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16. Abstract

This report describes the results of a feasibility study comprising Phase I of a Central Avalanche Hazard Forecasting Program for mountain passes in the State of Washington.

The report describes existing weather and avalanche data sources, and suggests improvements and additions for improved input to and feedback from a centralized avalanche forecaster's office which will improve avalanche predictions for all passes within the State.

WSDH and consultant efforts and results during FY 75 are described, and specific recommendations for Phase II, implementation of avalanche hazard forecasting, are provided.

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CENTRAL AVALANCHE HAZARD FORECASTING

PHASE I

A FEASIBILITY STUDY

(Fiscal Year 1975)

FINAL REPORT

Prepared for Washington State Highway Commission, Department of Highways, in cooperation with the U.S. Department of Transportation, Federal Highway Administration

TABLE OF CONTENTS

SUMMARY

INTRODUCTION

Washington State Department of Highways (WSDH) activities and projects prior to and including 1974, made it evident that more reliable avalanche forecasting methods were needed to improve the Department's avalanche control activities.

Studies by the University of Washington and Avalanche Control Consultants, Olympia, Washington, indicated these needs for accurate forecasting information, and in June, 1974 a number of recommendations were made for program direction.

A series of meetings with representatives of WSDH, the Department of Natural Resources (DNR), Parks and Recreation, the National Weather Service (NWS) and National Forest Service (NFS), the University of Washington, and independent consultants formed the basis for a Central Avalanche Hazard Forecasting feasibility study research proposal, in January, 1975. A revised version of this proposal became WSDH Project No. HR 551. This study is the first phase of a two-phase program. The second phase will implement the recommendations of HR 551.

PROBLEM STATEMENT

Developing avalanche forecasts requires a combination of applied sciences—a "new" science, in which there is little experience. The planned avalanche control program needed a competent meteorologist skilled in snow-related sciences to explore the feasibility of central avalanche hazard forecasting.

The immediate problem was finding a trained forecaster for this central avalanche forecasting office. Discussions between WSDH, DNR, and NWS produced a plan for joint-agencies to share services during the winter of FY 75 to determine manpower needs for the WSDH program, with plans for continued joint-agency sharing if Phase I proved the concept feasible.

STUDY OBJECTIVES

Long range objectives of the two-phase study include:

1. Establish whether centralized avalanche hazard forecasts can be developed with a reasonable degree of accuracy—better than an "educated guess"—for activating avalanche control operations.

2. Determine if a central forecaster can accurately forecast avalanche hazards for several mountain passes, each subject to diverse weather conditions.

3. The feasibility of (1) and (2) will determine whether an ongoing central avalanche forecaster position should be filled by a qualified staff forecaster, by sharing the services of a qualified forecaster with another agency, or by contracting with a consultant forecaster.

4. Evaluate multi-agency forecasting system involving federal and state agencies and private companies who might participate in the input/output of such a system.

5. Determine instrumentation requirements for effective avalanche hazard forecasting.

6. Develop and write forecasting procedures for inclusion in the avalanche control manual.

Specific objectives for Phase I include:

1. Establish whether a joint-agency forecaster service is administratively feasible.

2. Determine if there is a work-load conflict in the seasonal needs of the joint-agencies.

3. Orient a meteorologist in the specific areas of snow mechanics and central avalanche forecasting, with expectation that developing such expertise and procedures will be valuable in establishing a more comprehensive research program for Study Phase II.

WORK PLANS

The work plan for Phase I was a seasonal study including orientation briefings while meteorological and avalanche history data were studied and compiled. These data would then be evaluated and the resulting report would conclude Phase I. Specific Phase I activity plans include:

1. Establish joint-agency communications link.

2. Determine and establish present and future needs for operation of Central Avalanche Forecasting:

   a. Weather observations

   b. Data collection

   c. Observation stations

   d. Instrumentation

   e. Personnel

   f. Communicatons

3. Acquainting the meteorologist with highway maintenance operations.

4. Field orientation for meteorologist in observation, instrumentation, and control.

5. Compile meteorological data and avalanche history file.

6. Review FY 75 operation and make recommendations and prepare plans for FY 76.

7. Prepare and submit FY 75 interim study report.

PROGRAM ACTIVITY

Initial plans to share a fire warning meteorologist with the Department of Natural Resources were not completed due to changes in staff assignments. A staff meteorologist from the WSDH Environmental Planning Section was briefed in avalanche control, observation, and forecasting; but it became evident that assignment conflicts would not permit him a continuing role in the program.

At this point, WSDH decided to retain a professional avalanche consultant, Mr. Norman A. Wilson of Norden, California to analyze the Department's resources and determine what was needed to complete study objectives.

After background orientation in the WSDH avalanche control program, the consultant completed his assignment and prepared a comprehensive report with recommendations for department action. The complete text of his report is included as an Appendix to this Report.

A joint-agency communications link between WSDH and NWS was arranged and an equipment list developed. Equipment will be installed during Phase II.

A single season's observations and efforts are not enough to develop a complete avalanche forecasting program, but enough progress has been made to set up a basic organization, to be modified or expanded as future experience dictates.

Personnel and scheduling conflicts encountered during Phase I indicate that future investigations might be better conducted by the Geophysics Program and Department of Civil Engineering, University of Washington, operating under contract to WSDH.

CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

These conclusions and recommendations are based on the consultant's report and on Washington State Department of Highways (WSDH) efforts and experience during FY 75. It should be recognized that, as the avalanche forecasting program continues, additional needs will arise. Avalanche forecasting is a new, little-understood science. Washington State is assuming a pioneering role in this field—helping to expand knowledge and improve the safety of our mountain travelers.

Discussions with various public agencies and private concerns in Washington State and British Columbia resulted in a number of tentative working arrangements which must be formalized as soon as practicable. Specific and detailed comments are contained in the consultant's report in the Appendix.

RECOMMENDED WSDH WEATHER AND AVALANCHE REPORTING NETWORK

	Data Source	Agency
1.	Mt. Baker Ski Area	U.S. Forest Service (USFS)
2.	Washington Pass	WSDH
3.	Stevens Pass	WSDH
4.	Mission Ridge Ski Area	Ski area/USFS
5.	Snoqualmie Pass	WSDH
6.	Crystal Mountain Ski Area	Ski area/USFS
7.	Mt. Rainier National Park	National Park Service
8.	White Pass	WSDH
9.	Olympic National Park	National Park Service
10.	British Columbia reporting stations on Vancouver island and Mainland coast	Atmospheric Environment Service—Environment Canada

11. Kootenay Pass	British Columbia Department of Highways (BCDH)
12. Allison Pass	BCDH
13. Fraser Canyon	BCDH
14. Schreiber Meadows	U.S. Geological Survey (USGS)
15. Marten Lake	USGS
16. Easy Pass	USGS
17. Jasper Pass	USGS
18. Park Creek Ridge	Soil Conservation Service, U.S. Department of Agriculture (SCS)
19. Lone Pine Shelter	SCS
20. Bumping Ridge	SCS
21. Surprise Lakes	SCS
22. Trough #2	SCS
23. Mt. St. Helens	WSDH

RECOMMENDED EQUIPMENT AND INSTALLATIONS

Reporting Station	Recommended Equipment and Installations
Mount Baker	a. Radio telemetry system, Mt. Baker guard station to Glacier ranger station
	b. Possible replacement of tele-temp system
Stevens Pass	a. Summit structure: office and minimum accommodation
	b. Recording apparatus in summit structure
	c. Relocate snow study plot

	d.	Install SCAN phone and WSDH radio in summit structure
	e.	Precipitation gauge and recorder
	f.	Man Berne radio and telephone on 24 hour basis
Snoqualmie Pass	a.	Weather Shelter with thermometers
	b.	Recording thermograph
	c.	SCAN telephone and WSDH radio at summit station
Crystal Mountain	a.	Foxboro recording thermograph
	b.	Wind recorder or dial readout
	c.	Thermistor and recorder, lower study plot to Snow Ranger office
	d.	Precipitation gauge recorder, lower study plot to Snow Ranger office
Mt. Rainier National Park	a.	Wind sensors with recorder
	b.	Thermistor with recorder
	c.	Precipitation gauge with recorder
White Pass	a.	Weather shelter with thermometers and mount
	b.	Foxboro recording thermograph
	c.	Snow stakes
	d.	8-inch can with stand and weighing scale

Olympic National Park	a.	Radio telemetry system, Hurricane Ridge to Park Headquarters
	b.	Wind sensors with recorder
	c.	Precipitation gauge with recorder
	d.	Thermistor with recorder
	e.	Snow stakes
	f.	Weather shelter with thermometers
	g.	Recording microbarograph
Mt. St. Helens	a.	Radio Telemetry temperature system

INTER-AGENCY COORDINATION

Present informal working arrangements between WSDH, USFS, NWS and the National Park Service should be formalized to insure continued participation by all agencies.

Communication equipment to link the NWS Seattle office with WSDH Station 10, in Seattle should be installed in accordance with arrangements made between WSDH and NWS.

CONTINUATION OF STUDY

Evaluation of Phase I activities indicates that studies should be continued and Phase II implemented. It is recommended that a contract be established with the University of Washington to conduct a pilot forecasting study in conjunction with the National Weather Service to provide the Department of Highways with the information needed to accomplish the study's long range objectives.

DISCUSSION

INTRODUCTION

Due to scheduling and workload problems, it was necessary to complete the Phase I work plan on an abbreviated schedule. In order to complete the planned activities, the Washington State Department of Highways (WSDH) decided to retain an avalanche consultant with wide experience in snow phenomena. The complete text of his report is included in the Appendix.

WEATHER OBSERVATION DATA

The most important weather observation data needed for avalanche hazard forecasts fall into three vital, basic categories.

1. Daily minimum and maximum air temperatures, with additional readings taken during periods of special interest. Air temperature affects the type of snow falling, internal characteristics of the snow pack, and other factors which bear strongly on avalanche hazards. Temperature observations at Snow Study Plots are made with various types of maximum-minimum thermometers and recording thermographs. Observations from distant points usually involve thermistor sensors and radio or wire telemetry.

2. Wind force and direction are recorded, if possible, and observations are made at Snow Study Plots during periods of special interest. Wind force affects the amount of snow deposited in avalanche starting zones and tracks–in general, the stronger the wind, the more snow in starting zones. Wind direction tells the forecaster where snow is being deposited–which avalanche zones or paths are "loading up". Wind measurements are made with cup anemometers to measure force, and vanes to indicate direction. Both these instruments are subject to icing deposits which can make readings inaccurate or impossible. Heat lamps to prevent icing are only moderately successful. New wind measurement concepts currently being investigated by the University of Washington should be encouraged.

3. Precipitation is observed daily, or twice daily, at Snow Study Plots, with more frequent observation during periods of special interest. Snow or rain directly affect the amount and type of load on old snow surface. High intensity loading leads quickly to high avalanche hazard. High density (water content) snow means heavy loading and slab formation which can cause high avalanche hazard. Rain increases loading, warms and weakens existing snow packs, and may act as a lubricant between buried snow layers. Even a small amount of rain on unconsolidated new snow can rapidly develop a severe avalanche hazard. Precipitation is observed at Snow Study Plots using standard snow stakes and snow board, core sampler and weighing or measuring devices, rain can, recording precipitation gauge, and snow pillow. At remote locations, recording precipitation gauges and snow pillows provide the required data. Two other categories of weather observation data are essential for sophisticated and accurate avalanche forecasting.

4. Avalanche occurrence observations are made in the field by WSDH personnel, U.S. Forest Service (USFS) Snow Rangers, ski patrol personnel, National Park Service personnel, other agencies, the general public, and news media. At a minimum these observation reports should include:

a. Location (name of avalanche path)

b. Time of occurrence (estimated if not witnessed)

c. Size of avalanche and roadway situation (how much snow deposited, etc.)

d. Solid debris involved (tree limbs, whole trees, rocks)

e. Damage to vehicles, structures, or persons

f. Avalanche trigger—natural or artificial (explosives, artillery, skier, hiker, snowmobile, animal)

Experienced observers should also include:

g. Avalanche classification (hard or soft slab, loose, wet, dry, etc.)

h. Origination zone

i. Percent of path involved

j. Avalanches which halt before reaching road

k. Other observations of interest

Immediate, accurate reports of avalanches may indicate possible or imminent hazards elsewhere in the forecasting region, as well as possibility of future avalanches at the same location later in the season. In the long term a comprehensive avalanche history permits more effective hazard evaluation and control at that location.

5. Snowpack observations should be performed by experienced observers and should include:

a. Snow depth

b. Character of old snow surface

c. Layers within the pack

d. State of metamorphism of individual layers

e. Ram penetration

f. Other observations of interest

COMMUNICATION REQUIREMENTS

Data should be communicated from all observation points to the central forecaster's office as swiftly and directly as possible, using whatever systems are available (commercial telephone, SCAN line and FTS line systems, NWS teletype, other teletype, WSDH radio system, radio-telephone patch-over, or even direct telemetry from remote locations to selected receiving points).

In all cases, the philosophy of communications planning and scheduling must be to simplify communication mechanics so that reporting is swift and convenient, and that the process causes minimum interference to other work loads.

DATA REPORTING METHODS

All highway, ski area, and National Park Service reporting stations except White Pass currently report weather data on NWS or USFS standard data forms. These standard forms show all the data needed by the avalanche forecasting network.

Special WSDH reporting forms are needed only for White Pass and Mission Ridge. The standard form does not fit White Pass's needs, and Mission Ridge's reliance on indirect communication requires a simpler form with spaces only for information reported by that station.

The network center should use a form showing information needed by the forecaster to evaluate weather characteristics and forecast impending weather developments and resultant avalanche hazard. This form does not include all information used at the Passes to determine precise timing and sequence of control activities.

Communications schedules described in the consultant's report appended to this document were developed around the existing capabilities and schedules at the reporting stations. Some stations will report daily or twice daily, while others will report more often. Avalanche control personnel at Stevens and Snoqualmie Passes will report and receive information round-the-clock during avalanche hazard periods.

The data gathering-reporting-central forecasting system is a unique and vast cooperative effort. System scope is international in that Canada's Atmospheric Environment Service and the B.C. Department of Highways (BCDH) have offered to share their data. Management at the Crystal Mountain Ski area has offered to install telephone equipment at its live-in mountaintop station so the central forecaster can obtain data during evening hours. These direct communications complement and reinforce telemetry systems (and their technical problems) and enhance overall reporting system capability.

RECOMMENDED DATA REPORTING NETWORK

This section describes the data and equipment available and/or needed at the reporting stations. The listing is very brief and not necessarily complete. The consultant's report in the Appendix provides a more detailed discussion of the network.

1. The USFS Guard Station in the Mt. Baker Ski area currently has instrumentation to measure wind force and direction; maximum and minimum temperatures with some data telemetered from a Study Plot at 4000 feet elevation; and both telemetered and Study Plot precipitation data. Precipitation readings from Glacier are telemetered directly to NWS in Seattle. A pressure recording microbarograph at the ski area is not telemetered. Instrumentation at this location is adequate for avalanche hazard forecasting system needs, with the possible exception of a faulty tele-temp system which should be inspected and replaced if necessary. Data from this location is not easily available at all times. Communication should be improved to make data available to the network seven days a week.

2. WSDH observers at Washington Pass presently provide information on wind force and direction, temperature, precipitation, and barometric pressure. This instrumentation is adequate for the avalanche hazard forecasting system.

3. WSDH observers at Stevens Pass provide data on wind force and direction, temperature, precipitation, and barometric pressure. Some of the equipment in use belongs to the Forest Service. A renovated WSDH maintenance garage used during FY 75 is scheduled for demolition. Recording apparatus should be installed in a new structure at the summit which would also serve as an office and minimum overnight accommodations for the avalanche crew. SCAN phone and WSDH radio should be installed at the new structure, and Berne radio and telephone should be manned around the clock.

4. USFS and ski area observers at Mission Ridge currently provide information on wind force and direction, temperature, and precipitation. Icing problems affect the wind information, and communications are limited.

5. WSDH observers at Snoqualmie Pass provide information on wind direction and force, temperature, precipitation, and barometric pressure. Communications at this site are excellent. A new Standard Weather Bureau weather shelter with a recording thermograph and two sets of maxi-mini thermometers should be installed along with a SCAN telephone at the summit observation station.

6. USFS and ski area personnel at Crystal Mountain currently provide data on wind force and direction, temperature, and precipitation. All data (except wind data) is gathered at Snow Study Plots, which limits availability. Additional telemetry would increase the value of this data. Additional instrumentation at the summit house (elev. 6800 feet) to record wind and temperature data while it is unoccupied would increase the value of evening reports available from this location.

The ski area management has offered to install commercial telephone service at Summit House to facilitate evening communication with the network.

7. National Park Service observers at Paradise, in Mt. Rainier National Park now provide temperature and precipitation data from a Snow Study Plot. This location is highly desirable as an observation site. Additional equipment required includes telemetered wind force and direction data, a thermistor and recorder, and an automatic weighing precipitation gauge and recorder at the Study Plot, and recorders for the thermistor and precipitation gauge in Ranger Headquarters.

8. No weather observation data is now available from White Pass. In order to provide temperature, precipitation, and avalanche occurrence data, a Snow Study Plot with standard snow stakes, 8-inch can with stand and weighing scale, a weather shelter with maxi-mini and current thermometers should be established along with a recording thermograph installed in the WSDH Maintenance station. WSDH personnel would act as observers.

9. No data is presently available from Olympic National Park. Wind, temperature and precipitation observations telemetered from Hurricane Ridge would be extremely valuable to the network and should be given highest priority. Equipment needed includes telemetering wind force and direction sensors (with heat lamps), thermistor, and precipitation gauge, as well as standard Snow Study Plot and weather shelter with mini-maxi and current thermometers—all to be installed at Hurricane Ridge, with recorders at Park Headquarters. A recording microbarograph should also be installed at Park Headquarters. Avalanche occurrence reports should be made at all locations mentioned in (1) through (9). Detailed recommendations for these reports are included in the consultant's report (Appendix).

10. Atmospheric Environment Service (AES), the Canadian counterpart of NWS, has kindly agreed to make desired data available to the network via Canadian and U.S. weather teletype systems. Daily weather observations provided to AES by the British Columbia Department of Highways (BCDH) will broaden the network data base, along with observations from western British Columbia reporting stations and Vancouver Island.

11. The U.S. Geological Survey maintains several remote telemetry locations in western Washington which could provide valuable data to the network. All system data is available twice daily on NWS teletype. Only temperature data is now available, but remote telemetering precipitation gauges are scheduled for some stations.

12. Department of Agriculture Soil Conservation Service is installing forty remote telemetry stations in Washington. A number of these sites will provide data valuable to the network, including some which will provide wind force and direction and precipitation data, in addition to temperature.

13. There is currently no source of high elevation temperature data from south-western Washington. A remote telemetering temperature sensor station located at about 8000 feet elevation on Mt. St. Helens could provide substantial warning of temperature inversions and overall rising

temperatures in the Cascades. Data could be transmitted by radio directly to NWS and thence, to the forecaster's office.

SNOQUALMIE PASS OPERATIONS

FY 75 winter operations began in September 1974 with three weeks of repairing existing equipment installations, along with installing newly designed and built instrument mounts at remote sites. The old maintenance garage at Snoqualmie Summit was converted into a comfortable, efficient office. A simple cot and sleeping bag made night observations possible without large overtime expenditure.

Except for one remote temperature recorder, all observation equipment is wired into, stored in, or installed within a 100 foot walk of the office door. Base data collected during FY 75 operations is contained in WSDH files.

The FY 75 avalanche observation team was made up of two observers, using some ingenious working schedules to insure maximum coverage with minimum overtime. Two people can adequately collect basic weather data, but much more could be done with more personnel. It was impossible to man the high elevation Snow Study Plot for coordination with low elevation data collections; to determine effects of certain wind conditions in the starting zones; or to make post-avalanche observation of stratification in recently released avalanches to compare with conclusions based on weather-period plots. When avalanche control measures begin, one additional person is essential—two new people would be most desirable.

Observation equipment functioned well and proved adequate to the task. The only additional need was for hand held portable radios.

Some equipment shifts are expected. When the East Snowshed hazard is bridged, the temperature system there can be reinstalled at the 5600 foot level of Denny Mountain. Alpental Ski Area management has offered to make wire for this installation available in return for use of the data.

Weather information from NWS, in Seattle was sent by teletype to WSDH Station 10 twice daily, then relayed to station 58 at Snoqualmie Pass and station 28 at Stevens Pass. This information is rather general, and in periods of special interest, the Snoqualmie Pass avalanche crew called NWS for further information and passed it on to the Stevens Pass crew. This system was simple and effective. Information received was enough for observation scheduling, and in addition provided the means to anticipate avalanches and provide advance warning of significant snowfall to aid maintenance crew operations.

Weather conditions in mountain areas take a heavy toll of equipment and telemetry wiring. Considerable repair and protection is required in this area for future operations.

A small powder magazine should be built atop the East Snowshed slide path to eliminate hand-carrying explosives on steep terrain in difficult conditions. Such a structure and a small emergency shelter can be easily built, inspected, and licensed.

All important avalanche paths should be inspected during the warmer seasons, making notes and diagrams to study conditions fostering avalanches and indicate how to control them.

The avalanche crew anticipates working with the University of Washington on equipment installations if the University is awarded the avalanche research study contract for Phase II.

AVALANCHE CONTROL EFFICIENCY AT STEVENS PASS

Stevens Pass control activities during FY 75 were analyzed according to parameters developed in FY 74. A brief description and some comments are included in this section. Control efficiency was calculated separately for each of the three major avalanche areas. Base data used for these calculations is contained in WSDH files.

1. In the "Old Faithful" avalanche area, with a total of 30 known natural avalanches, 12 reached the highway and ten of these blocked the highway. Of 114 known artificially induced avalanches, 36 reached the highway, of which 22 blocked it. These are all the avalanches actually observed and recorded. The chance of error in the total number of both known and artifically induced avalanches is high due to poor visibility in starting zones. The values for avalanches reaching the highway are reasonably accurate, since they were observed directly from the involved highway. Of the total 144 avalanches observed, 114 or 79 percent were artificially induced. 75 percent of the avalanches reaching the highway were artificially induced, and 69 percent of the avalanches which blocked the highway were artificially induced.

2. In the Tunnel Point area (upper-middle-lower) two of six known natural avalanches reached the highway–neither blocked it. Six of 17 known artificial avalanches reached the highway–none blocked it. 74 percent of avalanches observed and recorded were artificially induced, as were 67 percent of the avalanches reaching the highway. No natural or artificial avalanches blocked the highway during the study period.

3. In the "Pole Pile" avalanche area, two of eight natural avalanches reached the highway, and both blocked it. Of 18 known artificial avalanches, five reached the highway, but none blocked it. 69 percent of all known avalanches were artificially induced, and 71 percent of avalanches reaching the highway were artificial. No artificially induced avalanches blocked the highway. Compared to FY 74, in all three areas, a higher percentage of observed avalanches and avalanches reaching the highway were man-made. The percentage of artificial avalanches blocking the highway was higher at "Old Faithful," while there were no blockages at either Tunnel Point or "Pole Pile" in FY 75.

SUMMARY OF FY 75 PERCENTAGES

	Old Faithful	Tunnel Point	Pole Pile
Artificial avalanches / Total avalanches	79%	75%	69%
Artificial avalanches reaching highway / Total avalanches reaching highway	75%	67%	71%
Artificial avalanches blocking highway / Total avalanches blocking highway	69%	0%	0%

The percentages do not accurately reflect program efficiency. For example, if in a particular winter three natural avalanches and twenty five artificial avalanches block the highway—each blockage causing a four hour road closure—the effective percentage for artificial versus natural closure would be 25/28 or 89% with a total road closure of 112 hours. 89 percent indicates quite good forecasting, but no one appreciates twenty eight four-hour closures. If, instead, for the same winter, forecasting were good enough to reduce the natural occurrences to two four-hour closures and reduce the artificial blockages to three four-hour closures, while the number of avalanches just reaching the highway or blocking two or three lanes increased to eighty with an average thirty minute delay, efficiency would be 60% with five closures totaling 20 hours and eighty 30-minute closures, totaling 40 hours.

Sixty percent effectiveness is not impressive, but of the eighty five closures, eighty would be only thirty minutes long. A thirty minute traffic delay has much less adverse impact than a four-hour closure.

FY 75 control emphasis was placed on the most critical avalanche area, "Old Faithful," eight critical avalanche paths which affect nearly 3000 feet of highway. Combined control results using hand explosives and artillery were good.

Indicated percentages were 79, 75, and 69 percent. If the ratio of artifically induced avalanches can be improved to around 90 percent with about 85 percent of avalanches reaching the highway man-induced, the number of natural or artificial avalanches blocking the highway should be reduced to the point where the natural vs. man-made percentage won't matter.

Perhaps program effectiveness can be determined by another means, catergorizing all avalanche occurrences into three types.

1. Active control measures—avalanche control missions—designated the most effective means to stabilize critical avalanche areas—based on a good avalanche forecast.

2. Passive control measures—monitoring critical avalanche areas without active control—this method was used when traffic was light, manpower at a minimum unless put on overtime, or when equipment problems prevented a control mission—natural activity anticipated.

3. Natural avalanche occurrence—actual uncontrolled avalanches that either hit or blocked the highway with no hazard forecast and no control measure anticipated. During FY 75 winter in the "Old Faithful" area there were:

A = Total active control measures = 23

B = Total passive control measures = 10

C = Total natural avalanche occurrences = 5

Avalanche control effectiveness using these parameters was:

$$\frac{\text{Total Control Measures}}{\text{Total Occurrences}} = \frac{33}{38} \text{ or } 87\%$$

Obviously, various values and formulae produce different effectiveness percentages. The program's overall goal must be to provide maximum safety to the highway user and to minimize the number and duration of long term closures. This may mean increasing the number of short traffic delays due to stepped-up control missions.

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APPENDIX

A WEATHER OBSERVATION AND REPORTING NETWORK
FOR PREDICTION OF AVALANCHE HAZARD CONDITIONS
IN THE CASCADE MOUNTAINS OF WASHINGTON STATE

May 1975

Agreement #Y 1687

Prepared for Washington State Highway Commission, Department of Highways, in cooperation with U.S. Department of Transportation, Federal Highway Administration

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16. Abstract

Describes weather observations used in avalanche hazard forecasting. Describes instrumentation used in weather observations and methods of data recording and transmission.

Recommends weather data acquisition at specific sites and methods and scheduling of transmission of acquired data to a central point for analysis.

Recommends analysis procedures and procedures for transmission of forecasts to the field.

17. Key Words
Avalanche hazard, Weather, Weather Observations, Wind, Temperature, Precipitation, Data reporting, Avalanche Hazard Forecasting, Communications

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HWY FORM 341-004 6/72

TABLE OF CONTENTS

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

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Introduction

This report is prepared in performance of Agreement Y-1687. The Project Assignment as defined in the Agreement is:

> "Establishment of the basic data requirements necessary for the establishment of an avalanche data system and the development of an avalanche prediction system on the mountain passes listed herein. The Consultant shall determine the following with regard to each such individual mountain pass:
>
> 1. Specific data required for avalanche prediction.
> 2. Equipment required to obtain data.
> 3. Personnel required.
> 4. Communications requirements including types and various methods of communication.
> 5. Data reporting formats consistent with objective of avalanche prediction reflecting source of information, schedules for analysis, correlation of weather data, and all other information deemed necessary by the Consultant.
> 6. Establishment of schedules for analysis and correlation of data gathered culminating in formulation of avalanche forecasts for specific zones.
>
> The mountain passes concerned under this agreement are as follows: Washington Pass, Stevens Pass, Snoqualmie Pass, Chinook Pass, and White Pass."

Discussions and field work necessary to accomplishment of the project, including formulation of this report, were performed during April and May, 1975, at various locations throughout the State and at the writer's office. Various public agencies and private entities who could provide information necessary to accomplishment of the Department objective were interviewed. Tentative working arrangements with these entities were arrived at in principle: these tentative arrangements are defined in the body of this report. All such arrangements must be formally concluded by the Department. In recognition of lead time required for formalizing agreements with other public agencies, it is recommended that formal requests for information and/or specific services be initiated with appropriate dispatch.

Discussion

A. Weather observation data

Weather observation data used in formulation of avalanche hazard forecasts fall into three vital, basic categories;

1. Air temperature
2. Wind
3. Precipitation

Two other items are vital to ultimate sophistication of avalanche hazard forecasts;

4. Avalanche occurrences
5. Studies of the snow pack

Implications of these data are briefly described in the following pages, together with generalized descriptions of methods of observing and compiling the data.

1. Air temperature

   a. Daily: minimum, maximum

   b. At observations: current temperature

   Air temperature relates to: falling snow crystal types; propensity for slab formation in falling snow; strength of snow on the ground; and metamorphic processes within the snow pack. Of particular concern in the Northwest is the storm which deposits substantial amounts of new snow while temperatures are well below the freeze point followed by rain or very wet snow caused by a significant rise in temperature.

   Equipment used in temperature observations:

   At Snow Study Plot:

   Minimum-maximum-current thermometers, various types

   Recording thermograph, usually clock-driven drum with 7-day chart

   Usually from distant points, occasionally from Snow Study Plots:

   Remote telemetry: various types, thermistor predominates usually telemetered by wire, can be radio telemetered

2. Wind force and direction

   At observations: current force and direction. If recording instrumentation is available, periodic readings and significant peak velocity periods, plus variations in direction are also noted.

   Wind force relates to the amount and intensity of snow deposition in avalanche starting zones and tracks. Amount of deposition is estimated through a correlation of observed wind forces and snow depositions observed at Snow Study Plots. Strong winds can mean snow depositions in starting zones many times greater than Study Plot depositions. A rule of thumb could be cited here: the stronger the wind, the more snow in the starting zones.

The rule of thumb also applies at times during clear weather. When unconsolidated snow is available on the surface at high elevations, strong winds can transport large amounts of snow from windward slopes to leeward slopes. If winds are of sufficient force and there is sufficient snow available, blizzard conditions will prevail at locations selected by the wind and terrain. Wind force also relates to potential slab formation within deposited snow. (Slab avalanches constitute one of the more serious avalanche hazards.)

Wind direction tells the avalanche forecaster where the snow is being deposited. This holds true during precipitation periods and during windy clear weather periods. Thus, wind direction is a prime indicator of which avalanche zones or paths are "loading up". (Normal storm winds from the southwest load north and east-facing slopes while scouring south and west-facing slopes. A 90° wind shift to the southeast would load north and west-facing slopes.)

Equipment used in wind observations:
Available equipment is limited at this time to these well-known types: Cup anemometer for wind force, and vane for wind direction. This equipment is most informative if installed at high unobstructed points: however, at such points the equipment frequently becomes coated with heavy storm-borne rime deposits. The rime deposits may cause the anemometer and vane to give inaccurate readings; may render the equipment inoperable until the rime is cleaned off; or may tear the equipment apart. Thus, when installed at the most advantageous points, the equipment is most difficult to maintain and is likely to be rendered unreliable at times of greatest need: During snow storms. Heat lamps of various types are used to discourage rime deposits on wind equipment. The lamps are, at very best, only moderately successful on the West Coast.

At this time, Mr. Phil Taylor of the University of Washington is experimenting with a different concept of wind observation and recording which may lead to resolution of the riming problem. The experiments should be encouraged and pursued.

3. Precipitation

Observed daily, sometimes twice daily, at Snow Study Plots. Also at shorter intervals during peri ds of interest.

Precipitation, whether snow or rain, relates directly to the amount and type of load applied to the old snow surface. Intensity of the loading is a major factor of interest. High intensities lead quickly to high avalanche hazard.

Density (water content) of newfallen snow relates directly to the load factor. High densities mean heavy loading plus the liklihood of slab formation. These factors lead generally to high avalanche hazard if sufficient precipitation is deposited.

Rain falling on snow constitutes application of load, weakens the snow structure by warming, and may cause lubrication of a buried impermeable layer within the pack. The effect of rainfall on snow will vary with the amount and temperature of the falling rain. The effect will vary also with the character of the snow the rain falls upon. For example: a small amount of rain on unconsolidated new snow may mean rapid development of avalanche hazard. Greater amounts of rain are required to create hazard in well-consolidated old snow.

Equipment in standard use in observations of precipitation:

At Snow Study Plots:
- Standard snow stake and snow board
- Core sampler and weighing or measuring devices
- Rain can
- Recording precipitation gauge
- Snow pillow

At Remote Locations: Recording precipitation gauge
Snow pillow

Experience shows that the most accurate system for measuring snowfall is the well-tended Snow Study Plot using standard stakes and snow boards from which snow density is calculated. Precipitation intensity is also measured at the Snow Study Plot, by means of short interval snow boards.

Recording precipitation gauges can, in selected locations and under many conditions, provide valuable precipitation data. Their efficiency is adversely affected by strong wind and by buildup of snow on the gauge orifice. Where these problems can be overcome, the gauge is particularly useful in automatically recording precipitation intensity. Data can be recorded on a clock-driven drum chart or can be telemetered to a distant recorder.

4. Avalanche occurrence observations
These observations are made in the field. The value of the observations varies with the degree of precision. The following factors are valuable components of a reported avalanche occurrence:
   a. Location (name of avalanche path)
   b. Time of occurrence, estimated if not witnessed.
      Example: time estimate could be based on report by highway maintenance personnel who drives from point A to point B in one half hour, then, while returning to A, observes fresh avalanche debris in roadway.
   c. Size of avalanche
      Roadway situation: estimated depth of deposition at inside cut and at outside cut or birm; estimated breadth of deposition in roadway; distance avalanche travelled (did it stop in the roadway or did it travel beyond roadway?)
   d. Solid debris involved
      Does avalanche deposition contain solid debris? Tree limbs, whole trees, rocks?

e. Damage

To vehicles, structures, persons.

f. Avalanche trigger

Natural, artificial. (Artificial would include explosives, artillery, skier, hiker, snowmobile, animal.)

The above observations can be effectively made by persons with minimum training. Experienced observers will also include the following useful information if visibility allows:

g. Classification of avalanche

Slab (hard or soft), loose, dry, wet, other factors
If slab, depth of fracture

h. Origination zone

i. Percent of path involved

j. Avalanches which halt before reaching road

k. Other observations of interest

These observations are of both immediate and long-term interest to the avalanche hazard forecaster:

Immediately, well-defined observations of avalanche occurrences may provide clear indication of incipient or imminent hazard elsewhere. In the near term, knowledge of avalanche occurrences at specific sites allows sophisticated evaluation of the degree of potential hazard at these sites at later dates during the same season. In the longer term, comprehensive history of a site allows formulation of specific criteria for use in hazard evaluation and control of that site.

Avalanche occurrences will be reported by Highway Department personnel, Forest Service Snow Rangers, ski patrol personnel, National Park Service personnel, other contributing entities, the general public, and news media.

Where active avalanche control programs are in progress, most avalanches reported will be artificially triggered. At other locations, most reports will be of avalanches that were triggered by natural causes.

The preceding observations are quantitative. They variously lend themselves to reporting from widely scattered locations by personnel of varied interests and degrees of expertise or training. They are acceptably transmitted through an intermediary, although direct communication between observer and recorder is preferable.

The following observations are basically qualitative: some are even subjective. A high degree of understanding of snow is necessary to useful reporting of these observations. Where possible, direct communication between observer and recorder/forecaster is extremely desirable.

5. Snowpack observations

Numerous snowpack observations performed by experienced observers are used in avalanche hazard evaluation in conjunction with the observations listed in items 1, 2, 3, and 4. Snowpack observations include:

a. Snow depth
b. Character of old snow surface
c. Layers within the pack
d. State of metamorphism of individual leyers
e. Ram penetration
f. Other

B. Mechanics of communication

Timely communication of data from many distant observers to the forecaster necessitates the use of numerous forms of communications equipment and systems including commercial telephone (Comtel), SCAN line and FTS line systems, National Weather Service teletype system, teletype transmissions via international routings, the Highway Department radio system, radio-telephone patch-over, and in several instances, radio telemetry from remote instruments directly to selected receiving points.

A concept basic to clarity and efficiency of any communications plan is that the actual communication be as swift and as direct as possible. This implies that this data reporting system should involve as few intermediaries as are necessary. Target design of this system, then, is for direct reporting from data source to the forecaster. However, where work schedules or technical limitations preclude direct reporting, intermediaries are programmed to relay objective data.

An elementary but necessary consideration in formulation of the reporting system is the time-availability of certain observers at communications points. Certain cooperating observers' work schedules allow them only minutes at a telephone or radio point at times that cannot be standardized. These observers must be programmed to render their reports at times convenient to them: therefore these observers must initiate the communication--in most cases, by commercial telephone.

In circumstances in which the observer will remain at a communications point for identifiable time periods after performing his observations, or where a reliable intermediary such as a secretary or radio operator will be on duty and can relay the data, the communication may be initiated by the forecaster at a time convenient to him.

A large proportion of the data observations are performed and will be scheduled for reporting within a relatively short time span. In order to minimize interference with the work schedules of those observers whose time at communications points is limited and is not identifiable, the Forecaster's office must be able to receive at least two incoming calls simultaneously: one directly to the Forecaster, another could be to a recording device.

Where WSDH personnel are reporting, use of the Department radio system will allow direct communication between Forecaster and most key points. It is anticipated that, during periods of particular interest, the Forecaster will converse very frequently with personnel in the field. This will be possible via a patch line: Forecaster-Station 10-observer mobile set. This capability apparently does not extend at present to the White Pass area due to technical limitations. Until this limitation is resolved, Forecaster-White Pass communications must be relayed via Yakima or Chehalis.

A cooperative arrangement for exchange of information with the Atmospheric Environment Service of Canada and the British Columbia Department of Highways has been discussed and tentatively arranged. A formal request initiated by the Washington State Department of Highways is now in order. Upon conclusion of the cooperative arrangement, information from Vancouver will be routed via teletype: Vancouver-Toronto-Washington D.C.-Seattle, and presumably, in the reverse sequence. This exchange should be beneficial to all participants.

In all cases, the philosophy used in formulation of the communications plan and schedule in this report is that the mechanic of communication and data reporting must be simple, swift, and convenient so that the process causes minimum interference to other work loads.

C. Data reporting forms

All highway, ski area, and National Park Service reporting stations except White Pass currently report weather data to the National Weather Service (NWS) or to the Forest Service using standard data forms issued by those agencies. These forms show all data needed by the network. It is not the intent of the network to add to the burden of paperwork.

Specialized WSDH reporting forms are recommended for only two reporting stations: White Pass and Mission Ridge. The standard form does not fit White Pass's needs. Mission Ridge must rely upon indirect communication, therefore needs a simpler form. Reliability in indirect communication is best obtained by simplicity. These individual forms contain spaces for only that information reported by the individual station. This system allows use of the form as a checklist to insure that all programmed data is included with each reporting and avoids use of a ponderous all-inclusive form at a station that reports only a few items.

The form recommended for use at the network center includes information needed by the central forecaster for his evaluation of weather developments and for forecasts of impending weather developments and resultant avalanche hazard. The form does not include all information which will be utilized at the Passes to determine precise timing and sequence of control activities.

The large data recording form recommended for use at the forecasting headquarters allows for ease in recording and ready reference in data correlation. For example: temperatures recorded on a time basis from various reporting stations can be compared one to the other at a glance, allowing rapid assimilation of changes and developing trends.

Personal preferences and work routines of various personnel will doubtless bring about revision of some of the formats, particularly at the central forecasting office. It is recommended that the principle of ready reference for rapid assimilation of information be retained in any future forms.

D. Timing of reports

Communications schedules are developed around discerned capabilities of the reporting entities. The stations are variously programmed for once daily, twice daily, and in some cases, more frequent reports, depending on data desired from the individual station and on availability of personnel. Avalanche control personnel at Stevens and Snoqualmie Passes will report and receive information around the clock during periods of incipient or of continuing avalanche hazard. During these same all-hours periods, reports of observed avalanche activity will be relayed from road maintenance crews to the central forecaster for corelation and evaluation.

Viewed as a whole, the data gathering-reporting-central forecasting system is a vast, cooperative, unique effort on the part of many contributing entities and persons. The system is international in scope in that the Atmospheric Environment Service of Canada and the British Columbia Department of Highways have freely extended the offer of whatever of their data WSDH desires. It is to be hoped that the exchange can be structured so as to be as beneficial to our Canadian neighbors as it will be to us.

Another example of the cooperative nature of this effort is at Crystal Mountain Ski Area. Here, management has offered to install telephone equipment at the ski area's expense at its live-in mountaintop station so that the central forecaster can obtain data during evening hours. Availability of data on such a basis complements and reinforces telemetered data sources, which are always subject to technical problems, and adds to the capability of the reporting system as a whole.

The Recommended Data Reporting Network

Existing data sources, additional data required, and recommended installations

Washington State Department of Highways Research Program Reports 8.4 (T. Fox) and 8.5 (M. Moore) discuss storm systems and other weather trends as they progress through Washington, and describe their effects on avalanche hazard from point to point. The data reporting network described in these pages is designed to supplement data already available through existing National Weather Service reporting stations in order to upgrade the central forecasting office's capability for short-term specific forecasts. An announced objective of this program is for the central forecaster to be able to provide four hours' warning of impending weather developments at specific points in the State.

Table 1 lists the recommended data network.
Table 2 is a summary of recommended installations.
Figure 1 shows geographic locations of data sources.

Data Sources

1. Mt. Baker Ski Area: U.S. Forest Service Guard Station, Weather observations and Avalanche Control Station

Data currently available, instrumentation in place:

Wind

Force and direction, telemetered from Panorama Dome, elev. 5000', to analog recorder at Guard Station

(1) anemometer and vane plus recorder

Temperature

Continuous readout telemetered from Study Plot, elev. 4000', to recorder in Guard Station

Standard minimum, maximum, and current readings at Study Plot

(1) thermistor, Yellow Springs recording system: This system apparently needs adjustment, possibly replacement

(1) weather shelter with thermometers

Precipitation

Continuous readout telemetered from Study Plot to recorder in Guard Station

Standard snow stakes at Study Plot

(1) weighing precipitation gauge and recorder

Also: (from Glacier) precipitation telemetered directly to NWS in Seattle from NWS precipitation gauge at Glacier Ranger Station

Barometric pressure-recording microbarograph at ski area (not telemetered)

Instrumentation at the site is adequate to the network's needs with the possible exception of the tele-temp system which should be inspected and replaced if necessary.

Availability of data from the site is currently limited. Weather observations at this site are performed by the Forest Service Snow Ranger on duty at the ski area only on Fridays, Saturdays, and Sundays of each week during the ski season (and holiday periods). Weather data for the balance of the week is needed for the network. The site is not served by telephone: radio is the sole method of communication at present.

Data desired from the area is available by radio to the network three days per week. To accumulate needed data on the balance of the weekdays there appear to be two alternatives:

1. Institute a radio telemetry system that would automatically transmit data from the Guard Station, where it is presently recorded, to the Ranger Station at Glacier. Unless unforseen technical difficulties present themselves, it is assumed that the telemetering vehicle could be the Forest Service radio system currently in use. The proposed system has been discussed in detail with Mr. Phil Taylor, Radio Technician, Department of Atmospheric Sciences, University of Washington, who gave the proposed system his tentative blessing, subject to his further investigation, including inspection of the radio equipment on site.
2. Perform the observations on site the balance of the week. This would require the services of a Forest Service employee for approximately one hour per day, four days a week. The District Ranger will make this service available if WSDH will fund those hours.

Of these alternatives, the first would provide the most timely and most reliable information on a daily all-weather basis. The second alternative is dependent on road availability and, doubtless, to some extent on the work load of the individual who will perform the observations. Those times of WSDH's greatest interest in weather data are precisely the times when access to the observation site is likely to be difficult, time consuming, or even unmanageable.

In the writer's opinion, alternative number one is the method of choice.

Discussions regarding the availability of information to the network were held with:

Mr. Robert Hetzer, District Ranger
Glacier Ranger Station
Glacier, Wn. 98244

and with:

Mr. Paul Frankenstein
Recreation Forester
Mt. Baker-Snoqualmie National Forest

A request for available data and for permission to accumulate data on a seven-day basis via one of the two alternatives presented should be addressed to: Mr. Robert Hetzer

Proposed data gathering-communications procedure and schedule: Mt. Baker

a. Data observations available at Glacier Ranger Station or at Guard Station
b. Observer-recorder: Snow Ranger or designate
c. Person reporting data to network: Snow Ranger or designate
d. Reporting schedule: 0815-1615
e. Communications link: Friday-Sunday: Forest Service radio to Shuksan Maintenance Station (WSDH), then WSDH radio Bellingham-Station 10-NWS. Calls initiated by Mt. Baker Guard Station
Monday-Thursday: SCAN-Comtel-call initiated at Seattle.

2. Washington Pass: WSDH observers

Data currently available, instrumentation in place:

Wind

Force and direction, telemetered from Cutthroat Ridge, elev. 6800', to recorder at Summit Station

Force and direction, telemetered from Summit of Washington Pass, elev. 5470', to recorder at Summit Station

(2) anemometers, (2) vanes, (2) recorders

Temperature

Temperature telemetered from Cutthroat Ridge to recorder at Summit Station

Temperature telemetered from Summit of Washington Pass to recorder at Summit Station

(2) thermistor-sensors, (2) recorders

Precipitation

Standard snow boards and stakes at Study Plot at Summit Station

Barometric pressure: recording microbarograph at Summit Station

Additional data, instrumentation required:

None

Proposed data gathering-communications procedure and schedule: Washington Pass

a. Data observations at Summit Station and Snow Study Plot
b. Observer-recorder: WSDH contractor
c. Person reporting data to network: WSDH contractor
d. Reporting schedule: 0700-1700 plus intervals during periods of interest
e. Communications link: WSDH radio via Station 10-Station 20-Washington Pass. Call initiated at Seattle

3. Stevens Pass: WSDH observers

Data currently available, instrumentation in place:

Wind

Force and direction telemetered from Skyline Ridge, elev. 4880', to recorder at Stevens Summit, elev. 4100', WSDH observation station (Schmidt Haus)

Force and direction telemetered from near upper terminal chairlift #5, elev. 4800', to recorder at Forest Service Guard Station, Stevens Summit

(2) anemometers, (2) vanes, (2) recorders. Note: recorders are at separate locations

Temperature

Temperature telemetered from upper end of Old Faithful avalanche zone, elev. 4660', to recorder at the highway near the avalanche zone

Temperature telemetered from upper terminal Big Chief lift, elev. 4840', to Forest Service Guard Station at summit (non-recording)

Foxboro thermograph at Schmidt Haus

Standard minimum, maximum, and current readings at Forest Service Guard Station Study Plot

(2) telemetering thermistor-sensors, (1) recorder, (1) dial readout

(1) Foxboro continuous recorder, (1) standard weather shelter with thermometers

Precipitation

Continuous readout telemetered from Study Plot to Forest Service Guard Station

Standard snow boards and stakes at Study Plot

Barometric pressure

(2) recording microbarographs, one at Summit, one at Berne

The observations system at Stevens Pass is composed of Forest Service and WSDH equipment. Most observations are performed by Department personnel, the balance being observed and recorded by Forest Service personnel. As the system now stands, a near sufficient amount of information is achieved, but only by dint of time-consuming travel from point to point to gather items of information. For example: In order to learn temperature for the previous six hours at Summit and Old Faithful, plus precipitation at Summit, the observer must visit Schmidt Haus, then the readout site near Old Faithful, then the Forest Service Study Plot. In the interest of efficiency, time, and manpower, these observations should all be available at a single location.

WSDH personnel intend to install two additional telemetering thermistors at high elevations just east and west of the Summit, with readouts at Summit and Berne Snow Camp. These installations will complete a comprehensive coverage of elevations at points critical to assessment of temperature inversions at the Pass area.

WSDH personnel also desire to install and use a new Snow Study Plot immediately west of the summit on the north side of the highway, for these reasons: 1. The Forest Service plot is overgrown by trees, does not give a representative snow catch; 2. The plot is intruded upon by skiers whose passage alters and confuses snow readings; and 3. All-hours observations at the plot by WSDH personnel disturb the sleep of the Snow Ranger at the Guard Station.

The completed system, including existing equipment and the proposed installations, will provide a sufficiency of information for the network's purposes.

The existing communications system does not include full-time manning of the radio and telephone at Berne. This lack results in inefficient use of avalanche crew manpower and equipment in a variety of operational situations. It also results in a frequent inability to communicate with avalanche personnel at critical times: i.e., when the needed personnel are off-duty and asleep in their rooms or are otherwise away from their radios. For maximum efficiency and safety, the communications system should operate on a 24-hour basis, as the avalanches do.

Recommendations:

1. Centralize snow studies and weather observations
   a. Install structure at summit capable of housing all recorders and of serving as office and minimum overnight accommodations for WSDH avalanche crew.
   b. Install all recording apparatus in new structure. This will require installation of cables from existing recording locations to the new structure. Temperature readout at Berne can remain in place.
   c. Relocate Snow Study Plot. Install standard stakes, weather shelter with thermometers, and precipitation gauge. Wire gauge to recorder in new structure. Relocate Foxboro recorder in new structure.
2. Communications requirements
   a. SCAN phone and WSDH radio at new summit structure
   b. 24-hour manning of Berne radio and telephone

Proposed data gathering-communications procedure and schedule: Stevens Pass

a. Data observations at Summit Station, Snow Study Plot, Berne
b. Observer-recorder: WSDH personnel
c. Person reporting data to network: WSDH personnel
d. Reporting schedule: 0545-1510 plus intervals during periods of interest. Note: this schedule ties in with Snowline reporting schedule: 0600-0850-1100-1520
e. Communications link: as convenient to situation. If avalanche hazard is incipient or present, direct communication via SCAN to NWS, or by WSDH radio to field mobile radio. If no avalanche hazard, Stevens Pass personnel may initiate call via SCAN to re-

corder at NWS. Calls may be initiated either by Stevens Pass or by Seattle personnel.

4. Mission Ridge Ski Area: Forest Service and ski area observers

Data currently available, instrumentation in place:

Wind

Force and direction, telemetered from upper terminal of Chinook Chair lift, elev. 6500', to base area

(1) anemometer, (1) vane, (1) recorder

Temperature

Recording thermograph at 6500' (non-telemetering)

Standard minimum, maximum, and current readings at Study Plot, elev. 4400'

(1) thermograph

(1) weather shelter with thermometers

Precipitation

Standard snow stakes at Study Plot

Data from this site may prove to be of marginal value to the network due to its geographic location and other factors. However, I recommend that data available here be analyzed for possible correlation with avalanche hazard periods influenced or engendered by air moving toward the passes from the northeast of from the southeast. If appropriate analysis shows that information from the site does not prove a valuable addition to other available reports, the use of Mission Ridge data could be discontinued.

Wind information from the site cannot be considered totally reliable due to rime deposits that frequently render the anemometer and vane at the site inoperable. Usual procedure at the area is for the lift attendant to clear the rime from the instruments at or about 0900 each day, after which a reliable wind reading is available for a period.

Communications with the site are limited at present to one commercial telephone line. Due to work schedules and other personnel factors at the ski area, observations data will not be reliably available to the network until 1100 each morning.

A further consideration in analysis of the usefulness of Mission Ridge observations is that equivalent data will be available from a nearby telemetering Soil Conservation Service station at elev. 5310'. The analysis should include consideration of the reliability and timeliness of each reporting site. Pending such analysis, my recommendation is for the following procedure:

a. Data observations and transmission to communications point at base of area
b. Observer-recorder: Snow Ranger and/or ski area personnel
c. Person reporting data to network: ski area ticket department personnel (these are only personnel reliably at telephone)
d. Reporting schedule: 1100
e. Communications link: SCAN-Comtel. Calls initiated at Seattle.

Discussions regarding the availability of information to the network were held with:

Mr. Walter Hampton
Mission Ridge
P.O. Box 542
Wenatchee, Wn. 98801

and with:

Mr. Charles F. Banko, District Ranger
Leavenworth Ranger Station
Leavenworth, Wn.

Requests for data per the above procedure and schedule should be addressed to Mr. Hampton and to Mr. Banko.

5. Snoqualmie Pass: WSDH observers

Data currently available, instrumentation in place:

Wind

Force and direction telemetered from a tower at elev. 3800' to recorder at Snoqualmie Summit observation station

(1) anemometer, (1) vane, (1) recorder

Temperature

a. Continuous readout telemetered from tower, elev. 3800', to recorder at summit observation station

b. Continuous readout telemetered from thermistor at elev. 3600' to recorder at east snow shed (This system is scheduled for removal when the roadway is relocated. It will be transferred to Denny Mountain, elev. 5600'.)

c. Minimum, maximum, and current readings at Study Plot at summit

Note: WSDH personnel advise these thermometers not reliable: should be replaced.

(2) thermistors, (2) recorders

Precipitation

Continuous readout telemetered from precipitation gauge at Study Plot to Forest Service Guard Station at summit

Standard snow stakes at Study Plot

(1) automatic precipitation gauge and recorder

Barometric pressure

(1) recording mibrobarograph at summit observation station

Communications are excellent. Hyak station is manned on a 24-hour basis during the snow season. WSDH radio, SCAN, and Comtel are located at Hyak.

Additional requirements:

(1) weather shelter (Standard Weather Bureau type)

(1) recording thermograph--clock-driven, with 7-day chart

(2) sets mini-max thermometers

SCAN telephone at summit observation station

Proposed data gathering-communications procedure and schedule: Snoqualmie Pass

a. Data observations at Summit Station and Snow Study Plot

b. Observer-recorder: WSDH personnel

c. Person reporting data to network: WSDH personnel

d. Reporting schedule: 0630-1630 plus intervals during periods of interest

e. Communications link: as at Stevens Pass: If avalanche hazard is incipient or present, direct communication via SCAN to NWS, or by WSDH radio to field mobile radio. If no avalanche hazard, Snoqualmie Pass personnel may initiate call via SCAN to recorder at NWS. Calls may be initiated either by Snoqualmie Pass or by Seattle personnel.

6. Crystal Mountain Ski Area: Forest Service and ski area personnel observers
   Data currently available, instrumentation in place:
   - Wind
     - Force and direction telemetered from Summit House, elev. 6800', to analog recorder at Forest Service Snow Ranger office
     - (1) anemometer, (1) vane, (1) recorder
   - Temperature
     - Standard minimum, maximum, and current readings at two study plots, elev. 4400' and 6400'
     - (2) weather shelters with (2) sets thermometers
   - Precipitation
     - (1) recording weighing precipitation gauge at Study Plot elev 4400'
     - (2) sets standard stakes at two study plots

The above weather observations system contains all basic data elements. However, all data except for wind data must be gathered at the snow study plots. Additional telemetry is required in order to achieve maximum benefit (in this case, more than one daily reading of all data) of information available here. Requirements here would be for installation of recording apparatus in the Snow Ranger office that will give continuous readouts of temperature and precipitation at the lower study plot.

In addition to the observations mentioned above, temperature and wind observations at Summit House, elev. 6800', are available during evening hours through the courtesy of the ski area management and of the full-time Summit House resident. Sole requirement for these observations would be installation of a recording Foxboro thermograph and a wind recorder or dial readout at Summit House. Area management has offered to install commercial telephone service at Summit House to facilitate evening hour communication with the network.

Installation of the recording instruments mentioned in the preceding paragraphs will make all key data elements available on a reliable, twice daily basis, plus interval readings of wind, temperature, and weather conditions at Summit House during lift operating hours and evening hours.

Installation of recording apparatus at Summit House will be extremely simple as the windsensors are located at the house. Approximately 1500' of wire is required for transmission of data from the lower snow study plot to the Snow Ranger office.

Summary of recommendations, Crystal Mountain:

Install:	Equipment	Location
1.	Foxboro recording thermograph	Summit House
2.	Analog wind recorder or non-recording dial readouts	Summit House
3.	Thermistor and recorder	Lower Study Plot to Snow Ranger office
4.	Precipitation gauge and recorder	Lower Study Plot to Snow Ranger office

Discussions regarding the availability of information to the network, and regarding installation of recommended equipment were held with:

Mr. Don Christiansen, Manager
Crystal Mountain Ski Area
Crystal Mountain, Wn.

Mr. Robert Anderson, Ski Patrol Leader
Crystal Mountain Ski Area

Mr. Lloyd McGahuey, Snow Ranger
White River Ranger District
Enumclaw, Wn.

Mr. Jim Krates, District Ranger
White River Ranger District
Enumclaw, Wn.

Mr. Paul Frankenstein
Recreation Forester
Mt. Baker-Snoqualmie National Forest

Requests for data and permission to install recommended equipment should be addressed to Mr. Christiansen and to Mr. Krates.

Proposed data gathering-communications procedure and schedule: Crystal Mountain

a. Data observations at Snow Ranger office
b. Observer-recorder: Snow Ranger or ski patrol
c. Person reporting data to network: Snow Ranger or ski patrol
d. Reporting schedule: ± 0800-0900, ± 1600-1700 (schedule cannot be defined precisely due to varying work requirements) plus interval readings from Summit House.
e. Communications link:
   1) Scheduled reports: will be called in from Crystal to Seattle
   2) Interval readings: SCAN-Comtel. Call initiated at Seattle at times of interest.

   An arrangement should be concluded with Crystal Mountain whereby toll charges incident to reports to the network will be paid by WSDH.

7. Mount Rainier National Park: National Park Service personnel observers
   Data currently available, instrumentation in place: (Paradise, elev. 5500')
   - Wind
     - None
   - Temperature
     - Standard minimum, maximum, and current readings at Study Plot
     - (1) weather shelter with thermometers
   - Precipitation
     - Standard snow stakes at Study Plot

   Paradise's geographic location plus the availability of Park Service personnel who will act as observers make Paradise a highly desirable observation station.

   Equipment requirements, Paradise:
   - a. Anemometer and vane with tower, and recorder
     Sensors installation adjacent to parking lot and Paradise Inn, recorder in Ranger Headquarters at Visitor Center
   - b. Thermistor and recorder
     Thermistor at Study Plot, recorder in Ranger Headquarters
   - c. Automatic weighing precipitation gauge and recorder at Study Plot, recorder in Ranger Headquarters

   All above telemetry can be by wire. Snow Study Plot is approximately 800' northwest of Ranger Headquarters: wind sensor site is approximately 900' east of Ranger Headquarters.

   Discussions regarding the availability of information to the network and regarding installation of recommended equipment were held with:

   Mr. Peter Thompson
   Visitor Protection Specialist
   Mt. Rainier National Park
   Longmire, Washington

   Mr. Thompson suggests that arrangements for the above installations and reporting of observations would best be accomplished by means of a Memo of Understanding, rather than by means of a Cooperative Agreement. Mr. Thompson's thinking, in this regard, is that a Memo of Understanding will allow that all arrangements be handled at the Park level. Mr. Thompson expressed a note of urgency in any negotiations of this nature: he stated that WSDH should institute its request as soon as possible so that procedures and installations can be in operation by the coming winter.

A request for data and permission to install recommended equipment should be addressed to: Mr. Daniel J. Tobin, Superintendent
Mt. Rainier National Park
Longmire, Washington

Proposed data gathering-communications procedure and schedule: Mt. Rainier National Park

a. Data observations at Paradise Ranger Headquarters
b. Observer-recorder: Park Ranger on duty
c. Person reporting data to network: Communications Clerk, Longmire
d. Reporting schedule: 0830-1530
   Note: Mr. Thompson stated that weekend afternoon reporting may be difficult at times.
e. Communications link: Park radio to Communications Clerk. SCAN-Comtel. Call will be initiated at Seattle.

8. White Pass: WSDH personnel observers

Data currently available, instrumentation in place:

None

Data required:

Temperature

Precipitation

Avalanche occurrence

Equipment requirements: at WSDH Maintenance Station, elev. (approx) 4300':

a. Weather shelter with minimum, maximum, and current reading thermometers installed at Snow Study Plot

b. Mount for weather shelter, tall enough to stand above maximum snow depth

c. Foxboro recording thermograph, installed in Maintenance Station

d. (3) standard snow stakes (24-hour, 8-hour, cumulative)

e. 8-inch can with stand and weighing scale

Proposed data gathering-communications procedure and schedule: White Pass

a. Data observations at WSDH Maintenance Station Snow Study Plot

b. Observer-recorder: Maintenance Supervisor or designate

c. Person reporting data to network: Communications clerk, Yakima Station 50

d. Reporting schedule: 0845-1545 plus intervals during periods of interest

e. Communications link: WSDH radio to Station 50, SCAN to Seattle. Call will normally be initiated by White Pass-Yakima. During periods of interest, Seattle may initiate calls.

9. Olympic National Park: National Park Service personnel observers

Data currently available, instrumentation in place:

None

Data desired:

Wind, temperature, and precipitation observations at Hurricane Ridge

Equipment requirements:

Equipment	Location for installation
Telemetering wind force and direction sensors with heat lamps	Hurricane Ridge
Telemetering thermistor	Hurricane Ridge
Telemetering precipitation gauge	Hurricane Ridge
Standard snow stakes, 8-inch can and weighing scale	Hurricane Ridge
Weather shelter with minimum, maximum, and current thermometers	Hurricane Ridge
Recorders for wind, temperature, precipitation	Park Headquarters
Recording microbarograph	Park Headquarters

Radio telemetry is required here. There is no telephone service to Hurricane Ridge and the road to the site is frequently closed due to weather conditions and avalanche hazard. As at Mt. Baker, it is assumed that the telemetering vehicle can be the Park Service radio system currently in use. Electrical power service to the site is reinforced by a standby deisel generator of more than adequate output. Adequate housing for telemetry apparatus is available.

It is anticipated that the recommended installation at Hurricane Ridge will prove a key source of data to the network. The recommended installation is, therefore, assigned highest priority.

Discussions regarding the availability of information to the network

were held with: Mr. Roger Allin, Superintendent
Olympic National Park
Port Angeles, Washington

A request for data and for permission to install the recommended system should be addressed to Superintendent Allin.

Proposed data gathering-communications procedure and schedule: Olympic National Park

a. Data observations at Park Headquarters
b. Observer-recorder: Park Ranger on duty or communications clerk
c. Person reporting data to network: Park Ranger or communications clerk
d. Reporting schedule: 0805-1605 plus intervals during periods of interest
e. Communications link: SCAN-Comtel. Call will be initiated at Seattle

Avalanche Occurrence Reports

Reports of avalanche occurrences from all the preceding reporting stations (numbered 1 through 9) are desired as follows:

Stevens, Snoqualmie, and Washington Passes presently submit monthly compilations of avalanche occurrences to the U. S. Forest Service and/or the University of Washington, Department of Atmospheric Sciences. Copies of these reports should be submitted to the central forecaster.

In Addition:

At the time of observation, the above Passes should report the location (name of slidepath), time of occurrence, aspect, and classification of the first observed avalanche of a hazard period to the central forecaster by SCAN or WSDH radio. Further avalanches occurring during the same hazard period should be reported to and discussed with the central forecaster at convenient times on a daily basis, after control activities, or when particularly interesting avalanche events occur.

White Pass at present employs no qualified avalanche observers. White Pass should submit the simplified monthly weather and avalanche summary included with this report, plus reports of the first observed occurrence of a hazard period and particularly interesting avalanche events as described in the preceding paragraph.

In addition, I propose incorporation, into the daily observations at the Passes, of the following daily WSDH Hazard Index to provide ready reference as to the degree of hazard experienced on a given date at the Passes.

WSDH Hazard Index

Code	Definition
a.	A few sluffs: No avalanches that would bury a car
b.	Many sluffs and/or 1 avalanche that would bury a car
c.	More than 1 avalanche that would bury a car
d.	More than 3 avalanches that would bury a car or 1 large destructive avalanche that would damage car and injure occupants
e.	More than 1 large destructive avalanche or an avalanche that deposits solid debris in road

The National Parks should be asked to report first avalanche observed, as mentioned in preceding paragraphs, plus interesting occurrences.

The ski areas will have performed avalanche control activities, when hazard is present, prior to reporting to the network. These reporters should be asked:

1. If natural avalanches occurred before control commenced
2. Aspects and ranges of sizes and types of natural occurrences, and numbers (few or many) of occurrences
3. Approximate number of artificially triggered slides, plus their range of aspects, sizes, and types
   (Note: ski areas will experience so many avalanches with their control activities that it would be unrealistic to report specific slides, hence the request for "range" only.)

Due to the necessity of an intermediary at Mission Ridge, a further simplification of avalanche data reports is recommended. (See Mission Ridge form).

10. Atmospheric Environment Service, a Division of Environment Canada
The Atmospheric Environment Service (AES) is the Canadian counterpart of the U.S. National Weather Service. AES has kindly agreed to make desired data available to the network via Canadian and U.S. weather teletype systems.

The British Columbia Department of Highways contributes daily weather observations to AES from three southern B.C. mountain passes. These data, which are in process of being expanded and sophisticated, will broaden the data base of the network.

Further, observations from western B.C. reporting stations, including Whistler Mountain Ski Area, elev. 6000', and Vancouver Island should prove of value in tracking and evaluating storms as they move south and east. AES advises that no reports of wind, temperature, or precipitation from the west coast of Vancouver Island are yet available, but are intended to be in the future.

Discussions regarding the availability of these data were held with:

Mr. G.H. Muttitt, Officer in Charge
Pacific Weather Central
416 Cowlie Crescent
Vancouver International Airport South
Vancouver, B.C.

and:

Mr. Thomas Gigliotti
Pacific Weather Central

and:

Mr. G. L. Freer, Senior Avalanche Coordinator
Department of Highways
Parliament Buildings
Victoria, B.C. V8V 2M3

Requests for data should be addressed to Mr. Muttitt and to Mr. Freer. Mr. Muttitt will require, as part of the request, a specific listing of desired data and appropriate "headings" to which the data should be addressed.

Mr. Freer will be interested in an exchange of data: he will address an appropriate request to WSDH in the near future.

Data desired:

a. Wind, temperature, precipitation, and barometric pressure as available from B.C. Highways observation stations at Allison Pass, elev. 4400', Fraser Canyon, elev. 450', and Kootenay Pass, elev. 5800'
b. Wind, temperature, precipitation, and barometric pressure from Whistler Mountain Ski Area
c. Wind, temperature, precipitation, and barometric pressure as available from the following southwestern B.C. stations: YUR, YYJ, YA2, YEP, YSQ, and YIW

Data will be issued in the form of a daily bulletin to the appropriate Seattle NWS teletype "heading".

11. U.S. Geological Survey, Department of Interior

The U.S. Geological Survey maintains a system of remote telemetry stations in western Washington. Most of these stations are located at relatively low elevations in drainage bottoms. Four of the stations are located at relatively high elevations near Baker Lake: these stations will provide valuable information to the network.

All of the system data is channelled into the NWS teletype, twice daily, is thus readily available to the network.

As of the dates of my contacts with USGS, only temperatures were reliably available at the four stations: however, USGS intends to install remote telemetering tipping bucket precipitation gauges equipped with propane heaters at three of the four stations. If these installations are successful, these data will also be channelled into NWS teletype.

Remote recording stations of interest:

Code	Name	Present data	Additional future data
12002	Easy Pass elev. 5200'	Temp.	Precip.
12003	Marten Lake elev.3600'	Temp.	--
12004	Schreiber Mdw. elev. 3400'	Temp.	Precip.
12005	Jasper Pass elev. 5400'	Temp.	Precip.

At this time, station readouts are programmed twice daily, 0300 and 1500, but can be programmed more often or can be interrogated on demand during USGS office hours at WSDH's request.

Discussions regarding availability of data were held with:

Mr. Robert Adsit, Electronics Technician
U.S. Geological Survey
Tacoma, Wn.

and:

Mr. John Cummans, Sub District Chief
U.S. Geological Survey
1305 Tacoma Ave. South
Tacoma, Wn. 98402

Mr. Cummans should be contacted to make known WSDH's use of these valuable data.

12. Soil Conservation Service, Department of Agriculture

The Soil Conservation Service is in the process of installing a system of forty remote telemetry stations in Washington. A number of the proposed sites will provide data of value to the network. Observations are programmed for daily readouts with hourly and on-call capability. Many of the proposed sites are scheduled to provide wind force and direction and precipitation in addition to temperature.

Five observation sites are scheduled for completion during 1975:

Site	Latitude	Longitude	Elevation	Data
Trough #2 (south of Wenatchee)	47° 14'	117° 23'	5310'	Wind, temp, precip
Surprise Lakes (Lewis R. drainage)	46° 06'	121° 45'	4250'	Wind, temp, precip
Lone Pine Shelter (Lewis R. drainage)	46° 16'	121° 58'	3800'	-- Temp, precip
Park Creek Ridge (Lake Chelan)	48° 27'	120° 55'	4600'	-- Temp, precip
Bumping Ridge (Bumping Lake)	46° 47'	121° 20'	4440'	-- Temp, precip

Sites of interest that are scheduled for future installations are:

Site	Latitude	Longitude	Elevation	Data
Quartz Mt. (near Bluet Pass)	47° 04'	121° 05'	6200'	Wind, temp
Steamboat Mt. (above Lewis R.)	46° 09'	121° 44'	5425'	Wind, temp
Tunk Mt. (north of Riverside)	48° 33'	119° 12'	6055'	Wind, temp
Hart's Pass (north of Mazama)	48° 43'	120° 39'	6500'	Wind, temp, precip

(cont.)

Site	Latitude	Longitude	Elevation	Data
Rainy Pass (Route 20)	48° 34'	120° 43'	4780'	Wind, temp, precip
Plains of Abraham (Mt. St. Helens)	46° 13'	122° 09'	4400'	-- Temp, precip
Corral Pass (above American R.)	47° 01'	121° 28'	6000'	-- Temp, precip
Lyman Lake (east of Holden)	48° 12'	120° 55'	5900'	-- Temp, precip

Discussions regarding availability of data were held with:

Mr. Robert T. Davis, Snow Survey Supervisor
Soil Conservation Service
Room 360, U.S. Courthouse
Spokane, Wn. 99201

A request for data should be addressed to Mr. Davis.

Proposed data gathering-communications procedure and schedule: Soil Conservation Service

a. Data observations and compilation at Spokane
b. Observer-recorder: SCS personnel
c. Person reporting data to network: SCS personnel
d. Reporting schedule: Indefinite at this time, must be arranged with Mr. Davis
e. Communications link: SCAN-Comtel. Call will be initiated at Seattle

13. Mount St. Helens: Remote telemetering station. Elevation circa 8000'

Analysis of the proposed network and of additional reporting stations scheduled for future installation by SCS reveals one important gap--a reporting of high elevation temperature fluctuations in southwestern Washington. Rising temperatures are frequently felt in southwestern Washington five to ten hours before northeast-moving warm air reaches the Passes. Round-the-clock temperature observations from this area could give substantial warning of temperature inversions and overall rising temperatures in the Cascades.

Recommendation:
Install a remote radio telemetering temperature sensor at circa 8000' on Mt. St. Helens. The installation could be located on a windswept prominence on the "Dog's Head" or "The Boot" from which line-of-sight transmission to Seattle is possible. Dr. E.R. LaChapelle advises that the data could be transmitted to an antenna at NWS, thence to a recorder or reading dial in the forecaster's office.

Equipment required:

(1) Remote telemetering installation, including sensor, transmitter, batteries, and housing

(1) Receiver-recorder at NWS

Discussions regarding the recommended installation were held with:

Mr. Roger L. Long, District Ranger
Mt. St. Helens Ranger District
Amboy, Washington 98601

and:

Mr. Jerry Hutchins
Gifford Pinchot National Forest
500 W. 12th St.
Vancouver, Washington 98660

A request for permission to install a telemetry system on Mt. St. Helens should be addressed to Mr. Long. Mr. Long views the WSDH network with approval and wishes to be included in the distribution list of warnings.

Schedule for Analysis and Correlation of Data: WSDH personnel, NWS, Seattle

Personnel required:

- Non-hazard periods
  - Meteorologist or assistant, one 8-hour shift per day
- Incipient hazard periods and continuing hazard periods
  - Meteorologist, assistant, alternating on duty. Suggest 12-hour shifts, overlapping by one hour. 24-hour coverage required.

Communications equipment required:

- SCAN telephone. Primarily for outgoing calls, with bell and blinking light signal, with switch to deactivate bell when desired.
- Comtel. Primarily for incoming calls, with bell, light and switch as above plus automatic answering-recorder attachment. Recorder attachment for use when WSDH personnel are not able to answer the call immediately.
- WSDH remote radio instrument, patched over to Station 10. Primarily for direct contact with WSDH avalanche personnel in the field. With bell, light, and switch as above.

Data inputs from the various network stations are structured around the normal work day at each station; therefore, the bulk of the reports will arrive at NWS shortly after 0800 and again toward the end of the working day, around 1600. Personnel at the reporting stations will respond to requests for data at intervals during the working day when and if they are available to communications and to their instrumentation. Reports from Washington, Stevens, and Snoqualmie Passes will commence at approximately 0600 during non-hazard periods and will be available on an around-the-clock basis during avalanche hazard periods.

USGS and SCS remote telemetering stations will provide valuable data. Performance capability of the individual stations must be identified and evaluated by the network meteorologist. All these sites can be interrogated on demand; can thus provide immediate data at desired times during USGS or SCS agency office hours.

A gap of some 16 hours is discerned, during which little information will be available to NWS from the network except during periods of incipient or continuing hazard. During these hazard periods, communications with the Passes will be nearly continuous.

The operating schedules of personnel at the network center must be weather-dependent, as are the schedules of all WSDH field personnel.

The following regimen for data collection, analysis, correlation, formulation of forecast, and communication to the field is proposed:

A. Non-hazard period

(No precipitation, no strong winds, no substantial temperature increases in previous twelve hours. Direct action avalanches not expected if status quo remains.)

1. 0600 Analyse NWS data and forecasts (this continues throughout day)
2. Call for, receive and record Stevens and Snoqualmie Pass inputs
3. Call for, receive and record inputs for balance of network except Mission Ridge

   Items 1 through 3 should be complete by 0900.

4. Note all inputs as symbols and/or numerically on chart for graphic representation
5. Analyse and correlate chart (Item 4) with NWS forecasts
6. Formulate specific weather and avalanche hazard forecasts
7. Disseminate forecasts in this order, commencing 1100 or earlier if critical:
   a. Stevens Pass
   b. Snoqualmie Pass
   c. White Pass
   d. Washington Pass
   e. Mt. Rainier National Park
   f. Olympic National Park
   g. Mt. Baker (Glacier Ranger District)
   h. Crystal Mountain Ski Area (Snow Ranger or patrol leader)
   i. Mission Ridge Ski Area (telephone clerk, thence to Snow Ranger or patrol leader)
   j. Mt. St. Helens Ranger District

k. Mt. Baker-Snoqualmie National Forest Headquarters, Seattle (Mr. Paul Frankenstein)

8. Teletype or telephone desired data to AES, Canada, and to B.C. Highways

B. Incipient or continuing hazard period

(Precipitation, strong winds, or substantial temperature increases imminent or in progress. Direct action avalanches expected.)

1. Network center manned 24 hours
2. Incoming NWS data and forecasts continuously analysed and correlated with network inputs
3. Specific weather and avalanche hazard forecasts updated and disseminated as they change. Emphasis and priority to Stevens, Snoqualmie, and White Passes
4. Operation continues until hazard period ends.

WSDH - Forest Service Avalanche Warnings

Mt. Baker-Snoqualmie National Forest Headquarters has been circulating Washington State avalanche warnings via radio, TV, and newspapers. The warnings issued have been of immense assistance to Snow Rangers, Park Rangers, and others concerned with public safety, and have had a profound effect on the public itself.

The Forest Service-issued warnings have been based on avalanche hazard forecasts that were of necessity less sophisticated than WSDH's network forecasts will be. WSDH network forecasts, utilizing more frequent data, from more reporting stations, could well be incorporated into the Forest Service warnings, or could be issued as a joint Forest Service-WSDH service.

Desirability of the above service has been discussed with:

Mr. Paul Frankenstein, Recreation Forester
Mt. Baker-Snoqualmie National Forest
Seattle, Washington

Mr. Frankenstein should be contacted regarding the suggested service.

Table 1

Recommended WSDH Weather and Avalanche Reporting Network

Data source	Agency
1. Mt. Baker Ski Area	U.S. Forest Service
2. Washington Pass	WSDH
3. Stevens Pass	WSDH
4. Mission Ridge Ski Area	Ski area/U.S. Forest Service
5. Snoqualmie Pass	WSDH
6. Crystal Mountain Ski Area	Ski area/U.S. Forest Service
7. Mt. Rainier National Park	National Park Service
8. White Pass	WSDH
9. Olympic National Park	National Park Service
Atmospheric Environment Service-Environment Canada	
10. British Columbia reporting stations on Vancouver Island and mainland coast	
British Columbia Department of Highways	
11. Kootenay Pass	
12. Allison Pass	
13. Fraser Canyon	
United States Geological Survey	
14. Schreiber Meadows	
15. Marten Lake	
16. Easy Pass	
17. Jasper Pass	
Soil Conservation Service, U.S. Department of Agriculture	
18. Park Creek Ridge	
19. Lone Pine Shelter	
20. Bumping Ridge	
21. Surprise Lakes	
22. Trough #2	
23. Mt. St. Helens	WSDH

Table 2

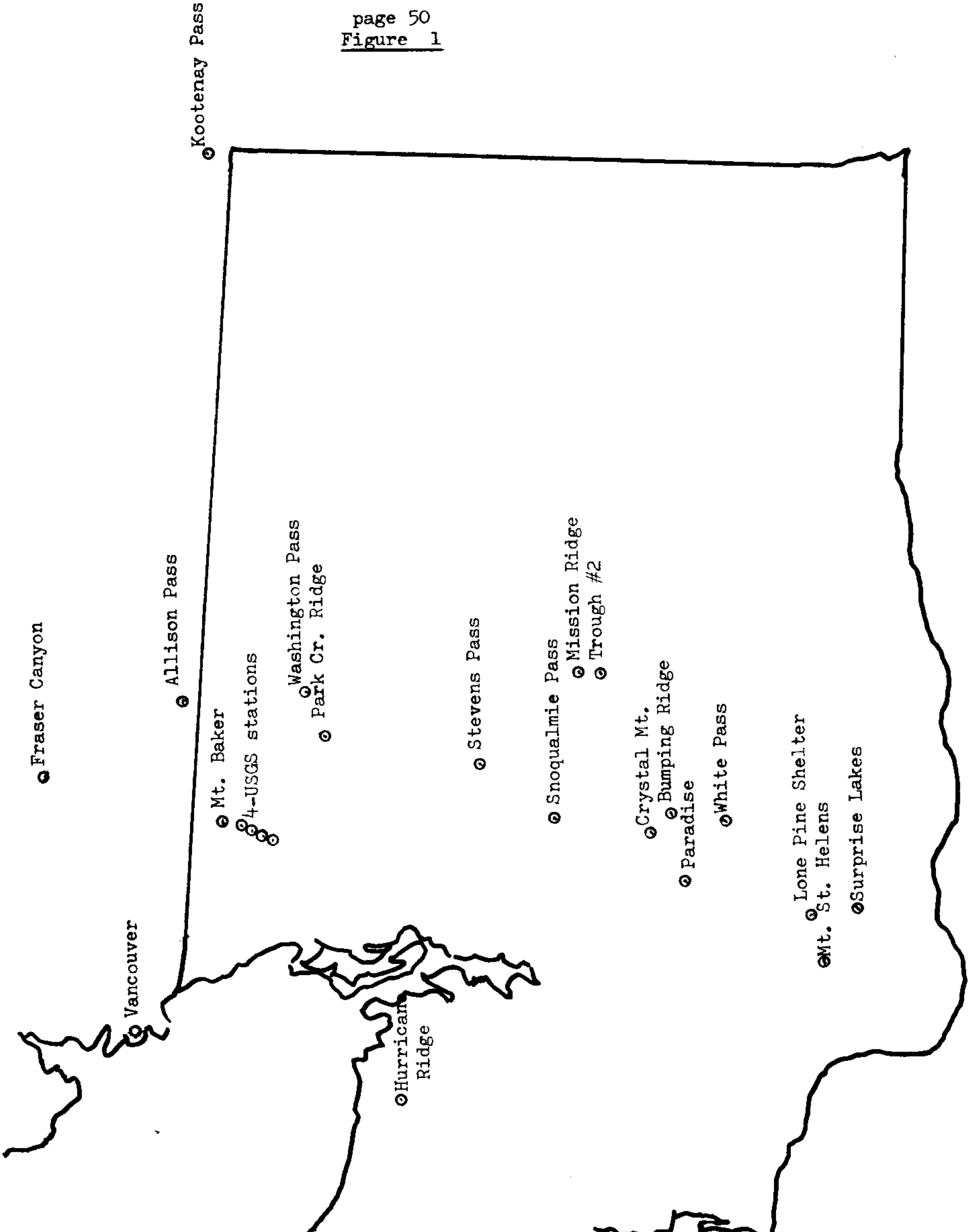
Summary of Recommended Installations Page one of two

Reporting station	Recommended equipment and installations
Mt. Baker	Radio telemetry system, Mt. Baker Guard Station to Glacier Ranger station
	Possible replacement of tele-temp system
Stevens Pass	Summit structure: office and minimum accommodation
	Install all recording apparatus in summit structure
	Relocate Snow Study Plot
	Install SCAN phone and WSDH radio in summit structure
	Precip. gauge and recorder
	Man Berne radio and telephone on 24-hour basis
Snoqualmie Pass	Weather shelter with thermometers
	Recording thermograph
	SCAN telephone and WSDH radio at summit station
Crystal Mountain	Foxboro recording thermograph
	Wind recorder or dial readout
	Thermistor and recorder, lower study plot to Snow Ranger office
	Precipitation gauge recorder, lower study plot to Snow Ranger office
Mt. Rainier National Park	Wind sensors with recorder
	Thermistor with recorder
	Precipitation gauge with recorder
White Pass	Weather shelter with thermometers and mount
	Foxboro recording thermograph
	Snow stakes
	8-inch can with stand and weighing scale

Summary of Recommended Installations, cont. Page two of two

Olympic National Park	Radio telemetry system, Hurricane Ridge to Park Headquarters
	Wind sensors with recorder
	Precipitation gauge with recorder
	Thermistor with recorder
	Snow stakes
	Weather shelter with thermometers
	Recording microbarograph
Mt. St. Helens	Radio telemetering temperature system

Figure 1


Kootenay Pass
Fraser Canyon
Allison Pass
Mt. Baker
4-USGS stations
Washington Pass
Park Cr. Ridge
Stevens Pass
Snoqualmie Pass
Mission Ridge
Trough #2
Crystal Mt.
Bumping Ridge
Paradise
White Pass
Lone Pine Shelter
Mt. St. Helens
Surprise Lakes
Vancouver
Hurricane Ridge