MARSHALL UNIVERSITY

College of Information Technology and Engineering

FINAL REPORT

Title: ROCK FALL RATING, EVALUATION AND DATA MANAGEMENT SYSTEMS FOR HIGHWAY AND RAILWAY ROCK SLOPES.

TRP 99-07

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Executive Summary

Abstract
Thousands of rock cuts have been made through the development of highway and railway systems in the Appalachian states, including West Virginia, Kentucky and Ohio. Rock cuts have the potential to create hazards to the public and require high railway and highway maintenance costs. The current project involves the application of an established rockfall hazard rating system and the use of technologies, such as GPS, laser scanner. The project established and promoted the sharing of knowledge of rockfall characteristics in the states of the Appalachian Mountain region. A knowledge base of the best remediation practices and associated costs will be established in the near future. All rockfall rating data can be found on the SharePoint portal site **http://cite006.marshall.edu**.

Project Objectives:
1. Develop rock slope evaluation methodologies for West Virginia, in collaboration with the Kentucky Transportation Center, WVDOT, ODOT and industry;
2. Conduct rock slope site evaluations and long-term monitoring of selected sites utilizing various instrumentation;
3. Further tri-state (WV, OH, KY) collaborative highway and rail transportation ground control projects.

TASKS
1. Review current rock slope evaluation and rock mass classifications systems for rail and highways. This will include a workshop with experts from Marshall University, WVDOT, OHDOT and industry participants. ***Completed.***
2. Develop a GIS Data Base for rock slope evaluation data. Preliminary data will include location data using GPS, digital photos, laser scanner images. ***Completed.***
3. Develop knowledge management system for rock slope remediation in coordination with WVDOT, Kentucky Transportation Center, ODOT and other interested entities. ***Completed.***
4. Evaluate the potential application of GPR, and other technologies, to facilitate the investigation and monitor of selected highway and railway rock slopes. ***Completed.***

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ROCK FALL RATING, EVALUATION AND DATA MANAGEMENT SYSTEMS FOR HIGHWAY AND RAILWAY ROCK SLOPES.

1.0 Introduction

Mountainous areas make up a large part of the United States, especially in the Appalachian and Cordilleran regions and Pacific Northwest. Roads and other structures built to provide access frequently have to be cut out of existing slopes which often causes an unavoidable risk of rockfall onto the roadway. The project objectives are to: 1) review current rock slope evaluation and rock mass classification systems for rail and highways; 2) develop a GIS data base for rock slope evaluation data and a knowledge management system for rock slope remediation projects. The evaluation of the rock slopes has been conducted using the Rockfall Hazard Rating System (RHRS), a system of evaluation originally developed by the Oregon Department of Transportation. This is a quick and comparatively simple method of roadcut evaluation based on nine constant criteria. Rockfall data can be found on the Sharepoint portal site **http://cite006.marshall.edu** .

In order to promote the sharing of knowledge of rockfall characteristics in the states of the Appalachian Mountain region the Appalachian States Coalition for Geohazards in Transportation was founded, involving the principal geological and geotechnical entities in the Appalachian states: railway industry, federal and state highway administrations, U.S. Corps of Engineers, and state and federal geological surveys. Until recently, the danger from rockfalls on highways and railways has not been evaluated in a systematic way. Highway building contractors have historically used ripping and blasting methods to develop the roadway site. These traditional construction methods result in fracturing and disturbing the surrounding rock causing future rock slope movement (Pierson and Van Vickle, 1993). Sections of hillside often have to be cut and blasted in order to open enough space to build roads. These roadcuts often have safety precautions built into them in an attempt to reduce the risk of hazardous rockfall, such as catchment ditches, terracing, fencing, or other means of either prevention or protection in the event of an occurrence. Although recent highway construction methods do not disturb the ground as much as those of the past, serious highway rock slope and rockfall hazards remain at both the old and new roadcuts. Many roadcuts need to be monitored closely or repaired as they represent a threat in the near or long term. If a slope needs remedial work, common options are rock bolts, walls, catch fences, and mesh (O'Malley, 2000). If the problem is more serious, terracing or cutting the slope may be necessary.

1.1 Data Base and Knowledge Management.

The knowledge sharing across the Appalachian states is being facilitated initially using SharePoint Team Services (Microsoft) software, which is a new web site solution for groups that want to be able easily manage group knowledge, data and activities (see web site **http://cite006.marshall.edu** and Appendix III) . The knowledge management system being developed is a systematic process of finding, selecting, organizing, distilling and presenting information for geotechnical engineers and geologists from state to state, and importantly facilitates the capture of on knowledge and solutions to technical problems in each state. Up to fifty members will be able to use the website.

1.2 Rockfall Rating

A system is needed which would enable a highway department to be able to determine which slopes pose the highest threat to safety, and then work accordingly. Numerous slope hazard-rating systems have been introduced in order to provide the highway engineer with a useful evaluating and highway maintenance toll. Many of these systems, however, are technically demanding and too time-consuming to be practical for a large-scale project. The Rock Quality Designation (RQD) and Rock Mass Quality (Q) are examples where boring and technical study of the slope are required (Waltham, 1994). The nation of Jordan has used an evaluation system based on Q, seismic risk, slope geometry, precipitation, and drainage that has worked well for them (Al-Homoud and Tubeileh, 1997). But these evaluation systems are quite useful but generally impractical. The Rock Hazard Rating System (RHRS), however, is a system developed that can rate slope hazards with a minimum of time and expense. Originated in 1993 by the Oregon Department of Transportation with input from the Federal Highway Administration as well as a number of state highway departments, the RHRS is a modification of a study done by C. O. Brawner and Duncan Wyllie (1984) and later work by Wyllie (Pierson and Van Vickle, 1993). A certain amount of geological knowledge is required for the rating of geological characteristics, but a trained geologist does not necessary have an advantage in conducting a rock slope than a person with general geological background. The Rock Hazard Rating System is not intended to give the strength of the rocks themselves, or to predict a failure on a given slope. Its purpose is to provide a guide to allow the department overseeing the highway system to be able to come to a general consensus on which slopes pose the highest risk for failure, and thus, need to be repaired first as funds become available. The RHRS is based on observation of the rockfall section and its various parameters.

2.0 Rockfall Hazard Rating System (RHRS)

There are six steps in the RHRS. They are (Pierson and Van Vickle, 1993):

1. Creating a geographic slope inventory or database
2. A preliminary rating in which the slopes are grouped roughly as A, B, and C
    a. slopes with A slopes being the worst
3. A detailed rating of the A (and if possible, B) slopes using the nine parameters
    a. of the RHRS to further break down the general groupings
4. A cost and design analysis of the slopes
5. "Project design and development" to prepare and advance the work on the rockfall sections
6. "Reviewing and updating the database"

Of these six steps, only the first three pertain to the evaluation itself, but the rest are necessary for remediation of the problem.

The principal steps in the RHRS include (Pierson and Van Vickle, 1993): Creating a geographic slope inventory or database; and a detailed rating of the A slopes (worst) (and if possible, B) using the nine parameters:

- Slope Height: Rockfalls from higher slopes have a higher potential energy, and so have a higher score than a lower slope. Slope height is measured in a vertical line from the top of the slope to the base, see Figure 1. . It is not the length of the slope (Pierson and Van Vickle, 1993).

  The slope height can be determined in two different ways. The first way is by using an inclinometer (Figure 1) to determine the angles in degrees at eye level at the top of the section from both the far and near sides of the road. The following equation is then used to solve for height (Pierson and Van Vickle, 1993):

  $$\text{Total Slope Height} = \frac{(x) \sin a * \sin b}{\sin (a-b)} + \text{H.I.}$$

  Where H.I.=height of the instrument
  X= roadway width
  a= angle from the near side of the road
  b= angle from the far side of the road

Figure 1: Determining the rock slope height using an inclinomoter.

The other method used for measuring the slope height is the laser profiler. This allows the height to be measured almost instantaneously without having to use mathematical formulas (Figure 2). The profiler must be adjusted, then aimed and fired at the top and bottom of the slope. The correct height will show on the screen if the proper levels have been used. The primary drawback to using the laser profiler is that heavy vegetation will block the laser beam, so it cannot be used with great accuracy in a thickly vegetated area.

Figure 2: Using the laser gun and slope profiling instrument.

- Geological Character: Two categories of geological problems can cause rockfall are scored for each slope: The first category is differential erosion or oversteepening, which usually occurs when a more resistant layer of rock overlies a less resistant layer. The underlying layer erodes faster, leaving the upper layer unsupported in an overhang. This is especially common in West Virginia, where massive sandstone often overlies shale, see Figure 3. Erosion features are looked for in this category, such as "oversteepened slopes, unsupported rock units, or exposed resistant rocks on a slope" (Pierson and Van Vickle, 1993).

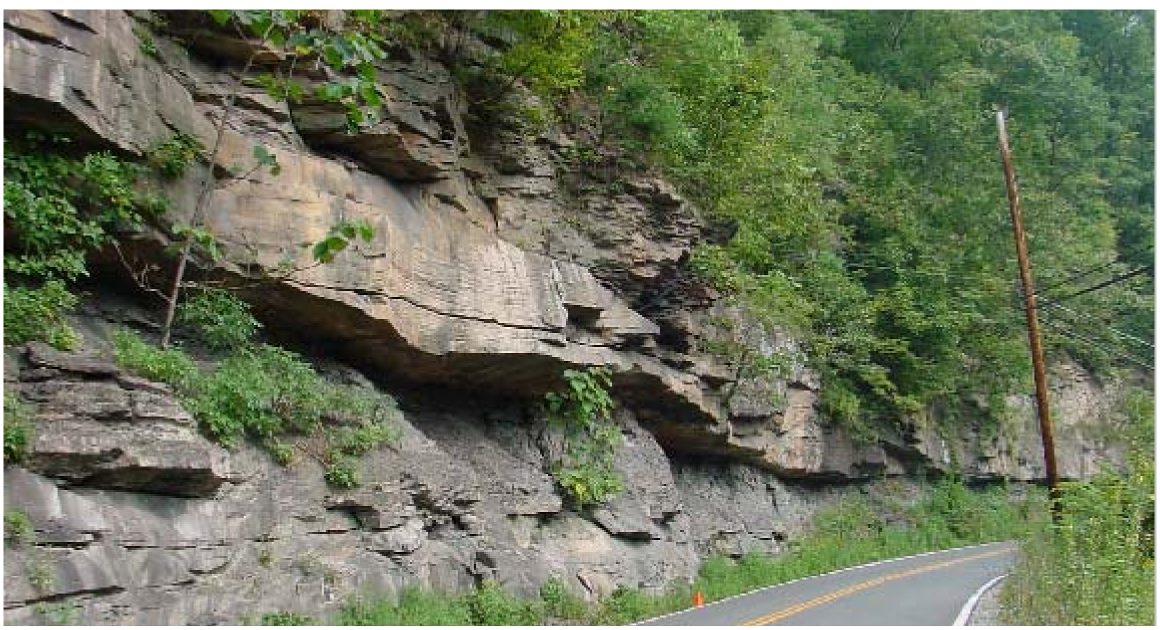

Figure 3. High slope showing differential erosion with an overhanging sandstone, which usually occurs when a more resistant layer of rock overlies a less resistant layer.

The other category is used where structural discontinuities such as "joints, faults, bedding planes, or fissility" are the primary cause of rockfall, see Figure 4. Foliation and fractures are also included in this category (Pierson and Van Vickle, 1993). The strength of fractured rock is more dependent on fracturing than it is on the actual strength of the rock type (Palicki, 1997). Joints with an orientation toward the road or at an angle to it are much more dangerous than slopes with a more favorable orientation. Slopes with a strike direction perpendicular to the road are more dangerous than those with a strike parallel to the road. Both of these categories are scored for each slope, but only the dominant condition is used in the final rating (Pierson and Van Vickle, 1993), even though both erosion and discontinuities may be very active in the same slope. For a given slope, one of these is probably more influential in rockfall and this is the one that is used.

Figure 4: Structural discontinuities such as "joints, faults, bedding planes, or fissility" are the primary cause of rockfall

- Percent of Decision Sight Distance: This compares the distance that a driver needs to react to stop or swerve his car at a given speed (West, 1995). The actual distance is determined by placing a six-inch cone at the place of lowest visibility, and then measuring the maximum distance that it can be seen at eye level in the direction in which vision is most restricted. The posted speed limit is used to get the Decision Sight Distance from a chart modified from Table III-3 of AASHTO's "Policy on Geometric Design of Highways and Streets". When the actual sight distance is obtained, the Percent of Decision Sight Distance is calculated by using the following equation (Pierson and Van Vickle, 1993):

$$\frac{\text{Actual Sight Distance (measured)}}{\text{Decision Sight Distance}} \times 100\% = \text{Percent of Decision Sight Distance}$$

- Climate and Presence of Water: The amount of water on the slope, precipitation, and length of freezing periods ("water and freeze-thaw cycles") are assessed for this category. "Areas receiving less than 20 inches per year are 'low precipitation areas.' Areas receiving more than 50 inches per year are considered 'high precipitation areas'" (Pierson and Van Vickle, 1993). Precipitation is primarily important because of freeze-thaw, while ground water on the slope increases the total load and reduces the friction in the joints (West, 1995). According to Lee (1989), freezing and thawing is probably the dominant cause of cliff breakup in Vermont.

- Average Vehicle Risk: Average Vehicular Risk (AVR) is the probability that a vehicle will be in an area at the time of a rockfall event. If a slope receives a high overall score, usually it scores high on the AVR. It is obtained by putting slope length, average daily traffic, and the posted speed limit into the following equation (Pierson and Van Vickle, 1993):

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

  Where ADT = Average Daily Traffic

  A rating of 100% means that, on average, there will be one car in the area at all times, a rating of over 100% means that there will usually be more than one vehicle present at any given time (Pierson and Van Vickle, 1993).

- Ditch Effectiveness: The effectiveness of a highway ditch is judged by its ability to catch falling rocks and prevent them from reaching the roadway. Scoring should follow the following guidelines (Pierson and Van Vickle, 1993):
  Good Catchment-All or nearly all falling rocks are retained in the catch ditch
  Moderate Catchment-Falling rocks occasionally reach the roadway
  Limited Catchment-Falling rocks frequently reach the roadway
  No Catchment-No ditch, or ditch is totally ineffective. All or nearly all falling rocks reach the road.

- Roadway Width: This category shows the amount of room that a driver has to swerve out of the path of rocks or debris. The roadway width is measured perpendicular to the center stripe, from one edge of the road to the other edge. Paved shoulders are measured as part of the roadway, but unpaved shoulders are not (Pierson and Van Vickle, 1993). See figure 5. If the width of the road varies throughout the section, the width used should be the minimum, and on divided highways, only the part that is accessible to the driver is measured (Pierson and Van Vickle, 1993).

Figure 5: Measuring the width of road.

- Block Size or Volume: The size or volume of a rockfall event can play a large role in its severity. A large rock has more kinetic energy than does a smaller one, and a large volume of debris can choke up a road causing more damage. Larger amounts also block off more of the road, making it harder to avoid an accident.

- Rockfall History: Past occurrences are often the best means of predicting future rockfall, and this should always be taken into account when rating slopes. Highway maintenance personnel are usually the ones who know the history of a rockfall section. If the score from the rating differs greatly from its history, then the rating should be reconsidered (Pierson and Van Vickle, 1993).

- Overall Rating: These categories are scored and the points are added up. The highest score is not necessarily the most dangerous slope, but is the most likely slope to cause problems. Priority should be placed on those slopes with the highest scores.
    - Rock slopes are given a category ‘A’ that have a high potential for rocks falls and have a high historical rockfall activity; category ‘B’ is given for moderate risk.slopes. For this project category ‘A’ slopes scored over 400 points.

These parameters are normally assigned points based on the general RHRS chart (Pierson and Van Vickle, 1993) if the local terrain corresponds to that of the chart. If it does not, then the points assigned are at the discretion of the rater. For example, the slope height that gets the highest score from the chart is 105 feet. If the highest roadcut in an area is only 75 feet, than the system will need to be modified to fit the situation so that 75 feet becomes the highest score.

3.0 Discussion of Results

The slopes evaluated were all in counties of West Virginia; McDowell, Fayette, Pocahontas, Tucker, Pendleton, Upshur, Lewis, Braxton, Wetzel, Marshall, Brooke, and Wood counties in highway districts 6, 7, 8, 9, and 10. The majority of these sections are in rural, largely unpopulated areas where the daily traffic is very low except on roads heavily traveled by coal trucks. This means that the danger of highway slope rockfalls to people in the area is not very high comparatively, but appropriate cleanup and repair are frequently required. The slopes assigned were usually among the most troublesome in their respective districts. As a result, sweeping statements cannot be made about West Virginia road cuts in general, but some generalizations can be derived from the results. The average length of the evaluated rockfall sections is 0.14 miles (0.23 km). The majority of these slopes are shale or interbedded shale and sandstone, although a few are composed primarily of jointed or massive sandstone. Differential weathering is very pervasive among the interbedded slopes, as the shale usually underlies the sandstone and weathers quickly, leaving behind overhanging ledges or rocks. The time taken to rate each slope section ranged between an hour and an hour and a half. Out of the thirty slopes evaluated, eight were classified as 'A' slopes and twenty-two as 'B' slopes. All of the 'A' sites scored over 400. The average score of 327 qualifies as a mid-B slope. Most of the slopes are not dangerous to motorists but are incurring high maintenance costs. Therefore, as the highway departments have finite resources the RHRS rating system can serve as a guide to set priorities for slope repair and maintenance.

3.1 Influencing Factors

Slope Height: Slope height was not very influential in the overall score by itself, except when the altitude was considerably higher than average. The heights ranged from 21 feet to 229 feet. On the scale used to rate slope height, a slope needs to score about 30 in order to make an appreciable difference in the score, that is, a slope of at least 80 feet high. Only eight sites were in this general range. Even so, there appears to be a general, though perhaps tentative, correlation between slope height and overall score, see the graph in Figure 6.

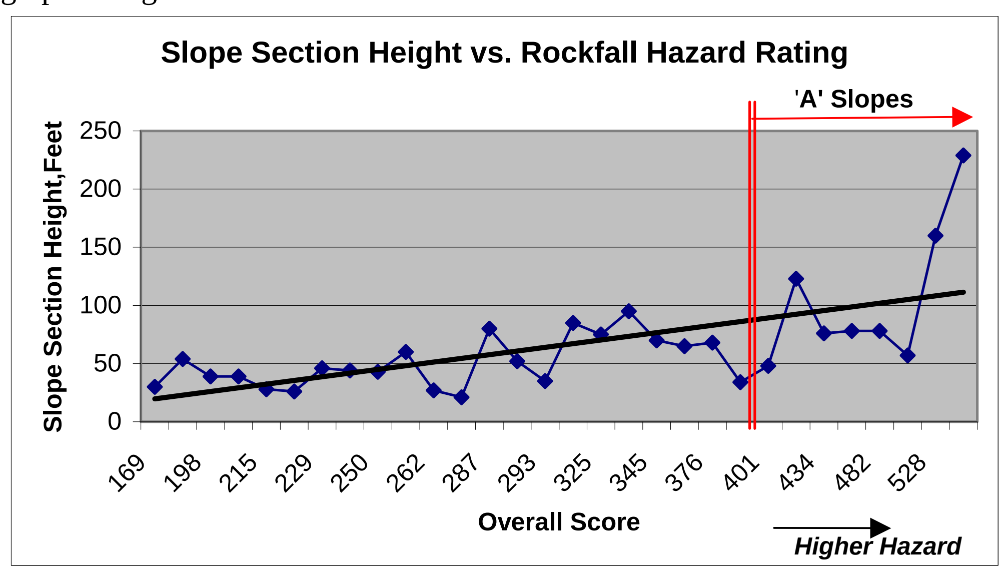

Figure 6: Highway slope height and the overall Rock Hazard Rating Score

It may be that slopes that were the highest also have a tendency toward more problems in other areas than did the slopes of lower stature.

Geologic Character: The majority of the rockfall sections evaluated were influenced by differential erosion. Of the thirty sites, twenty-one were dominated by differential erosion (Figure 2) and nine by structural conditions (Figure 3). This would be expected because of the common stratigraphy of interbedded shale and sandstone in West Virginia. Several of these slopes consisted of alternating fissile and platy shale. Many of the slopes were influenced by both differential erosion and structural controls, especially slopes of jointed sandstone. The type of geological character did not seem to make an appreciable difference in the overall score. A structurally influenced slope had the highest score by over 100, but it is also the highest by 134 feet. The extreme height differential is most likely the primary cause for this result. Apart from this slope, structural and erosional slopes had roughly equivalent score, all other characteristics being equal.

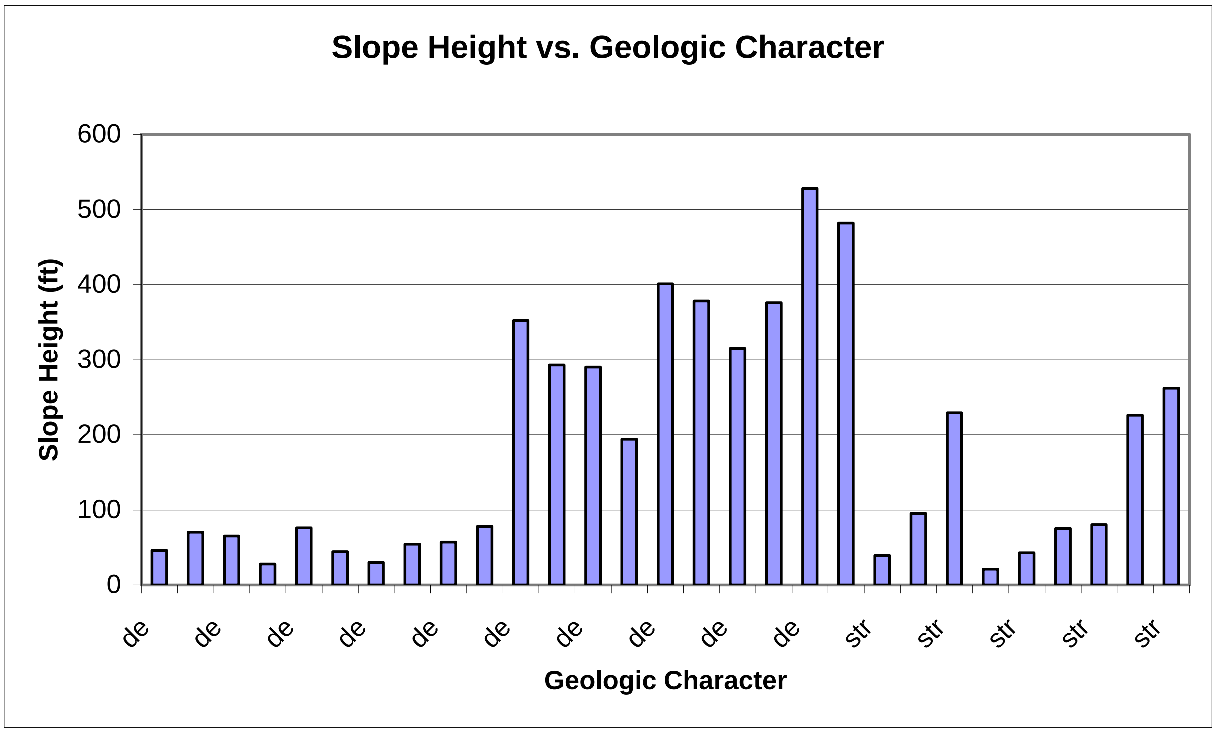

Figure 7: Relationship between the height and geological character of the highway slop.

Percent of Decision Sight Distance: Sight distance stretched from very good to extremely poor at the sites. The shortest sight distance was 90 feet with a score of 100 and the longest was 1200 feet (365.9 m), which scored 1. Some of the sites had a better sight distance, but had vegetation or overhangs that blocked otherwise good vision. The average sight distance was 349 feet, which according to the AASHTO chart is only adequate for speeds slightly less than 25 mph (Pierson and Van Vickle, 1993). One of the fourteen sites that scored a 100, Upshur county WV 20 MP (Mile Post) 33.07, had a 55 mph speed limit. This makes these sites dangerous for more than just the potential rockfall.

Climate and Presence of Water: Because West Virginia has a humid temperate climate; the climatic indicators did not change for any of the slopes. The part of the score that did affect the results was the presence of water on the slope. All but five of the slopes had intermittent water on them; the five probably had continuous water on them. The continual presence of water could be enough to make the difference between an A slope and a B slope, because the presence of water greatly enhances the probability of rockfall. This is especially true as the presence of the moderate freezing periods allows freeze-thaw to occur.

Average Vehicular Risk: AVR was a significant component of the overall score. Many of these rockfall sites are positioned in low-traffic locations. Therefore, the AVR was very low for twenty slopes, each of which scored under 20. Of the remaining ten, seven scored 100, which is the highest score given. The Average Daily Traffic (ADT) of these seven sites extends from 4,800 to 19,500, with an average of 11,786 vehicles per day passing through the site area. The AVR scores for the twenty slopes ranged from a low of 400 to 8,500 with an average of about 3,115. The other principal factor of AVR is the length of the section, as longer sections tend to have a higher traffic rate. The high AVR sections average 0.27 miles in length, while the low AVR sites averaged closer to 0.1 miles long. All the sites with section lengths of less than 0.1 miles are in the low AVR score group. Location of the site is also an important factor, because a highly traveled, short site can easily have more than a longer, but more secluded site.

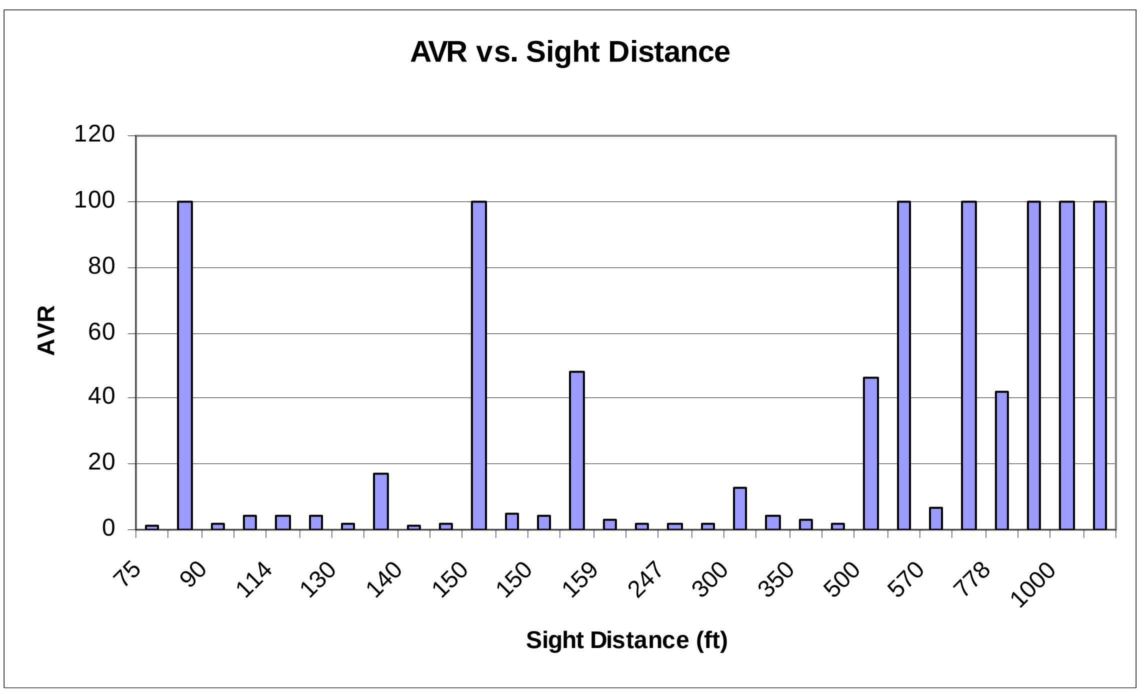

Figure 8: Relationship between the average vehicle risk (AVR) and driver distance of sight.

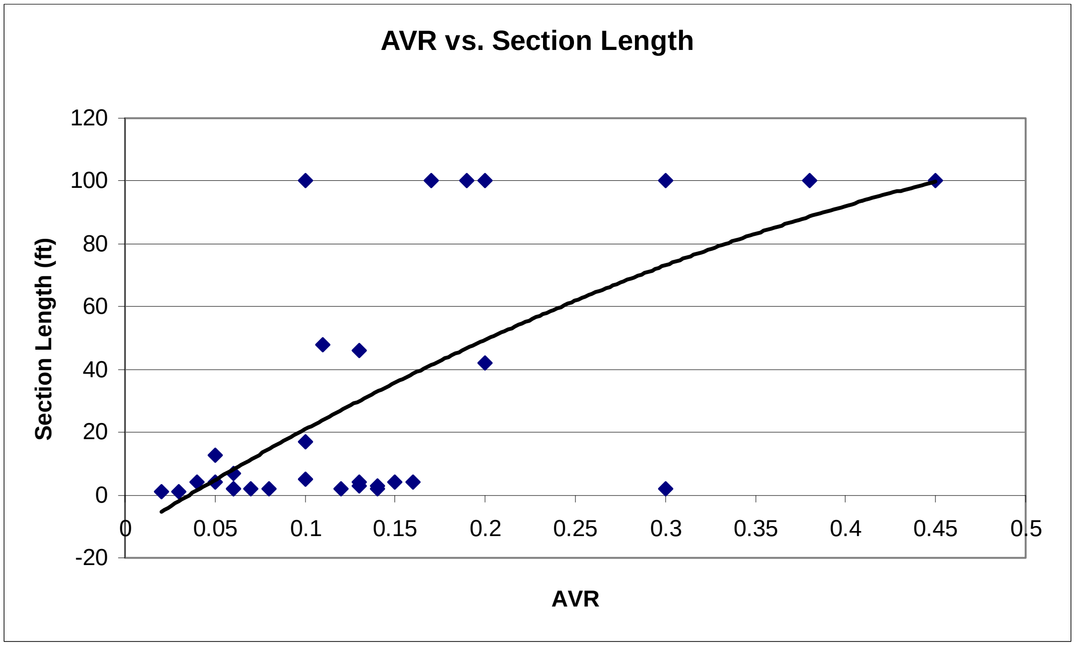

Figure 9: Relationship between the average vehicle risk (AVR) and length of highway slope section being evaluated.

Ditch Effectiveness: The ditch effectiveness of the road cut sections varied greatly, from moderately effective to very ineffective. This allowed for a very wide range in score (Figure 10).

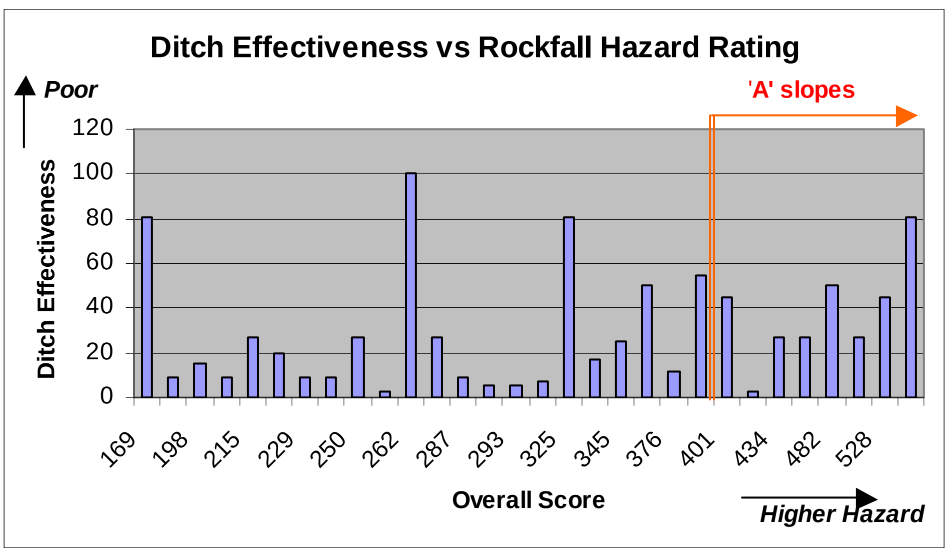

Figure 10: Relationship between the effectiveness of the highway ditch and the overall Rock Hazard Rating Score

Scores varied from 3 for effective catchment to 81 for almost completely ineffective catchment. Only five of the ditches were very effective. Sixteen were of limited usefulness, and of these four were ineffective. Almost all of the rockfalls on these slopes landed on the road. The depth and width of the ditches are not always the reasons for poor performance, as shape and location also contribute to poor catchment. Many were located directly under sections with protruding rocks and ledges that can launch the falling rocks past the catchment ditch into the road.

Roadway Width: This is one of the categories that shaped the overall score. Width varied from 15 feet to 48 feet, with a mean of 27 feet and score 2 to 100. Some sites have unpaved areas that could be used in an emergency, but since they varied in quality, they were not counted.

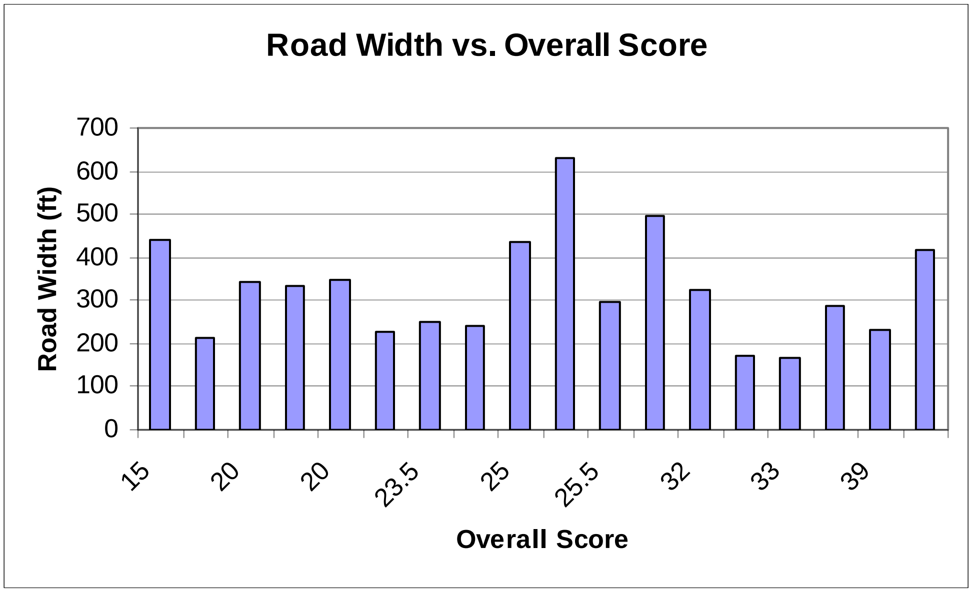

Figure 11: Relationship between the roadway width and the overall Rock Hazard Rating Score

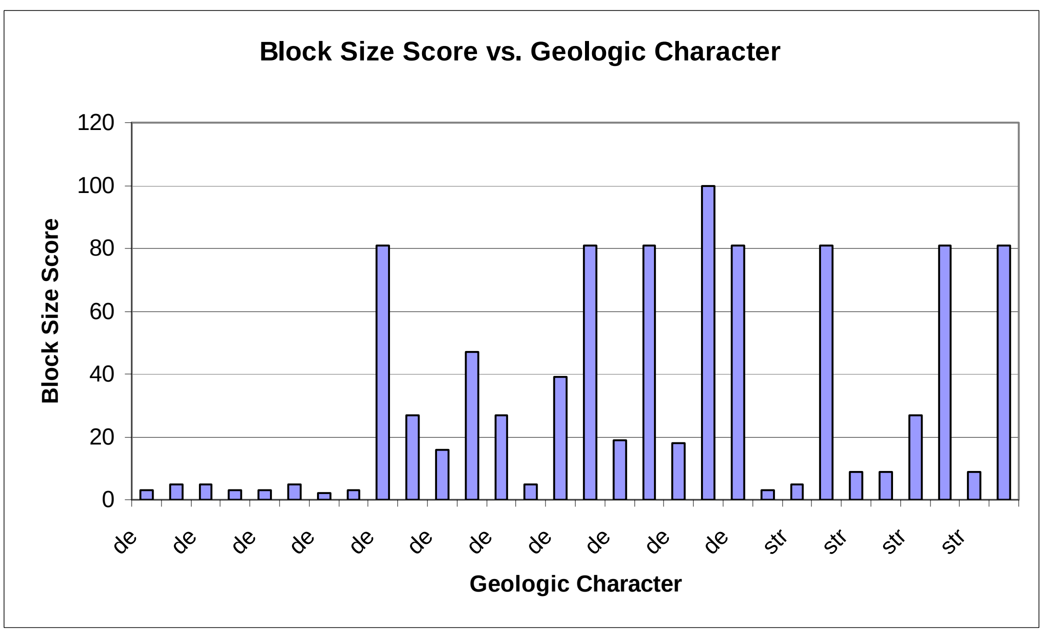

Figure 12: Relationship between potential rock fall size and slope geological character.

Block Size or Volume: Block size, or volume in certain areas, was not a serious problem for the most part. Structural slopes do seem to have considerably larger block sizes than do differential erosion slopes (Figure 12).

Rockfall History: The rockfall history of the slopes was not available. This category was scored primarily on the debris and rocks found close to the road and on the rest of the slope's score. Therefore, the procured estimates may or may not be accurate, but compared to the overall score, most appear to be close. There is one major exception to this, and that is the highest rated slope, to which we assigned a low rockfall history score. Most of the high score was given for potential, and not because of past events.

Recommendations

Further resources are needed to evaluate the numerous sites across the state of West Virginia. West Virginia Department of Transportation should work closely with neighboring states such as Kentucky and Ohio. This is already being done to some extent through the newly created Appalachian States Coalition for Geological Hazards in Transportation.

Conclusions

Of the slope design criteria that we found to influence the degree of rockfall hazards slope height was not a major factor in rockfall hazard determination, unless the slope was overwhelmingly higher than normal. Rockfall history also would play a large part, but the necessary information was not available. Also, the Geologic character was not an important factor. As a shale slope can get the same score as a massive sandstone slope, which is probably much less likely to fail than the shale the lithologic type, not included in the RHRS should be taken into account. Rock strength would be too difficult to determine for a quick analysis, but rock type should be considered.

The slope rankings will assist the highway personnel to set priorities for remedial as funds became available. It is not known whether the state will adopt the RHRS and use results of this study. In this study, the RHRS has proven to be a very useful tool for its purpose, which is to provide a quick but reliable warning system and ranking of rockfall sections.

It is incumbent upon the state of West Virginia and neighbouring states to share information, knowledge from lessons learned developing solutions to technical problems and databases. Each state has an abundance of data stored in their own database. The goal of the research is to develop a system, initially using the Microsoft SharePoint Team Services software to facilitate this function.

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Appendix I

Rockfall Hazard Evaluation Sites
In West Virginia

(For complete data see website portal http://cite006.marshall.edu)

Rockfall Hazard Rating System Location Summary

District 6

County	Route	Mile Post	Score	Rating	Latitude	Longitude
Marshall	WV 250	33.52A	582	A	39^o 57' 59.532" N	80^o 44' 24.719" W
Marshall	WV 250	33.52B	482	A	39^o 57' 59.532" N	80^o 44' 24.719" W
Marshall	WV Alt 2	0.5	401	A	39^o 54' 30.960" N	80^o 47' 18.650" W
Marshall	WV Alt 2	2	378	B	39^o 54' 07.509" N	80^o 45' 50.198" W
Brooke	WV 67	3.01	376	B	40^o 13' 53.035" N	80^o 35' 51.594" W
Brooke	WV 67	2.37	315	B	40^o 14' 23.926" N	80^o 38' 53.348" W
Wetzel	WV 20	25.1	293	B	39^o 35' 18.750" N	80^o 47' 03.261" W
Wetzel	WV 20	13.8	290	B	39^o 32' 36.790" N	80^o 39' 48.975" W
Brooke	WV 27	0.25	262	B	40^o 16' 09.450" N	80^o 36' 08.770" W
Wetzel	WV 7	3.2	257	B	39^o 37' 19.380" N	80^o 51' 08.990" W
Wetzel	WV 2	2.35	226	B	39^o 36' 55.945" N	80^o 54' 47.150" W
Wetzel	WV 2	11.5	198	B	39^o 42' 45.860" N	80^o 49' 21.285" W

District 7

County	Route	Mile Post	Score	Rating	Latitude	Longitude
Lewis	US 19	23.72	494	A	39^o 02' 08.053" N	80^o 28' 13.257" W
Braxton	WV 4	20.1	439	A	38^o 39' 37.524" N	80^o 45' 33.432" W
Lewis	US 33	27	287	B	39^o 00' 46.641" N	80^o 19' 07.067" W
Upshur	WV 20	33.07	170	B	39^o 05' 07.98" N	80^o 12' 48.85" W

District 8

County	Route	Mile Post	Score	Rating	Latitude	Longitude
Tucker	WV 72	28.35	434	A	39^o 12' 07.256" N	79^o 43' 18.599" W
Pocahontas	WV 66	13	325	B	38^o 23' 13.194" N	79^o 54' 24.760" W
Pendleton	US 33	4.24	242	B	38^o 51' 32.389" N	79^o 26' 07.079" W
Pendleton	US 33	2.42	169	B	38^o 52' 26.462" N	79^o 28' 01.245" W

District 9

County	Route	Mile Post	Score	Rating	Latitude	Longitude
Fayette	US 60	11.7	629	A	38^o 09' 08.808" N	81^o 10' 45.445" W
Fayette	US 60	12.6	297	B	38^o 08' 29.85" N	81^o 10' 20.75" W
Fayette	US 60	7.5	250	B	38^o 08' 02.975" N	81^o 13' 11.029" W
Fayette	US 60	14.4	233	B	38^o 08' 33.92" N	81^o 09' 16.743" W

District 10

County	Route	Mile Post	Score	Rating	Latitude	Longitude
McDowell	WV 80	2.5	349	B	NA	NA
McDowell	WV 16	12.6	345	B	37^o 17' 47.860" N	81^o 40' 07.867" W
McDowell	WV 80	1	336	B	37^o 21' 45.657" N	81^o 48' 01.88" W
McDowell	US 52	NA	229	B	37^o 25' 28.710" N	81^o 30' 17.424" W
McDowell	WV 16	12.48	211	B	37^o 17' 47.860" N	81^o 40' 07.867" W

Appendix II

Example of Data Sheet for the
Rockfall Hazard Evaluation Sites

RHRS DATA SHEET

District	10	County	McDowell	Highway#	WV 16	Speed Limit	35
Side of Road	Left	Date	8/16/01	Rated By	TDC	ADT	1,900
Beginning M.P.	12.6	Ending M.P.	?	Class	B		
Latitude	37° 17' 47.860" N						
Longitude	81° 40' 07.867" W						

CATEGORY	REMARKS	CATEGORY SCORE	
Slope Height (ft)	70	Slope Height	22
Ditch Effectiveness	Mod-Low	Ditch Effectivness	25
Average Vehicle Risk (%)	13.5	AVR	2
Sight Distance (ft)	130		
Percent Decision Site Distance	24.8	Sight Distance	100
Roadway Width (ft)	20	Roadway Width	81

Geologic Character		Geologic Character	
CASE 1		CASE 1	
Structural Condition		Structural Condition	
Rock Friction		Rock Friction	
CASE 2		CASE 2	
Differential Erosion Feat.	Numerous	Diff. Erosion Feat.	65
Diff. in Erosion Rates	Large	Diff. In Erosion Rates	27
Block Size/Vol (ft/yd^3)	1.5	Block Size	5
Climate			
Precipitation	Moderate	Climate	9
Freezing Period	Short		
Water on Slope	Intermittent		
Rockfall History	Occasional	Rockfall History	9
		TOTAL SCORE	345

Comments:

Slope Length is .06 miles
Outcrop located just south of War, WV
Erosion is more severe, but jointing is a large problem here as well

Appendix III

SharePoint Portal Description

1. SharePoint Team Services – Transportation Geohazards Knowledge Management & Sharing Enterprise

   The website belongs to Knowledge Management System. Knowledge Management System is a systematic process of finding, selecting, organizing, distilling and presenting information in a way that improves an employee's comprehension in a specific area of interest. Knowledge management helps an organization to gain insight and understanding from its own experience.

   - **Software Research**

   K – Station
   http://www-3.ibm.com/software/webservers/portal/
   HUMMINGBIRD EIP
   http://www.hummingbird.com/products/evals/index.html
   SharePoint Portal Server
   http://www.microsoft.com/sharepoint/portalserver.asp
   SharePoint Team Services
   http://www.microsoft.com/frontpage/sharepoint/
   Coreport 3g
   http://www.corechange.com/products/products.asp

   We will have up to fifty members to use this website. Considering that SharePoint Portal Products can work with Microsoft Windows Explorer, Microsoft Office applications and Web browsers, we selected Microsoft products.

   - **Web Design**

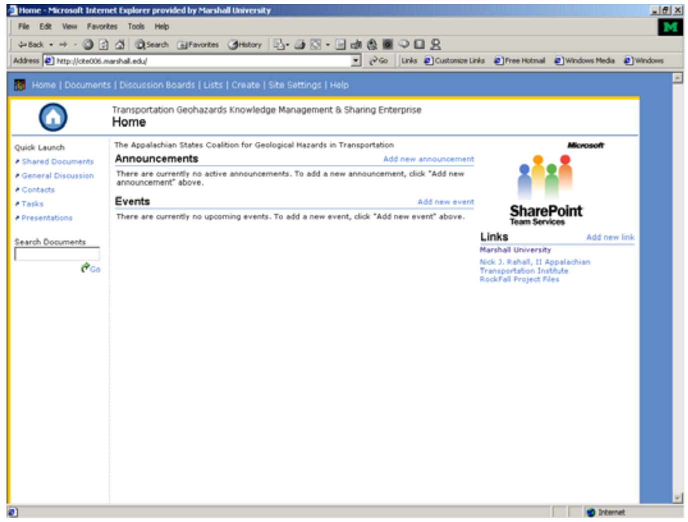
     During the first step of development, we used SharePoint Portal Server, which had power functions:

     i. Publishing on a dashboard site.
     ii. Searching across multiple locations.
     iii. Document access based on user roles.
     iv. Version tracking of multiple documents.
     v. Document routing for review and approval.

   However, since some of our users are not on the Marshall Campus, and SharePoint Portal server is used for intranet, we set up the website by SharePoint Team Services, which can realize internet access.

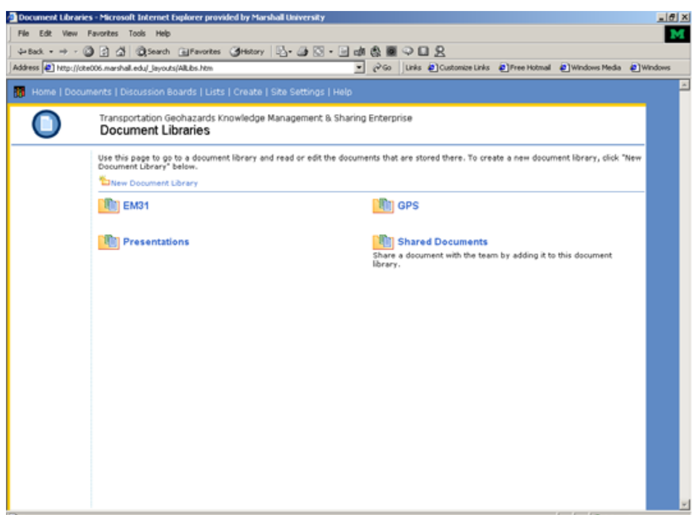
2. **SharePoint Team Services Features:**

   - Team Web Site Template
     SharePoint Team Services instantly provisions a fully functional, preprogrammed and configured web site to which team members can contribute directly from within their web browser (4.0+ versions).

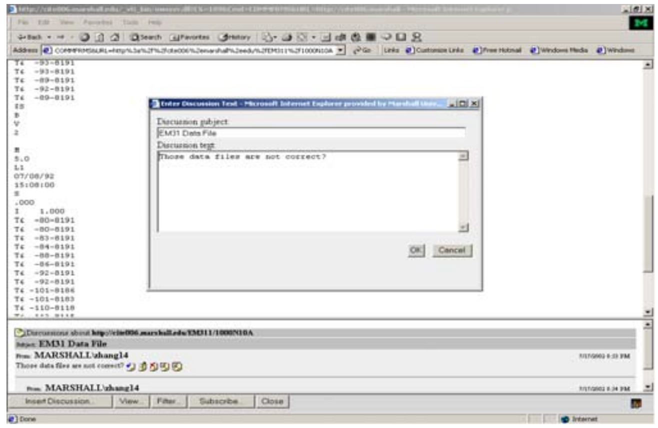


- List Functionality
  One of the major components of SharePoint Team Services based web sites is list. Lists are a means of displaying items of information that contains similar elements items such as contacts, announcements, tasks, and events. They are logical groups of information.

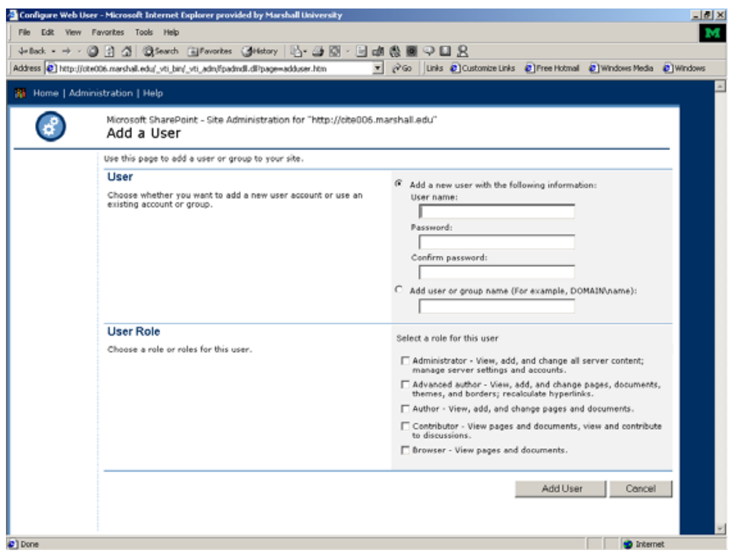
- Document Libraries
  Document Libraries can store, share and search documents on our web site. We can create as many different document libraries as we need as well as specify templates for specific libraries. Document libraries allow team members to simply upload documents via their Web browsers.



- Discussion
  Our web site provides the ability for team members to create newsgroup-style discussions about subjects that affect the team. Members may also use the discussion features to conduct online discussions about documents that are saved as web pages without affecting the source content of the document.



- Security and Permissions
  Administrators can use Web-based pages to create user accounts and set unique permissions for those accounts on their team web sites. Users can also turn off anonymous access so only those with explicit permissions can access their web sites.



- System Requirements

Server/Processor	Pentium 200 MHZ
Memory	256 MB RAM
Hard Disk	80GB
Operating System	Microsoft Windows 2000 Server
Database	**SQL Server 2000**

Conclusion
The project web site provides a place for knowledgeable workers to easily find, share, and publish information. It can help us work better in document management, content searching and team collaboration. Because more and more data is continually being generated, there is a need for a faster server and a web administrator to maintain the site daily.