

THE ROCKFALL HAZARD RATING SYSTEM

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by:

Lawrence A. Pierson, C.E.G.
Chief Engineering Geologist

OREGON DEPARTMENT OF TRANSPORTATION

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<p>The development and dissemination of the Rockfall Hazard Rating System (RHRS) is complete. RHRS is intended to be a proactive tool that will allow transportation agencies to address rationally their rockfall hazards instead of simply reacting to rockfall accidents. The RHRS provides a defensible, standardized way to spend the limited construction funds available by numerically differentiating the apparent risk at rockfall sites.</p> <p>Much of the RHRS's rating is subjective. Proper training in its application is necessary to ensure the consistency of ratings between different raters. The responsibility for slope evaluations and design concepts should rest with experienced individuals.</p> <p>The Oregon Department of Transportation (ODOT) began developing the RHRS in 1984. Funding from a Federal Highway Administration (FHWA) sponsored pooled-fund, Highway Planning and Research (HPR) Grant allowed ODOT to complete development of the system, test it at over 3,000 sites, prepare an RHRS Implementation Manual, and conduct five multi-state training workshops around the country. The workshops gave participants an introduction to the RHRS and guidance on how to implement the system.</p>					
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TABLE OF CONTENTS

INTRODUCTION	1
DEVELOPMENT PROCESS	2
THE RHRS	2
Slope Survey	2
Preliminary Rating	3
Detailed Rating	3
Preliminary Design and Cost Estimates	8
Project Identification and Development	8
Annual Review and Update	8
SYSTEM LIMITATIONS	9
BENEFITS	9
WORKSHOPS AND MATERIALS PROVIDED	9
ADDITIONAL WORK NEEDED	10
CONCLUSION	10
BIBLIOGRAPHY	11

LIST OF FIGURES

FIGURE 1: PRELIMINARY RATING SYSTEM	3
FIGURE 2: SUMMARY SHEET OF THE ROCKFALL HAZARD RATING SYSTEM	4

LIST OF TABLES

TABLE 1: DECISION SIGHT DISTANCE	5
TABLE 2: WORKSHOP DATA	9

THE ROCKFALL HAZARD RATING SYSTEM

INTRODUCTION

Transportation agencies are expected to provide a safe highway system for the public. This is not a simple task to accomplish. This objective is made more difficult when our highways pass through terrain requiring rock cuts. In mountainous states such as Oregon, many miles of roadway pass through steep terrain where rock slopes adjacent to the highway are common. Some of these man-made slopes are over a hundred feet high. Many are situated near the base of rugged natural slopes that extend hundreds of feet further upslope. There is an inherent rockfall potential at such sites. This potential is compounded by the way our highway systems have evolved. Until recently, it was standard construction practice to use overly aggressive blasting and ripping techniques to construct rock slopes. Although this facilitated excavation, frequently, it resulted in slopes more prone to rockfall. Where these conditions exist, agencies are faced with the difficult task of reducing the risk of rockfall.

A standardized methodology has been developed that provides agencies with a proactive and logical way to set rockfall project priorities and allocate limited repair funds. The program includes an inspection of all rock slopes along a state's highway system to identify where rockfall would most likely affect the roadway. Once located, these sections are rated relative to each other by trained personnel to identify which present the greatest risk. This process is entitled "The Rockfall Hazard Rating System" (RHRS).

Oregon began the RHRS development process in 1984. These earlier efforts are documented in technical report number FHWA-OR-EG-89-01 titled "Report on the Shakedown Test of Oregon's Rockfall Hazard Rating System." The final phase of RHRS development began in July, 1989 when ODOT was selected to perform the HPR pooled-fund study entitled "The Rockfall Hazard Rating System." Funding for the study was provided by the following agencies:

State Highway Departments

- | | |
|------------------|---------------|
| 1. Arizona | 6. New Mexico |
| 2. California | 7. Ohio |
| 3. Idaho | 8. Oregon |
| 4. Massachusetts | 9. Washington |
| 5. New Hampshire | 10. Wyoming |

Federal Highway Administration

- | | |
|--------------------------------------|-----------------------|
| 1. CTIP (Direct Federal) | 3. Office of Research |
| 2. Office of Technology Applications | |

The funding support from these agencies is gratefully acknowledged and sincerely appreciated.

The principal objective of the study was to complete development of an effective RHRS and to facilitate implementation of the system in other states by conducting training workshops. Through full-state implementation in Oregon, the RHRS was tested at over 3,000 sites. Narratives for each rating category were finalized and forms and other rating aids were developed. This information was documented in the RHRS Implementation Manual which was distributed to attendees at the various regional workshops. The workshops were presented at the Northwest, Southwest, Midwest, Northeast and Southeast Regional Geotechnical Conferences held at Glenwood Springs, Colorado; Sacramento, California; Indianapolis, Indiana; Stowe, Vermont; and New Orleans, Louisiana, respectively.

DEVELOPMENT PROCESS

When Oregon began the pooled-fund study (FHWA Contract No. DTFH61-89-C-00078) a prototype of the RHRS had already been developed. A Research Advisory Committee (RAC) was formed to oversee the completion of the system. The RAC was comprised of representatives from each of ODOT's five Region Engineering Geology Groups and from the Headquarter's Office. The RAC contributed numerous innovative ideas and modifications to the final RHRS as experience in its application was gained. These modifications were guided by the following four performance standards:

1. Was the system understandable and universally applicable?
2. Did the narrative adequately explain each item to be rated?
3. Could several different raters achieve uniform results?
4. Did resulting scores accurately assess the rockfall hazard?

Full-scale testing of the system was an invaluable opportunity. The state of Oregon was an ideal location to test the RHRS. The State's variable climate, traffic volumes, roadside slope geometries, and geology provided a wide range of conditions that resulted in a universally useable system.

THE RHRS

The RHRS is a process that allows agencies to manage the rock slopes along its highway system by providing a rational way to make informed decisions on where and how to spend construction funds. The process requires a greater commitment and focus on the rock slope issue than is commonly the case for many agencies. This commitment consists of additional working hours and dollars to complete the initial survey, to update the database regularly, and to develop remedial programs aimed at reducing the rockfall risk at the worst sites. In addition, a properly trained and experienced staff is needed to perform the slope evaluations and to develop remedial designs.

The RHRS contains six main features.

1. A uniform method for slope inventory.
2. A preliminary rating of all slopes.
3. The detailed rating of all hazardous slopes.
4. A preliminary design and cost estimate for most serious sections.
5. Project identification and development.
6. Annual review and update.

These features are summarized in the following subsections. For a more detailed description, refer to Report No. FHWA-OR-EG-90-01, titled "The Rockfall Hazard Rating System Implementation Manual."

Slope Survey

The slope survey is an essential feature of the RHRS that requires an agency to accurately determine the number and location of its rockfall sites. For the purpose of the RHRS, a rockfall section is defined as "any uninterrupted slope along a highway where the level and occurring mode of rockfall are the same." Accurate delineation of the rockfall section is important. Grouping separate cut slopes into one long section will diminish the value and the flexibility of the resulting database. It is best to approach the survey without preconceived notions of how many sites there are or where the most hazardous sites are located.

Preliminary Rating

The purpose of the preliminary rating (Figure 1) is to group the rockfall sections inspected during the slope inventory into three broad, more manageably sized categories. Without this step, many additional hours would be spent applying the detailed rating at sites that had only a low to moderate chance of ever producing a hazardous condition.

FIGURE 1: PRELIMINARY RATING SYSTEM

CLASS \ CRITERIA	A	B	C
ESTIMATED POTENTIAL FOR ROCK ON ROADWAY	HIGH	MODERATE	LOW
HISTORICAL ROCKFALL ACTIVITY	HIGH	MODERATE	LOW

The RHRS is primarily interested in the rockfall potential at a site. The "estimated potential for rock on roadway" is therefore the controlling element of this rating. The "historical rockfall activity" rating is used as a modifier of the preliminary rating where clarification is needed. The preliminary rating is a subjective evaluation of the rockfall potential that requires experienced, insightful personnel to make these judgments.

The preliminary evaluation is a critical step in the RHRS process, especially where there are a large number of slopes to consider. Initially only the "A" rated sections should be evaluated with the detailed rating system. This will economize the effort while directing it toward the most critical areas. The "B" rated sections should be evaluated as time and funding allows. The "C" rated sections receive no further attention and therefore are not included in the RHRS database. In Oregon, of the 3000 slopes surveyed, roughly one-half were included in the database as either "A" or "B" rated slopes. Of these 1500 sites, 550 received an "A" rating and were further evaluated with the detailed rating.

Detailed Rating

The detailed rating includes 10 categories that, when evaluated, scored, and totalled, allows an agency to numerically differentiate rock slopes from the least to the most hazardous. Slopes with higher scores present the greater risk. The detailed rating is included as Figure 2 on page 4. The 10 categories represent the significant elements that contribute to the overall hazard. The four columns of criteria to the right correspond to logical breaks in the increasing hazard associated with each category. Accordingly, the scores above each column increase from left to right. The scores increase exponentially from 3 to 81 points, and are representative scores of a continuum of points from 1 to 100. An exponential system provides a rapid increase in score that quickly distinguishes the more hazardous sites. Using a continuum of points allows the rater flexibility in evaluating the relative impact of conditions that are extremely variable. Some categories require a subjective evaluation while others can be directly measured and then scored. Following is a summary of each category:

- 1. Slope Height** – This item represents the vertical height of the slope. Rocks on high slopes have more potential energy than rocks on lower slopes; thus they present a greater hazard and receive a higher rating. Measurement is to the highest point from which rockfall is expected. If rocks are coming from the natural slope above the cut, the cut height plus the additional slope height (vertical distance) is measured.
- 2. Ditch Effectiveness** – The effectiveness of a ditch is measured by its ability to restrict falling rock from reaching the roadway. In estimating the ditch effectiveness, the rater should consider several factors, such as: 1) slope height and angle; 2) ditch width, depth and shape; 3) anticipated quantity of rockfall per event; and 4) impact of slope irregularities (launching features) on falling rocks. Evaluating the effect of slope irregularities is especially important. These features can completely negate the benefits expected

**FIGURE 2: SUMMARY SHEET OF THE
ROCKFALL HAZARD RATING SYSTEM**

CATEGORY		RATING CRITERIA AND SCORE				
		3 POINTS	9 POINTS	27 POINTS	81 POINTS	
SLOPE HEIGHT		25 FEET	50 FEET	75 FEET	100 FEET	
DITCH EFFECTIVENESS		Good catchment	Moderate catchment	Limited catchment	No catchment	
AVERAGE VEHICLE RISK		25% of the time	50% of the time	75% of the time	100% of the time	
PERCENT OF DECISION SIGHT DISTANCE		Adequate sight distance, 100% of low design value	Moderate sight distance, 80% of low design value	Limited sight distance, 60% of low design value	Very limited sight distance 40% of low design value	
ROADWAY WIDTH INCLUDING PAVED SHOULDERS		44 feet	36 feet	28 feet	20 feet	
G E O L O G I C C H A R A C T E R	C A S E 1	STRUCTURAL CONDITION	Discontinuous joints, favorable orientation	Discontinuous joints, random orientation	Discontinuous joints, adverse orientation	Continuous joints, adverse orientation
		ROCK FRICTION	Rough, Irregular	Undulating	Planar	Clay infilling, or slickensided
	C A S E 2	STRUCTURAL CONDITION	Few differential erosion features	Occasional erosion features	Many erosion features	Major erosion features
		DIFFERENCE IN EROSION RATES	Small difference	Moderate difference	Large difference	Extreme difference
BLOCK SIZE		1 Foot	2 Feet	3 Feet	4 Feet	
VOLUME OF ROCKFALL/EVENT		3 cubic yards	6 cubic yards	9 cubic yards	12 cubic yards	
CLIMATE AND PRESENCE OF WATER ON SLOPE		Low to moderate precipitation; no freezing periods; no water on slope	Moderate precipitation or short freezing periods or intermittent water on slope	High precipitation or long freezing periods or continual water on slope	High precipitation and long freezing periods or continual water on slope and long freezing periods	
ROCKFALL HISTORY		Few falls	Occasional falls	Many falls	Constant falls	

from a fallout area. Valuable information on ditch performance can be obtained from maintenance personnel. Scoring should be consistent with the following descriptions:

- 3 points Good Catchment All or nearly all falling rocks are retained in the catch ditch.
- 9 points Moderate Catchment Falling rocks occasionally reach the roadway.
- 27 points Limited Catchment Falling rocks frequently reach the roadway.
- 81 points No Catchment No ditch or ditch is totally ineffective
All or nearly all falling rocks reach the roadway.

3. Average Vehicle Risk (AVR) – This category measures the percentage of time that a vehicle will be present in the rockfall hazard zone. The percentage is obtained by using an equation (shown below) based on slope length, average daily traffic (ADT), and the posted speed limit at the site. A rating of 100% means that on average a car will be within the defined rockfall section 100% of the time. Where high ADT's or longer slope lengths exist, values greater than 100% will result. When this occurs it means that at any particular time more than one vehicle is present within the measured section. The AVR directly relates to the potential hazard as well as the significance of the route. The equation used is:

$$\frac{\text{ADT (cars/day)} \times \text{Slope Length (miles)} / 24 \text{ (hours/day)}}{\text{Posted Speed Limit (miles/hour)}} \times 100\% = \text{AVR}$$

4. Percent of Decision Sight Distance (DSD) – The DSD is used to determine the length of roadway in feet a driver must have to make a complex or instantaneous decision. The DSD is critical when obstacles on the road are difficult to perceive, or when unexpected or unusual maneuvers are required. Throughout a rockfall section the actual sight distance can change appreciably. Horizontal and vertical highway curves along with obstructions such as rock outcrops and roadside vegetation can severely limit a driver's ability to notice a rock on the road.

The decision sight distance recommended by AASHTO can be determined from the table below. The relationships between decision sight distance and the posted speed limit were modified from Table III-3 of AASHTO's "Policy on Geometric Design of Highways and Streets(4)." The distances listed represent the low design value. The posted speed limit through the rockfall section should be used.

TABLE 1: DECISION SIGHT DISTANCE

Posted Speed Limit (mph)	Decision Sight Distance (ft)
30	450
40	600
50	750
60	1,000
70	1,100

Once determined these two values can be substituted into the following equation to calculate the "Percent of Decision Sight Distance."

$$\frac{\text{Actual Sight Distance}}{\text{Decision Sight Distance}} \times 100\% = \text{ } \%$$

5. **Roadway Width** – This dimension, measured perpendicular to the highway centerline from edge of pavement to edge of pavement, represents the available maneuvering room to avoid a rockfall. This measurement should be the minimum width when the roadway width is not constant. On divided roadways only the paved portion available to the driver should be measured.

6./7. **Geologic Character** – A slope's geologic conditions are evaluated with these categories. Use the Case 1 categories for slopes where joints, bedding planes, or other discontinuities, are the dominant feature of the slope that leads to rockfall. Case 2 is used for slopes where differential erosion or oversteepening is the dominant condition that controls rockfall. The following is a description of these categories:

Geologic Character – Case 1

Structural Condition "Adverse" as used here refers to joints that allow block, wedge, planar or toppling failures. "Continuous" refers to joints greater than 10 feet in length.

3 points	<u>Discontinuous Joints, Favorable Orientation</u> Slope contains jointed rock with no adversely oriented joints, bedding planes, etc.
9 points	<u>Discontinuous Joints, Random Orientation</u> Slope contains randomly oriented joints creating a variable pattern. The slope is likely to have some scattered blocks with adversely oriented joints but no dominant adverse pattern is present.
27 points	<u>Discontinuous Joints, Adverse Orientation</u> Rock slope exhibits a prominent joint pattern, bedding plane, or other discontinuity, with an adverse orientation. These features have less than 10 feet of continuous length.
81 points	<u>Continuous Joints, Adverse Orientation</u> Rock slope exhibits a dominant joint pattern, bedding plane, or other discontinuity, with an adverse orientation and greater than 10 feet in length.

Rock Friction This parameter directly relates to the potential for a block to move relative to another. Friction along a joint, bedding plane or other discontinuity is governed by the macro and micro roughness of the surfaces. Noting the failure angles from previous rockfalls on a slope can aid in estimating general rock friction along discontinuities.

3 points	<u>Rough, Irregular</u> The surface of the joints are rough and the joint planes are irregular enough to cause interlocking. This macro and micro roughness provides an optimal friction situation.
9 points	<u>Undulating</u> Macro rough but without the interlocking ability.
27 points	<u>Planar</u> Macro smooth and micro rough joint surfaces. Friction is derived principally from the roughness of the rock surface.
81 points	<u>Clay Infilling, or Slickensides</u> Low friction materials, such as clay, separate the rock surfaces negating any micro or macro roughness of the joint planes. Slickensided joints can also have a very low friction angle and may belong in this category.

Geologic Character – Case 2

Structural Condition Case 2 is used for slopes where differential erosion or oversteepening is the dominant condition that leads to rockfall. Erosion features include oversteepened slopes, unsupported rock units or exposed resistant rocks on a slope that may eventually lead to a rockfall event. Rockfall is caused by a loss of support either locally or throughout the slope. Common slopes that are susceptible to this condition are: layered units containing more easily weathered layers that when eroded undermine more

durable rock; talus slopes; highly variable units such as conglomerates, mudflows, rock/soil slopes etc. that weather allowing resistant rocks and blocks to fall as the matrix material is eroded.

3 points	<u>Few Differential Erosion Features</u> Minor differential erosion features that are not distributed throughout the slope.
9 points	<u>Occasional Erosion Features</u> Minor differential erosion features that are widely distributed throughout the slope.
27 points	<u>Many Erosion Features</u> Differential erosion features are large and numerous throughout the slope.
81 points	<u>Major Erosion Features</u> Severe cases such as dangerous, erosion-created overhangs; or significantly oversteepened soil/rock slopes or talus slopes.

Difference in Erosion Rates The rate of erosion on a Case 2 slope directly relates to the potential for a future rockfall event. The degree of hazard caused by erosion and thus the score given this category should reflect how quickly erosion is occurring; the size of rocks, blocks, or units being exposed; the frequency of rockfall events; and the amount of material released during an event.

3 points	<u>Small Difference</u> Erosion features take many years to develop. Slopes that are near equilibrium with their environment are covered by this category.
9 points	<u>Moderate Difference</u> The difference in erosion rates allows erosion features to develop over a few years.
27 points	<u>Large Difference</u> The difference in erosion rates is such that noticeable changes in the slope develop annually.
81 points	<u>Extreme Difference</u> The difference in erosion rates allows rapid development of erosion features.

Only one set of scores, either Case 1 or Case 2, is included in a slope's rating. In some instances it may be difficult to determine which Case to use. In those situations, both Cases may be rated but only the scores from the highest scored Case are recorded.

8. Block Size or Quantity of Rockfall Per Event – This measurement should be representative of whichever type of rockfall event is most likely to occur. A decision on which to use can be determined from the maintenance history or estimated from observed conditions when no history is available. This measurement will also be beneficial in determining remedial measures.

9. Climate and Presence of Water on Slope – Water and freeze/thaw cycles both contribute to the weathering and movement of rock materials. If water is known to flow continually or intermittently from the slope it is rated accordingly. The impact of freeze/thaw cycles can be interpreted from knowledge of the freezing conditions and its effects at the site. The criteria for this category should be adjusted to fit the agencies' regional conditions to assure proper score separation.

10. Rockfall History – This information is best obtained from the maintenance person responsible for the slope. This information is an important check on the potential for future rockfalls.

3 points	<u>Few Falls</u> – Rockfalls have occurred several times according to historical information but are not a persistent problem. If rockfall only occurs a few times a year or less, or only during severe storms, this category should be used. This category is also used if no rockfall history data is available.
9 points	<u>Occasional Falls</u> – Rockfall occurs regularly. Rockfall can be expected several times per year and during most storms.
27 points	<u>Many Falls</u> – Typically rockfall occurs frequently during a certain season, such as the winter or spring wet period, or the winter freeze-thaw, etc. This category is for sites where frequent rockfalls occur during a certain season and is not a significant problem during the rest of the year. This category may also be used where severe rockfall events have occurred.
81 points	<u>Constant Falls</u> – Rockfalls occur frequently throughout the year. This category is also for sites where severe rockfall events are common.

Preliminary Design and Cost Estimates

It is important when planning highway construction projects to properly identify the desired result. The desired result is what determines the project limits, the estimated construction costs, the right-of-way needs, etc. Trying to retrofit a different, more appropriate rockfall design after these items have been established is frustrating at best and can be completely unworkable. Recognizing this, the fourth step of the RHRS process requires a preliminary design and cost estimate be included as part of the RHRS database. With this information, rockfall projects can be properly funded and developed.

The goal of this step is to provide an appropriate method to deal with the rockfall problem that can later be refined by more detailed investigation and analysis. Experience is generally the best test of the reasonableness of a rockfall remedial design. More than one design approach to reduce the rockfall risk should be considered for each site. Frequently a combination of many techniques will work best.

The rockfall design cost estimate calculated is strictly the cost of the rockfall remedial measures. This allows for better comparisons to be made between rockfall projects.

Project Identification and Development

There are many ways to use the RHRS to identify and advance projects for construction.

1. **Projects can be advanced based on their score.** This is the most obvious use of the system. Realizing that the most hazardous slopes are those at the top of the list, those projects will be funded for construction as funds become available.
2. **Projects can be advanced based on their score relative to their estimated construction cost.** This in effect is a modification of the benefit/cost method. Keeping in mind that all "A" rated slopes are hazardous, the preliminary cost estimate for the top rated slopes is divided by their RHRS score and a list is generated with the lowest dollar to RHRS point ratios at the top. Projects developed from this list will provide the greatest system wide hazard reduction with a fixed amount investment.
3. **Projects can be developed based on the remedial approach.** Rockfall sections containing similar construction features will be grouped into a single project. By doing this, a larger quantity will be contracted. This can result in more straightforward, more easily managed contracts with lower unit bid prices.
4. **Projects can be developed based on the proximity of rockfall sites along a section of roadway.** Because the rockfall sites have been identified and remedial measures properly determined, a larger contract can be let and a major reduction in a route's overall hazard can be realized.

Annual Review and Update

The final step of the RHRS is to perform annual reviews of all rated slopes and to inspect any newly constructed slopes. If any slopes in the database have been modified by construction or maintenance activities, they should also be reviewed and rerated. Eventually, all slopes in the RHRS database should be evaluated with the detailed rating. Once all slopes are rated, an agency can redefine what constitutes an "A" or "B" rated slope using a range of agency determined scores rather than the subjective evaluation criteria applied during the preliminary rating, or they may elect to drop the letter designation entirely.

SYSTEM LIMITATIONS

The Rockfall Hazard Rating System provides agencies with a method to address their rockfall problems by providing a relative rating between slopes. For the most part, though, this relative rating is subjective. Although the slope evaluation process is as straightforward as possible, there is still a range of values that a slope could receive. Much of this depends on the abilities of the raters and how consistently they interpret and apply the rating criteria. Keep in mind that all "A" and "B" slopes have the potential of supplying rock onto the roadway.

Agencies will always be expected to react to rockfall accidents no matter where that particular section appears on the RHRS priority list. The tendency to overreact should be resisted. Sites where an accident

has occurred should be reevaluated with the detailed rating to determine if the rockfall incident has increased or decreased the rockfall potential. The level of investment at the site should be consistent with the new potential relative to the other sites.

BENEFITS

It is not reasonable to expect an agency to have at their disposal enough funds necessary to deal with all safety related issues at once. However, it is necessary to have a system in place from which projects are identified and developed as funding is made available. ODOT's experience has been that this is legally defensible. Although the RHRS as a defense has not been tested in Oregon to date, ODOT has for many years had a priority list for developing rockfall construction projects. The sites listed were those identified as having an accident history and/or excessive maintenance costs. The list generally contained only about 100 sites and was not based on the rockfall potential but on the rockfall history. The sites were prioritized based on a benefit/cost analysis. Even so, because ODOT had a definite, planned approach to deal with rockfall sites as funds were made available, litigations brought against the state because of rockfall accidents were either settled out of court or findings favorable to the state resulted. The agency feels that having a more accurate, state-of-the-art process for developing the priority list will serve them better in this regard.

WORKSHOPS AND MATERIALS PROVIDED

The RHRS workshops were taught at the five Regional Geotechnical Conferences sponsored by the FHWA. The pilot workshop was conducted at the Northwest Geotechnical Conference held at Glenwood Springs, Colorado in August of 1990. Improvements to the workshop format and visual aids were made following this pilot effort based on suggestions from several FHWA reviewers. The workshop schedules and approximate attendances are included on the following Table.

TABLE 2: WORKSHOP DATA

WORKSHOP	LOCATION	DATE	APPROXIMATE ATTENDANCE
Northwest	Glenwood Springs, CO	08/20/90	110
Northeast	Stowe, VT	09/25/90	40
Midwest	Indianapolis, IN	10/04/90	50
Southeast	New Orleans, LA	11/01/90	20
Southwest	Sacramento, CA	04/16/91	130

Response from attendees has been positive. Requests for the Implementation Manuals has exceeded the 400 copies that were prepared as part of the contract.

In addition to the workshop manuals, six full sets of the workshop slide presentation along with 14 additional sets of the 20 custom slides from the presentation have been provided to the FHWA. A complete set will be made available by the FHWA to each of the agencies that helped fund this study.

ADDITIONAL WORK NEEDED

The RHRS has been thoroughly tested and refined during the contract period resulting in an effective, universally applicable system. However, some adjustments will be needed by individual agencies to

accommodate their exact needs and organizational structure. In addition, further training would benefit agencies that will implement the RHRS. The attendees at the workshops were generally representatives from their states. Detailed training reaching a broader audience within the individual states, primarily those who would direct statewide implementation and those who would perform the surveys and ratings, would facilitate implementation. The training would reduce implementation time and improve the consistency of the results. The training should consist of detailed instruction of the RHRS, classroom exercises in its application, and performance of actual field ratings at sites typical in the state.

CONCLUSIONS

The Oregon DOT's engineering geology staff has spent many hours designing, testing, and redesigning the system. The process has been manageable, and was completed while maintaining a busy normal workload. It was very beneficial having the engineering geologists responsible for creating and maintaining the RHRS database. Their expertise added to the value of the finished product.

ODOT's experience with the Rockfall Hazard Rating System has been favorable. Management now has a uniform process that can help them make informed decisions on where to allocate money for rock slope projects. They welcome having quality information to use in this area of project development. The agency believes the issue of public safety is properly being addressed and that greater legal protection is afforded the agency by having the RHRS in place.

The RHRS has received widespread attention as a result of the workshops. Many states are either discussing or actively planning implementation, and a few have already begun to use the RHRS. This broad acceptance speaks well for the applicability of the system within other agencies, the value of implementing a standardized methodology, and the approach the FHWA selected to share the results of this research effort with other states.

Many deserve credit for the RHRS including the ODOT engineering geologists who shared their expertise and judgement in completing the development of the system, those individuals in the FHWA who acted as reviewers and as organizers for its dissemination and of course the many agencies who shared the cost of the entire effort. A large share of the credit also belongs to ODOT's management who had the vision to accept a better way to manage rock slopes and the willingness to allow the assignment of their staff's time and effort to this applied research project.

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