	1	1	1	1	1	1
repeater	1	1	1	1	1	1
portables	12	20	20	12	20	20
boundary signs	150	150	150	150	150	150
avalanche signs	150	150	150	150	150	150
rope for sign lines	10M'	10M'	10M'	10M'	10M'	10M'
small tools, equipt.	✓	✓	✓	✓	✓	✓
office, storage	1	1	1	1	1	1
snow study, instrmts.	✓	✓	✓	✓	✓	✓
explosives magazines						
major	1	1	1	1	1	1
overnight	1	1	1	1	1	1

* at Sherwin Station
** at Solitude Lodge

Estimated costs, major equipment and facilities:

- explosive charges, complete w/cap, fuse, igniter	$ 4.25 each
- expl. prep. facility - (a simple, isolated, wooden structure)	1000.00
- overnight facility - (sleeping & cooking space within a lodge)	no est.
- avalaunchers	850.00 each
- firing positions - various types	3000.00 each
- avalauncher projectiles (complete w/propellant & explosive)	10.00 per rd.
- rescue caches (complete)	1500.00 each
- rescue beacons	160.00 each
- radio system	
base station	1500.00
repeater (installed)	4000.00
portables	950.00 each
- boundary signs	no est.
- avalanche signs	no est.
- rope for sign lines	3 - 5 cents per foot
- small tools, equipt.	2000.00
- office, storage space (within base lodge)	no est.
- snow study & weather instruments	6000.00
- explosives magazines	
major	4000.00
overnight	1500.00

Snowcreek

Addendum to Avalanche Hazard Studies and Control Plan

Special Comments re lift plan received 23 September 1985

Lifts 2a & 2b

2a -high spans, elaborate tower protection, and careful tower siting will be required to protect against flowing snow pressures and windblast -- detatchable chair factor is positive factor. Unstable ground is possibility.

2b -less exposure than 2a, but above logic applies to lower degree.

lift 2

crosses major avalanche zones above Solitude Flat -- windblast is a major problem here -- high spans, tower protection, and careful tower siting required.

lift 3

high spans and protection required as mentioned above, especially in the lower portion of the lift.

lift 6

this lift line crosses twin, high-velocity avalanche zones. windblast and flowing snow pressures are major problems. high spans required, plus elaborate tower protection. upper terminal would lie in narrow safe zone between very active avalanches. Advise against this installation. Recommend shorten lift to safe ridge approximately 1,000' down the lift line.

lift 7

this lift traverses across same avalanche zones as lift 2. same problems as lift 2, slightly lower degree.

Addendum - page 2

lift 8

high spans and protection will be required, no special problems otherwise. lower terminal must be located on safe ground -- on 'safe peninsula' with other lift terminals shown on Canyon Lodge site. protection of lower lift terminal at precise site shown on lift plan would be extremely expensive.

lift 10

protection of this lift would be extremely expensive, especially the lower terminal. windblast and flowing snow pressures are major problems at this site. Advise against this installation.

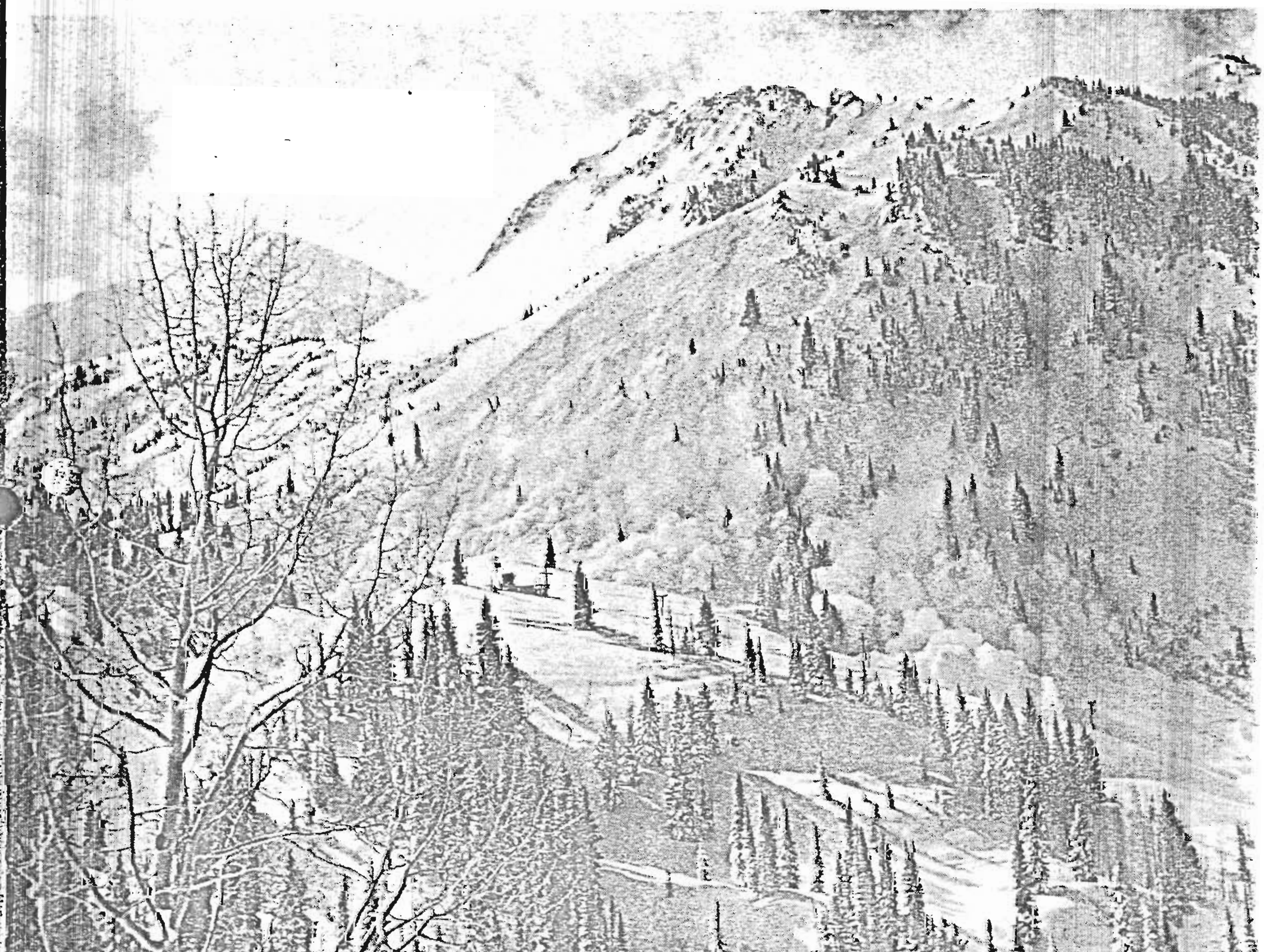
lift 11

some avalanche protection will be required for line towers. possibility of unstable ground should be considered.

other

various segments of other lifts will require protection. protection required will add to lift costs; but no special problems are anticipated.

Ski area planning for avalanches



USDA FOREST SERVICE

NATIONAL AVALANCHE SCHOOL

RENO, NEVADA
NOVEMBER 10–14, 1975

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INTRODUCTION

During the early years of ski sport in this country, the terrain and weather factors that influence avalanche occurrence and the destructive forces of snow avalanches were little understood. Evidence of avalanche activity and destruction went largely unrecognized or unheeded by ski area planners in their zeal to exploit what appeared ideal lift, lodge, and ski run terrain. Early planning philosophy hinted, fatalistically, that avalanches were like earthquakes, unpredictable as to time or location. Abetting this philosophy was the human compulsion to assume that such things happen to others, not to oneself.

Figure 1. A ski lodge, with avalanche debris within a few yards of the left wall. A diversion wall will be installed to protect the lodge.

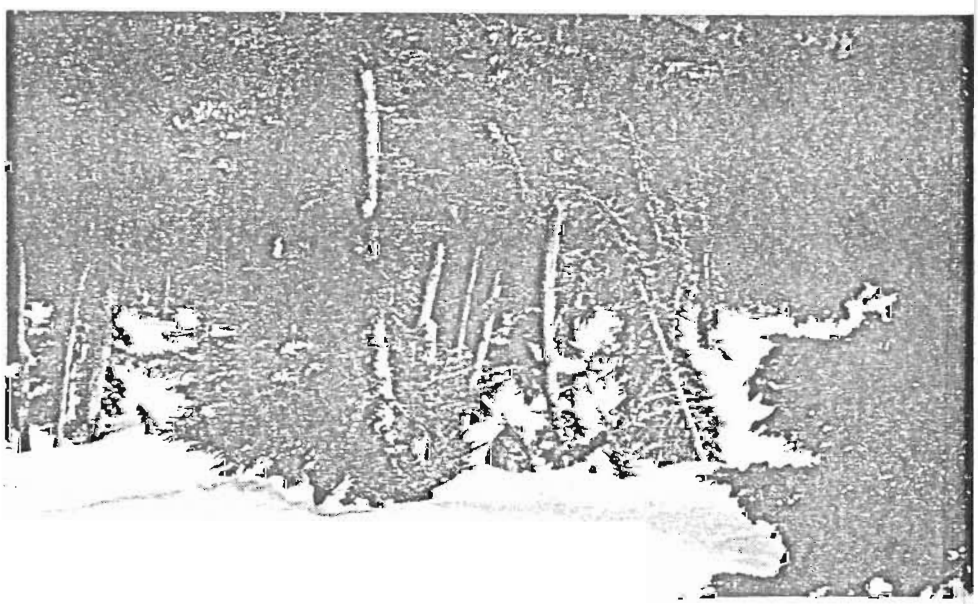


Figure 2. Evidence of avalanche activity; note branches pruned, broken tops.

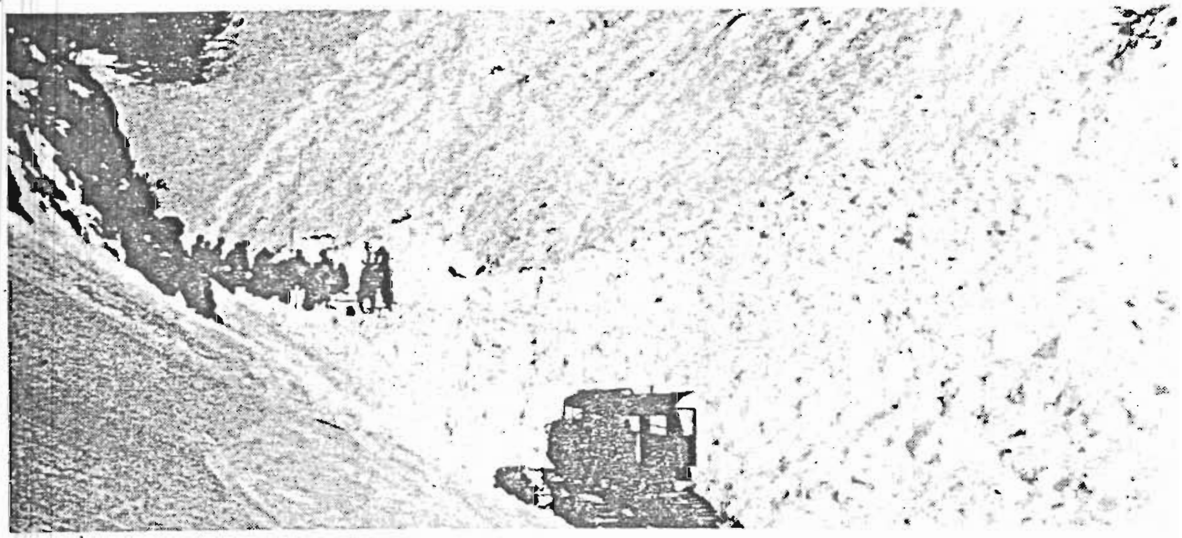


Figure 3. A small avalanche that claimed a victim. The slide ran 90', was 18" deep at the fracture line.

As ski developments have proliferated since World War II, a body of knowledge and experience in dealing with avalanche phenomona has grown that now equips planners to enter mountainous terrain and to design ski facilities that are very nearly immune to avalanche. Similarly, planners now have the background and experience to be able to recognize overpowering avalanche situations where they exist, and must sometimes advise against a ski development or specific portions of a development.

Regarding the avalanches themselves, few recognized that very small avalanches are capable of knocking over, burying, and killing people on skis, nor did they realize how fragile their steel structures would be in the face of thousands of tons of snow in motion.

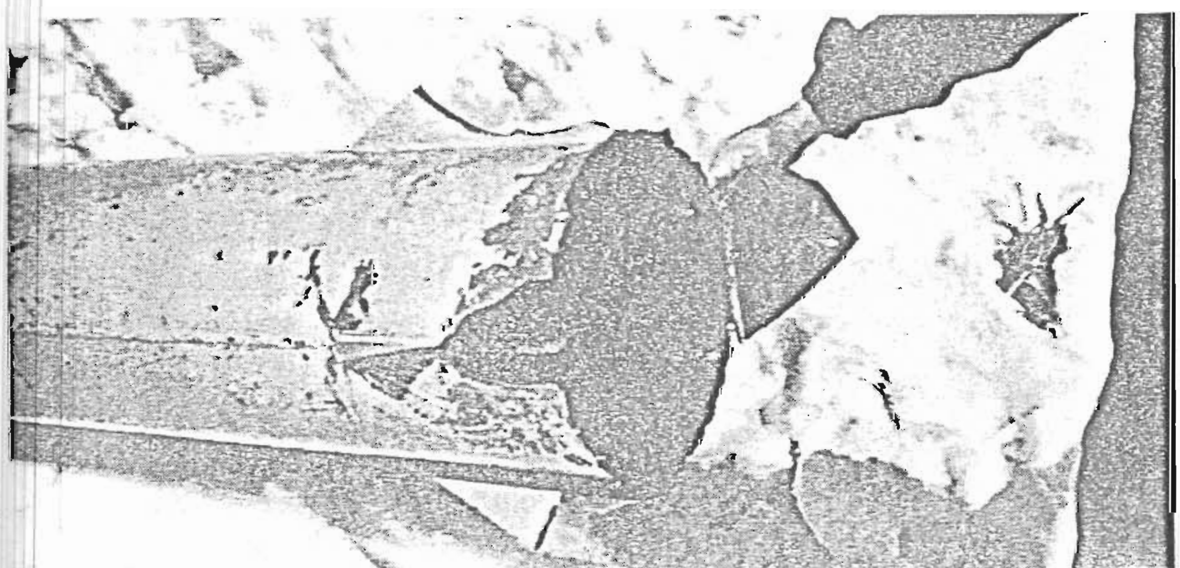


Figure 4. A steel tower, torn like paper by an avalanche.

As planning expertise has grown and technology has changed, the early fatalistic philosophy has ceased to be acceptable. The public rightfully expects planners, developers, operators, and administrators to make the best use of modern avalanche technology to protect them from avalanche hazards.

A second consideration in planning for avalanche is economics. It is poor business practice not to plan thoroughly for avalanche. In a few days in January, 1972, this lesson was brought forcefully home to several ski areas. These areas, separated by as much as 1,000 miles, suffered:

1. Loss of two lives in an avalanche, burial of five other skiers.

2. Loss of one lift, possible damage to one other, plus a very near miss for the night slope grooming crew.

3. Loss of two residence-cabins, not occupied at the time of the avalanche.

4. Loss of several days' revenues when an entire ski area was evacuated as a protective measure. In this last instance, the base area and access road are criss-crossed by major avalanche paths.

Other areas, at other places and times, have experienced similar disasters and near disasters. The list of these is long. Thoughtful planning and operating procedures could have prevented these occurrences.

This planning guide is written with three broad goals in view:

1. To assist ski area planners by identifying critical planning considerations related to snow avalanches.

2. To provide guidelines for the use of Administrators when reviewing development proposals, development plans, or when conducting feasibility studies.

3. To explore avenues that may present solution of avalanche related planning problems.

Critical Planning Considerations

Adequate avalanche planning for installation and operation of ski area facilities will protect the skiers that use those facilities. Thus, the primary consideration dealt with in this guide is planning that will provide avalanche-free ski lifts, base facilities, gathering places, and parking lots; minimum hazard ski slopes; and operating procedures that yield safe conditions on those ski slopes and access roads that are threatened by avalanche. This concept leads logically to the following priority considerations in evaluation of and planning for a ski development.

I. Fixed facilities must be avalanche free or protected under all conditions.

a. Lodge.

b. Parking lot.

c. Lift terminals - Line towers exposed to avalanche must be protected with structures.

d. At least one minimum hazard slope per lift-served area. Medium and high hazard slopes should be readily controllable by avalanche crew.

II. Access road avalanche problem must be carefully weighed to determine whether it is a crippling economic factor.

III. Operations

a. Realistic, practical.

b. Provide safety.

I. Fixed facilities

These first priority items are absolute requirements. If the facilities mentioned (lodge, parking lot, lift terminals and one minimum-hazard slope per lift-served area) are not in avalanche-free locations, the area must rely on control operations to protect them, and allow them to be operated, and experience has shown that control operations are frequently impossible--or extremely dangerous and time consuming--when protection is most urgently needed. The great storms that continue over extended periods have a way of crippling lifts and over-snow vehicles that are relied on for control operations, and even of stopping the most energetic and dedicated ski-and-climbing-skin-equipped avalanche man. There should be no exception to the requirement for avalanche free lodge and parking areas. It is sometimes physically possible, but rarely economically feasible to protect lift terminals with structures or barriers: therefore a proposal to install a protected lift terminal in a slide path must be studied carefully for effectiveness of the structures or barriers and the cost factors involved.

Line tower locations can frequently be adjusted to take advantage of natural protection or to span above avalanche paths along the lift line. Where line towers are unavoidably placed in avalanche paths they must be protected with structures or barriers.

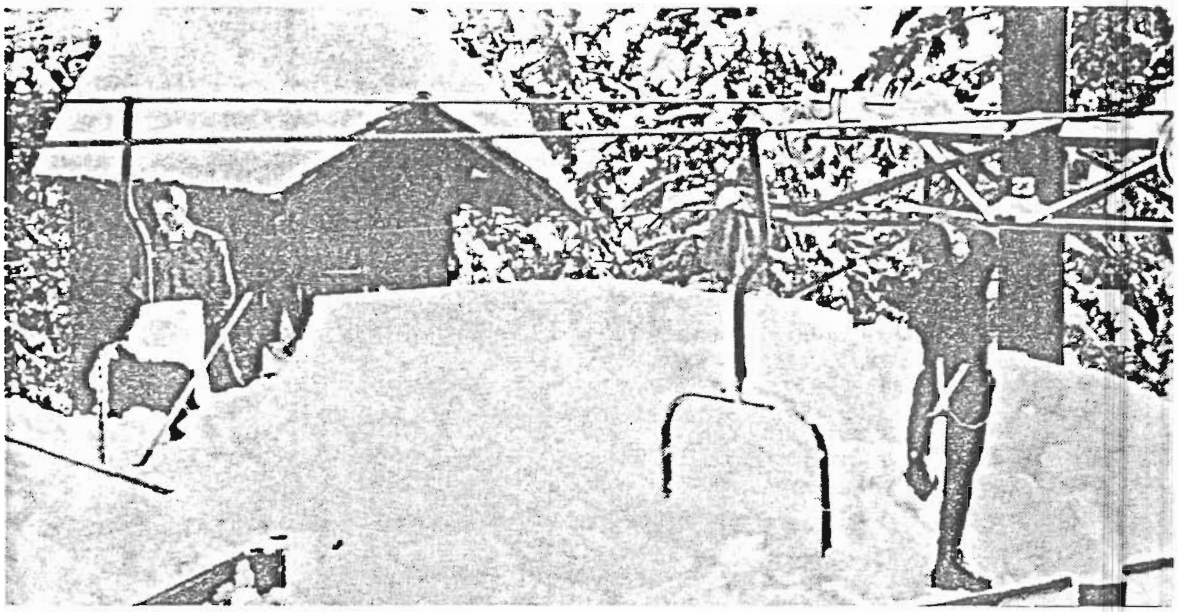


Figure 5. Lifts are frequently inoperable when most needed for avalanche control. One reason why the activities of control crews cannot always be relied on to protect fixed facilities.

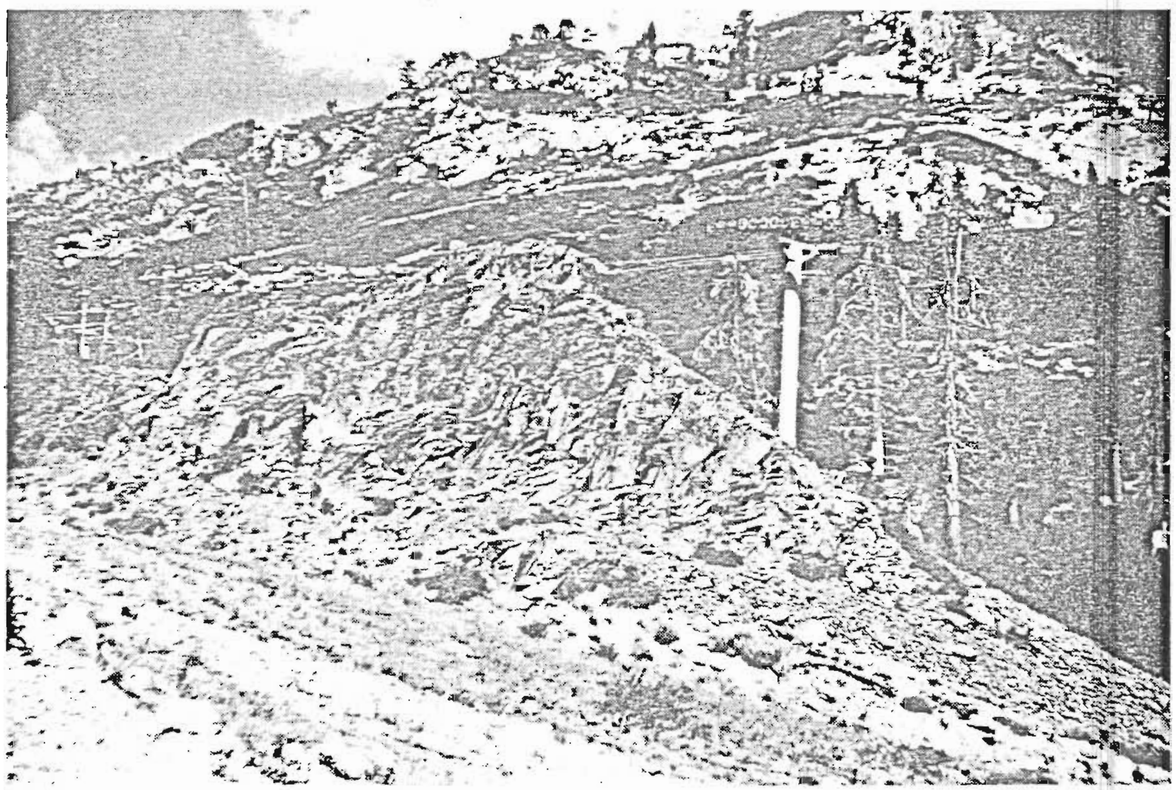


Figure 6. This tower location takes advantage of a large volcanic outcrop for protection from an avalanche to the left.

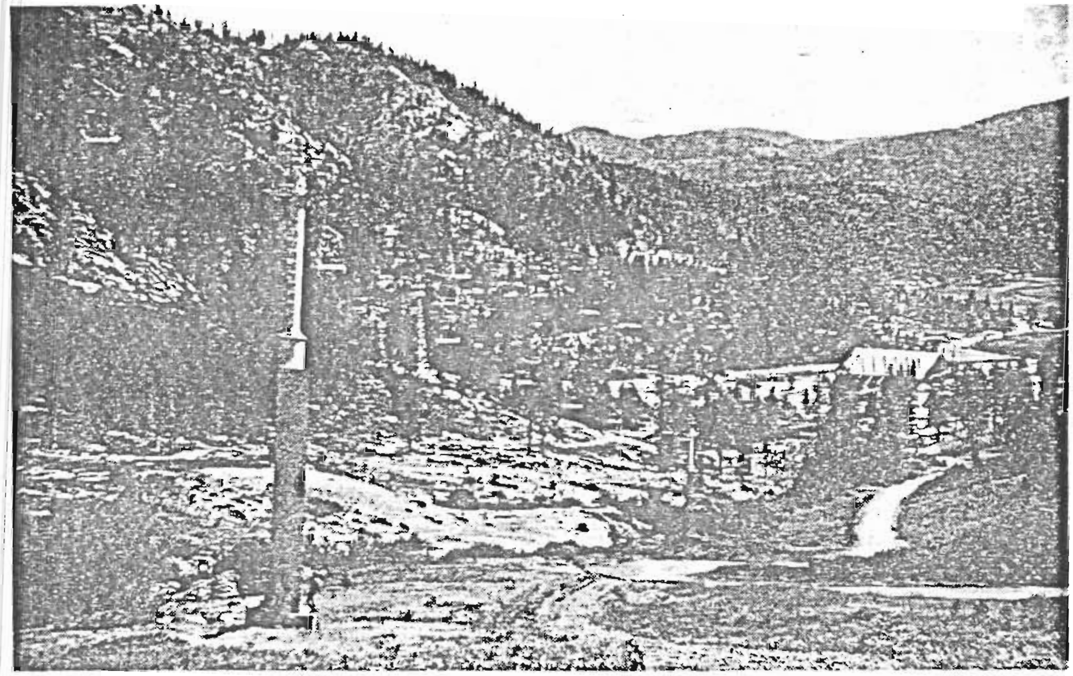


Figure 7. This lift passes above an avalanche runout zone. Note that the very tall towers at the ends of the span are protected with steel vees due to their locations at the edges of this large avalanche. Person at bottom of tower, on left, gives scale.

Protection of line towers is usually relatively simple; however, the planner must be aware of the occasional possibility of avalanches from more than one direction and design his protection appropriately. For example, if a sheet steel avalanche wedge incorporated into a tubular tower is designed to protect against an avalanche from

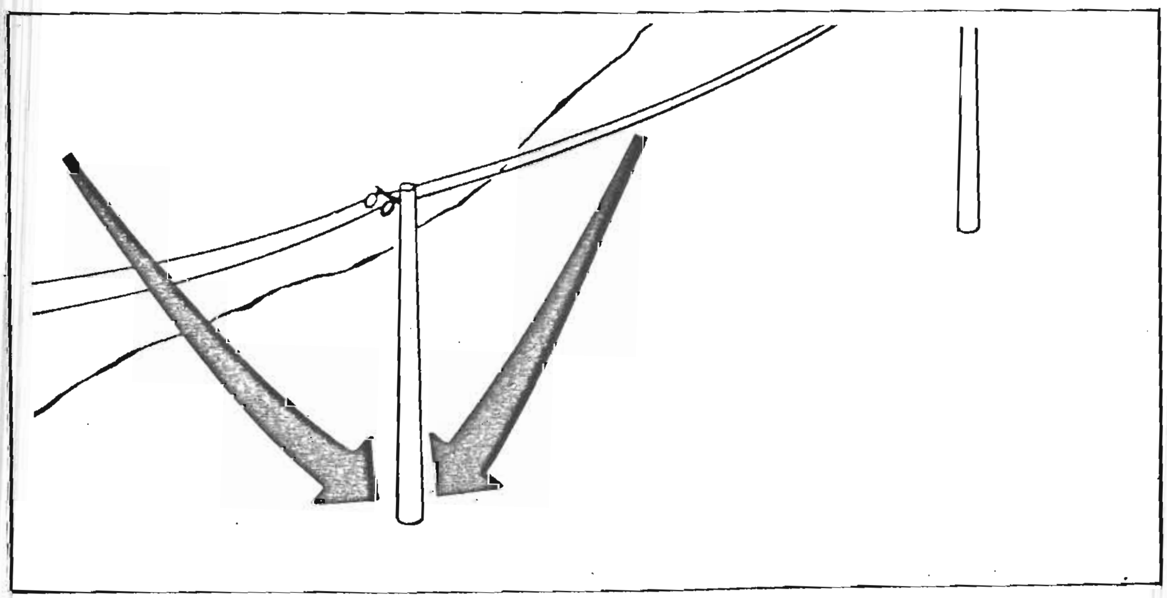


Figure 8. A steel vee here could not protect against both avalanches. Other protective measures must be used.

the west, but is struck broadside by an avalanche from the south, then the wedge simply creates a very broad surface for the avalanche to impact upon.

Where the possibility of avalanches from two directions exists, a very high, very stout concrete foundation may be necessary. The planner must also adapt his protective structures to the nature of the avalanche path he faces. Example: a sheet steel wedge attached to a tubular tower is not reliable where trees or other solid debris can be expected in the avalanches.

Where possible, each lift-served area should contain at least one top-to-bottom minimum hazard ski run. If this goal is achieved, the lift will be usable under all weather and avalanche conditions. Thus the lift will constitute a greater economic asset than one for which control operations are an absolute necessity each time avalanche hazard appears. Minimum hazard trails allow on-time, all-weather availability and operation, even while control operations are in progress elsewhere in the area.

Avalanches that threaten ski slopes must be controlled or the slopes must be closed to skiing. With this in mind, the planner should design his lift system to provide access to the avalanche trigger zones so that control operations can be performed with maximum efficiency and a minimum of lost time.

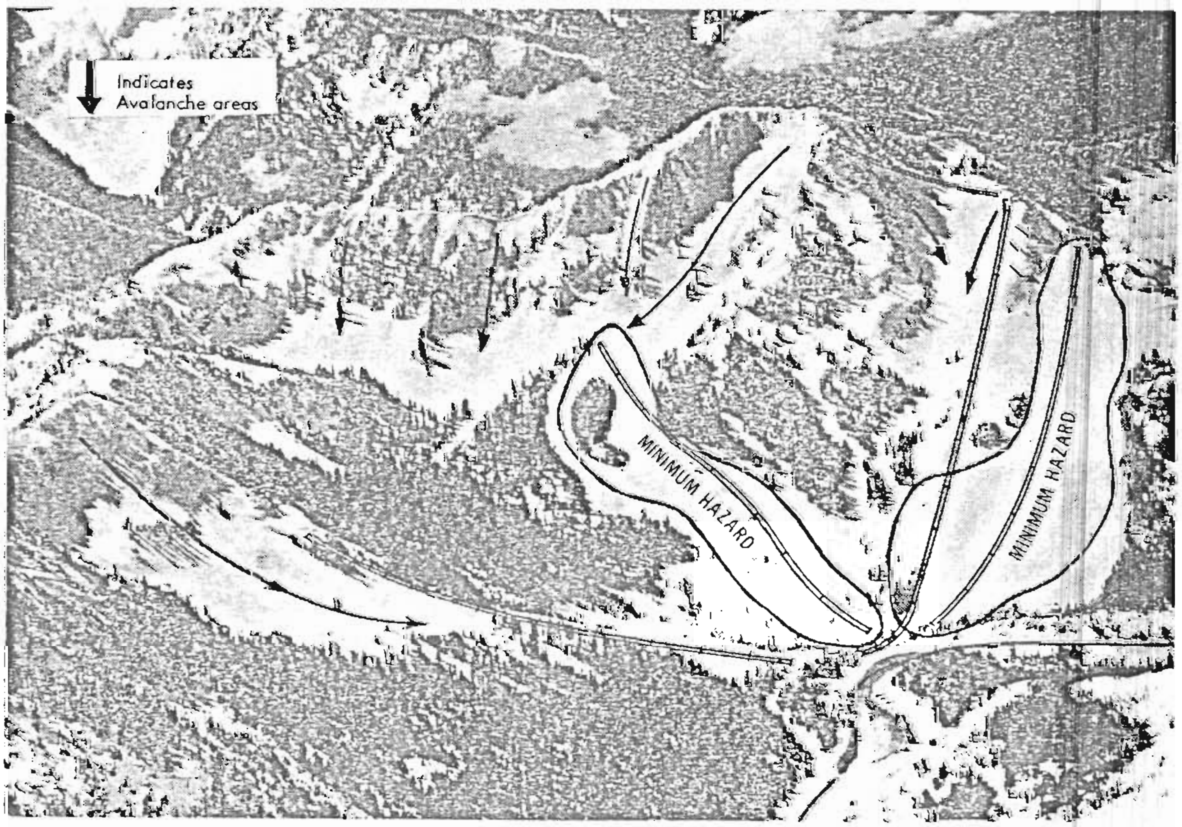


Figure 9. A ski area that provides minimum hazard slopes. These slopes can be used while avalanche control is being performed in other portions of the area.

II. Access road avalanche problem

Every effort must be expended to place access roads in avalanche free locations. Short term economic considerations should not be allowed to dictate positioning a roadway in an avalanche zone. A major ski area, developed in conjunction with a land development, placed its three-mile access road on the north side of a valley so that land (which is avalanche free) on the south side of the valley would be available for subdivision. The road was thus subject to several high intermittent avalanche paths that: Required regular, difficult, and expensive control operations; cause road clearing problems; and frequently close the ski area. The lots were sold, and the ski area suffers under the continuing self-imposed burden. The obviously better long term solution would have been to place the road on the south side, relinquishing a few salable lots.

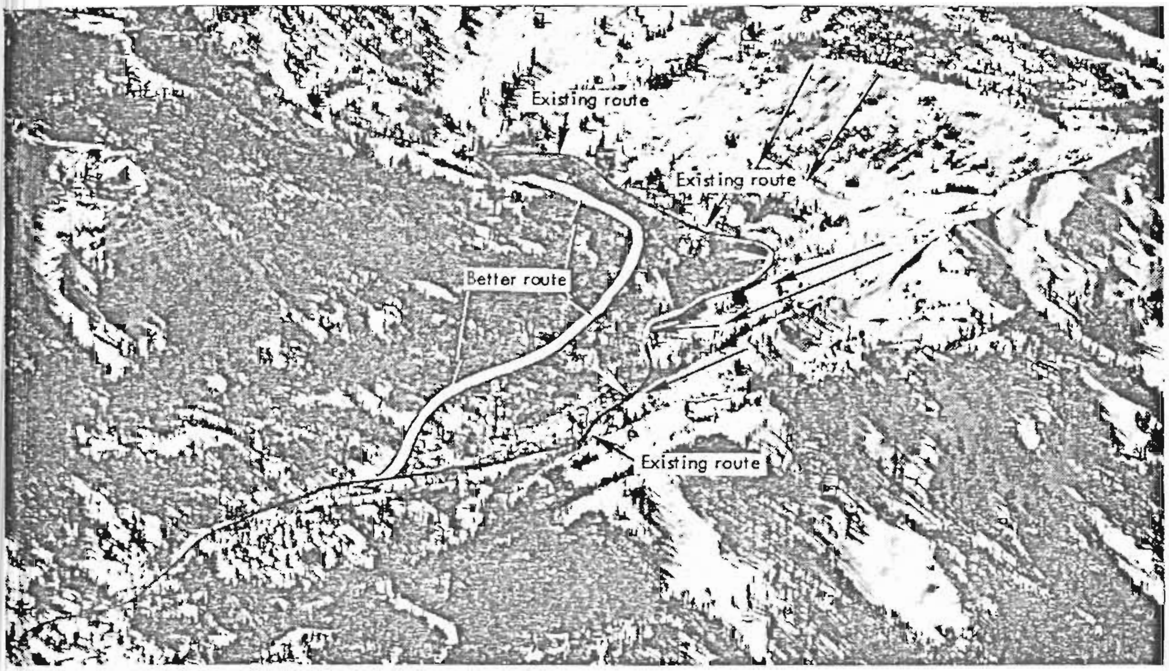


Figure 10. A ski area access road menaced by avalanches. The road could have been installed on the south side of the canyon where an avalanche-free route is available, but the land was devoted, instead, to subdivision.

If the access road cannot be placed in a completely avalanche free location, the economic feasibility of the entire ski development may be in doubt. The following factors must be weighed in determining whether a road avalanche problem constitutes a crippling situation, or just an annoyance. The difference here lies in the answers to several questions:

1. What is the scope and the degree of difficulty of the ski area avalanche control problem; will the road avalanche problem compound an already difficult situation?

2. How easy or difficult is the road avalanche problem, and how frequently must it be [illegible]t?

3. Are the road avalanche trigger zones accessible to control crews or is artillery required? Artillery is not readily available. The avalauncher, while a useful tool in many avalanche situations, has limitations.

4. Can the control job be done--practically, reliably, and without constituting a crippling drain on the ski area's resources of manpower and finances?

5. What legal problems will be encountered if the ski area does attempt to control the road avalanches? This includes consideration of closures, warnings, and injury or damage resulting from performance--or non-performance--of avalanche control. Is this factor manageable or unmanageable due to uncontrollable outside influences? (Homeowners, other businesses)

In general, if the ski area avalanche problem is not difficult, a reasonably simple road avalanche problem will not constitute an unsupportable economic or logistic drain; however, the answer to any one of these questions could be the basis to decide against development of the ski area.

III. Operations

The final consideration in planning a ski development is a realistic and practical plan for operation of the facilities and control of the avalanche hazard. The plan must give full regard to public and personnel safety while providing recreation opportunities commensurate with the highest and best use of the land. It is not enough for a developer to guarantee that the facilities will be operated only when conditions are safe: his plan must give reasonable assurance that the facilities will be safely operable.

Area Planning - Requirements

Comprehensive terrain and climate analysis is the first step in evaluation of a potential ski area. This means on-the-ground winter and summer studies of the entire development site. Slope angles and aspects should be analysed and recorded. Vegetation should be studied for avalanche damage, growth patterns and disaster species. These observations, and the distribution of avalanche debris should be carefully recorded. Snow deposition patterns should be recorded and annual snow and rainfall and snowpack information acquired. Correlation of all this data allows an avalanche map to be drawn. The avalanche map graphically illustrates locations of avalanche paths and runout zones within the development area; and, the expected sizes and frequencies of activity of those avalanche paths.

The second step is the process of fitting the proposed ski facilities and ski runs into the avalanche map, using the priorities established earlier in this guide as basic guidelines.

The terrain and climate analyses can be efficiently performed as follows:

1. Obtain the best quality maps available of the subject area, photo-topos if possible. Study these maps, acquire a general feeling for the lay of the land.

2. Terrain observations, summer.

   a. Analyze the terrain.

      1. Slope angles.

      2. Slope aspect.

      3. Residual snow patterns.

   b. Analyze the vegetation.

      1. Growth patterns.

      2. Disaster species.

      3. Damage.

      4. Debris.

   c. Study the area from the air, using a slow-flying fixed wing aircraft or helicopter. Acquire quality low angle aerial oblique photos of the area.

   d. Record data and observations on maps and photos.

3. Terrain observations, winter.

   a. Snow deposition patterns.

      1. Drift zones.

      2. Scour zones.

   b. Avalanche activity.

      1. Location.

      2. Size, type.

      3. Occurrence.

   c. Acquire closeup winter photos of avalanche paths, from the air or from other vantage points. Oblique aerial photos of the entire area in winter are helpful.

   d. Record data and observations on maps and photos.

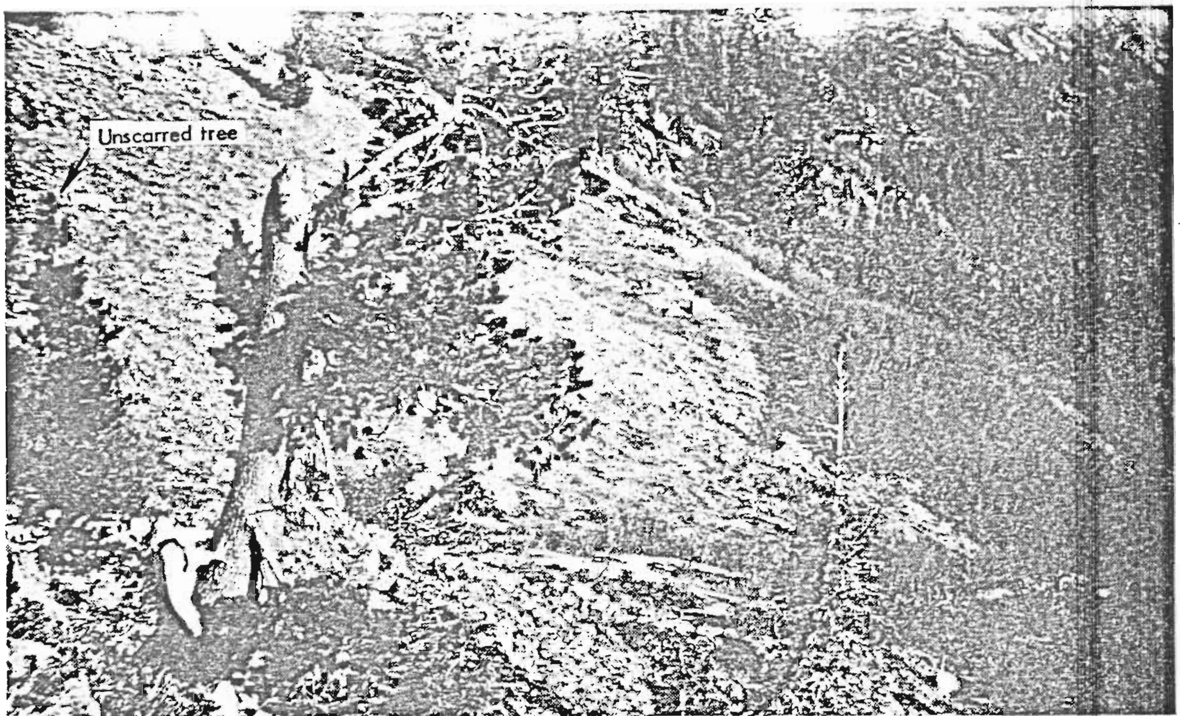


Figure 11. Avalanche Evidence. Some trees may escape damage throughout many avalanche cycles while others lose branches or are broken off. Some tree species, when young, bend more readily than other species, thus escape avalanche damage. Many trees are completely beneath the sliding surface when destructive avalanches occur--as in the picture showing an unscarred tree below the level of its broken-topped neighbor.

4. Weather observations.

   a. Acquire all available data, history.

      1. Overall climate pattern, Weather Bureau is a good source.

      2. Nearby weather observation stations, snow courses.

      3. Existing nearby ski areas.

      4. Highway maintenance stations.

      5. Residents, newspapers.

   b. Basic observations at subject area.

      1. Minimum.

         a. Cumulative snow stakes at key points.

         b. Periodic field observations, wind-temperature-water content of new snow.

2. Desirable.

a. Standard snow study plot observations (see Snow Safety Guide #2).

b. Recording wind and temperature instruments.

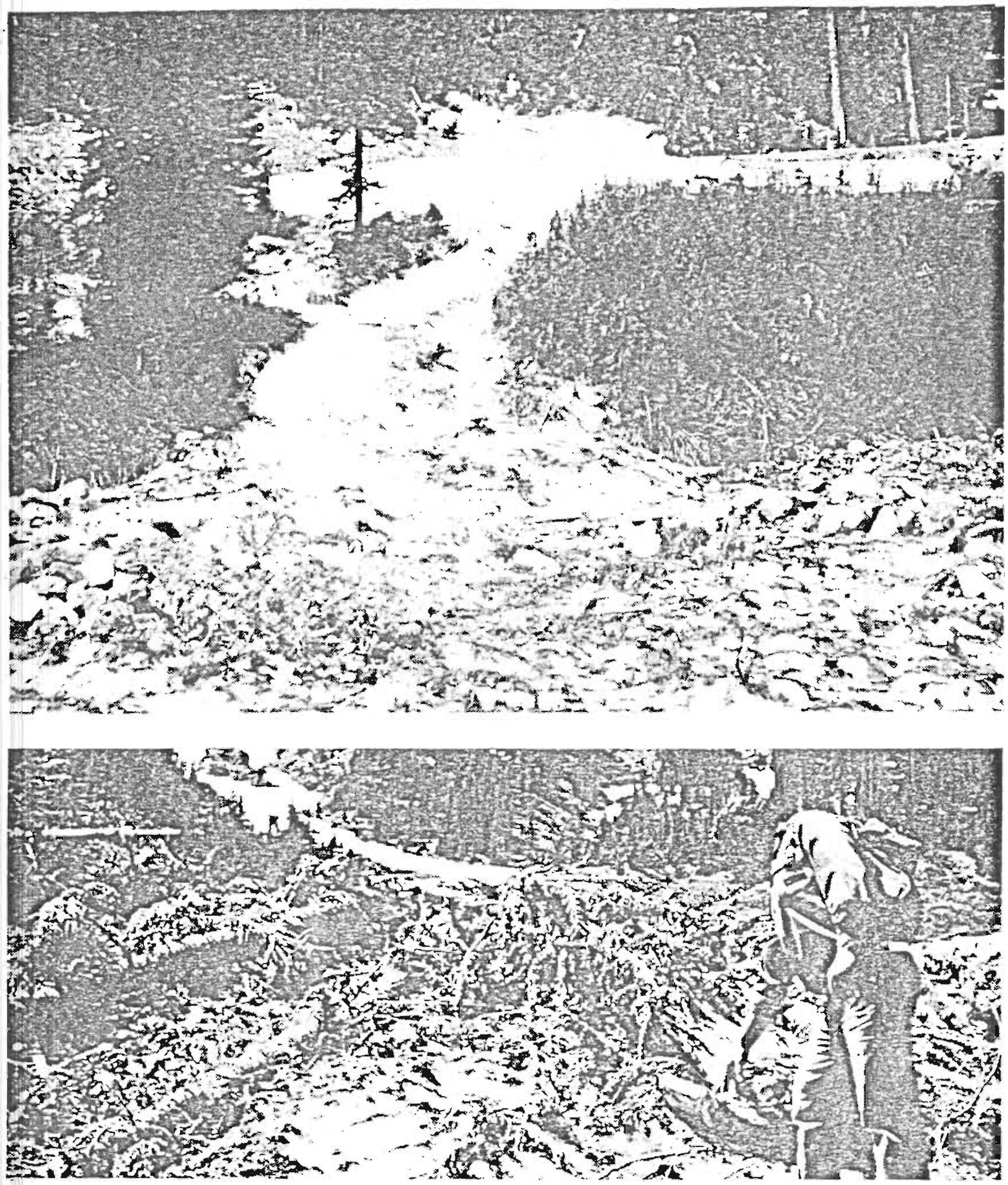


Figure 12. Avalanche evidence in the runout zone.

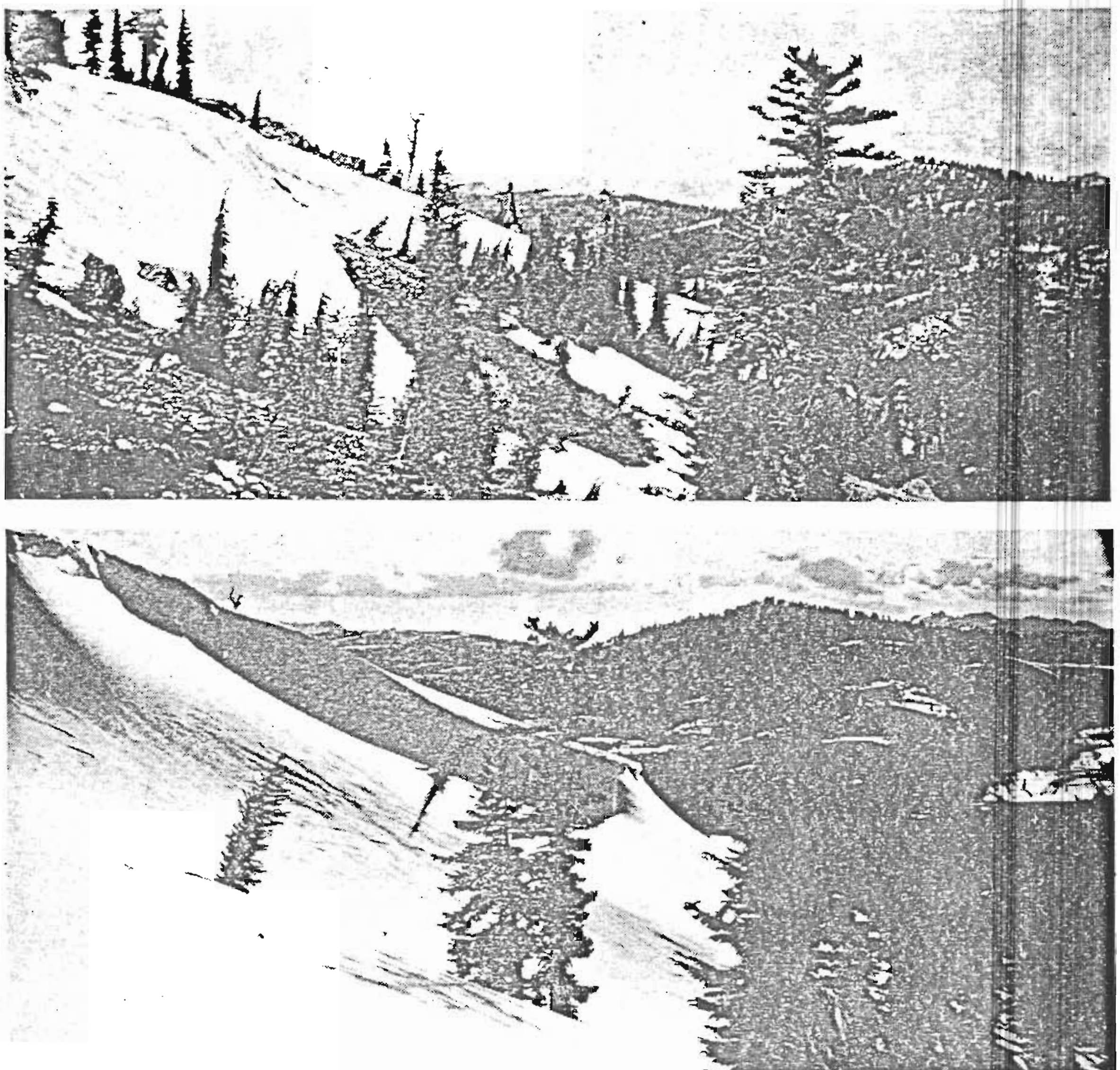


Figure 13. Residual snow patterns seen in the summer reveal drift areas. Deep drift zones are heavy snow creep areas and possible avalanche trigger zones.

5. Correlate all data gathered and observations made to produce the avalanche map, showing avalanche paths and zones, with hazard classification of the individual hazard zones. One system to classify individual avalanche paths and zones is as follows:

a. Minimum hazard. This classification indicates practical absence of hazard. Examples: A building fully protected by natural or artificial barriers; a slope not likely to avalanche.

b. Low intermittent hazard. This indicates occasional exposure to avalanches of dangerous size. Examples: A slope not steep enough to avalanche in dangerous volume except under extreme conditions; a structure close enough to a slidepath to be damaged only under climax avalanche conditions.

c. High intermittent hazard. This indicates areas frequently subject to avalanches of dangerous size. Example: A high-angle slope of sufficient dimensions so that hazard is likely to exist with every major storm or under delayed-action avalanche conditions. (The distinction between low and high intermittent hazard is frequency.)

Figure 14. A lift terminal placed in the extreme runout zone of a major avalanche path. Although evidence showed the avalanche had travelled this far sometime in the past, it had not been observed to do this since the area was developed (14 years earlier). Thus, the developer accepted the risk of using this otherwise desirable location.

d. High intermittent hazard, not controlled. Indicates highly hazardous areas which are not feasible to control.

Operating plans should have sufficient data that the following types of information will be available:

a. Manpower and skill requirements which must be available to cope with avalanche situation.

b. Projected cost of implementing plan.

c. Equipment needs.

d. Control methods to be employed together with access routes.

1. Do not consider installation of a fixed facility in an avalanche exposed location if there is no sure way to protect it permanently. Inexperienced developers frequently state that they are willing to risk the chance of avalanche damage to a facility in the interest of getting quick approval of a desired project. Such statements are usually made in absence of full appreciation of the avalanche potential and with at least a bit of the "it can't happen here" philosophy. Such installations, even if only mildly exposed to avalanche hazard, require single-minded, perfect judgement in operations procedures--at all times, every winter--to insure public safety. For example: Consider a key lift, the upper terminal exposed to high elevation, high intermittent avalanches that rarely reach down to the lift area. Operations personnel must control the hazard or close the lift. Naturally, pressure is on the operations personnel to keep the lift running. Such pressure, under difficult or marginal conditions on a Saturday morning, creates fertile ground for misjudgement and ensuing tragedy.

All too often, installation of facilities in exposed situations has led to a later desire to tear down and rebuild elsewhere, effectively multiplying the cost of the facility and the impact on the environment.

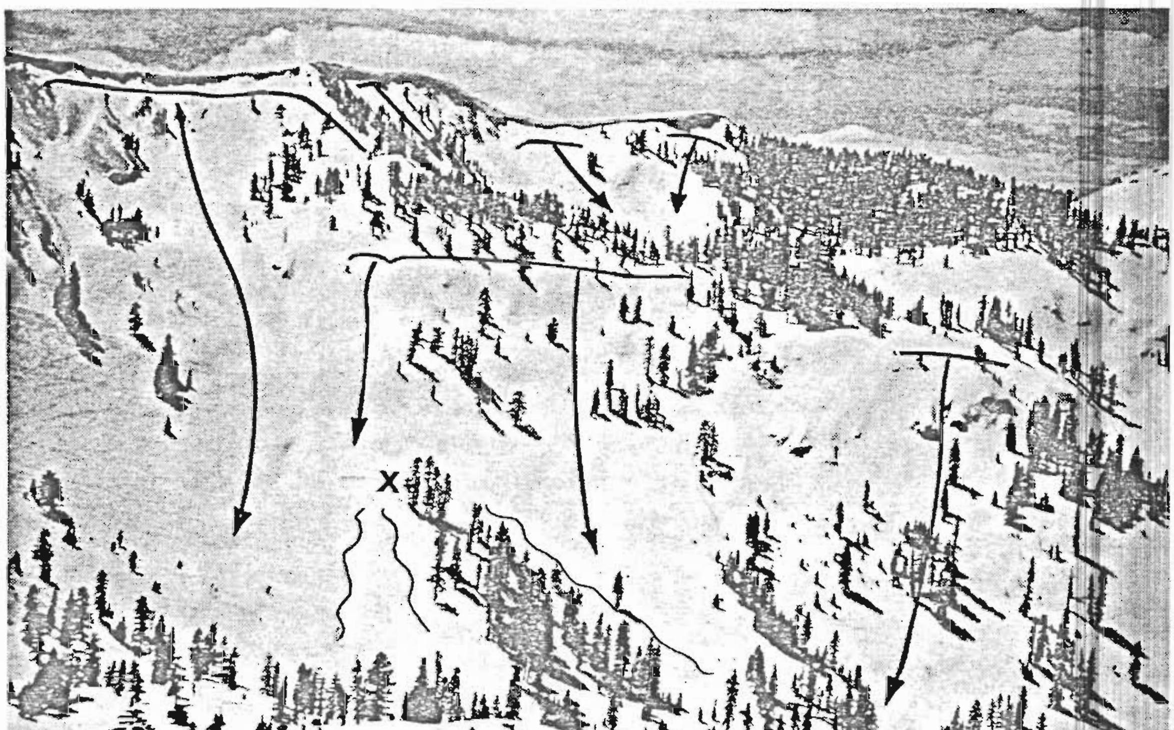


Figure 15. An upper lift terminal is located at X, beneath the 800' slope above it. This lift, serving intermediate terrain, must be protected by avalanche control crews whenever hazard appears, even though the hazard may not normally affect the ski terrain.

2. Do not create impossible situations, such as a ski area with an overwhelming avalanche problem. Avalanche control techniques have limitations--both economic and physical. All factors presented here must be weighed against the state of the art in avalanche control.

3. Do not consider a development plan that does not include the comprehensive terrain and weather analyses outlined earlier. The avalanche map must be complete and accurate and development plans must fit logically into it. The accuracy of the analyses and the avalanche map must be demonstrated.

4. When clearing ski trails in steep terrain, do not create avalanche paths by cutting continuous swaths through the timber, or by removal of islands of trees which served as anchors.

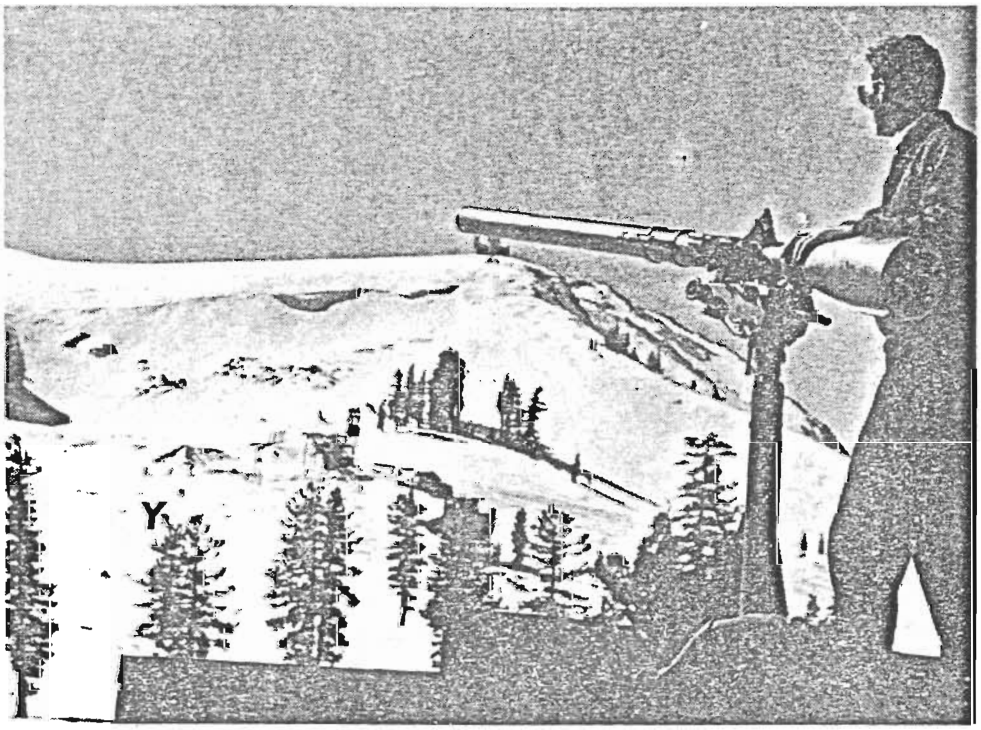


Figure 16. An upper terminal in a very marginal position. Avalanches from the 300' avalanche slope above buried the terminal frequently, and caused major damage several times before the lift was shortened. The upper terminal is now at Y.

5. Do not consider an avalanche control plan that is based solely on availability of military artillery. Overall development planning must provide for avalanche control independent of military artillery as we look to the time in the future when it will no longer be available.

6. Do seek advice and consultation from a variety of competent consultants both in industry and government. An interdisciplinary approach is a necessity in development planning, and the avalanche consultant is an important member of the team. The efforts of the team must be directed by the developer and the administrator who should establish parameters to guide the technicians.

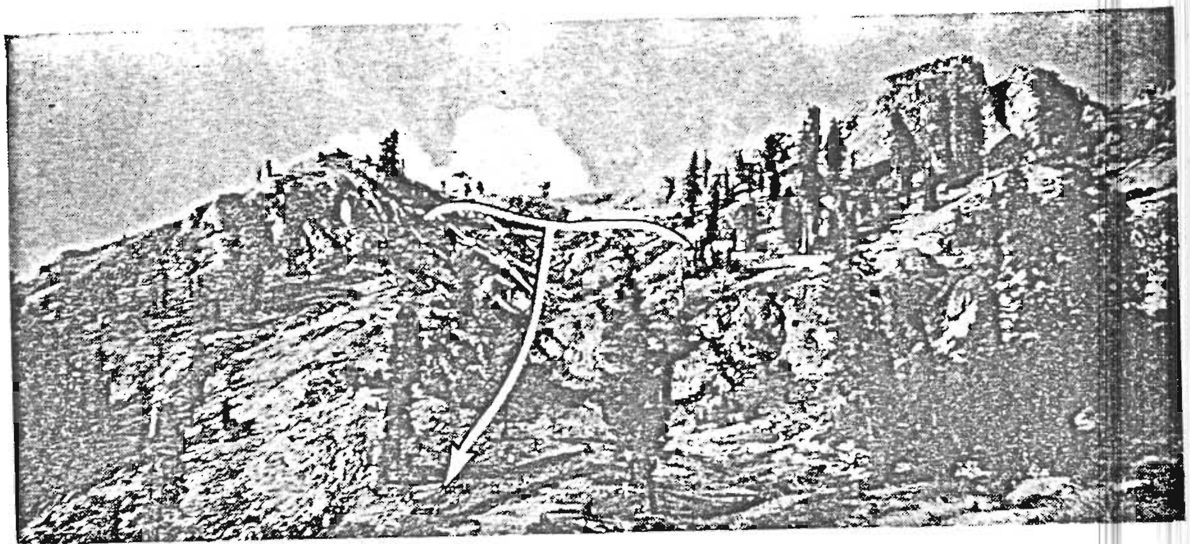


Figure 17. A ski slope after trees were removed. In the natural state the slope produced scattered avalanches regularly, large avalanches rarely. Since tree removal the slope regularly looses major avalanches that deposit large debris blocks on the ski slopes below.

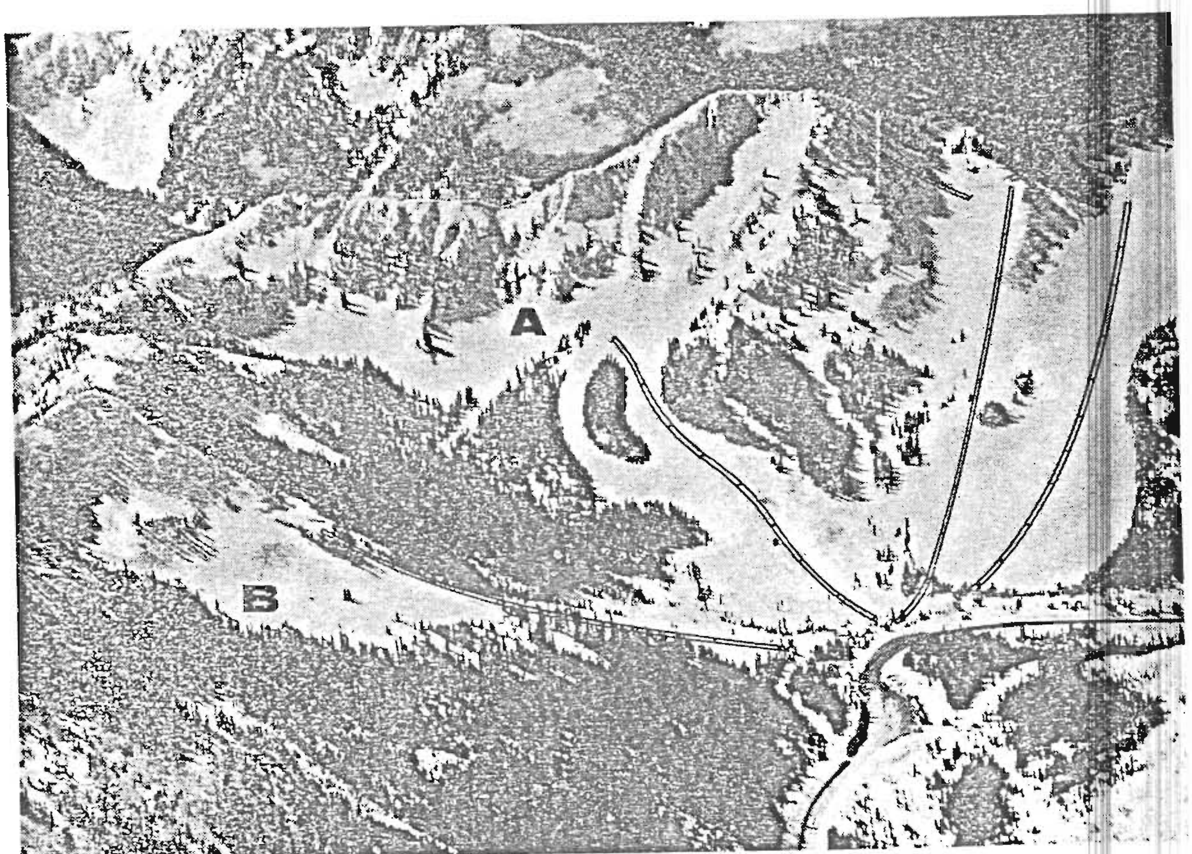


Figure 18. This lift system does not provide adequate access to the trigger zones, thus artillery is required to protect ski runs A and B. The Avalauncher may prove a suitable substitute for artillery here.

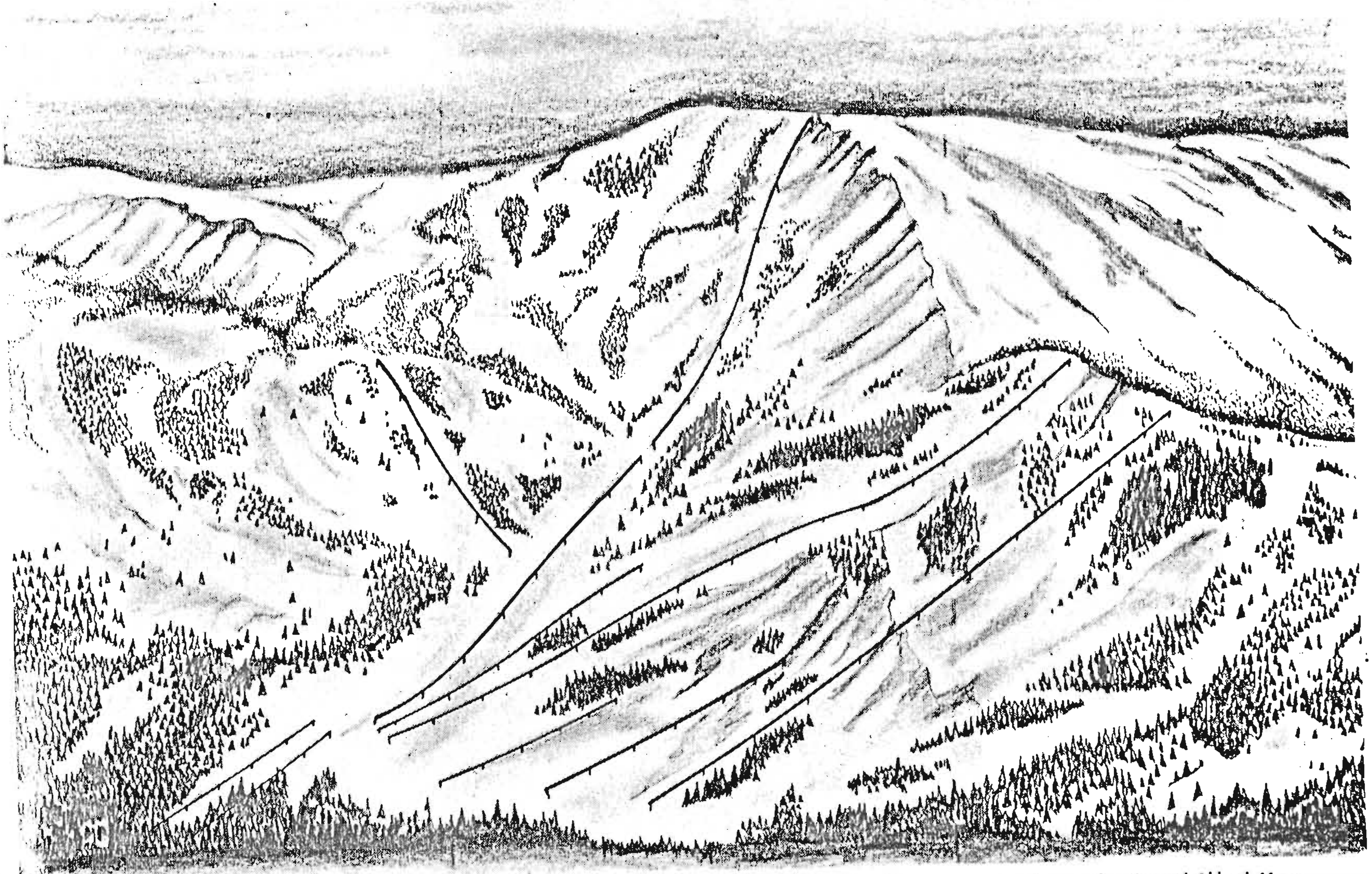


Figure 18a. The avalanche crew is able to reach all trigger zones via this lift system and mostly downhill skiing.

PLANNING PROBLEM EXAMPLES

Typical planning problems follow, with solutions that may apply: Applicability varies with local terrain, weather, and snowpack. Solutions are listed in order of practicality for most circumstances; however, specific problems generally require tailormade solutions.

A. Lift terminal exposed to avalanche.

1. Relocate.

2. Break lift in two, relocate one portion.

3. Provide artificial protection.

B. Avalanche crosses lift line.

1. Span avalanche path, using tall towers on both sides if necessary.

2. Protect line towers in or on edges of path.

C. Artificial avalanche protection needed.

1. Provide structural protection, elliptical towers, sheet steel vees, tall concrete foundations, concrete vees--whichever is applicable.

2. Provide earthen diversion wall or mounds.

3. Create snow stabilization structures in avalanche starting zone.

D. Cornice problem.

1. Prevent cornice formation with jet roofs.

2. Prevent cornice formation with snow deposition fences.

E. Snow creep.

1. If electricity is available, install heat wires.

2. Install vee splitters, or braces.

Snow creep is the slow downhill movement of an entire snowpack. Snow creep is related to snow settlement, is a massive, nearly incalculable force that acts upon any surface it contacts. As with glaciers and moving water, the snow nearest the surface moves faster than the snow at the bottom of the pack due to the drag of the terrain and vegetation. Creep bends steel, pushes towers over or out of line, and moves unheated buildings.

Sheet steel vees and elliptical towers have successfully been used to resist snow creep, but very stout anchorages are essential. Where electricity is available, low voltage heating coils have been successfully and economically utilized to prevent snow creep effect on line towers by melting the snow as it contacts the towers.

The destructive capability of creep is greatest on steep slopes, but creep is present in some degree on all slopes. Depth of snow pack, magnitude of slope above an object, and ground surface are critical elements.

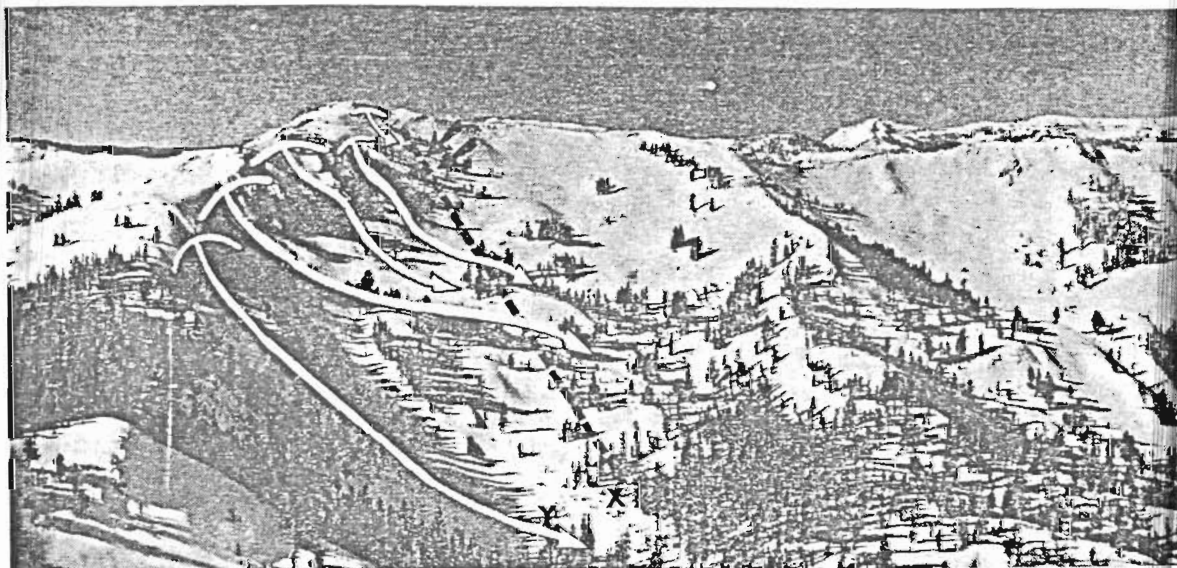


Figure 19. This lift was installed by a ski area that desired a high elevation lift to enhance early season potential. Avalanches from the left forced the ski area to build in a less than ideal lower terminal location (X), as the ideal location (Y) is regularly overrun by large avalanches. High spans were designed into the lift to bridge over avalanches farther up the lift line. Line towers were installed on protected knolls and outcrops. Snow creep is a severe problem at two line towers (black arrows). The upper terminal, although within 200' of the ridge, suffers damage from snow creep and occasional climax avalanches. Thus the planning was not an unqualified success.

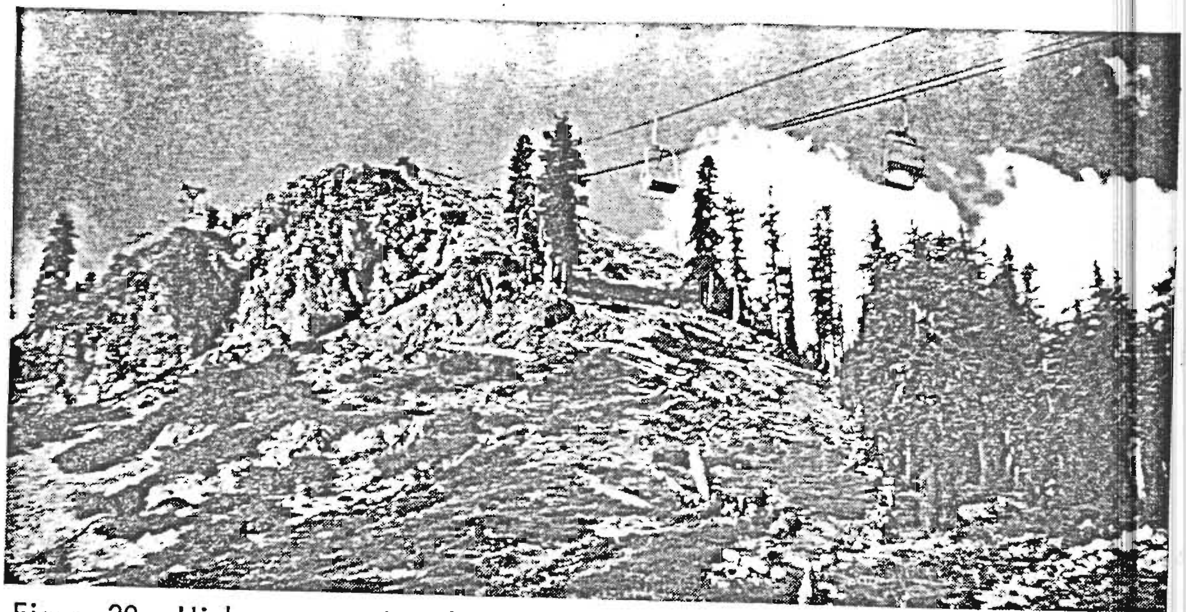


Figure 20. High span used to bridge a major avalanche path. Note the tower on the rock outcrop at upper left. The chairs are over 100' above the snow.

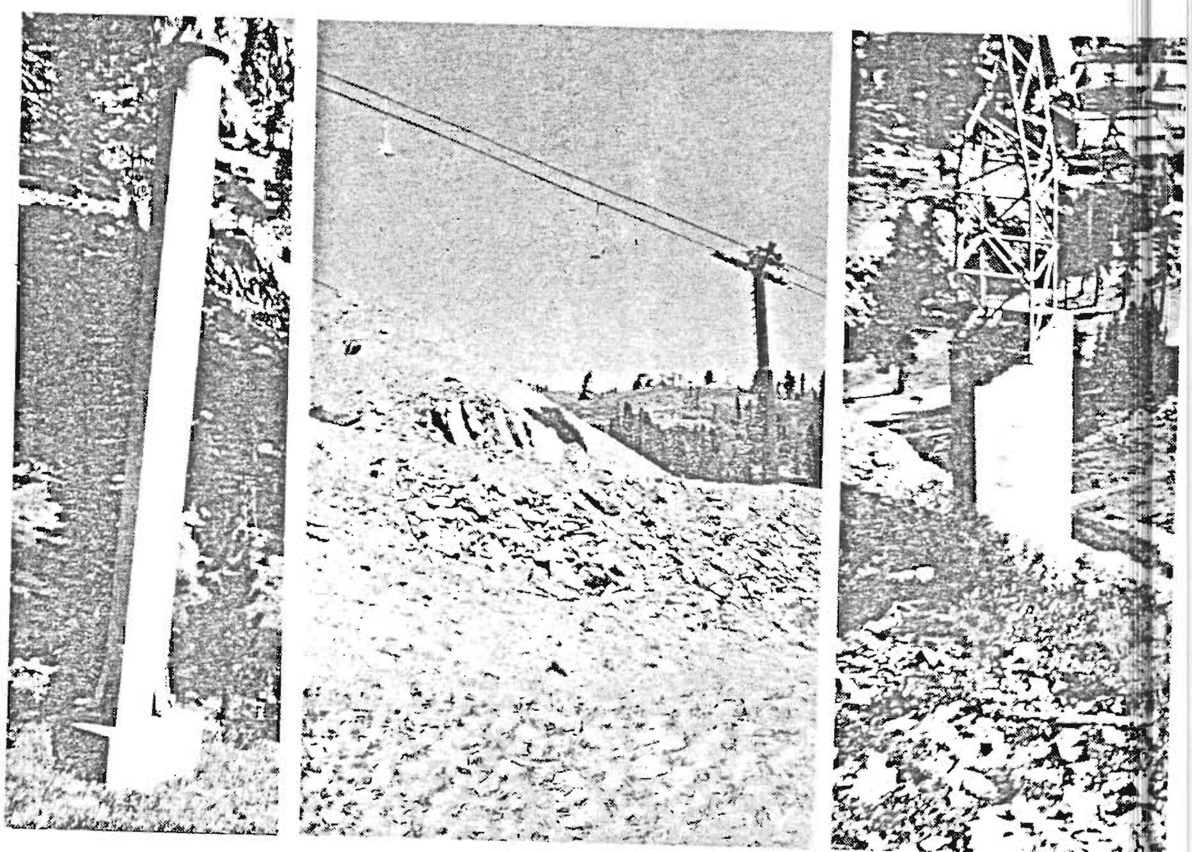
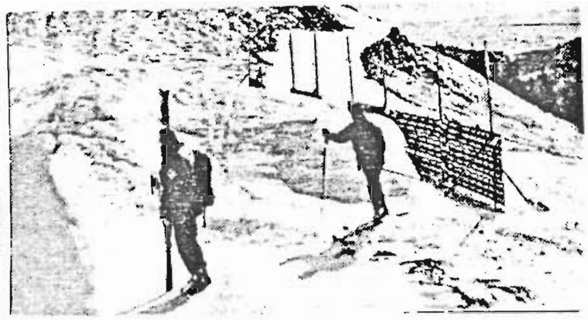


Figure 21. Protective measures. Each protective device must be designed for the specific situation. No single solution applies at all locations due to varying terrain, snow, and economic factors.

The picture shows an experimental installation featuring several different types of roofs. The last four roofs on the right were not effective.



Snow deposition structures. Note the heavy deposition to left of the structures. These structures prevented cornice formation at left of picture.

Figure 22. Structures designed to prevent formation of cornices. Jet roofs on the left. Snow deposition structures on the right.

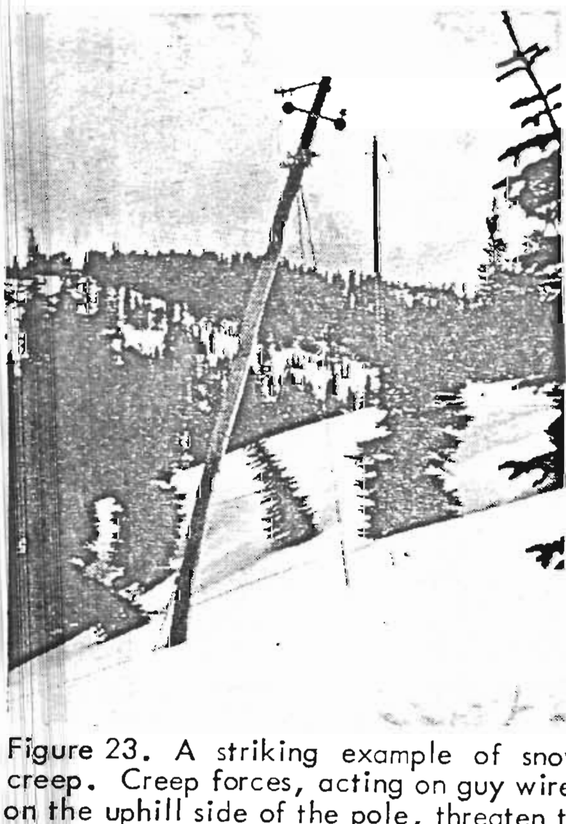


Figure 23. A striking example of snow creep. Creep forces, acting on guy wires on the uphill side of the pole, threaten to break the pole.

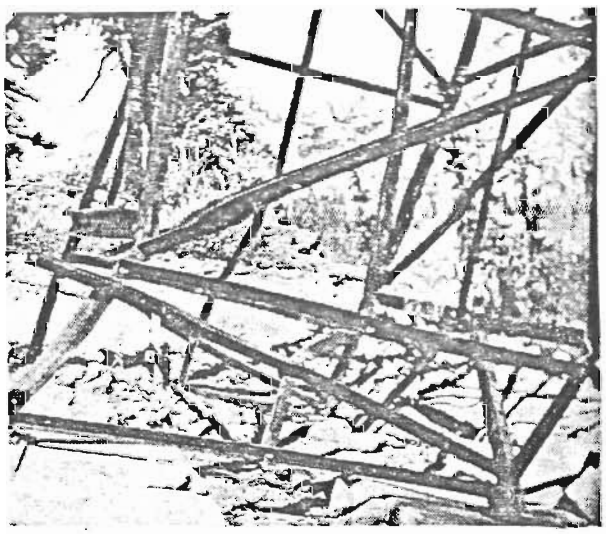


Figure 24. Snow creep damage to a structural steel tower.