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Contributed Papers

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The West Virginia Academy of Science was founded at Morgantown, November 28, 1924. The Academy was incorporated under the Code of West Virginia on May 9, 1959 as "a nonstock corporation, which is nor organized for profit but for the advancement of learning and scientific knowledge."

West Virginia Academy of Science
Proceedings

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Proceedings of the West Virginia Academy of Science

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Published as a peer reviewed journal by the West Virginia Academy of Science, Inc. Manuscripts for Publication (which are normally, but not necessarily read at an annual meeting of the Academy) should be sent to the Editor, R.W. Taylor, College of Science, Marshall University, Huntington, WV 25755. Proof, edited manuscripts, and all correspondence regarding papers for publications should be directed to the Editor. For additional information call 304-696-2338.

Applications for membership in the Academy and dues should be sent to Dr. Ian Jenness, Treasurer, WVAS, Department of Biology, Davis & Elkins College, Elkins, WV 26241. Changes of address should be sent to Dr. Jenness, at the above address Correspondence concerning library exchanges should be directed to Director of Libraries, West Virginia University, Morgantown, WV 26506.

INSTRUCTIONS TO AUTHORS

1. General Policy

The West Virginia Academy of Sciences' publication policy is intended to implement the goal of publication of the Proceedings by the Academy through stimulation of research on the part of West Virginia scientists and Academy members by providing an outlet for publication of their research results. Within the limits of available resources, the Academy will attempt to maximize the number of articles it can publish, while maintaining standards by the peer review process. Where selection must be made, the sole criterion for judgement will be the quality of the research involved. Articles of a local or regional nature, as well as those of broader scope, will be encouraged. Articles will not be discriminated against because of their subject matter, as long as they satisfy the requirement of the By-Laws that they be "...of a scientific nature" (Section VII, Article 1).

The Academy will consider papers that report the results of original research or observation. The Academy will not publish papers that have been published elsewhere. Each manuscript will be reviewed by the Publications Committee and by referees. Manuscripts longer than 15 pages of double spaced typed copy normally will not be accepted. Membership in the Academy is a requirement for publishing in the Proceedings. With joint authorship, at least one author must be a member of the Academy. No author, or coauthor, may submit more than two papers for any volume of the Proceedings. Ordinarily, papers offered for publication have been presented at the annual meeting of the Academy, but presentation is not a requirement for publication and the editor will accept papers for review on a continuing basis. Publication is not automatic. The Proceedings editor also solicits outstanding expository papers.

2. Abstract for Annual Meeting

A 'call-for-abstracts' announcement is mailed to each member in the fall. This announcement includes all information for the submission of abstracts for papers to be presented at the annual meeting. Abstracts and an application for a place on the program of the annual meeting must be submitted on disk, along with two hard copies, to the editor. Please make every effort to submit your abstract in Word Perfect or Microsoft Word in PC format. The abstracts summarizing the results of the investigation must accompany the application for a place on the program of the annual meeting. The abstract will be published in the first number of the volume for that year.

3. Organization of Manuscripts

Each manuscript shall start with an abstract (no more than 250 words) that should summarize the primary results. The following sequence is suggested for organizing a paper: Introduction, Materials and Methods, Results, Discussion, Acknowledgments, and References Cited. Except for the introduction, each division of the manuscript should be labeled. Subheadings may be used. The text should be double spaced and pages should be numbered consecutively in the top right-hand corner of each page preceded by the author's last name.

In general, the introductory abstract will replace a summary. This abstract should be suitable for sending to international abstracting services for immediate publication if the paper is accepted for publication in the Proceedings.

Submit the original and two copies along with original photos, figures, and drawings to the editor.

4. **By-Line**

The author's name department, institution, city, state, and zip code should follow the title.

5. **Cover-sheet**

The cover sheet for each manuscript should include the title of the paper followed by the name, address, business phone number, fax number (if available) and e-mail address (if available) of the corresponding author.

6. **Figure and Table Preparation**

Each table or figure should be supplied with a legend sufficiently complete to make the table or figure intelligible without reference to the text. Footnotes may be used in connection with tables and figures where necessary. Footnotes should be avoided whenever possible in the text itself. Complicated formulas should be prepared with care in a form suitable for camera copy reproduction. Avoid such formulas in the text.

7. **Illustrations and Special Symbols**

Line drawings should be carefully made on good rag paper for direct photo reproduction. Each figure should be numbered. While drawings may be of any convenient size, they will be reduced to 3 x 4 inches. Letters, symbols, and figures should be not less than 1 mm high after reduction to printing. In exceptional instances, a full page drawing (8 x 11 in.) may be used. Either original drawings or glossy photographs (mounted on illustration board with rubber cement) may be submitted. Photographic prints should be on glossy paper and have good contrast. Each drawing should be labeled on the back with the author's name and the appropriate legends. Camera copy will be used to reproduce mathematical formulas as far as is practical.

8. **Literature Cited**

References are listed at the end of the manuscript under "Literature Cited" and must be cited in the text.

The titles of the papers cited and the inclusive page numbers must be given. References in the text may be either by year or by number. Examples: Hall and Campbell (1957) or [5]. Square brackets are recommended for references so that numbers in parentheses may be used to denote formulas in the text.

Example of a journal citation at the end of paper:

5. Hall, J. L., and R. Campbell. 1957. Polarization of ethanol in benzene. Proc. W. Va. Acad. Sci. 29:53-57.

Example of a book citation:

6. Stacey, M., and S. A. Barker. 1960. Polysaccharides of microorganisms. Oxford Univ. Press. London. 228 pp.

9. **Disk Submission of Revised Manuscripts**

All manuscripts accepted by the peer reviewers, need to be revised according to instructions and submitted to the editor on disk.

10. **Proof**

Galley proofs will be sent to authors for corrections. Make corrections on margins of the proof. Proofreader's marks may be found in dictionaries, or in style manuals (e.g., "Style Manual for Biological Journals"). Changes in text after the manuscript is in galley proof are quite expensive and in general are not permitted. Galley proofs must be corrected and returned promptly (within ten days).

11. **Reprints**

A reprint order blank will be sent with the galley proofs. This should be returned with the corrected proof.

12. **Cost of Publication**

Authors will be billed by the Academy for pages in excess of the maximum allowed, see item 1. The cost of figures which require halftone screens, such as photographs, will also be billed to the authors. Currently, a page charge of $12.00 per page is in effect and the author will be sent a pro forma invoice to see if payment can be secured from the author's institution, company, research grant, etc. Failure to honor page charges will not prevent publication of a paper, but payment in a timely fashion will greatly assist the publication program of the Academy.

April 1, 1995
Annual Meeting of the West Virginia Academy of Science
Marshall University

EXECUTIVE SESSION 8:30 am , Ralph Booth Presiding

1. Mr. Booth passed out copies of the revised By-Laws.

2. A discussion concerning the dues structure came to the floor. It was moved, seconded, and passed that the following dues structure be adopted:
    a. regular member-$10 per year
    b. sustaining member--two times regular
    c. life member--ten times regular member
    d. student member-- regular member

3. The 1996 meeting will be at Concord College on April 20, 1996.

4. Treasurer Ian Jenness presented:
    a. A list of members who had not paid dues for three years.
    b. The treasurer's report.
    c. A bank certificate of deposit (value $8,526.32) that will mature in April 1995. Ian will cash in the CD, buy a new CD for $5,000 and put $3,526.32 in the checking account.

5. Roger Seeber, State Science Fair Coordinator, passed out a report containing data about the state science fair.

6. The October 1995 planning meeting for the 1996 Annual Meeting was tentatively set for October 8, 1995 at Concord College.

7. Ed Keller stated that the 1993 PROCEEDINGS contained eight papers, seven were accepted and one was rejected. The 1993 PROCEEDINGS is expected to go the printer in July 1995.

GENERAL SESSION 12:20 PM RALPH BOOTH Presiding

1. Ralph Taylor of Marshall University was thanked and presented with a plaque for arranging the meeting at Marshall.

2. Treasurer Ian Jenness presented his report:
    a. Cash receipts: $3420.00
    b. Expenses: $2649.00
    c. Balance: $770.00
    d. CD of $8526, $5000 to be reinvested, $3526 to be deposited into checking account.

3. David Blades, Chairman of the nominating committee, presented a slate of candidates to the Academy. The nominees are: President Elect, Ron Preston; Treasurer, Ian Jenness; Library Subscriptions, John Warner; Proceedings Editor, Ralph Taylor; Science Fair Coordinator, Roger Seeber; and, Recording Secretary, Phil Cottrill. It moved, seconded, and voted by acclamation that the slate of officers for 1995-1996 be accepted.

4. The 1996 Annual Meeting of the Academy will be held at Concord College on April 20, 1996.

5. PROCEEDINGS update: Tom Weaks spoke on behalf of Ed Keller. The 1993 PROCEEDINGS is nearly ready to go to the printer. The 1994 PROCEEDINGS may be published before the 1993 edition.

6. The Academy thanked Roger Seeber for administering the Science Fair.

7. Ralph Taylor presented the outstanding West Virginia high school science teacher award to Bernard Adkins, a biology teacher at Wayne County High School.

8. Ralph Booth reported that the CD ROM project of science academy abstracts was available. It covers abstracts from 1984 to the present.

9. Ralph Booth transferred the Academy gavel to incoming president, Marcia Harrison.

10. The general meeting ended at 12:40 PM.

AWARDS PRESENTATION at 4:00 PM

1. The West Virginia Academy of Science Best Student Paper award went to Roger Boggs.

2. The Host Institution (Marshall University) Award went to Dale Suiter.

3. The West Virginia Academy of Science Best Poster Award went to Candace Steed.

State of West Virginia

AGREEMENT FOR INCORPORATION
OF
WEST VIRGINIA ACADEMY OF SCIENCE, INC.

Under the provisions of chapter thirty-one of the code of West Virginia, one thousand nine hundred thirty-one, as amended, the undersigned incorporators agree to associate themselves for the purpose of establishing a nonstock corporation, which is not organized for profit but for the advancement of learning and scientific knowledge, as follows:

ARTICLE I. NAME

The name of the corporation shall be

WEST VIRGINIA ACADEMY OF SCIENCE, INCORPORATED

ARTICLE II. PRINCIPAL OFFICE

The post office address of the principal office of the corporation shall be West Virginia University, Morgantown, West Virginia.

ARTICLE III. PURPOSE

The purpose and objects for which the corporation is formed are the advancement of scientific knowledge and the promotion of scientific work in West Virginia.

The corporation is organized and shall be operated exclusively for the educational purposes set forth in the preceding paragraph, and in furtherance thereof it is authorized to accept, hold, administer, invest and disburse such funds and properties of any kind or character as may from time to time be given to it by any persons or corporations, absolutely or in trust, as the case may be, and in general to do all things that may appear necessary and useful in accomplishing these purposes. All of the assets and earnings of the corporations shall be used exclusively for educational purposes as herein above set forth, including the payment of expenses necessarily incident thereto, and no part of such assets and earnings shall inure to the benefit of any employee, officer or member of the corporation, or of any other individual, except in payment of reasonable compensation for services actually rendered or expenses necessarily incurred. No part of the activities of the corporation shall be for the carrying on of propaganda or otherwise attempting to influence legislation.

ARTICLE IV. MEMBERSHIP

The initial membership of the corporation shall be composed of the original incorporators and all existing members of the former unincorporated West Virginia Academy of Science. Eligibility for future membership shall be determined by the by-laws adopted by the corporation.

ARTICLE V. MANAGEMENT

The direction and management of the corporation shall be vested in an Executive Committee composed of the President, the Past President, the President Elect, the Secretary, and the Treasurer.

ARTICLE VI. INCORPORATORS

The names and addresses of the incorporators are as follows:

Virgil G. Lilly	Morgantown, West Virginia
Walter A. Kochler	Morgantown, West Virginia
George Hunt	Fairmont, West Virginia
John D. Draper	Bethany, West Virginia
Herald D. Bennett	Morgantown, West Virginia
B. R. Weimer	Bethany, West Virginia
Nellie Ammons	Morgantown, West Virginia
E. E. Myers	Philippi, West Virginia
A. R. Collett	Morgantown, West Virginia

WE, THE UNDERSIGNED, for the purpose of forming a corporation do make and file this agreement; and
IN WITNESS THEREOF, we have hereunto affixed our signature this 24th day of April, 1959.

Virgil G. Lilly B. R. Weimer

Walter A. Koehler Nellie Ammons

George Hunt E. E. Myers

John D. Draper A. R. Collett

Herald D. Bennett

Note: The Certificate of Incorporation of the West Virginia Academy of Science was issued by the Honorable Joe F. Burdett, Secretary of State for West Virginia on May 9, 1959. The Certificate of Incorporation was admitted to the record by Robert H. Bowlby, Clerk of the County Court of Monongalia County,.May 25, 1959. At present the Charter is on deposit in the Rare Book Collection of the West Virginia University Library.

By-Laws
of the
West Virginia Academy of Science

SECTION I

Membership

(1). The Academy shall consist of regular members, sustaining members, life members, and emeritus members.

(2). Regular members shall be persons who are engaged in or interested in any field of science, and each shall pay, in advance, an annual fee as established by the Executive Committee.

(3). Any individual, institution, or organization may become a sustaining member by payment of a minimum annual fee as established by the Executive Committee.

(4). By a single payment as established by the Executive Committee any regular member of the Academy may become a life member, retaining all the privileges of regular membership.

(5). Emeritus membership may be extended to any person who has been a regular member for a minimum of fifteen (15) years and who has retired from service. An emeritus member shall be exempt from further payment of dues but shall retain all rights of regular membership. By majority vote the Executive Committee may elect to emeritus membership in the Academy any qualified member.

(6). Candidates for membership in the Academy shall submit an application accompanied by the first year's dues. Election to membership in the Academy shall be by majority vote of the Executive Committee subject to final review by the membership at the next annual meeting.

(7). The dues submitted by any person, organization, or institution with the application for membership shall be accepted in settlement for the current fiscal year if election occurs between July 1 and December 31 and for the ensuing fiscal year if election occurs between January 1 and June 30.

SECTION II

Fees

(1). Each member with the exception of life members and emeritus members, shall pay in advance to the Treasurer of the Academy the annual fee established by the Executive Committee and due on July 1.

(2). Immediately after the annual meeting the Treasurer shall send to each member a statement of dues payable, and after November 1 a second notice shall be sent to persons whose dues are in arrears. Members who allow their dues to be unpaid for two years, having been duly notified by the Treasurer, shall be dropped from membership by the Executive Committee.

SECTION III

Officers and Executive Committee

(1) The officers of the Academy shall be a President, a President-Elect, a Secretary, a Treasurer, an Assistant Treasurer, the Editor of the Proceed ings, and the Director of the West Virginia State Science and Engineering Fair.The term of office shall be two (2) years. Each will serve for the term indicated or until a successor has been elected. The president shall not be eligible to succeed himself/herself in that office, unless filling an unex pired term, but he/she shall be succeeded automatically by the President-Elect. The election of officers shall take place at the annual meeting, and the term of office of each shall start at the beginning of the next fiscal year following election. Nominations shall be made by a nominating committee and may also be made from the floor at the time of the meeting.

(2) In addition to any specific duty or duties hereinafter mentioned and to any special duties which may be assigned by the Executive Committee or the Academy, the duties of the officers shall be those commonly assigned to officers of associations.

(3). The Executive Committee shall consist of the President, the President Elect, the Secretary, the Treasurer, and the immediate past President and shall have the authority to fix the time and place of meetings; to appoint all standing committees and special committees-except the Auditing Commit-tee, which, as is hereinafter provided in Section XII (1) of these By-Laws, is appointed by the President--the Editor of the Proceedings, the Editor of the News Letter, and the Delegate to the American Association for the Advancement of Science; to prepare a budget; and to transact such other business as may need attention between the meetings of the Academy. The Delegate to the American Association for the Advancement of Science shall be expected to attend all meetings of the Executive Committee and to act in an advisory capacity to that committee. Three members of the Executive Committee shall constitute a quorum.

(4) The Executive Committee shall hold no fewer than two meetings each year. It may hold additional meetings at the call of the President.

(5) The Secretary and the Treasurer shall be eligible for re-election for consecutive terms.

(6) If for any reason the office of the President is vacated during the fiscal year, the President-Elect shall become President immediately. If any other office is vacated during the fiscal year, the Executive Committee shall elect a successor to serve until the end of that fiscal year.

SECTION IV

Standing Committees

(1). The standing committees of the Academy shall be: Membership, Publica tions, Speakers Bureau, State Science Fair, and Necrology.

(2). The Membership Committee, consisting of three members, shall seek to increase the membership. It shall be empowered to appoint subcommittees to assist in the work.

(3). The Publications Committee, consisting of a representative from each section of the Academy shall be responsible for editing and publishing the official publications of the Academy.

(4). The Speakers Bureau Committee shall secure and furnish to interested groups information concerning members of the Academy who are currently available for addresses on scientific subjects.

(5). The State Science Fair Committee shall assist an cooperate with the Junior Academy of Science in the promotion of a State Science Fair.

(6). The Necrology Committee shall report to each annual meeting the name of every member of the Academy who died since the last meeting and shall prepare appropriate resolutions for Academy records and for each family concerned.

SECTION V

Meetings

(1). The regular annual meeting of the Academy shall be held in the spring at the time and the place determined by the Executive Committee. A special session shall be called at any time at the written request of twenty regular members or by a majority vote of the Executive Committee.

(2) Robert's *Rules of Order* revised shall govern the conduct of meetings where not otherwise provided for in the Charter and By-Laws of this Academy.

(3). No meeting of this Academy shall be held without thirty days notice to the membership.

(4). Twenty regular members shall constitute a quorum of the Academy for the transaction of business.

SECTION VI

Fiscal Year

(1) The fiscal year of the Academy shall be from July 1 to June 30, inclusive.

SECTION VII

Publications

(1). The Academy shall publish its Proceedings and other papers approved by the Publications Committee. All papers presented to the Academy for publication shall be of a scientific nature. A copy of the Proceedings shall be sent to each member in good standing.

(2). A News Letter shall be issued quarterly and sent to each member.

SECTION VIII

Sections of the Academy

(1) Members, not less than ten in number, may by special permission of the Academy form a section for the investigation of any branch of science. Each section shall bear the name of the science which it represents, for example: the Geology Section of the West Virginia Academy of Science. Each section shall be empowered to perfect its own organization as limited by the Charter and By-Laws of the Academy.

SECTION IX

Affiliated Societies

(1) Any group of workers, numbering at least ten individuals, in any field of scientific interest may be recognized by the Academy as an affiliated society and be provided with facilities for its sessions in connection with the regular meetings of the Academy. The prospective affiliate shall make application to the Academy for affiliation. The petition, with the approval of the Executive Committee, shall be submitted to the Academy in annual session, and a two-thirds vote of the Academy members present shall be required for affiliation. At least ten of the members of the affiliating organization shall maintain membership in the Academy.

SECTION X

Miscellaneous

(1) The President shall appoint annually an Auditing Committee of three who.shall examine and report in writing upon the accounts of the Treasurer.

(2) The Articles of Incorporation and By-Laws shall be published in the Proceedings at intervals and shall be available from the Secretary at any time. The membership list in its entirety may be published in the Proceedings at intervals.

(3). The Nominating Committee appointed by the President shall consist of three members and shall nominate candidates for the offices of President-Elect, Secretary, and Treasurer, taking into account, so far as feasable, a fair distribution of officers in the different fields of science.

(4). These By-laws may be amended by a three-fourths vote of the members present at any regular meeting of the Academy.

Note: These By-Laws were adopted at the regular business meeting of the Academy on April 23, 1994.

Contributed Papers of the 1995 Annual Meeting

A Field Investigation of the Knight Landslide East Pea Ridge, Barboursville, WV

Clairene Bailey and Dewey D. Sanderson

Department of Geology
Marshall University
Huntington, WV

ABSTRACT

One of the most common geologic hazards in the Tri-state area of West Virginia, Ohio, and Kentucky is landslides. A small landslide in the East Pea Ridge area of Barboursville was investigated in detail over a period of nearly two years. The slide was triggered by the construction of a utility trench along a new road for a new housing subdivision.

The study included detailed theodolite surveying of the topography, mapping of the scarps, a seismic refraction survey, a resistivity survey, soil sampling, tree trunk inclination measurements, and measurement of precision control stakes. The site investigated is approximately 150 by 250 feet with natural slopes of 13 ° and 26 °. The slide, which occurred on the lower gentler slope, is approximately 90 feet long, 40 feet wide at the head and opens to 100 feet at the toe.

The study revealed that a small gully incised into sandstone bedrock on the upper slope has built a small alluvial fan where the break in slope occurs. Discharge from storms coming down the gully filters, in large part, into the fan and helps saturates the colluvium of the lower slope. A refraction seismic survey indicates the colluvium on the lower slope overlies weathered shale. The colluvium was found to host a perched water table within 9 inches of the ground surface. A resistivity survey showed a higher degree of water saturation along the main scarp. We conclude that a set of natural conditions created an unstable slope due to excess moisture and the construction activity removed sufficient support from the lower side of the slope causing it to fail.

INTRODUCTION

Two of the most commonly recurring geologic hazards in the tri-state area of West Virginia, Kentucky and Ohio are landslides and flooding. It is obvious that excess water from rainfall is the cause of flooding, but is less obvious that excess water in slopes causes landslides . Cultural activity increases the occurrence of both flooding and landslides. Construction costs, be it for roadways or building sites, are frequently higher as a result of landslides. Sharpe (1968) reported that

West Virginia spends a significant amount of money repairing roadways damaged by mass movement of earth materials.

The U.S. Geological Survey (Rudbruch-Hall, et al, 1982) showed that West Virginia, of all states, has the greatest proportion of its area having a high incidence of landslides. Further, the Appalachian region has the highest incidence of slide activity in the country. It has long been recognized that the common occurrence of landslides in Appalachia is due to a combination of topographic, climatic, vegetative and lithologic conditions (Sharpe, 1968; Lessing, et al, 1976; Rudbruch-Hall et al, 1982).

There is a paucity of detailed landslide investigations reported in the literature for West Virginia. However, the West Virginia Geologic and Economic Survey conducted an overview investigation of over 1,000 landslides in an area covered by 28 (7.5 minute) topographic quadrangles (Lessing, et al, 1976). Most often the slides were found to occur in the sedimentary Pennsylvanian age Conemaugh group strata. Other work by Hall(1974) revealed that the greatest frequency of slides were found to occur on slopes with angles of 25-30% (14°-17°).

The area of our study falls within the Barboursville quadrangle which was also investigated by Lessing and others (1976). The Barboursville quadrangle covers a portion of the western Cumberland plateau having topographic relief of approximately 400 feet; relief in the study area is about 125 feet. The Knight landslide is in the East Pea Ridge area of Barboursville (see Figure 1), southwestern West Virginia. The ancestral Teays River valley floor forms Pea Ridge and trends in an east to west direction. Lessing and others (1976) show a low incidence of slides in the former course of the Teays River; only three slides are indicated in the approximately 3 square miles of East Pea Ridge, which represents only about 2% of the land area. Beyond the abandoned Teays stream valley, nearly 90% of the land is designated as slide prone.

The Knight landslide is located in a new housing development where an existing road was extended to gain access to the properties being developed. Following construction of a concrete slab road into the subdivision, a utility trench was excavated along the upper side of the road which resulted in a slope failure. After removal of the soil that was pushed into the road by the slide, the base of the slope was filled with 8-10 inch size crushed limestone riprap in an attempt to stabilize the slope.

The authors have found the investigation of landslides is useful when considered from two perspectives: first, what were the conditions that set up the slope instability and second, what triggered the slide. Both natural and human activity can set up and trigger slides. Often it is important to make an assessment as to the setup and triggering of a slide when it involves litigation. The objective of this study was to determine the conditions that set up the slide. In this case, we believe, the triggering event was the excavation of the utility trench.

The landslide site is situated on an undeveloped, north facing, wooded slope (Figure 2). The slide area is moderately forested with deciduous trees 6-12 inches in diameter, a few pine trees, and low brush. The adjacent properties to the north and south of the slide have homes in line with the slide.

Pea Ridge (Fig. 1) is underlain by nearly horizontal, Pennsylvanian age Conemaugh strata consisting of alternating sandstones, siltstones, and shales. The drainage from the study site leads to the Guyandotte River located approximately one-half mile to the north. The hilltop above the study site is the ancestral Teays River Valley floor. River cobbles from the former Teays River were found during the site investigation. A small gully, found on the steep hillside, approximately 10 feet wide and 5 feet deep is eroded into bedrock.

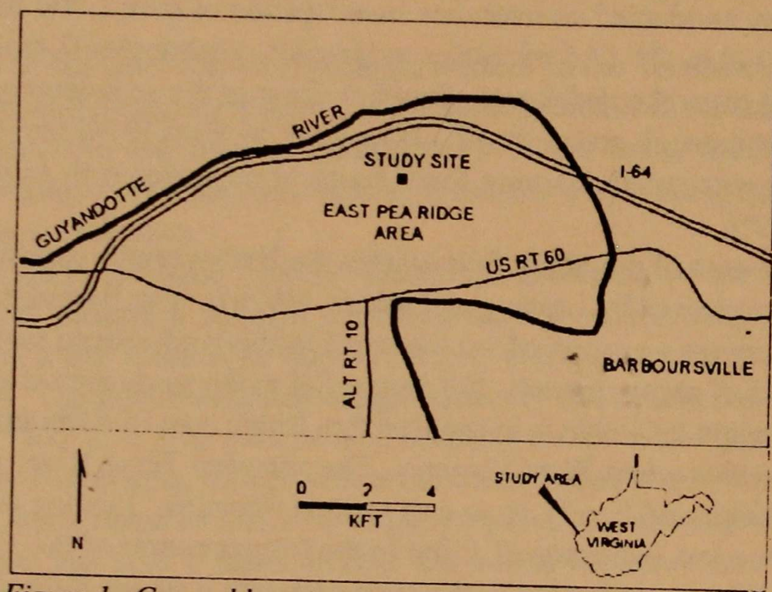

Figure 1. General location map of study, Pea Ridge area, Barboursville, Cabell County, West Virginia.

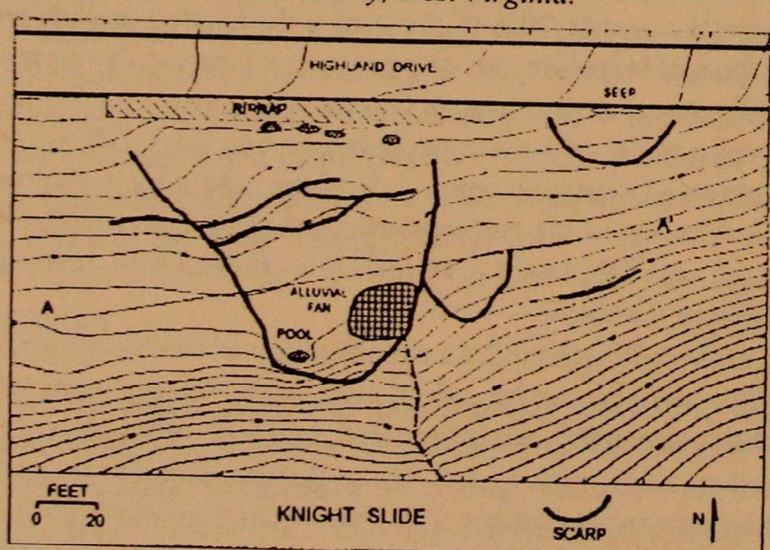

Figure 2. Site map of Knight landslide contoured at a 2 foot interval.

METHODS OF INVESTIGATION

A number of techniques were used to study this slide and the results helped to give a more complete understanding of the cause and dynamics of the mass movement. Detailed mapping of a 250 by 150 foot area (Figure 2) was accomplished with a Nikon theodolite equipped with a Cubic Precision EDM. Highland Drive was arbitrarily assumed to extend east-west which is nearly the case. Horizontal and vertical coordinates were computed to an accuracy of 0.01 ft. The theodolite was used to define topography and features with more than 140 measurement points across the site. The data, after being reduced, were contoured with the computer software, SURFER. Surveying was also used to establish the road, riprap and bench mark locations as well as non-cultural features such as the drainage, springs/seeps, and scarps. Repeated measurements were made on four pairs of control stakes on each side of the slide to monitor movement over time.

A Bison portable refraction seismograph with a sledge hammer as an energy source was used to determine the depth to bedrock. The seismic profile was laid out parallel to the hill centered across the middle of the slide. The velocities gained by the technique were used to estimate the composition of the earth materials and their thickness.

Direct observations of the subsurface lithologies were gained by exposure of the bedrock in the drainage and at the head of the main scarp. Soil samples were taken with a 3/4 inch diameter sample tube that was pushed into the soil to a depth of three feet. The samples were visually examined for composition. Additional information on the composition and nature of soil was obtained from the Cabell County Soil Report published by the Soil Conservation Service (1989). Soil samples from a depth of two feet were collected and taken to the laboratory and dried for determination of moisture content. The holes made by the soil sampler provided a simple way to monitor water levels that in some holes were very near ground surface.

A second geophysical technique was used to probe the subsurface. A Soiltest resistivity meter was used to measure electrical conductivity of the soil. Four electrodes in the Wenner configuration were moved across the site creating a profile coincident with the soil and refraction traverses. With a 5 foot electrode spacing, the electrical resistivity of the soil is effectively being measured at the depth of the electrode spacing (Robinson and Coruh, 1988). The resistivity is an index of the moisture and mineralogy of the rock or soil. If the soil is of uniform mineral and size composition, a decrease in the resistivity indicates an increase in the moisture content. If the moisture is relatively uniform, a decrease in the resistivity indicates an increase in the percentage of conductive minerals.

An unstable slope can affect vegetation on the slope; trees may by tilted or even toppled by slope movement. Small amounts of movement disturbing the root system can easily kill trees without any apparent change in the tree's normal vertical trunk. Five trees that had some initial tilt were selected for monitoring by driving two nails into their trunks that could be used as a reference for tilt measurement. The direction in which trees were tilted was measured to indicate the nature of ground movement.

RESULTS

As seen in Figure 2, the slide is fan shaped opening to the north. The crown or head of the slide is situated at the topographic break in slope. The toe of the slide is presently at the back of the riprap, but originally it extended to the road. There are numerous other lesser scarps with vertical displacements ranging from two inches to four feet. Besides the downward movement, there was also horizontal motion as noted by the movement onto the road when the slide first formed. Water was observed in seeps and in a pool at the base of the steep slope where bedrock is exposed. Water only intermittently flows in the small drainage at the head of the slide during and after a rain.

Surveying was the most useful technique employed in this investigation. Figure 2 is the base map of the site showing the topography along with the locations of relevant features. The two general spacings of the contours south of the road define the moderate and steep slopes at the site. The steep slope of the hill averages 27° or nearly a 50% grade. The lower slope, upon which the slide developed, ranges from 10°-15° in steepness or a 17-27% grade.

The principal features of the slide are the scarps. Eight scarps were delineated and are shown in Figure 2. The largest arcuate scarp outlines the main slide block fanning outward from the base of the steep slope to the road. Subsidence at the crown of this main scarp is approximately four feet and has exposed bedrock. Vertical displacements along the margins of the main scarp range up to one foot. Three scarps, trending parallel to the road, occur in the toe of the slide. A graben-like structure has developed between these toe scarps; the vertical displacement attains 2 feet.

Immediately to the east of the main scarp is another arcuate feature that terminates on the east margin of the main scarp. It appears to be younger than the main scarp. A partially developed scarp with minor displacement extends off the west side of the main scarp. The two remaining scarps to the east appear to be associated with older inactive slides that did not fully develop.

Results of the surveyed paired control stakes spans 15 months. During this time the stake pairs across the crown and lateral margin showed no significant vertical movement greater than 0.04 feet, an amount in the range of measurement error. The toe of the slide did show a net rise of 0.07 feet(0.84 inches) for both stakes, but no differential movement between the stakes.

The seismic refraction survey was conducted along Line A-A'(Figure 2). This was also the location of the resistivity and soil moisture profiles. The time-distance plot(Figure 3) from the refraction survey reveals a two layer case. The first layer has a velocity of 910 ft/sec that is attributed to the top layer of colluvium. The second layer yields a velocity of 5900 ft/sec and is interpreted to be bedrock composed of weathered shale. Sandstone and siltstone are usually characterized by faster seismic velocities. The depth to the interface between the two material is 16 feet at a position of 20 feet in front of the bedrock at the head of the slide.

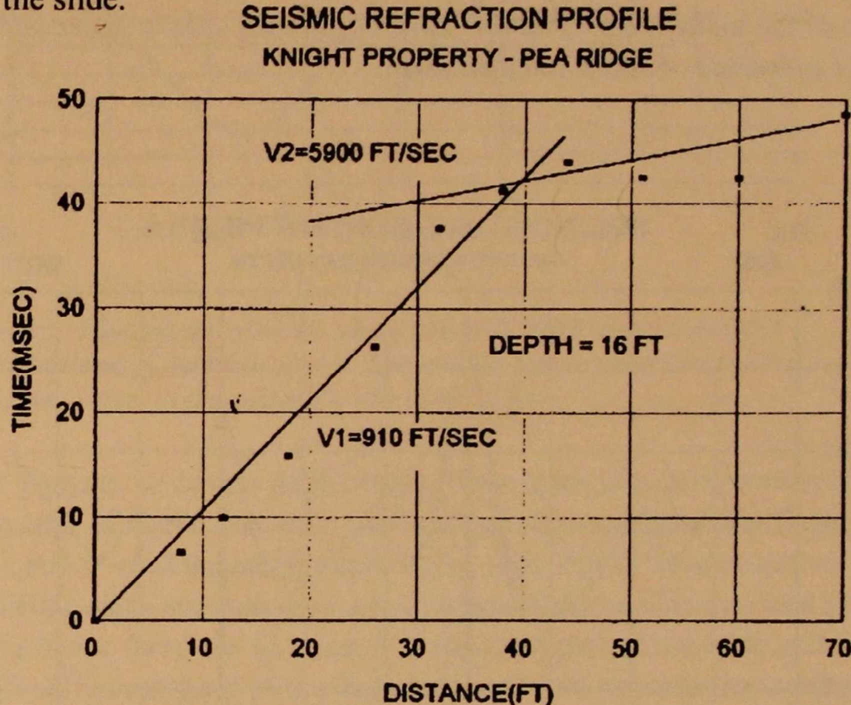

Figure 3. Time-distance seismic refraction profile along line A-A' showing a two layer case.

The bedrock exposed in the intermittent stream bed is a fine grained sandstone to siltstone, generally thin bedded. In the outcrop exposed by the slide, the rock is a fine grained sandstone, medium bedded. These are the only places where bedrock is exposed. The colluvium contains fragments of sandstone and siltstone that have been derived from the steep back slope. The colluvium is a relatively dense red-brown silty clay with partially disintegrated sandstone clasts. The clay content of the colluvium is undoubtedly related to the weathering of the shale upon which the lower slope rests. The colluvium, as cited above, is about 16 feet thick some 20 feet in front of the head wall outcrop. On the steep back slope the soil cover is seen to be from 1-2 feet thick. The break in slope at the back of the slide is due to the change in lithology from the overlying sandstone, which is able to maintain a steeper slope, to the less resistant underlying shale.

Figure 4 shows the results of the 21 moisture measurements made along the same profile as the refraction survey. The moisture contents averages about 20%, except for two values that are greater than 27%. The positions of the high readings coincide with the main scarp margins. The results of the resistivity profiling, as illustrated in Figure 5, show two areas where the resistivity of the soil is low. These two low resistivity zones also occur along the sides of the main scarp. The low zone on the east side is wider and falls within the influence of small satellite scarp.

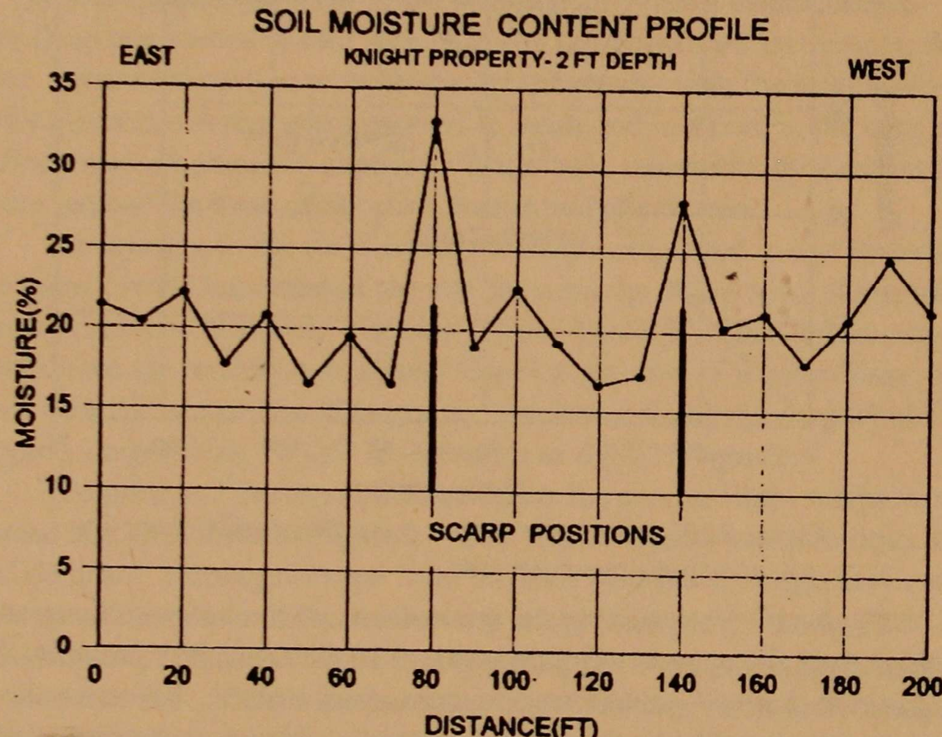

Figure 4. Soil moisture content along line A-A' showing increased moisture where the line crosses each side of the main scarp. Samples were at a depth of 2 feet.

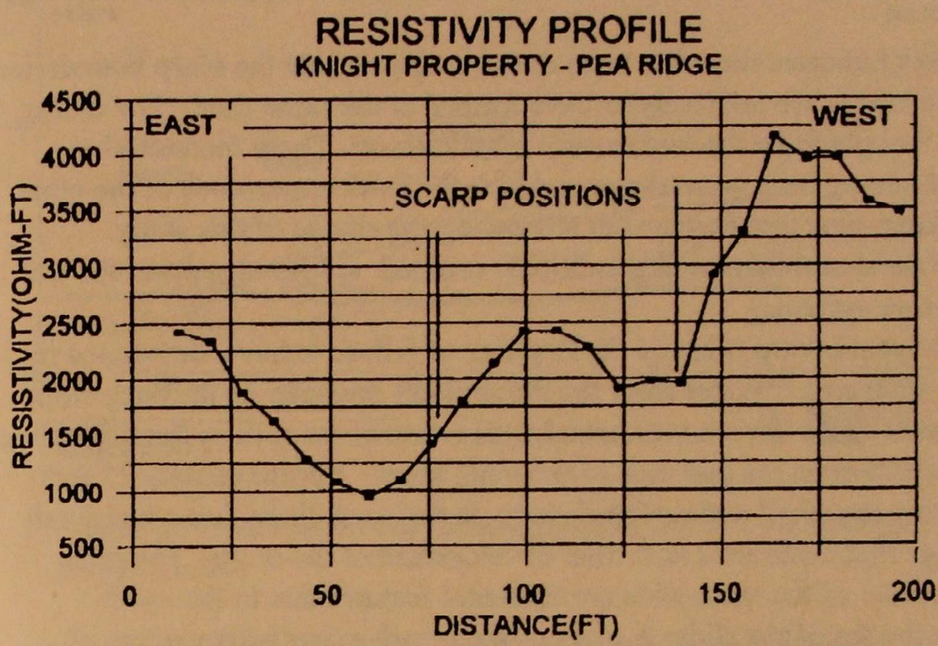

Figure 5. Electrical resistivity along line A-A' with lows associated with positions of the main scarp. The greater low is coincident with increased water in the soil under the alluvial fan.

During the course of the study, three trees fell, two pines and one unknown type of deciduous tree. Both pines fell toward the road, while the other tree fell toward the steep slope. Other fallen trees were observed in the vicinity of the slide and may or may not be related to soil movement. Within the main slide block there are 15 trees, 8 in the front part of the slide and 7 in the back half. All seven trees in the back half are tilted towards the steep slope while in the front portion four are tilted toward the road and four to the back. Over the nearly two years of the study, the five trees selected for tilt monitoring showed as much as 7° change in trunk inclination. Two of the trees in the toe of the slide showed no significant change in trunk inclination, but two trees in the crown of the slide showed a change of 2° and 7° toward the back slope.

DISCUSSION

The wide variation of data types allows for a more complete picture and understanding of how the slide formed and functioned. Since the trigger mechanism of the slide is known, the focus of the discussion will be on the conditions that setup the slide.

Scarps define the area of influence of the unstable slope. They represent places where the earth material failed. Before failure, most earth materials go through a stage of plastic deformation. The area of tilted trees extends approximately 50 feet beyond the limits of the scarps on the lower slope and this indicates there has been deformation outside the scarp boundaries.

All scarps are not likely to have formed at the same time. The oldest scarps are thought to be the two eastern most features. These features show evidence of having been worn down and lack the fresh appearance of the other scarps. A large pine tree in this area fell during the course of this study. Apparently the destabilized soil conditions resulted in loss of support for the pine tree's root system.

The main scarp is likely the first line of failure to have developed in the current slide area. Water from the intermittent drainage on the back slope is the probable cause for saturation and weakening of the soils in the main slide and satellite scarp on the east side of the main scarp. Approximately 25 feet downhill from the small undeveloped scarp on the west, there has consistently been seepage that could lead to further development of the scarp. The three scarps in the toe of the main slide are tensional features due to the uplift recorded in the toe of the slide. A graben-like trough exists between two of these scarps. A curvature in the slip plane would account for the observed motion in the toe . Soil sampling in the toe area penetrated voids not seen at the surface. These tensional features make the soil more permeable to water infiltration.

Figure 2 shows that the contours tend to diverge in the area of the slide, bulging out to the north in the toe area and swinging toward the steep slope in the crown area. If the contours were to extend straight through the toe area, the present elevation is greater than it was in the past, prior to the slide. The higher elevation indicates material has been gained in the toe of the slide and is referred to as the accumulation zone (Bromhead, 1986). This suggests a component of upward movement. Extending straight contours through the head area indicates that the elevations were formerly higher and this is designated as the degradation zone (Bromhead, 1986). Combining these two effects shows that the back area has been dropped down at the same time the front part of the slide was being uplifted. The measurements on the paired stakes all support this suggestion. All seven of the tilted trees in the back area of the slide are tilted to the south, consistent with the contour pattern and inferred motion.

The rock ledge exposed at the head of the slide probably extends along the nearby hillside. The front face of the rock ledge has a slope of 60°, about twice as steep as the relatively steep hillside above. It appears to be a buried ledge covered by debris from above. At the head of the slide where the rock is exposed, there was a three foot deep pool of water during much of the study, but it dried up by the end of the study.

The intermittent drainage is well defined on the back slope where it has incised into the bedrock, but on the gentler front slope it is poorly defined along the east side of the slide. The abrupt change in grade at the base of the steep slope causes the intermittent stream to deposit its sediment load and build a

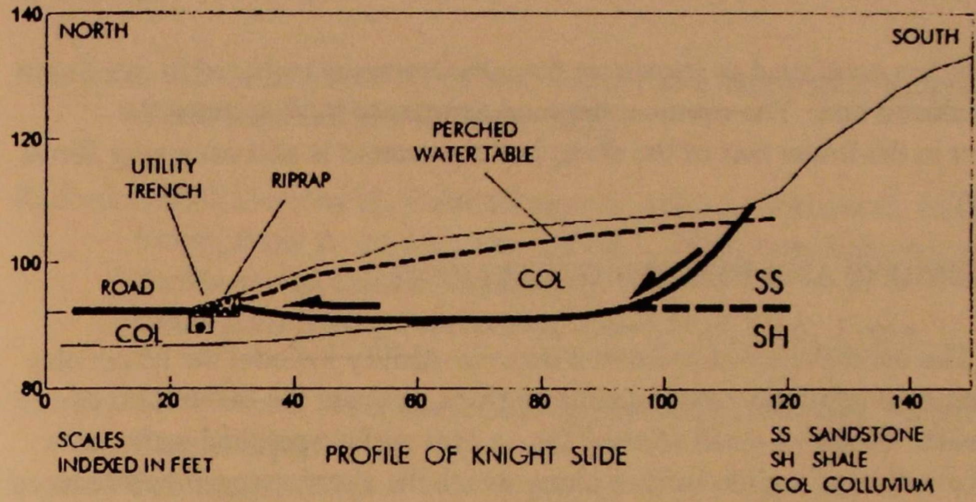

Figure 6. Cross section of the Knight slide illustrating geologic interpretation.

small alluvial fan. Fans are typically quite porous and absorb most of the water flowing over them unless the discharge is very large. It is believed that much water enters the slide area from this small drainage. The five locations at which water was encountered during soil sampling occur within the bounds of the main scarp. Several springs occur at the toe of the slide.

The underlying weathered shale acts as a barrier to the downward infiltration of water and it accumulates on the interface defined by the refraction survey. This in effect creates a perched water table. In periods of little rain, the water would be expected to move down the shale surface by interflow and is likely the explanation for the loss of water in the pool at the back of the slide. The base of the colluvium and perched water table is likely the surface along which the slip occurred. Figure 6 shows a cross section of this interpretation.

The measurements and observations of this slide were used to classify it according to Easterbrook (1993) . The two mass movements that were considered in classifying the feature were a slump and an earthflow. A slump is a rotational block having a well defined curved failure surface. Surface features tend to be rotated backward out of their original positions. There is evidence that rotation has taken place, the back tilted trees and the deviation of the contours. An earthflow involves the translation of material down slope rather than rotation. The material in an earthflow is usually saturated and tends to develop a bulbous toe form. The Knight slide shows slump attributes in the back area and earthflow in the toe area. Combination slides are not at all uncommon (Sharpe, 1968).

The initial movement of the slide reportedly was in late spring to early summer, 1993, just two months before the commencement of this investigation. The greatest amount of movement appears to have taken place at that time.

Movement has continued as shown by the measurements included in this report, but at a reduced rate. The riprap at the road appears to have stopped the movement in the lower part of the slide, but movement is still occurring above the riprap.

CONCLUSIONS AND RECOMMENDATIONS

The conditions that promoted slope instability include: the heavy clay soil resting on a relatively impermeable bedrock of shale, the infiltration of surface water through a small alluvial fan, a near surface perched water table and the formation of a glide surface along which the shear strength was reduced by excessive moisture. These conditions collectively created an unstable mass. The event that released the slide was the notching of the toe area for the extension of Highland Drive and the cutting of a utility trench along the south side of the road. As long as the small drainage off the back slope feeds water into the alluvium fan at the base of the steep slope, the landslide is likely to exhibits periods of instability. The slide and slope can be stabilized by conveying the water across the lower slope so it does not infiltrate the subsurface. An artificial, impermeable channel would serve the purpose.

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RANGE OF (*Glaucomys sabrinus fuscus*), A FEDERALLY ENDANGERED SUBSPECIES OF THE NORTHERN FLYING SQUIRREL, IN WEST VIRGINIA

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Abstract

The subspecies of the northern flying squirrel, *Glaucomys sabrinus fuscus*, was added to the federal list of endangered species in 1985. When listed, this subspecies was known from 10 specimens collected in West Virginia (Randolph and Pocahontas counties) and 2 specimens from Highland County, VA. Surveys (nest box monitoring and live-trapping) conducted in West Virginia from 1985 through mid-1996 yielded 769 *G. s. fuscus* captures at 81 sites (many with multiple capture locations) in six counties (Greenbrier, Pendleton, Pocahontas, Randolph, Tucker, and Webster). Squirrels were captured at elevations ranging from 872m near Mountain Lick Creek, Pocahontas County to 1417m on Red Spruce Knob, Pocahontas County; however, the subspecies may reach its greatest elevation on Spruce Mountain, Pendleton County, where it has been captured at 1414m and suitable habitat occurs to near the top of Spruce

Knob (1426m). This squirrel is associated with red spruce (*Picea rubens*) and northern hardwood forests, and, most often, a mixture of these two forest types. At a few sites, eastern hemlock (*Tsuga canadensis*) or balsam fir (*Abies balsamifera*) provide a coniferous habitat component, especially where red spruce is scarce. In West Virginia, this squirrel's range extends southwestward, following the Allegheny Mountains, from Canaan Heights and the northwestern edge of the Dolly Sods Wilderness Area (both in Tucker County) in the north to Briery Knob (Pocahontas County) and Rabbit Run (Greenbrier County) in the south. Southern flying squirrels (*G. volans*) were captured at 19 (23.5%) of the sites where *G. s. fuscus* was found.

Introduction

The northern flying squirrel (*Glaucomys sabrinus*) is one of two species in the genus *Glaucomys*. It occurs in forested areas over most of northern North America, and its range extends southward following mountain ranges in both the East and West (Hall, 1981). This squirrel is usually found in areas dominated by coniferous or mixed coniferous-deciduous forest types (Wells-Gosling and Heaney, 1984). Twenty-five subspecies are recognized in North America including two subspecies, *G. s. coloratus* and *G. s. fuscus,* found in the central and southern Appalachian Mountains (Hall, 1981).

G. s. fuscus was described by Miller (1936) based on specimens collected near Cranberry Glades, Pocahontas County, WV. Prior to 1985, this subspecies was known from 12 specimens. Ten specimens were collected in three areas of West Virginia: Cranberry Glades (Pocahontas County), Cheat Bridge (Pocahontas and Randolph counties), and Shavers Mountain near Stuart Knob (Randolph County); two specimens were collected in Highland County, VA (Stihler *et al.*, 1987) (Table 1). In 1985, following a status survey of the two southern Appalachian northern flying squirrels (Linzey, 1983), the U.S. Fish and Wildlife Service placed both Appalachian subspecies on the list of federally endangered species effective 31 July 1985 (Fed. Reg. 50:126). Threats cited in the listing package included loss of suitable habitat and possible competition (both direct competition for resources and by the transmission a nematode parasite) with the more common southern flying squirrel (*G. volans*).

Because the vast majority of the suitable habitat for this species (boreal forests) in West Virginia occurs on the Monongahela National

Forest (MNF), protection of northern flying squirrels on the MNF is critical to the recovery of this animal. Appendix X of the MNF Land and Resource Management Plan (USFS, 1986), developed through consultation with the USFWS, defines occupied and potential habitat for this squirrel, and provies guidelines to protect and manage habitat for this squirrel. As a result of the requirements of this management plan and recovery actions outlined in the species' recovery plan (USFWS, 1990), extensive surveys were conducted to determine the range, distribution, life history, and status of *G. s. fuscus* in West Virginia. This paper delineates the range of this squirrel in West Virginia.

Materials and Methods

Much of the potential habitat for this squirrel in West Virginia was surveyed between 1985 and 1996 through the placement and monitoring of nest boxes and live trapping. Potential habitat for this squirrel was defined as high elevation boreal forest (greater than 1016m) with a forest cover of red spruce (*Picea rubens*), northern hardwoods, or mixed red spruce/northern hardwood forest types, and some trees larger than 30.5cm (12 in) d.b.h.; boreal forests at lower elevations were also surveyed. To assist in delineating areas of potential habitat, maps showing red spruce distribution, based on the interpretation of 1988 aerial photography, were obtained from the USFS - Forest Pest Management Section (FPMS) (Morgantown, WV). In addition to boreal forest types, selected high elevation oak sites (mainly *Quercus rubra*), such as Smoke Camp Knob (Pocahontas County), were surveyed to help define this subspecies' habitat preferences.

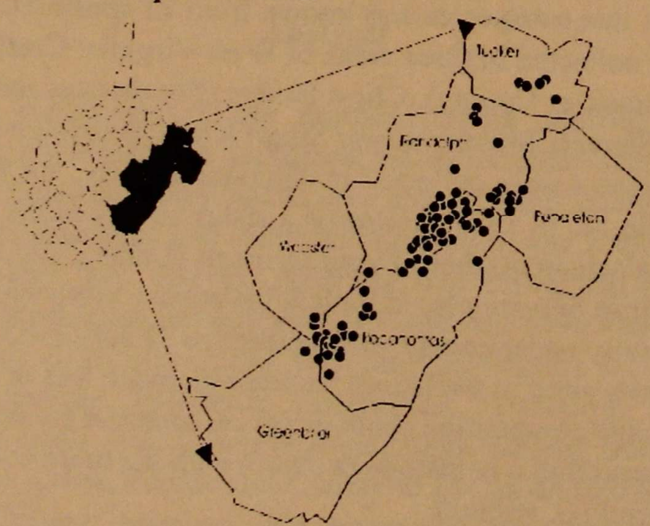

Figure 1.Locations of 81 sites where northern flying squirrels, *Glaucomys sabrinus fuscus*, were captured in West Virginia between 1985 and 1996. Each dot may represent multiple capture locations at a site.

Study sites were selected based on two sets of criteria. One set of sites was selected to provide data on distribution and habitat preferences. Some of these sites were monitored for several consecutive years to obtain data on population trends and life history. This set of sites included several areas, such as wilderness areas, where no management activities were planned, as well as areas where land management activities were occurring. The second set of sites was surveyed to meet the requirements of the Endangered Species Act and Appendix X of the MNF Land and Resource Management Plan. These sites were selected because proposed future actions could impact potential northern flying squirrel habitat; surveys were conducted to provide reasonable evidence that the area was or was not occipied by *G. s. fuscus.*

From 1985 to 1996 over 4,250 nest boxes were placed and monitored. The boxes were made of wood, and most had a sliding door on one side to allow for easy inspection of the box's contents (Stihler *et al.,* 1987). The nest boxes were mounted on tree boles at heights ranging from 2m to 6m. Boxes were monitored at least twice each year (spring and fall) for a minimum of two years. As a general rule, 15 boxes were placed at each survey site, usually along a transect.

Live-traps were used to survey over 50 sites. A standard trap array consisted of 40 wire live traps (size = 12.7cm x 12.7cm x 33.0cm). Most of the traps were attached to the tree boles using wire or bungee cords, although some traps were placed on the ground. A standard bait of peanut butter, unsalted rolled oats, and apple was usually used, but other baits (walnuts, dried mushrooms, sunflower seeds, etc.) were tried. Traps were set and inspected for a minimum of 4 consecutive nights. Typically, especially if inclement weather was likely, the traps were covered with waxed cardboard or plastic. When below freezing temperatures, snow, or rain were expected, a small plastic container and polyester batting were placed in the traps to allow captured animals to remain warm and dry.

Results

A total of 769 *G. s. fuscus* was captured between 1985 and 1996. Most of these (N= 550) were adults with a sex ratio of nearly 1:1 (male:female = 1:1.07, N=531) (Table 2). *G. s. fuscus* was captured at 81 sites (Table 1). These "sites" do not represent independent populations, but are based on Appendix X of the MNF plan. Appendix X defines "occupied habitat" as the area within 0.8km (0.5mi) of a capture location. Sites are thus defined as areas with no captures closer than 1.6km, i.e., "occupied habitats" are not contiguous. Northern flying squirrels were captured in six counties including new county records for Greenbrier, Pendleton, Tucker, and Webster counties (Table 1).

Table 1. Number of sites in West Virginia where northern flying squirrels, *Glaucomys sabrinus fuscus*, were captured and number of squirrels captured before and after the subspecies was listed as federally endangered (1985), by county.

County	Number of sites		Number of squirrels captured	
	Prior to 1985	1985-1996	Prior to 1985	1985-1996
Greenbrier	0	2	0	13
Pendleton	0	6	0	20
Pocahontas	4	38	4	330
Randolph	3	30	6	360
Tucker	0	5	0	29
Webster	0	3	0	17
Total	7	84[1]	10	769

[1] Represents 81 sites including three sites with capture locations in two counties.

Table 2. Summary of age and sex data for all northern flying squirrels (Glaucomys sabrinus fuscus) captured in West Virginia, 1985-1996.

Sex	Age				Total
	Adult	Juvenile	Nestling	Unknown	
Male	256	40	30	6	332
Female	275	27	12	2	316
Unknown	19	11	50	41	121
Total	550	78	92	49	769

The distribution of *G. s. fuscus* closely follows the distribution of red spruce in the higher elevations of the Allegheny Mountains in West Virginia. The subspecies' range extends southwestward from Canaan Heights and the northwestern edge of the Dolly Sods Wilderness Area (both in Tucker County) to Briery Knob (Pocahontas County) and Rabbit Run (Greenbrier County) (Figure 1). This subspecies reaches the eastern extent of its range at head of Stonecoal Run (Tucker County; 79° 23' 28" W) and the northern extent of its range at Canaan Heights (Tucker County; 39° 05' 54" N). *G. s. fuscus* was found as far west as Rabbit Run (Greenbrier County; 80° 25' 47" W) and as far south as Briery Knob (Pocahontas

County; 38° 08' 37" N). *G. s. fuscus* was captured at elevations ranging from 872m near Mountain Lick Creek (Pocahontas County) to 1417m on Red Spruce Knob (Pocahontas County). This subspecies may reach its greatest extent in elevation at Spruce Knob where it has been captured at 1414m, and suitable habitat extends to 1426m.

Although no detailed habitat measurements were taken at capture locations, some general comments on the habitat of this squirrel can be made from red spruce distribution maps and comments recorded on field data sheets. Almost all northern flying squirrel capture locations were in red spruce or mixed red spruce/northern hardwood forest types. *G. s. fuscus* capture sites were plotted on topographic maps showing red spruce distribution obtained from USFS-FPMS. These maps delineate spruce plantations and red spruce forest with an overstory composed of at 25% red spruce. Percent of capture locations in each forest type class were: 30.1% in red spruce stands containing over 50% red spruce; 32.1% in stands containing 25-50% red spruce; 36.6% in stands with 0-25% red spruce; and 1.2% in Norway spruce (*Picea abies*) plantations. At the few sites where observers noted that no overstory red spruce trees were present in the immediate area of the capture location, the forest overstory usually contained some coniferous component, either eastern hemlock (*Tsuga canadensis*) or balsam fir (*Abies balsamifera*); red spruce was usually present in the understory.

Southern flying squirrels, a species that may compete with *G. sabrinus* (Weigl, 1968), were observed at 19 (23.5%) of the sites where *G. s. fuscus* was captured. *G. volans* were also captured in high elevation oak forests, a habitat type where *G. s. fuscus* was not found.

Discussion

Although the 1985-1996 surveys yielded many captures of *G. s. fuscus*, this subspecies still appears to be rare and, with few exceptions, closely associated with red spruce and mixed red spruce/northern hardwood forest types. The authors believe that the range of the species in West Virginia, as depicted in Figure 1, is well defined, and that major extensions of the subspecies' range seem unlikely. Outside of West Virginia, this subspecies is known only from 14 specimens captured in Virginia near the Highland County, VA / Pocahontas County, WV line (Rick Reynolds, pers. comm.). These captures do not extend the range of this subspecies in any of the four cardinal directions. Although the range of this animal in West Virginia has been delineated, much still remains to be learned about its life history, population status, and habitat requirements.

Acknowledgments

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