Control Number: 38829

Item Number: 335

Addendum StartPage: 0

PUC DOCKET NO. 38829
SOAH Docket No. 473-11-1267

APPLICATION OF SHARYLAND UTILITIES, L.P. TO AMEND ITS CERTIFICATE OF CONVENIENCE AND NECESSITY FOR THE PROPOSED WHITE DEER TO SILVERTON 345 KV CREZ TRANSMISSION LINE IN ARMSTRONG, BRISCOE, CARSON, DONLEY, GRAY AND SWISHER COUNTIES

BEFORE THE STATE OFFICE OF ADMINISTRATIVE HEARINGS

DALE A. SMITH'S DIRECT TESTIMONY ON BEHALF OF O. DALE SMITH – ALLEN CURRIE SMITH TRUST

I. INTRODUCTION

Q. PLEASE STATE YOUR NAME AND ADDRESS.

A. My name is Dale A. Smith, my office address is 418 S. Polk, Amarillo, TX 79101 and mailing address is PO Box 15305 Amarillo, TX 79105. I am testifying on behalf of O. Dale Smith – Allen Currie Smith Trust ("Intervenor").

Q. IS O. DALE SMITH – ALLEN CURRIE SMITH TRUST AN INTERVENOR IN THIS DOCKET?

A. Dale A. Smith, as beneficiary of the O. Dale Smith – Allen Currie Smith Trust, has been granted intervenor status.

Q. WHAT IS YOUR BACKGROUND AND EDUCATION?

A. I was born and raised in the Texas Panhandle. I graduated from the University of Texas at Austin with a Bachelor of Business Administration in 1993 and graduated from Texas Christian University Ranch Management Program in 1994. Upon graduation I went to work for Cargill, the largest privately held company in the United States, as a management trainee in their cattle feeding division. Then in 1996 I went to work for Corsino Cattle Co. and JJOB Ltd. Two large cattle companies based in the Texas Panhandle. Growing up I was involved in my family's farming and ranching operations and continue to this day as a beneficiary of the Trusts that own parts of the SJ Ranch. I later became the managing partner in Corsino Cattle Co. and also began my employment with Palo Duro Oil & Gas which is a part owner of the historic JA Ranch. I am currently involved in the management of over 300,000 acres of land in Texas and manage an extensive stocker cattle operation running cattle in Mississippi, Florida, Texas, Oklahoma, New Mexico, and Colorado. I am also President of McLean Feedyard Inc.

Q. HOW LONG HAVE YOU BEEN ASSOCIATED WITH THE SJ RANCH?

A. I have been involved with the ranch since my family purchased the ranch in the early 1980's.

Q. WHAT IS YOUR INVOLVEMENT IN INDUSTRY ORGANIZATIONS?

A. I am currently on the board of directors for National Cattlemen's Beef Association and serve on the Property Rights and Environmental Management Committee. I am a director of Texas Cattle Feeders Association and served on the Executive Committee in 2010. I am a director of the Texas & Southwestern Cattle Raiser's Association and serve on the Natural Resource and Environment Committee. I am also a member of the Society of Range Management and served on a joint committee with TSCRA in selecting the yearly "Outstanding Range Management Award" for ranchers that practice outstanding range management. I was President of the Panhandle Livestock Association.

Q. WHAT QUALIFIES YOU AS AN EXPERT IN PRESCRIBED BURNING?

A. I was first exposed to prescribed burning on native rangeland at TCU Ranch Management. Then I conducted several prescribed burns under the guidance of the Natural Resource Conservation Service of the USDA. In March of 2003 I successfully completed the Prescribed Fire School conducted by the Texas Parks & Wildlife Department. I later successfully completed "L-180 Human Factors on the Fireline," S-130 Firefighter Training," and "S-190 Introduction to Wildland Fire Behavior" through the National Wildfire Coordination Group. Over the last fourteen years I have participated or have been the "Fire Boss" on almost 30 prescribed fires in the Texas Panhandle and have fought several large wildfires including the massive wildfire in March of 2006 that burned over a half million acres.

In 2006 I, along with others, formed the Texas Panhandle Prescribed Burn Association. I was the first President and currently serve as a director. I have organized several prescribed burn schools for members and have attend several continuing education classes hosted by Texas Parks & Wildlife, Texas A&M Extension Service, and the Natural Resource Conservation Service. Please visit the website www.tppba.org.

II. PURPOSE OF TESTIMONY

Q. PLEASE DESCRIBE THE SJ RANCH, ITS CURRENT USE, HISTORY, AND SPECIAL FEATURES.

My family purchased the "Steele Camp" portion of the SJ Ranch in 1981, and later purchased the Thornberry Pasture along the Salt Fork of the Red River from the Thornberry family. The SJ Ranch encompassed lands once held by notable cattlemen such as Charles Goodnight and Thomas Bugbee in the late 1800's (See Exhibit A). The Thornberry Pasture along the Salt Fork of the Red River was used as Charles Goodnight's horse pasture. Since my family has owned the ranch we have worked hard improve the range and wildlife habitat by using the Merrill System of Four Pasture – Three Herd Rotational Grazing System, completed extensive Mesquite, Yucca, and Sage control, conducted prescribed burns, water development to improve grazing distribution, and have worked to restore an old gravel pit back to native grass.

Because of the conservation work we have done at the Ranch, my family has won various conservation awards, such as: 1988 Wildlife Conservationist Region I Award and the Stake Plains SWCD #155 – 2003 Conservation Rancher Award for Currie Smith, my brother, who manages the ranch.

Q. WOULD THE SJ RANCH, BE AFFECTED BY ONE OR MORE OF THE TRANSMISSION ROUTES PROPOSED BY SHARYLAND UTILITIES L.P ("SHARYLAND")?

A. Yes. The ranch is located in Armstrong and Donley Counties and would be affected by the Routes 9, 10, and 11; and, specifically, the Links V, U, and BB.

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. My testimony describes the Ranch and explains the negative consequences that would result of the proposed Routes 9, 10, and 11 including links V, U, and BB is chosen in this docket to be the location of the new Sharyland CREZ transmission line.

Q. AS A BENEFICIARY OF THE O. DALE SMITH – ALLEN CURRIE SMITH TRUST, DO YOU HAVE A POSITION WITH RESPECT TO THE ROUTES AND LINKS SHOWN IN SHARYLAND'S CCN APPLICATION?

A. I oppose Routes 6-13 of Sharyland's proposed Whitedeer to Silverton 345kV CREZ Transmission Line; and, specifically, the links BB, U, and V. These links of the Routes would cross land owned by the Trust and would adversely affect the property as further explained below. I prefer the far Western Routes as they are the shortest, least expensive, and minimize impacts to native grasslands.

Q. HOW WOULD THE LINKS BB, U, and V AFFECT THE HISTORICAL AND CULTURAL VALUE OF THE SJ RANCH?

A. These Links would cross unspoiled native rangeland that is much the same as it was over 100 years ago. These lands have had no oil and gas development, wind farms, and have not been broken out for farmland. The Ranch consists of native mid to tall grass prairie that represents an ecosystem that once covered millions of acres in the Southern Great Plains. Most of this area is now farmed leave only small pockets of native prairie. Since the SJ Ranch consists of native prairie that is representative of the ecosystem that once encompassed millions of acres, the Ranch provides a significant historical and cultural value. Giant transmission lines crossing the SJ Ranch would have significant negative consequences. See Exhibits B & C for pictures of the native grass and wildlife habitat on the SJ Ranch.

Noted historian and former Curator of History at the Panhandle-Plains Historical Museum, William E. Green, PH. D, filed direct testimony in opposition of Routes 6-13, specifically Links T, U, V, Z, AA, BB, DD, EE, JJ", and KK of the 345kV Transmission Line CREZ project in Armstrong and Donley Counties. He stated, "These routes would encroach upon and mar the visual integrity of numerous sites and areas of historical and cultural significance, and could compromise the archeological integrity of known and unknown prehistoric sites."

Q. IS PRESCRIBED FIRE USED AT THE SJ RANCH TO IMPROVE WILDLIFE HABITAT AND RANGELAND MANAGEMENT?

A. Yes. Prescribed fire is an extremely valuable tool in managing native rangeland for the improvement of wildlife habitat, brush control, and grazing distribution. Prescribed burns also reduce the potential for catastrophic wild fires. The SJ Ranch has been conducting prescribed burns since 1999.

A letter from Linda Campbell of the Texas Parks & Wildlife states the importance of prescribed fire. She states, "As a science-based agency we join other resource professionals throughout the state in recognizing the importance of using prescribed fire to maintain and enhance habitats for a variety of native plant and animal species." A copy of this letter is attached as Exhibit D.

Q. DO YOU SEE ANY PUBLIC SAFETY OR ENVIRONMENTAL EFFECTS ON THE SJ RANCH FROM THE PROPOSED TRANSMISSION LINE LINKS ACROSS THE RANCH ESPECIALLY IN REGARDS TO CONDUCTING PRESCRIBED FIRES?

A. Yes. Smoke build up under electric transmission lines can create the potential for discharge similar to lighting. This can create an especially hazardous situation when conducting prescribed fires at the SJ Ranch. Please see Exhibit E on "Prescribed Burning Safety" published by Kansas State University.

Q. PLEASE DESCRIBE THE WILDLIFE HABITAT OF THE SJ RANCH?

A. The ranch has a very diverse population of wildlife. Game animals consist of White-tailed deer, Mule deer, Antelope, Rio Grande Turkey, Scaled Quail, Bobwhite Quail, and Mourning Doves. Waterfowl use the spring fed ponds and wetlands on the Salt Fork of the Red River. The Antelope herd on the SJ Ranch and surrounding ranches are the only viable herd in Armstrong and Donley Counties. We participated with the Texas Parks & Wildlife Department in their relocation program of Rio Grande Turkeys to other States in exchange for Desert Bighorn Sheep to re-stock their historic habitat in the Trans Pecos Region of Texas.

Non-game species, such as the Bald Eagle, have a significant winter roost directly in the path of the links U and BB. They have even been documented to nest on the ranch along the Salt Fork. Attached is a picture of the nest (Exhibit F). This is one of the very few nesting sites for Bald Eagles in the State of Texas, especially in the Texas Panhandle. The Bald Eagle is a "Threatened Species" according to the United States Fish & Wildlife Service. Neo-tropical migrants use the mature Cottonwoods, Willows and Hackberries as an important rest stop on their migration in the spring and fall area along the Salt Fork.

Q. HOW WILL CONSTRUCTION OF LINKS BB, U, AND V NEGATIVELY IMPACT WILDLIFE HABITAT ON THE SJ RANCH?

A. The construction, maintenance, supporting roads and the actual transmission line will be very disruptive to wildlife and their habitats. Mule Deer, Antelope, Scaled Quail, and Bobwhite Quail populations have been in decline largely because of habitat fragmentation. A giant transmission line across this area would greatly fragment prime habitat for these species. Links U and BB are especially detrimental to the riparian areas of the Salt Fork. Horned Toad, a threatened species would be negative affected as well, especially on the Link V.

Q. DOES THE SJ RANCH HAVE SPRINGS AND RIPARIAN HABITAT?

A. Yes. The Salt Fork Springs are located upstream and on the SJ Ranch. See Exhibits G & H for a picture of the springs. These springs were documented in the book "Springs of Texas Volume I" by Gunnar Brune. See attached Exhibit I. The SJ Ranch has several miles of riparian areas along the Salt Fork of the Red River.

Q. IS SOIL EROSION CAUSED THE CONSTRUCTION OF THE PROPOSED TRANSMISSION LINES A CONCERN?

A. Yes. The many of the soils of the SJ Ranch, if damaged by the construction and maintenance of the transmission lines, are highly susceptible to wind and water erosion. Sandy Bottomland, Mixed Land Slopes Sites, Deep Hardland Sites, and Sandy Loam Sites, as determined by the Soil Survey of Armstrong County, Texas, make up a large percentage of the SJ Ranch. Please see Exhibit J for a detail description. The transportation infrastructure to maintain the transmission lines will be another significant and on going cause of soil erosion. Please see September 2010 edition Rangeland Ecology and Management (Exhibit K) for a more scientific basis for this claim.

Q. DO YOU KNOW OF ANY RECOMMENDATION OF STATE OR FEDERAL AGENCIES INVOLVED IN THE CONVERSATION OF NATURAL RESOURCES MADE A RECOMMENATION TO THE PUBLIC UTILITY COMMISSION REGARDING WHICH ROUTE WOULD BEST MINIMIZE IMPACTS TO NATURAL RECOURCES?

A. Yes. The Texas Parks & Wildlife Department stated that Route 1 appears to best minimize impacts to natural resources and made several recommendations to minimize impacts on natural resources. This letter was submitted to the Public Utility Commission on January 6, 2011 and is located on the PUC Interchange for Docket # 38829 Item Number: 271.

Q. DO LINKS BB, U, AND V FOLLOW EXISTING RIGHT OF WAYS?

A. No. Links BB, U, and V do not follow any existing right of ways.

Q. DO LINKS BB, U, AND V FOLLOW OR PARALLEL APPARENT PROPERTY LINES?

A. Link BB parallels apparent property lines on less than 10%. Link U does parallel property lines. Link V parallels property lines for only 8% of length. This is based on the spreadsheet provided by Sharyland on Environmental Data for Alternative Route Evaluation (By Link) Whitedeer (Panhandle BA) to Silverton (Panhandle AC) 345kV Transmission Line Project and was submitted to the Public Utility Commission on January 3, 2011 and is located on the PUC Interchange for Docket # 38829 Item Number: 247.

B. CONCLUSION

Q. TO SUMMARIZE, PLEASE IDENTIFY THE PROPOSED TRANSMISSION LINE ROUTES AND SEGMENTS THAT YOU, AS AN INTERVENOR FOR O. DALE SMITH – ALLEN CURRIE SMITH TRUST OPPOSE.

A. I am opposed to Routes 6-13 and especially Routes 9, 10, and 11, including Links BB, U, and V. These proposed Links cross the SJ Ranch and would be tremendously harmful to the interest in the Ranch owned by the Trust as described above.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY

A. Yes.

"This is a true and accurate representation of what my testimony would be if it were to be given orally at the time of trial."

Respectfully Submitted,

[signature]

Dale A. Smith, Intervenor for
O. Dale Smith – Allen Currie Smith Trust

BEFORE ME, the undersigned authority, a Notary Public, in and for the State of Texas, on this day personally appeared Dale A. Smith, as Beneficiary of the O. Dale Smith – Allen Currie Smith Trust, who, after being duly sworn upon his oath stated the above is a true and accurate representation of what his testimony would be if it were to be given orally at the time of trial.

SUBCRIBED AND SWORN to before me by Dale A. Smith, to certify which witness my hand and seal of office this 14th day of January, 2011.

NOTARY PUBLIC STATE OF TEXAS
LINDA F. GRIGGS
Notary Public
State of Texas
My Comm. Exp 03-15-12

Linda F. Griggs

Notary Public, State of Texas
My commission expires: 3/15/12

Exhitbit A-1

J. C. Killough C. E. Killough

The Donley County Abstract Company

ESTABLISHED 1907

J. C. Killough & Son Abstracters and Conveyancers

Names of all parties.

Charles Goodnight and wife, M. A. Goodnight, of Donley County, Texas.

-TO-

Goodnight-Thayer Graded Cattle Company, a Corporation.

Character of Instrument: Warranty Deed.

Dated September 8th, 1897.

Filed for record September 25th, 1897.

Recorded in Volume 13, page 517, Deed Records of Donley County, Texas.

CONSIDERATION: $30,000.00 in hand paid by the Grantee, the receipt of which is hereby acknowledged.

ACKNOWLEDGMENT of Charles Goodnight and wife, Mary A. Goodnight, taken by T. S. McClelland, a Notary Public in and for Donley County, Texas, September 24th, 1897. Statutory form. Seal recited and recorded.

CONVEYING,

That portion of the Franklin County School Land located for said Franklin County by virtue of Certificate Nos. 1, 2, 3, and 4, and Patented to said Franklin County in Patent Nos. 615, 616, 617, and 718, and in Vol. 23, of date the 26th day of May, 1882, lying and being situated in the Counties of Donley and Armstrong, State of Texas, north of the Right of way of the Fort Worth and Denver City Ry and estimated to contain 15,057 acres being the same more or less.

It being the intention of the grantor in this conveyance to convey unto the grantee here all right and title and interest they may have in and to that certain patented lands situated in what is known as the "Buffalo Pasture" in the counties of Donley and Armstrong, State of Texas, lying north of the right of way of said R. R. Co.

Warrants title, except to a deed of trust executed by said Charles Goodnight to Henry P. Grout recorded in Vol. 1, page 538, and 546, and dated March 2nd, 1891, which the grantee herein assumes and agrees to pay.

J. C. Killough

C. E. Killough

The Donley County Abstract Company

ESTABLISHED 1907

J. C. Killough & Son Abstracters and Conveyancers

-EXTENSION AGREEMENT-

This agreement made and entered into in duplicate this 1st day of July 1897 by and between Francis Smith and Co. of San Antonio, Texas of the one part and Charles Goodnight and the Goodnight Thayer Graded Cattle Company a corporation duly incorporated under and by virtue of the laws of Missouri of the other part. Whereas the said Charles Goodnight did on the 2nd day March and on the 13th day of March 1891, make his two certain deeds of trust to Henry P. Drought, Trustee to secure Francis Smith & Co. Beneficiary in the payment of two principal promissory notes one for the sum of $30,000.00, due June 1st, 1896 and one for $13,000.00 due the 1st day of June 1896 and certain interest notes thereon described which said deeds of trust conveyed certain lands in Donley and Armstrong Counties, Texas, fully described therein, which said deeds of trust are recorded in Vol. 1 pages 538 et seq and 549 et seq. of the records of Donley County, Texas, * * * * * to which reference is here made for a more particular description of the lands to be conveyed and whereas the said two principal notes are now past due and payable in accordance with the terms and conditions of said notes and deeds of trust, and Whereas the Goodnight Thayer Graded Cattle Co. has assumed and becomes responsible for the payment of said two principal notes with interest thereon according to the terms of three interest notes attached to each of said two principal notes dated July 1st, 1897, as follows:

Due July 1st, 1898, $310.23,
Due July 1st, 1898, $1392.53,
Due July 1st, 1899, $310.23,
Due July 1st, 1900, $1392.53,
Due July 1st, 1900, $310.23

Therefore it is agreed between the parties hereto that the payment of said sum due on each of said principal notes, to wit; $23,208.83 and $5170.58 is hereby extended to the 1st day of July 1900 and the said Goodnight, Thayer Graded Cattle Co. and the said Charles Goodnight do hereby agree to pay to said Francis & Co. or order the balance due on said principal notes on the 1st day of July, 1900 and do also promise and agree to pay the said interest annually on the said 1st day of July each year until said principal is paid in full and to perform all other covenants specified in said notes and deeds of trust and the said Charles Goodnight and the said Goodnight-Thayer Graded Cattle Co. do further agree that said deeds of trust shall be and remain a good, valid and subsisting first lien on the real estate therein described for the securing the payment of said sum of money the time of payment of which is hereby extended and every clause, matter and thing therein contained shall remain in full force and effect except as herein expressly waived and for the securing of the payment of the interest thereon hereby agreed to be paid. And it is further agreed between the parties hereto that the said Charles Goodnight and the said Goodnight Thayer Graded Cattle Co. shall have the privilege of paying any part of the principal before the said 1st day of July, 1900 provided said payments shall not be made in sums of less than $1000.00 each and when so paid the interest on the principal sums so paid shall cease and the interest notes be entitled to a corresponding reduction that the said Charles Goodnight or the Goodnight Thayer Graded Cattle Co. shall give the said Francis & Co. a 30 days notice of their intention to pay any sum on account of the principal of the said debt or shall pay 30 days interest in advance on any sum so prepaid.

In witness Whereof. Dated August 23rd, 1907.

continued.

Exhibit A-3

(2) 2/416.

Francis Smith & Company
By H. P. Drought, of Said Firm.

ATTEST: Norton Thayer, Sec.
(SEAL)

Goodnight-Thayer Graded Cattle Co.
By Theodore F. Rice, President.

ACKNOWLEDGMENT of Theodore F. Rice, President of Goodnight-Thayer Graded Cattle Company, as the act and deed of said corporation and for the purposes and consideration therein expressed, taken by Henry T. Smith, a Notary Public in and for Cook County, Illinois, October 27th, 1897.

ACKNOWLEDGMENT of H. P. Drought, as a member of the firm of Francis Smith and Company, as the act and deed of said corporation, and for the purposes and consideration therein expressed, taken by A. H. Warden, a Notary Public in and for Bexar County, Texas.
Both certificates of acknowledgment in statutory form. Seals recited and recorded.

REMARK: An acknowledgment of Charles Goodnight is also attached, but records do not show that his signature is scribed thereon. Acknowledgment taken by B. C. McCaleb, County Clerk in and for Armstrong County, Texas, August 23rd, 1897. Statutory form. Seal recited and recorded. Abstracters.

Filed for record December 1st, 1897.

Recorded in Volume 2, page 416, Deed Records of Donley County, Texas.

Exhibit A-4

J. C. Killough

C. E. Killough

The Donley County Abstract Company

ESTABLISHED 1907

J. C. Killough & Son Abstracters and Conveyancers

Names of all parties.

Goodnight Thayer Graded Cattle Company,
a corporation, by Theodore F. Rice, Pres.,
Attest; Norton Thayer, Secretary. (SEAL)

-TO-

Thomas S. Bugbee.

Character of Instrument: Warranty Deed.

Dated November 29th, 1899.

Filed for record December 23rd, 1899.

Recorded in Volume 14, page 549, Deed Records of Donley County, Texas.

CONSIDERATION: $15,000.00 in hand paid by the Grantee, the receipt of which is hereby acknowledged, and the assumption of a lien made by a deed of trust from the Grantors herein payable to Francis Smith and Company, in the sum of $23,379.41 as shown in Volume 1, pages 538, and 546, Deed ofTrust records of Donley County, Texas.

ACKNOWLEDGMENT of Theodore F. Rice, as President of the Goodnight Thayer Graded Cattle Company, taken by Henry T. Smith, a Notary Public in and for Cook County, Illinois, November 29th, 1899. Statutory form. Seal recited and recorded.

CONVEYING,

That portion of the Franklin County School lands located for said Franklin County, by virtue of Certificates Nos. 1, 2, 3, and 4, and patented to said Franklin County in patents Nos. 615, 616, 617 and 618, in Volume 23, of date the 26th day of May, 1882, lying and being situated in Donley and Armstrong Counties, Texas, north of the right ofway of the Fort Worth & Denver City Railway Company, and estimated to contain 15,057 acres more or less. Together with other lands not wanted for the purpose of this abstract.

It being the intention of the Grantor herein to convey unto the grantee herein an undivided fifty five one hundredths being 55 per cent in all rights, title and interest it acquired from Charles Goodnight and wife by deed recorded in Vol. 13, page 517, Deed Records of Donley County, Texas.

Exhibit B

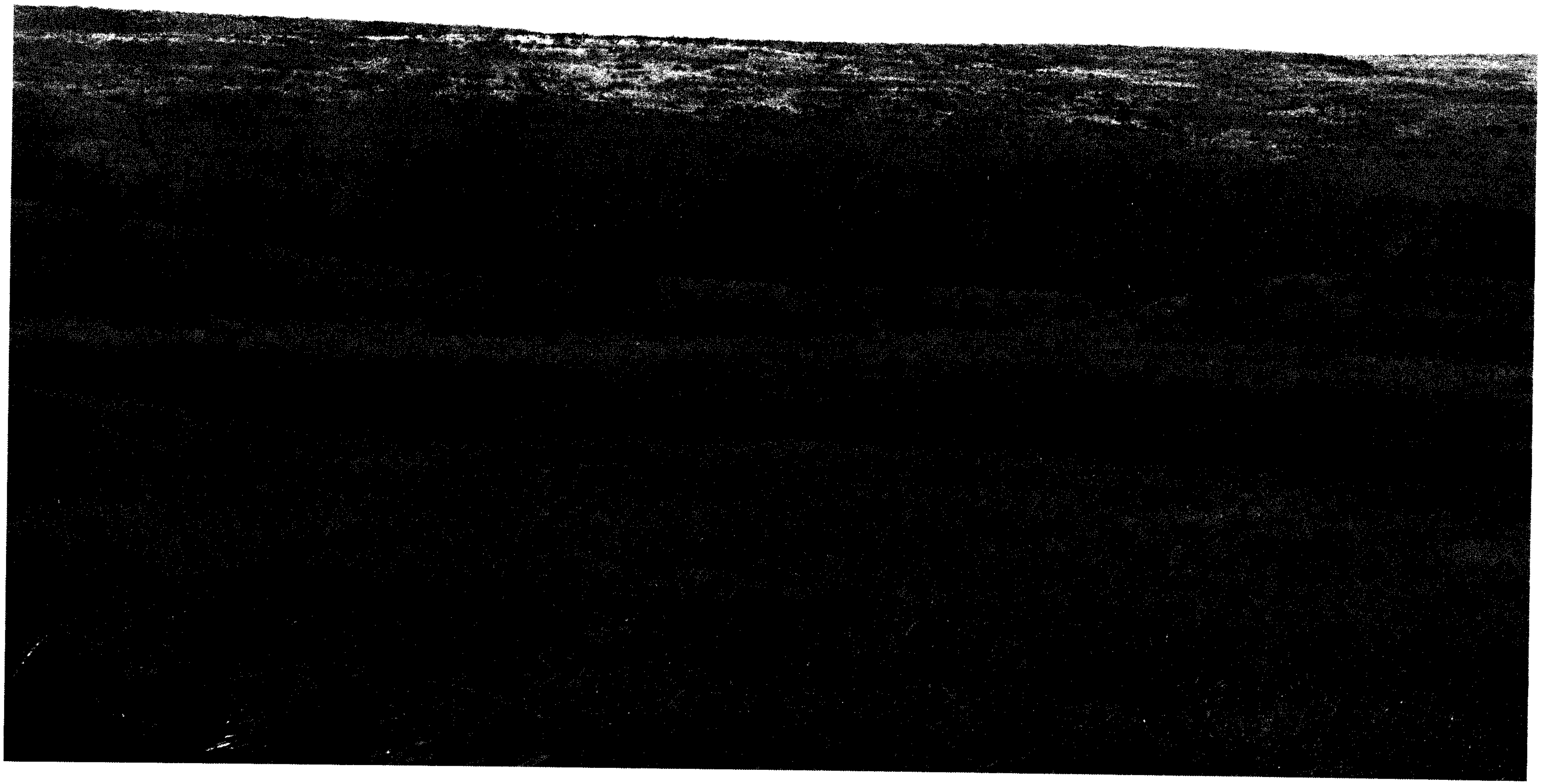


Exhibit C

Exhibit D

TEXAS PARKS & WILDLIFE

Life's better outside.®

January 11, 2011

Mr. Andrew Bivins
PO Box 15305
Amarillo, TX 79105

Dear Mr. Bivins:

This letter is to provide the Texas Parks and Wildlife Department's perspective on the use of prescribed fire to manage and conserve the natural resources of Texas. As a science-based agency we join other resource professionals throughout the state in recognizing the importance of using prescribed fire to maintain and enhance habitats for a variety of native plant and animal species.

The primary purpose of prescribed burning on TPWD lands is to simulate the effects of natural fire events. The application of fire fulfills numerous management objectives including reduction of excessive fuel loads, increased production of desired grasses, forbs and woody plants, control of invading species, increased species diversity and improved forage quality, and facilitation of the long-term objectives for plant community restoration and maintenance. Prescribed burning on TPWD lands is normally conducted in association with these management objectives and/or research endeavors designed to document the long-term effects of this practice on habitat quality or habitat restoration.

For over 30 years, TPWD biologists have provided advice and guidance to private landowners managing their lands to enhance wildlife populations. Our biologists support and encourage the use of prescribed fire to achieve the landowner's management goals while appropriately addressing specific resource management concems and objectives identified through the planning process. Over the last 5-7 years, our staff has been increasingly involved in assisting with the formation and growth of prescribed bum associations throughout the state.

The primary guidance document for TPWD, the 2010 Land and Water Conservation and Recreation Plan, includes a number of action items relating to prescribed burning. Progress on these measurable items is reported to the TPW Commission. In addition, the Wildlife Division Strategic Plan includes a strategy to "facilitate increased use of prescribed fire on both public and private lands". Last month, the Wildlife Division hired a Fire Management Coordinator who will be responsible for enhanced training, fire management planning, and collaboration with partners to achieve more on the ground implementation of prescribed fire on both public and private lands.

In summary, TPWD recognizes the importance of prescribed fire in maintaining natural resource diversity and furthering the agency's mission to manage and conserve the natural resources of the state. TPWD leadership and staff are committed to actions that will ensure both public and private land managers have the training, experience, and equipment to enhance native landscapes through the safe, effective use of prescribed fire.

Sincerely,

Linda Campbell

Linda Campbell
Program Director
Private Lands and Public Hunting

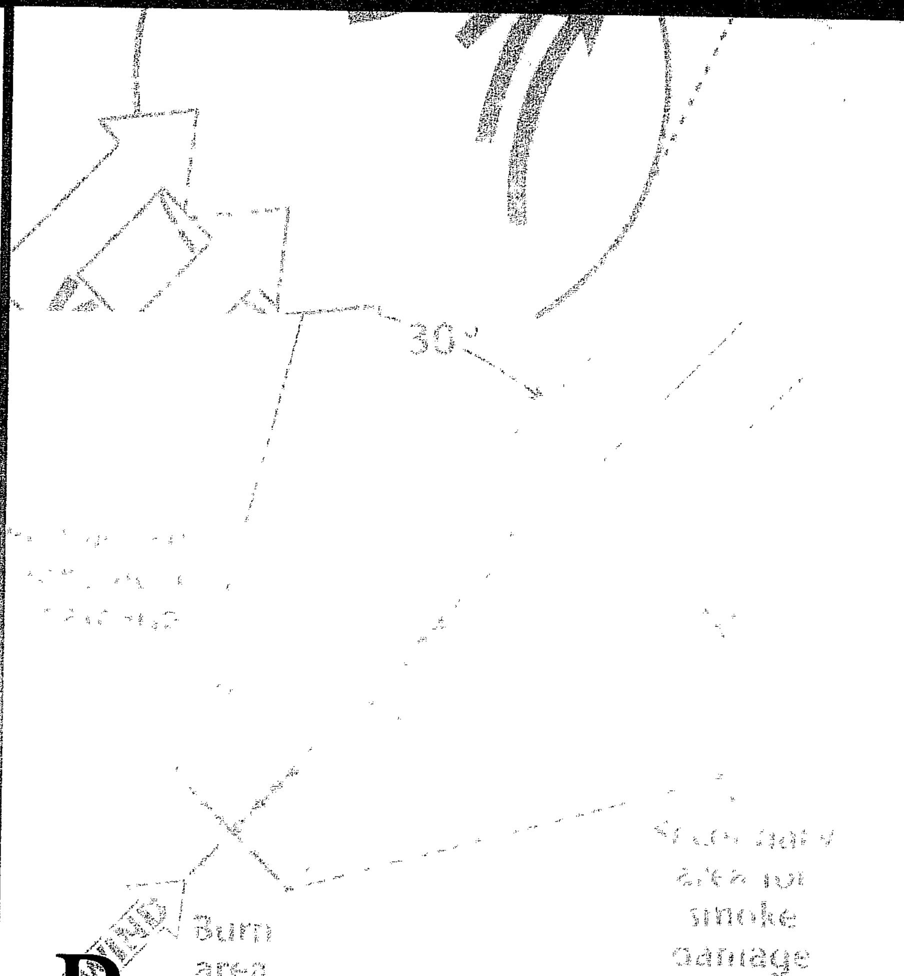
4200 SMITH SCHOOL ROAD
AUSTIN, TEXAS 78744-3291
512.389.4800

www.tpwd.state.tx.us

Exhibit E-1

Prescribed Burning Safety

K-STATE
Kansas State University



Prescribed burning has become a major, though potentially dangerous, management tool throughout Kansas. Poorly managed burns or ignorance of safety measures can lead to property damage and even injury or death. Even in well-managed burns, accidents can occur. Before, during and after every burn, safety should be the major consideration. Follow basic burning procedures, wear proper clothing, and be prepared for the unexpected.

Paul D. Ohlenbusch
Extension Specialist
Range and Pasture Management

James W. Kunkel
Fire Program Leader
State and Extension Forestry

Cooperatively developed by Kansas State University and Natural Resource Conservation Service-NRCS

Exhibit E-2

Personal Safety

Prescribed burning, like any management practice, must be accomplished with careful planning, understanding, and care. In addition to planning the burn and providing for adequate fire guards, it is important that everyone on the burn meet specific requirements. This is for the safety and protection of everyone.

Health Considerations People with known health problems, such as high blood pressure, heart conditions, certain allergies, and respiratory diseases, must not participate. Prescribed burning is a strenuous, stressful, and demanding job that requires good physical conditioning. Should a medical emergency occur, some people will have to be pulled away from fire control to provide emergency assistance. The result could be an uncontrolled burn (wildfire).

Clothing Clothing must be of natural fiber (cotton, wool, etc.) that covers the body, arms and legs (Figure 1). A cap or hat of natural material is needed to cover the hair. Gloves (preferably leather) and hightop boots are mandatory (steel-toed safety boots are prone to accumulating heat). Wear pant legs outside the boots, not inside. In areas where burning includes timber, brush or trees, a hard hat should be used.

Clothing made of most synthetic fibers, such as polyester and nylon, is a hazard to personal safety near fires. Some synthetic fibers can melt at temperatures common in prescribed burning, causing severe burns. While such incidents are rare, the risk of wearing synthetic materials should be avoided.

The one exception to the use of synthetic fibers is NOMEX™ (a registered trademark of Du Pont) or any other material designed for fire fighting. These are special fire retardant fibers and are used by fire fighters, military pilots, and race car drivers. Shirts, pants, and coveralls made of NOMEX™ are the best available alternative to natural fibers.

Public Safety

From the public's viewpoint, fire is dangerous and should be avoided. Always maintain good public relations and avoid situations that endanger the public. Dangerous situations can create legal liability.

Notification For both safety and legal reasons, certain groups should be notified before a burn to prevent unnecessary concern and danger. Check with local authorities.

Neighbors, the fire department, and law enforcement officials should be notified. This can prevent misunderstandings, unnecessary fire calls, and poor public relations. A procedure has been developed that is based on state regulations, experience, and common sense.

Neighbors Notifying neighbors can help in determining their attitudes toward burning and possibly help in finding assistance. Notifying neighbors of a burn can lead to cooperation in conducting the burn. With good relations, neighbors may be willing to share labor and equipment.

Fire Department State regulations, adopted in 1996, require anyone conducting a prescribed burn to notify the local fire department of the intended burn. The only exception is in counties that have chosen not to require notification. Working with the fire department is crucial. Contact the fire chief to determine state and local regulations and to develop specific plans for requesting emergency help. Problems may be avoided ahead of time by asking which neighbors, if any, report all fires.

Law Enforcement If a potential traffic hazard exists, notify local law enforcement personnel. Discuss the location of the burn with law enforcement officials to determine what needs to be done.

An example notification process has been developed. It is in the publication *Prescribed Burning: Planning and Conducting* (L 664).

Smoke Management

From a public safety standpoint, smoke presents the greatest safety hazard. Airports and public roads are the major concerns. The following situations merit special consideration:

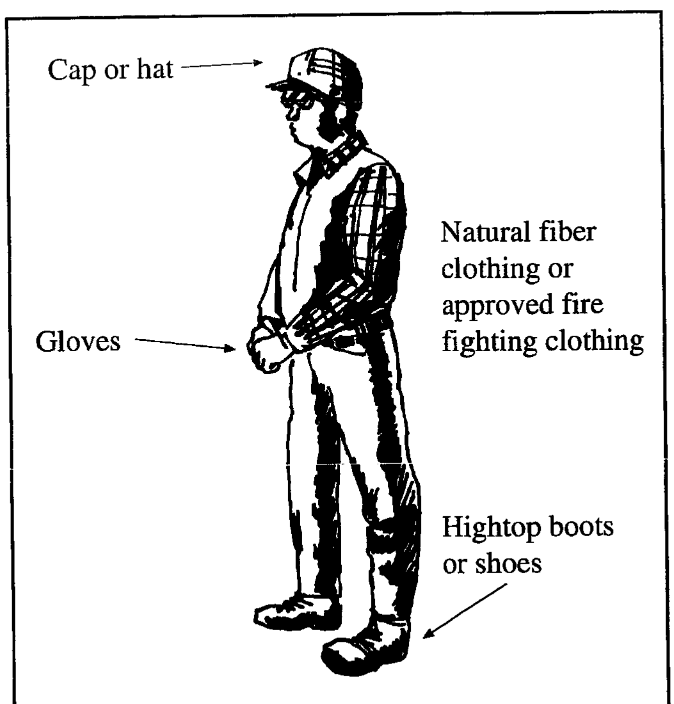


Figure 1. *Natural fiber clothing, or approved fire fighting clothing that covers the arms, legs, and body must be worn while working on a prescribed burn.*

Exhibit E-3

Public Roads Smoke moving over public roads creates a visibility problem (Figure 2) and should be avoided. Three alternatives are available when burning next to public roads. The most desirable is to burn with the wind blowing away from the road. The second option is to use burning procedures that limit the amount of smoke and/or causes the smoke to lift over the road. The last alternative would be to arrange for traffic control during the burning time. Such arrangements are often difficult to make due to the length of time involved and the need for law enforcement personnel.

Airports Burning near an airport is a major concern. Smoke over airports can cause poor visibility created by smoke. Turbulence and updrafts within the smoke column can create control problems for light aircraft. When planning burns near airports, select a time when wind directions will carry the smoke away from the airport. Also, notify airport authorities and discuss your plans with them.

Weather

Weather conditions must remain within acceptable limits to safely manage a prescribed burn. The main factors that need to be monitored are wind speed, wind direction, cloud cover, relative humidity, and temperature. These factors affect fire behavior and control. Acceptable ranges and limits for prescribed burns are summarized in Table 1. Burning when conditions are outside these ranges should rarely be done and only by experienced personnel.

Wind speed and direction are crucial to fire behavior. Wind speeds of 5 to 15 mph, steady from a desirable direction, are preferred. Listen to weather forecasts closely. Changes in wind direction, variable wind speed, or gusty winds, are unacceptable conditions. Wind speed is modified by relative humidity, temperature, and frontal movements. As relative humidity decreases and temperature increases, the effect of the wind is increased. Frontal movements can cause changes in wind direction and speed. Burning should not be performed if frontal movements are forecast within 24 hours.

Cloud cover plays a significant role in prescribed burning. As a rule, as cloud cover increases, it becomes more difficult to ignite and maintain a burn. Cloud covers of more than 0.7 (more than 70 percent of the sky is covered) and ceilings below 2,000 feet are conditions to avoid. When cloud ceilings are below 2,000 feet, smoke will stay near the ground and can cause visibility problems.

Relative humidity controls the rate at which fuel dries. Most grassy fuels change moisture content quickly as the relative humidity changes. During late morning and early afternoon hours, relative humidity can drop quickly, causing fire size and intensity to increase rapidly.

Temperature and relative humidity are related. As a rule, as temperature increases, relative humidity decreases. When temperatures exceed 80°F, people perform at lower efficiency, tire quickly, and require higher levels of fluids to maintain stamina. At low temperatures (below 55°F), people have problems working effectively and, if wet, can chill.

Figure 2. Smoke over a public road presents a hazardous situation to drivers and can create a legal liability for the land owner

Weather Forecasts The two best sources of weather information are NOAA Weather Radio and the Rangeland Fire Danger Index. NOAA Weather Radio is a recorded broadcast of current weather conditions and forecasts. These broadcasts are received on special radios at three different frequencies. Weather radios are available from many sources.

The Rangeland Fire Danger Index is a part of all weather forecasts issued in Kansas during periods of dry weather. The Rangeland Fire Danger Index is announced only when the levels are **Very High** or

Exhibit E-4

Extreme. When a Very High or Extreme Fire Danger Index is issued, atmospheric conditions are such that fires will start easily, move extremely fast, and become large and hot. Such fires will be extremely difficult, if not impossible, to control by normal fire fighting tactics. Burning under these conditions should be avoided. If possible, it is best to burn under **Moderate** or **High** Fire Danger Index levels.

Safety During the Burn

Communications Two types of communication during a burn are desirable: contact with a location that can relay a request for emergency assistance; and between crews working on the burn. Communications can be by CB, business band or similar radios, or cellular phones. Where service is available, cellular phones are the best alternative for requesting emergency assistance in most areas. It can be vital to have fast response by emergency help in case the fire gets out of control or an injury occurs.

Emergency situations Several dangerous situations can occur during a prescribed burn. Potential dangers can be minimized with good advance planning. Have escape routes planned, wear proper clothing, use well-maintained equipment, plan for good communications, and have a good overall plan for conducting the burn.

Probably the most frightening situation is to be in front of a head fire. This can occur as a result of unexpected wind shifts or from becoming disoriented. Unless the fire front is low and it's possible to determine that the depth of the fire is small, never attempt to run or drive through the fire. High temperatures, smoke, and lack of oxygen make it virtually impossible for a person on foot to walk or run through larger fire fronts. If matches or a lighter are available, a small fire can be started. Stay behind it until the main fire passes. If a person is in a vehicle in running condition, a similar approach can be used. If the vehicle is inoperable, the best option is to set a fire. If water is available, wet down an area around the vehicle and remain inside it. Try not to get in front of a head fire.

Crew Preparation Every person working on a burn should be briefed on the burning plan. This briefing should include designating who is in charge, the responsibility of each person during the burn, and the responsibility of each person in case the fire escapes. In addition, each person should be briefed on communication procedures for notifying emergency personnel if needed. This item is extremely important.

Each person working on the burn must be familiar with basic prescribed burning and fire fighting techniques. Persons who are not familiar with these basics pose a hazard to the entire operation and to themselves. Every effort must be made to train or familiarize each person on the techniques needed during the prescribed burn and what to do in case the fire escapes.

Equipment Operation Safe operation of all equipment should be first and foremost. Tractors and other vehicles should be operated by trained and experienced persons. Equipment operators should remain in communication with other personnel. Power-take-off shafts, belts, and other dangerous parts should be shielded and marked.

Night Burning Burning at night should be avoided. Darkness prevents the drivers of vehicles or personnel on foot from being able to find their way, see obstacles and landmarks, judge distances, and assess the overall fire situation. Night fires also appear more severe than they are and result in more false alarms.

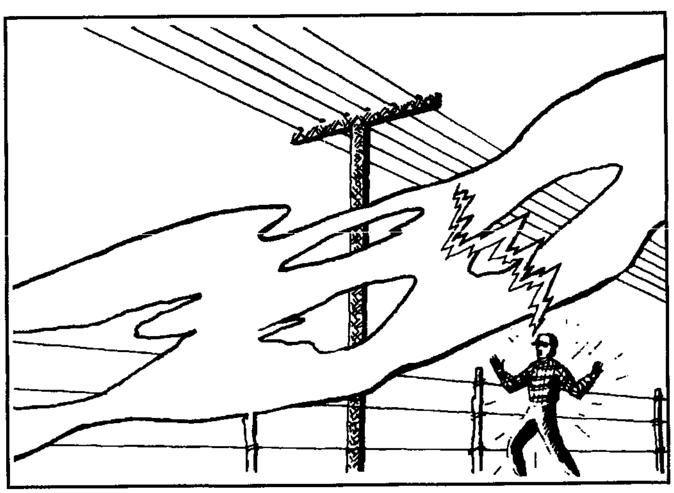


Figure 3. *Smoke buildup under electric power lines can create the potential for a discharge similar to lighting.*

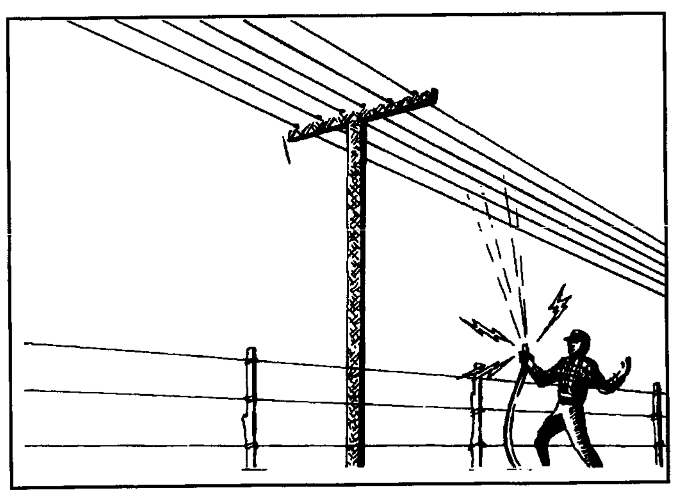


Figure 4. *Powerlines downed on fences can produce the produce the potential for electrical shock for long distances.*

Exhibit E-5

Special Concerns

Electrical power lines and oil and gas production and transmission equipment can pose special hazards for prescribed burns. Special consideration during the planning and conducting of a prescribed burn can eliminate or greatly reduce injury and damage from these factors.

Power Lines When burning under or near electrical power lines or high voltage transmission lines, exercise extreme care. The following situations can lead to injury or death:

Smoke Buildup Smoke consists of carbon particles, which can conduct electricity. If the concentration of carbon is high enough, an electrical discharge from the line to the ground, similar to lightning, can occur (Figure 3). The discharge hazard increases as line voltage increases, distance to the ground decreases, and the amount of smoke increases. Such discharges have killed fire fighters.

To reduce the potential for discharges, the fire front should not be allowed to cross under the lines in large areas. By properly coordinating the location of the burn with the wind direction or by lighting the fire parallel to the line, no major smoke buildup can occur.

Water and Power Lines When working below power lines with water hoses, extreme care must be taken to keep water streams out of overhead lines. Water will conduct electricity and the water stream will act as a conductor (Figure 4).

Downed Power Lines Power lines can be downed during a prescribed burn by vehicles colliding with poles or poles being burned. If power lines are downed, there are two hazards: the lines themselves and the combination of lines on wire fences (Figure 5).

When lines are downed they become hard to see and people or vehicles can run into them. Electrocution or serious shock injury can occur. Also, wildfires can be started by the downed lines arcing.

If lines fall on fences, a new hazard is created. Electricity will be conducted by the fence wires for long distances. The distance will be determined by the type of posts (steel posts may reduce the hazard) and the contact between wires at corner and pull posts. As long as the wires contact each other, there is the potential for shock.

Oil and Gas Production Burning near oil or natural gas production sites or around pipelines, pump stations, and storage facilities can be potentially hazardous. Explosions and/or fire at these sites can result. In all cases, during the planning of the prescribed burn, contact the company representative to determine what is needed to prevent damage. Leaks, open vents, and plastic lines and parts are potential hazards.

Weather Factor	Minimum	Maximum
	Preferred range	*Limit*
Wind speed	5-15mph	20 mph
Wind direction	steady, from one direction	
Relative humidity	40-70%	>30%
Temperature	55°-80°F	50°-85°F
Cloud cover	clear - 0.7 (70%)	
Ceiling	2,000-unlimited	

Table 1. *A summary of the preferred weather conditions for a prescribed burn.*

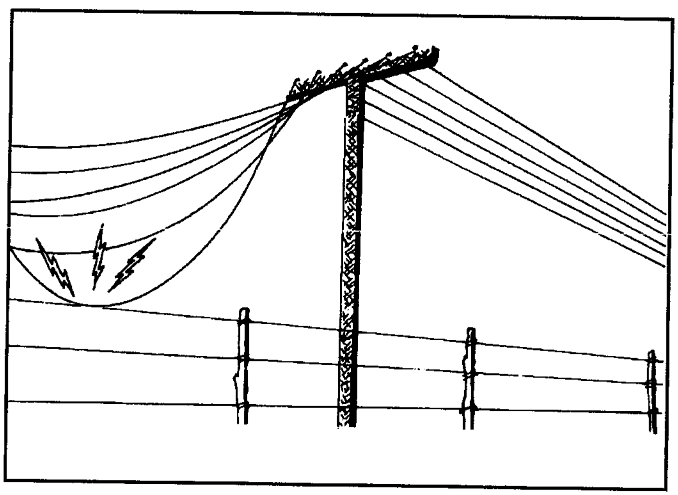
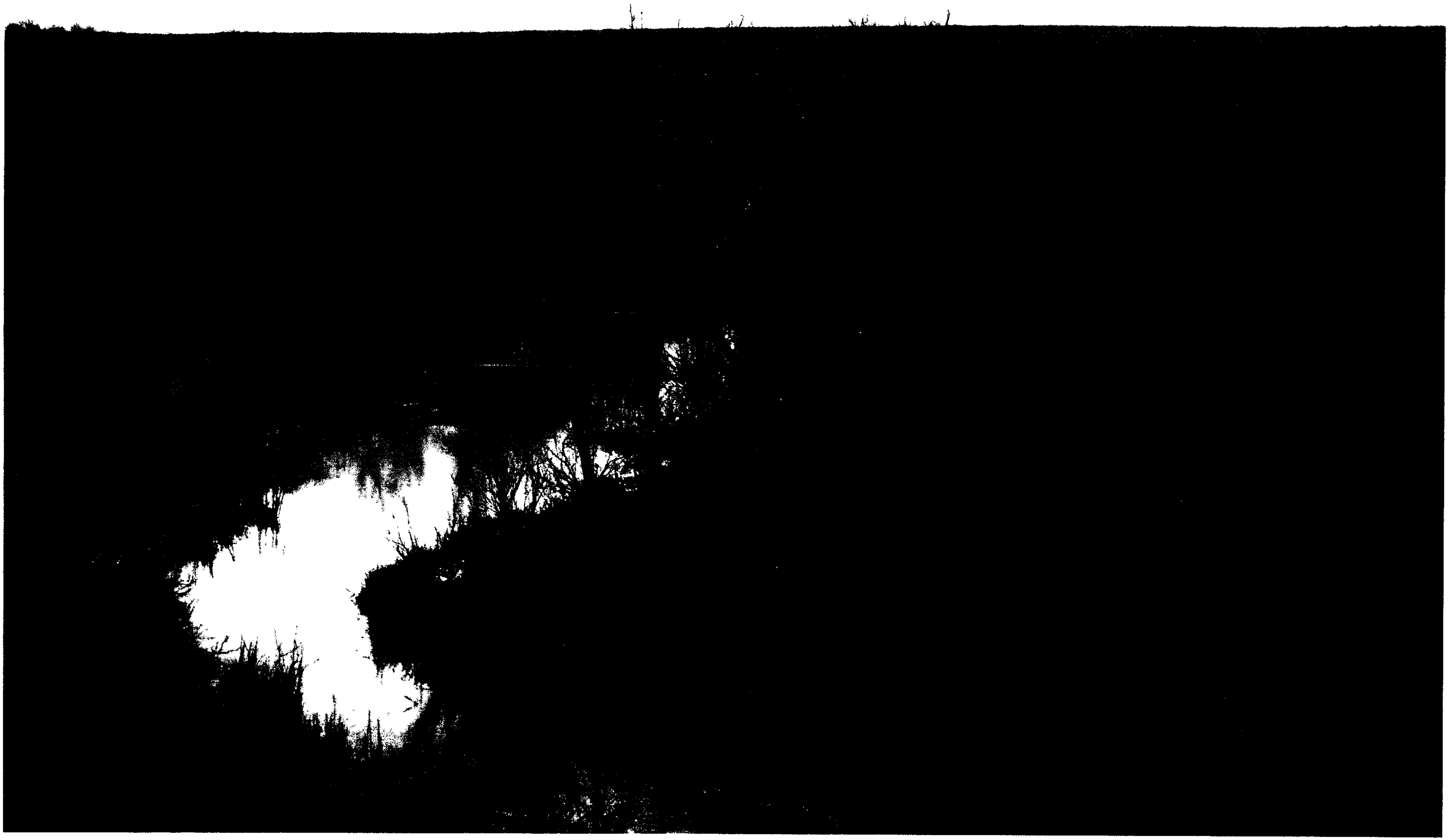


Figure 5 *Downed powerlines on fences can produce the potential for electrical shock for long distances.*

Exhibit F

Exhibit H



mortar tray or basin cut into a boulder by a prehistoric people. Most early maps called these springs **Cimarron Springs**. These include G. L. Gillespie's 1875 *Map of portions of Texas, New Mexico, and Indian territory*, Granger's 1878 *Map of Texas*, and Rand McNally's 1883 *Map of Texas and Indian territory*. They were also known as **Cameron Springs** in the past. By 1886 settlers had built a dugout here.

On May 5, 1979, Persimmon Springs produced 0.05 lps, which dripped from Wolfcampian sandstone into a basin at the head of a small ravine, just south of the ranch house. A small concrete dam retains the water. Frogs jump among the brookweed, swamp grass, and dewberries. Trees shade the pools, which contain much algal growth.

In 1854 Captain R. B. Marcy, while exploring for locations for the Texas Indian reservations (according to Williams and Lee, 1947),

> camped at a fine large spring near the head of one of the branches of the West Fork of the Trinity River.

This was six kilometers northeast of Olney on the present Hayden Farmer's ranch. Although much used formerly, the springs (7) are now only seeps from sandstone in a shallow well 1.5 meters in diameter. A few elm and hackberry trees stand at the site. Many oil wells pump nearby.

On Mesquite Creek 16 kilometers southwest of Archer City were once very small springs (8). An archeological site has been found here where an ancient people lived and relied upon the spring waters. Petroglyphs have been carved in the rock on a mountain to the northeast. The creek is now dry except for occasional surface runoffs. The mesquites are still there, along with some elm and other trees.

In 1854 Marcy also stopped at **Furr Springs (9)**, stating:

> Our noon halt today was upon the summit of a hill, where we found a spring of cool, wholesome water, surrounded with a luxuriant crop of grass, which afforded our cattle the very best pasturage.

Furr Springs are on Grover Furr's ranch seven kilometers east-northeast of Megargel. They are now the strongest in the county, producing 0.35 lps of slightly saline water on May 6, 1979. The water pours from a massive Wolfcampian sandstone at an elevation of 390 meters. There are rumors of buried gold here.

The water is used by the ranch house as well as by stock. A diversion has been built around the top of the ravine to protect the springs from floods and sediment. Killdeers fly among the swamp grasses, salt cedars, and plum thickets. Just downstream, oil-well brines have killed the vegetation and caused severe erosion.

Comanche Springs (10) are two kilometers northeast of Megargel on John Pechacek's farm. Here in 1859 the Comanches camped while making their weary exodus from Texas to Oklahoma. On May 6, 1979, 0.07 lps. trickled in Kickapoo Creek from seepage after recent rains. Elm, salt cedar, and mesquite trees shade the site. A windmill nearby steals water from the springs.

ARMSTRONG COUNTY

Most of Armstrong county's springs issue from Ogallala sand and gravel, which dip gently toward the east and toward the major streams. Some flow from Triassic Dockum or Santa Rosa sandstone which underlies the Ogallala. Usually the springs emerge from the base of the Ogallala or from Dockum sandstone where these formations rest upon the less permeable Permian shale, siltstone, sandstone, and dolomite.

The springs have been used by man since Paleo-Indian times. Coronado in 1541 found 11 Indian villages in Palo Duro Canyon. *Palo Duro* is Spanish for *Hard Wood* or cedar, which was much used by the Indians. Bolton (1949) described Coronado's entrance into the area:

> "Thus," says Castaneda, "the army arrived at the last barranca," a deep one [Palo Duro Canyon], "which extended a league from bank to bank. A little river flowed at the bottom, and there was a small valley covered with trees, and with plenty of grapes, mulberries, and rose bushes. This" — the mulberry — "is a fruit found in France and used to make verjuice. In this barranca we found it ripe." It is interesting to note that one of the mouths of the Palo Duro is today called Mulberry Canyon. "There were nuts, and also turkeys of the variety found in New Spain, and great quantities of plums like those of Castile."

Palo Duro Canyon was still a favorite winter campground of the Comanches in 1874, when General Mackenzie captured their horses (not ponies) near the mouth of Cita Canyon. *Cita* is the Spanish word for *Engagement*. As late as 1928 there were fresh-water springs in every tributary, nearly all of which flowed the year around. Waterfalls were numerous and much visited for outings.

These springs were the haunt of bears, buffalo, deer, wolves, panthers, elk, turkeys, ducks, and many other animals. Most of them have now disappeared, as have many plants which were associated with the springs. The usual plants still found in the spring environment include cottonwoods, willows, some salt cedars, grapevines, plum thickets, cattails, and rushes.

The water table in the Ogallala formation has fallen greatly in recent years. Pumping of ground water for irrigation has been the primary cause since 1950, but other activities of man caused a drop in the water table long before this. As a result, many springs have weakened and dried up. In addition, many ranchers are finding it necessary to deepen their windmill wells or to haul water to their stock.

There is also evidence of severe erosion in the past, in the form of partially healed gullies. Sand from these gullies has choked many stream channels and buried some springs.

The spring water is generally of a calcium bicarbonate type, fresh, very hard, and alkaline. The content of silica and fluoride may be high.

Most of the writer's field studies were made during the period August 4-9, 1978. It should be kept in mind that the spring flows observed were lower than average because of irrigation pumping and transpiration by plants at this season of the year.

In 1887 the Mulberry or Twin Bar ranch headquarters were established 11 kilometers southeast of Claude. The many fresh-water **Mulberry Springs (3)** emerged here then. The gardens were subirrigated by shallow ground water. Later frequent outings were held here. The present owner, Leroy Campbell, remembers when two boys from Claude drowned while swimming in a 10-meter-deep hole near the springs in 1926. The hole was filled with sand in the 1950s. In 1947 Mulberry Creek still ran in winter through the ranch, but quit soon after. However, 12 kilometers downstream at the road crossing there was still a discharge of 0.35 liter per second on August 6, 1978. According to Campbell, irrigation pumping is drying up the springs in this area.

Salt Fork Springs (1) are on the Salt Fork Red River on Don Thornberry's ranch nine kilometers northeast of Goodnight. On August 6, 1978, they produced a discharge of 0.65 lps among many minnows. This contrasts with a flow of 8.8 lps on March 25, 1940, which issued two kilometers farther upstream, at the Thornberry ranch house. Cottonwood trees extend another two kilometers upstream, indicating that the springs originally emerged here. The Salt Fork channel is largely filled with sand from severe gully erosion in the past.

Eight kilometers southeast of Goodnight are **Spring Creek Springs (5)**, which feed Spring Creek. The Spring Creek ranch is owned by Rick Klein and operated by Jim Jones. In the period 1905-1910 Charles Goodnight kept some buffalo here. The main spring waters flow over a ledge of Triassic sandstone at an elevation of about 825 meters, falling one meter into the corrals. On August 6, 1978, the spring poured out 2.4 lps amid much maidenhair fern, water cress, gourds, and other water-loving plants. A former pool below the springs has been filled in about three meters in the last 10 years, according to Jones. Several smaller springs trickle nearby, one of which irrigates a garden. Spring Creek still runs to Mulberry Creek except in the summer. Irrigation pumping, about four kilometers north, has not yet greatly affected these springs. Wild turkeys thrive here.

Blue Hole Springs (2) are nine kilometers southwest of Goodnight on the Mattie Hedgecoke ranch, administered by Beth Louviere. The water falls over a ledge of Triassic sandstone about five meters high into a pool containing tadpoles. (See Plate 5, e). The cliffs are draped with maidenhair ferns and shaded by large cedar trees. An old jeep trail, long unused, winds through the shinnery-covered hills to the springs. On August 5, 1978, 0.06 lps trickled over the falls, increased to 0.35 lps a short distance downstream by other springs. Similar springs occur on Indian Creek, three kilometers south, and in other nearby canyons.

Twenty-four kilometers south of Goodnight are the JA ranch headquarters and Paloduro community. Springs which once poured out at the headquarters were the scene of annual 4th of July barbecues for many years. These springs are now dry, but **Cottonwood Springs (4)**, nine kilometers north of the headquarters in Dutch Canyon, still flow 0.30 lps. According to Snooks Sparks, Cottonwood Springs once filled a 2-inch pipe. They were the source of Cottonwood Creek and were piped three kilometers to several tanks. The ranch is owned by Montie Ritchie and managed by John Farrar.

Baker Springs (6) were 15 kilometers west-northwest of Paloduro on Ed Reed's ranch. In 1940 they produced 0.31 lps. Now they are only a seep in a deep canyon covered with live oak and cedar. **Cox Spring**, 1½ kilometers northwest, once fed a pool four meters deep, but is now only a seep also.

Pleasant Springs (7) feed Pleasant Creek seven kilometers east of Wayside. They are on the Mattie Hedgecoke estate, managed by Lee Palmer. On April 1, 1940, they produced a discharge in Pleasant Creek

The plants on each range site can be grouped as decreasers, increasers, and invaders.

Decreasers are species in the climax vegetation that tend to decrease in relative amount under continued heavy grazing. They generally are the most palatable and nutritious plants on the given site. Blue grama and bluestem are decreasers.

Increasers are species in the climax vegetation that increase in relative amount as the most desirable plants are reduced by close grazing. They are commonly shorter and less palatable to livestock than decreasers. Buffalograss is a common increaser.

Invaders are plants that cannot withstand the competition for moisture, nutrients, and light in the climax vegetation. They come in and grow along with the increasers after the climax vegetation has been weakened or reduced by overgrazing or other disturbance. Many are annual weeds, such as cheatgrass and little wild barley, that provide some grazing early in spring. In some places, undesirable perennials, such as mesquite, yucca, cactus, and broom snakeweed, are common. These plants have little value for grazing and take two or three times as much moisture as buffalograss to produce a pound of dry forage. Invaders may be native to nearby sites, or they may be transported from a considerable distance.

Grass, like other plants, manufactures its food in its leaves and stems. If the leaves and stems are destroyed by continuous heavy grazing, the grasses do not have food for growth and maintenance. As the most palatable and nutritious plants are reduced under heavy grazing, the composition of the vegetation of a range site changes, and the condition of the range declines as the decreasers are replaced by increasers and invaders.

Range condition is the present state of the vegetation on a given site in relation to the climax vegetation for that site. Four classes of range condition are used to indicate the degree to which the climax vegetation has been changed by grazing or other use.

A range is in *excellent condition* if more than 75 percent of the vegetation consists of climax plants. It is in *good condition* if 50 to 75 percent of the vegetation is the same kind as that in the original stand, in *fair condition* if the percentage is between 25 and 50, and in *poor condition* if the percentage is less than 25.

Forage production capacity depends on soil, relief, exposure, range condition, and moisture supply.

One of the main objectives of range management is to keep rangeland in excellent or good condition. If this is done water is conserved, the climax vegetation produces moderate to high yields, and the soils are protected. A major problem is recognizing important changes in the vegetation. These changes take place gradually and can be misunderstood or overlooked. Growth following a heavy rainfall may lead to the conclusion that the range is in good condition, when actually the cover is weedy and the range is in poor condition. Some rangeland that has been closely grazed for short periods, but has been carefully managed, may have a rundown appearance that temporarily conceals its quality and its ability to recover.

Good range management requires knowing what kinds of grasses each site can produce, how these grasses respond to different grazing systems, and what measures serve to maintain or improve rangeland.

Generally, several sites are represented in any given area of range, but one will be preferred for grazing and will be the first site to be overgrazed. This key site can be used as a basis for managing and evaluating the amount of grazing the entire pasture can provide.

Descriptions of range sites

In this subsection the range sites in Armstrong County are described; the soils in each site are listed; and the important characteristics of the soils, the names of the principal grasses, and the total annual yield of herbage, excluding woody plants, are given.

LOAMY BOTTOM LAND SITE

This site consists only of Loamy alluvial land, a miscellaneous land type on nearly level to gently sloping bottom lands in draws and small valleys throughout the county. These bottom lands receive runoff from higher lying soils. Some areas are subject to frequent flooding and to the deposition of fresh materials. Some areas have a high water table, and some areas consist of saline soil material. If not protected, this site is subject to gullying and scouring. A typical area is along the upper part of the Salt Fork of the Red River and the upper part of Mulberry Creek.

Loamy alluvial land consists of stratified deposits of clay loam and sandy loam more than 20 inches deep. Permeability ranges from moderate to moderately rapid in the subsoil.

The climax vegetation is chiefly grasses. A few elm, chinaberry, and hackberry trees grow along waterways. Switchgrass, little bluestem, and blue grama are the principal decreaser grasses. They make up 40 to 70 percent of the cover and are least abundant where the soils are saline or the water table is high. The principal increasers are western wheatgrass, vine mesquite, alkali sacaton, tall dropseed, silver bluestem, and sedges. Alkali sacaton grows on saline soils. Sedges, prairie cordgrass, and tall dropseed are most abundant where the water table is high.

Continuous overgrazing permits invasion by buffalograss, sand dropseed, three-awn, wild sunflower, western ragweed, and mesquite.

Because of the extra moisture it receives as runoff, this site is highly productive if kept in good or excellent condition. It remains in good condition longer under heavy grazing than the Sandy Bottom Land site, but it responds less readily to management once it has deteriorated. Deferment of grazing, mowing to control weeds, and destruction of woody plants by chemical or mechanical means are necessary if the range condition is poor or only fair.

The basal herbage covers from 25 to 40 percent of the surface. In well-managed areas that have a high water table, the total annual herbage yield, excluding woody plants, ranges from 5,000 pounds per acre in dry years to 8,000 pounds per acre in wet years. In saline areas, the yield ranges from 4,000 to 6,000 pounds.

SANDY BOTTOM LAND SITE

This site consists of Sandy alluvial land, a miscellaneous land type on flat to gently sloping bottom lands along and slightly above the stream beds in draws and valleys on the Rolling Plains. This land type receives runoff from higher lying soils, and it is subject to overflow. Saline areas and areas that have a high water table are common.

A typical area is located where farm-to-market road 284 crosses the Prairie Dog Town Fork of the Red River.

Sandy alluvial land is nonarable. It consists mostly of stratified deposits of sand and loamy sandy alluvium. Surface drainage is medium. Internal drainage is rapid in most areas, but it is slow in areas that have a high water table. Because of the extra moisture it receives as runoff, this is one of the best range sites in the county. In dry periods it may provide the only green forage on the range.

The composition of the climax vegetation varies from place to place, depending on the origin of the alluvial deposits and the frequency of new deposits. The vegetation consists mostly of tall and mid grasses, including Indiangrass, switchgrass, bluestem, tall dropseed, Canada wildrye, alkali sacaton, and sedge. Decreasers constitute from 40 to 70 percent of the plant community, and increasers the rest. Indiangrass, switchgrass, and sand bluestem grow in the most favorable areas. Alkali sacaton makes up a high percentage of the vegetation in the saline areas. Alkali sacaton, tall dropseed, blue grama, silver bluestem, and sedge are the main increasers. A few woody plants, chiefly elm and cottonwood trees, occur in the climax vegetation on some of the bottom lands.

If the climax vegetation is not maintained, the site is invaded by noxious annual and perennial plants. These invaders include cocklebur, sunflower, sandbur, and western ragweed. Saltcedar is the main woody invader in the saline areas, and sand sagebrush in areas that have a low water table.

This site is highly productive if it is kept in good or excellent condition. It deteriorates more rapidly than the Loamy Bottom Land site if overgrazed, but it recovers more rapidly under good management. Grazing should be deferred and weeds should be mowed if the range condition is poor or fair.

The basal herbage covers about 20 to 40 percent of the surface. In well-managed areas where the water table is low or the soils are saline, the total annual herbage yield, excluding woody plants, ranges from 3,000 pounds per acre in dry years to 4,200 pounds per acre in wet years. In areas where the water table is high, production ranges from 4,000 to 5,500 pounds per acre.

DEEP HARDLAND SITE

This site consists mostly of smooth, nearly level to moderately sloping upland plains and some of the smoother erosional plains in the Palo Duro Canyon (fig. 22). A typical area is on the J. A. Ranch, 2 miles east of the ranch headquarters. The soils in this site are—

Abilene clay loam, 0 to 1 percent slopes.
Abilene clay loam, 1 to 3 percent slopes.
Bippus clay loam, 0 to 1 percent slopes.
Bippus clay loam, 1 to 3 percent slopes.
Bippus clay loam, 3 to 5 percent slopes.
Lofton silty clay loam.
Olton clay loam, 0 to 1 percent slopes.
Olton clay loam, 1 to 3 percent slopes.
Olton clay loam, 3 to 5 percent slopes.
Pullman silty clay loam, 0 to 1 percent slopes.
Pullman silty clay loam, 1 to 3 percent slopes.
Pullman silty clay loam, 1 to 3 percent slopes, eroded.
Roscoe clay.
Ulysses clay loam, 0 to 1 percent slopes.
Ulysses clay loam, 1 to 3 percent slopes.
Weymouth clay loam, 1 to 3 percent slopes.
Weymouth clay loam, 3 to 5 percent slopes.
Weymouth soil in Weymouth-Vernon complex.
Wichita loam, 0 to 1 percent slopes.
Wichita loam, 1 to 3 percent slopes.
Wichita loam, 3 to 5 percent slopes.
Zita clay loam, 0 to 1 percent slopes.
Zita clay loam, 1 to 3 percent slopes.

Figure 22.—Deep Hardland range site that has been properly grazed.

These soils are moderately deep or deep, and they are fertile. Their subsoil is moderately permeable to very slowly permeable. They have a high moisture-holding capacity. In places the intake of moisture is reduced by a surface crust and by a compacted layer, or "hoof pan," caused by trampling. If not protected, these soils are susceptible to slight wind erosion and to moderate or moderately severe water erosion.

The vegetation is mostly short grasses. Mid grasses grow only in the most favorable locations. About 70 percent of the vegetation consists of climax decreasers, such as blue grama, vine-mesquite, western wheatgrass, and side-oats grama. The rest of the climax vegetation is mostly increasers, such as buffalograss and silver bluestem. Some woody plants occur in the climax vegetation.

Overgrazing results in rapid invasion by pricklypear and mesquite trees. Other invaders are three-awn, broom snakeweed, and western ragweed.

This site is capable of high production of short and mid grasses. It deteriorates slowly, will maintain a sod even if heavily grazed, and responds to good management.

The basal herbage covers from 30 to 40 percent of the surface. Under good management, the total annual herbage yield, excluding woody plants, ranges from 1,400 pounds per acre in dry years to 3,000 pounds per acre in wet years.

MIXED LAND SITE

This site occurs on gentle to moderate slopes on the Rolling Plains. The soils in this site are—

Woodward loam, 1 to 3 percent slopes.
Woodward loam, 3 to 5 percent slopes.
Woodward loam, 5 to 8 percent slopes.
Woodward soil in Quinlan complex.

These shallow to moderately deep soils overlie very fine-grained sandstone of the red beds. They take water readily, but their capacity to store moisture and plant nutrients is moderate to moderately low. If not protected, they are highly susceptible to wind and water erosion. Small areas of colluvial-alluvial soils are included in this site. The nearly level soils of this site are arable, but because they are inaccessible they are not farmed.

The climax vegetation is mostly mid grasses. Blue grama, side-oats grama, and little bluestem are the principal decreasers. Buffalograss, silver bluestem, and sand dropseed are the principal increasers. The more common invaders are three-awn, mesquite, sandbrush, pricklypear, and yucca.

Continuous overgrazing results in buffalograss replacing blue grama, side-oats grama, and little bluestem in the range vegetation. Areas of range in fair or poor condition are bare or are occupied by the common invaders.

The basal herbage covers from 20 to 30 percent of the surface. Under good management, the total annual herbage yield, excluding woody plants, ranges from 2,200 pounds per acre in dry years to 3,000 pounds per acre in wet years.

MIXED LAND SLOPES SITE

This site is in the sloping and rolling areas transitional between the High Plains and the Rolling Plains. The landscape is characterized by rolling hills and ridges formed by the tributaries of the Prarie Dog Town Fork and the Salt Fork of the Red River (fig. 23). A typical area is in the northeastern corner of the county, south of the High Plains escarpment. The soils in this site are—

Berthoud-Mansker fine sandy loams, 3 to 8 percent slopes.
Berthoud soil in Berthoud-Potter sandy loams.
Berthoud soil in Rough broken land.
Mansker fine sandy loam, 1 to 3 percent slopes.

Figure 23.—Mixed Land Slopes range site in good condition.

These soils are mostly moderately deep, but in some places they are shallow or very shallow. They are limy throughout, and they absorb water readily. Fertility is low. If not protected, these soils are highly susceptible to wind erosion. Deep U-shaped gullies are common in areas that are in poor condition. The deeper, nearly level soils of this site are arable, but they occur only as small scattered areas.

Mid grasses predominate in the climax vegetation. About 50 percent of the cover consists of decreasers, chiefly side-oats grama and little bluestem, but also including some sand bluestem and Canada wildrye. Increasers, mainly blue grama, hairy grama, and silver bluestem, make up about 30 percent. Yucca, the chief invader makes up 25 to 40 percent of the vegetation in some places.

This site is capable of producing a good cover of mid grasses if it is properly managed. The basal herbage covers from 10 to 20 percent of the ground surface. Under good management, the total annual herbage yield, excluding woody plants, ranges from 2,500 pounds per acre in dry years to 4,000 pounds per acre in wet years.

HARDLAND SLOPES SITE

This site consists mostly of gently sloping and gently rolling areas bordering the High Plains. It includes playa rims and erosional plains in the Palo Duro Canyon. A typical area flanks the draw of Mulberry Creek southeast of Claude. The soils in this site are—

Berthoud-Mansker loams, 3 to 8 percent slopes.
Mansker loam, 1 to 3 percent slopes.
Mansker loam, 3 to 5 percent slopes.
Mansker loam, 3 to 5 percent slopes, eroded.

These soils take water readily. They are limy throughout, and their subsoil is moderately permeable. Generally they are shallow, and their capacity to hold moisture and plant nutrients is low. If not protected, they are highly susceptible to wind and water erosion.

Mid and short grasses make up the climax vegetation on the moderately deep soils. Mid grasses are dominant on the shallow soils. Decreasers, chiefly side-oats grama and little bluestem, make up about 40 percent of the climax vegetation. The rest of the climax vegetation consists of increasers, such as blue grama and buffalograss. Broom snakeweed, western ragweed, and weedy annuals invade areas of range in poor condition. Some spots are bare of vegetation.

If properly managed, this site is a good producer of mid and short grasses. It deteriorates slowly, even if heavily grazed, and recovers rapidly.

The basal herbage covers from about 15 to 25 percent of the surface. Under good management, the total annual herbage yield, excluding woody plants, ranges from 2,100 pounds per acre in dry years to 3,200 pounds per acre in wet years.

SANDY LOAM SITE

This site consists of nearly level to gently rolling uplands on the Rolling Plains. A typical area, mostly of Miles soils, is due east of Goodnight near the Donley County line. The soils in this site are—

Bippus fine sandy loam, 1 to 3 percent slopes.
Miles fine sandy loam, 0 to 1 percent slopes.
Miles fine sandy loam, 1 to 3 percent slopes.
Miles fine sandy loam, 3 to 5 percent slopes.
Vona fine sandy loam, 3 to 5 percent slopes.

These deep soils are moderately to moderately rapidly permeable. Their capacity to hold both water and plant nutrients is moderate, and they release water readily to plants. If protected by a good stand of grasses, they take water readily and lose little or none through runoff. If not protected, they are highly susceptible to wind erosion and moderately susceptible to water erosion.

The climax vegetation is chiefly mid grasses. It is approximately 60 percent decreasers, chiefly side-oats grama, little bluestem, Indiangrass, and switchgrass. About 30

Assessing Transportation Infrastructure Impacts on Rangelands: Test of a Standard Rangeland Assessment Protocol

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Abstract

Linear disturbances associated with on- and off-road vehicle use on rangelands has increased dramatically throughout the world in recent decades. This increase is due to a variety of factors including increased availability of all-terrain vehicles, infrastructure development (oil, gas, renewable energy, and ex-urban), and recreational activities. In addition to the direct impacts of road development, the presence and use of roads may alter resilience of adjoining areas through indirect effects such as altered site hydrologic and eolian processes, invasive seed dispersal, and sediment transport. There are few standardized methods for assessing impacts of transportation-related land-use activities on soils and vegetation in arid and semi-arid rangelands. Interpreting Indicators of Rangeland Health (IIRH) is an internationally accepted qualitative assessment that is applied widely to rangelands. We tested the sensitivity of IIRH to impacts of roads, trails, and pipelines on adjacent lands by surveying plots at three distances from these linear disturbances. We performed tests at 16 randomly selected sites in each of three ecosystems (Northern High Plains, Colorado Plateau, and Chihuahuan Desert) for a total of 208 evaluation plots. We also evaluated the repeatability of IIRH when applied to road-related disturbance gradients. Finally, we tested extent of correlations between IIRH plot attribute departure classes and trends in a suite of quantitative indicators. Results indicated that the IIRH technique is sensitive to direct and indirect impacts of transportation activities with greater departure from reference condition near disturbances than far from disturbances. Trends in degradation of ecological processes detected with qualitative assessments were highly correlated with quantitative data. Qualitative and quantitative assessments employed in this study can be used to assess impacts of transportation features at the plot scale. Through integration with remote sensing technologies, these methods could also potentially be used to assess cumulative impacts of transportation networks at the landscape scale.

Resumen

Los disturbios lineales asociados con el uso de vehículos (incluyendo vehículos todoterreno) en áreas naturales han incrementado dramáticamente en todo el mundo en décadas recientes. Esto ha sido causado por una variedad de factores que incluyen el aumento en la disponibilidad de vehículos todoterreno, la infraestructura asociada con el desarrollo (petróleo, gas, energía renovable, desarrollo ex-urbano) y actividades recreacionales. En adición a los impactos directos, la presencia y uso de estas calles puede alterar la resiliencia de áreas adyacentes a través de efectos indirectos tales como alteraciones en los procesos hidrológicos y eólicos del sitio, en la dispersión de semillas de especies invasoras, y en el transporte de sedimentos. Hay pocos métodos estandarizados para evaluar los impactos de las actividades de transporte sobre el suelo y la vegetación en pastizales áridos y semiáridos. La Interpretación de Indicadores para la Salud de los Pastizales (IIRH) es un método cualitativo que ha sido ampliamente utilizado y que ya está aceptado a nivel internacional para la evaluación de pastizales. Evaluamos la sensibilidad de IIRH a los impactos de calles, caminos y ductos en áreas adyacentes a estos disturbios, muestreando parcelas ubicadas a tres distancias de estos disturbios lineales. Hicimos esta evaluación en 16 sitios seleccionados al azar dentro de cada uno de 3 ecosistemas (las Planicies Altas del Norte, la Meseta del Colorado, y el Desierto Chihuahuense) para un total de 208 parcelas de muestreo. También evaluamos la repetibilidad de IIRH cuando es aplicado a gradientes de disturbios causados por calles y caminos. Para finalizar, examinamos qué tan correlacionadas estuvieron las evaluaciones de atributos de las parcelas con las tendencias de un grupo de indicadores cuantitativos. Los resultados indicaron que la técnica de IIRH es sensible a impactos directos e indirectos de las actividades de transporte y que la desviación a partir del estado de referencia disminuye a medida que la distancia al disturbio aumenta. Las tendencias en la degradación de procesos ecológicos detectadas con las evaluaciones cualitativas estuvieron altamente correlacionadas con los datos cuantitativos. Las evaluaciones cuantitativas y cualitativas utilizadas en este estudio pueden ser utilizadas para examinar los impactos de la infraestructura de transporte a la escala de la parcela. Por medio de la integración tecnológica de sensores remotos, estos métodos también podrían ser utilizados para examinar los impactos acumulativos de redes de transporte a la escala del paisaje.

Key Words: disturbance, indicators, off-highway vehicles, oil and gas, rangeland health, roads

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INTRODUCTION

The amount and extent of vehicle activity in rangelands of the world have rapidly increased in recent decades. This increase is due to a variety of factors including availability of all terrain vehicles, recreational activities, oil and gas development, and ex-urban development (Hansen et al. 2002; Williams 2003; Brown et al. 2005; Vias and Carruthers 2005; Watts et al. 2007; Leu et al. 2008). Development of renewable energy sources, including wind and solar, is predicted to lead to additional road development in rangelands. Wind power requires a road to each windmill, and both wind and solar power will require development of thousands of miles of new transmission lines, each of which requires a service road. Although numerous studies and review papers have investigated direct changes to soils and vegetation due to road and vehicle disturbances (see review by Forman and Alexander 1998), there is little guidance on how to assess and monitor roads and adjacent areas to detect changes in vegetation and soils due to vehicle-related disturbances. For effective local to landscape scale management of transportation networks, assessment and monitoring programs are needed that capture how roads, trails, and other development activities directly and indirectly alter ecological function (Treweek et al. 1998).

Direct impacts of transportation networks on soils and vegetation vary with road type (Brooks and Lair 2005). Direct impacts of improved local roads are not generally studied. Impacts on soil quality and vegetation communities are obvious and extreme, including total removal of surface soil horizons and all vegetation. Direct impacts of planned or unplanned trails (that are established by use and not engineered) are typically less certain and therefore have been more extensively studied. Impacts to soils include compaction and rutting of surface soils (Webb 1983; Lei 2004) resulting in decreased infiltration (Thurow et al. 1993) and increased soil erosion (Iverson 1980). Additionally, disturbance of soil surfaces can break up biological soil crusts and other soil stabilizing aggregates, resulting in increased erosion by both wind and water (Belnap 1995; Belnap and Gillette 1997; Li et al. 2009). Impacts on vegetation include mortality of all or part of the plant from vehicles crushing and reducing soil water and nutrients through soil degradation and loss (Lovich and Bainbridge 1999). Shifts in plant community composition can also occur in roads and trails due to the variation in species-specific resilience from repeated disturbance (Thurow et al. 1993; Yorks et al. 1997; Bolling and Walker 2000) and the introduction of exotic species (Lovich and Bainbridge 1999; Gelbard and Belnap 2003).

There is considerably less information on when and how far impacts on vegetation and soils extend beyond areas directly contacted by vehicles. Most of the literature on indirect impacts of roads and trails (hereafter referred to as roads) investigates impacts on wildlife such as habitat fragmentation (Theobald et al. 1997) and noise or visual disturbance (Reijnen et al. 1997). However, the presence and use of these roads has potentially altered the resilience of soils and vegetation in adjoining areas through indirect effects such as altered site hydrologic and eolian processes (Belnap and Gillette 1997; Li et al. 2009), invasive seed dispersal (Abella et al. 2009), and sediment transport (Belnap 1995; Gellis 1996; Fang et al. 2002; Ziegler et al. 2002; Fuchs et al. 2003; Grismer 2007). Furthermore, these indirect impacts will also vary with road type (planned or unplanned). For example, engineered roads may minimize erosion processes that impact road function but inadvertently cause greater alteration of landscape hydrologic processes (Forman and Alexander 1998). Conversely, unplanned roads may have less impact on landscapes when evaluated individually but, because they often occur as fairly dense networks, may have greater impact on some landscapes when evaluated cumulatively (Brooks and Lair 2005).

Secondary, unsurfaced roads and trails make up the majority of roads in rural areas of the western United States (Watts et al. 2007; Leu et al. 2008). Although there is a poor understanding of rate of change in infrastructure development in rural areas (Theobald 2001), secondary road types associated with energy development and recreational activities likely represent the majority of new roads in this area. In the Powder River Basin of northeastern Wyoming alone, the current Bureau of Land Management (BLM) management plan allows for establishment of an additional 17 754 miles (28 572 km) of roads and 26 157 miles (42 096 km) of pipelines and overhead electric lines to support energy development activities between 2003 and 2013 (BLM 2003, p. 2–18). The number of off-road vehicles owned in the United States almost tripled between 1993 and 2003, with rates of participation in off-highway vehicle recreation highest in the intermountain west (27% of persons 16 and older in Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming; Cordell et al. 2005). Effective management of ecosystem impacts associated with energy and recreation activities requires assessment and monitoring systems capable of detecting where on the landscape impacts are occurring and how those impacts are altering ecosystem function. Assessment and monitoring data from such a system can then help inform land managers what actions are necessary for mitigation of past and minimizing impacts of future activities.

The general goal of this study was to test the applicability of existing assessment and monitoring techniques for detecting impacts on rangelands due to roads, trails, and pipelines. If applicable, these techniques could then be used in conjunction with existing route inventory (Graves et al. 2006) and usage information to develop comprehensive travel management plans. Additionally, if similar methods could be employed to assess and monitor impacts of roads as are currently used in nonroad areas, results could be integrated into general resource management plans. The Interpreting Indicators of Rangeland Health (IIRH) protocol (Pellant et al. 2005) was selected for this study because it has a demonstrated ability to assess ecosystem processes, including soil nutrients, erosion, and moisture-related processes, and is widely applied by two US agencies primarily responsible for rangeland assessment and monitoring (Natural Resource Conservation Service [NRCS] and BLM). Such qualitative techniques are particularly useful because they can provide relatively rapid assessments of a wide range of ecological processes that are difficult to measure but necessary for understanding proximity to ecological thresholds (Bestelmeyer 2006). IIRH assessments done across a landscape can provide a snapshot of how ecological processes are affecting ecosystem resilience (Miller 2008) and restoration potential (King and Hobbs 2006).

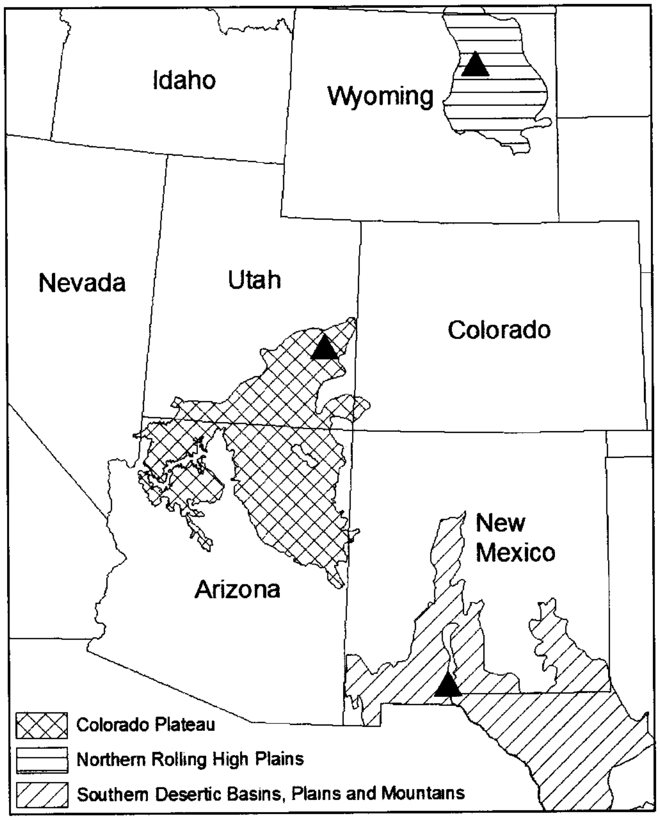

Figure 1. Study area locations (black triangles) and Natural Resources Conservation Service [NRCS] Major Land Resource Areas (USDA-NRCS 2002).

This study was designed to address three objectives: 1) assess the sensitivity of IIRH attributes and indicators to impacts on rangelands caused by roads; 2) test if variability among IIRH observer attribute ratings in road-related disturbance gradients limits the protocol's potential to detect these impacts; and 3) assess the extent to which trends in IIRH attribute departure classes for plots located in a disturbance gradient are correlated with trends in a suite of quantitative indicators. We use the results to illustrate how IIRH can be used to determine which ecosystem processes are impacted most and discuss how coupled qualitative-quantitative measures can be used to select monitoring indicators most likely to detect impacts of roads and other linear development infrastructure on rangeland ecosystem properties. Finally, we provide guidance for application of IIRH to rangelands impacted by roads.

MATERIALS AND METHODS

General Approach

The study was conducted in three semiarid regions of the western United States: the Northern High Plains (Wyoming), the Colorado Plateau (Utah), and the Chihuahuan Desert (New Mexico; Fig. 1; Table 1). Coupled qualitative and quantitative protocols were applied across a broad spectrum of impacts caused by common road and trail types in the three regions. The study was conducted at four sites for each of four road types in each of the three regions for a total of 48 sites sampled. Each site was divided into two to six plots, depending on disturbance type (Fig. 2). The intensive plot design used in this study was intended to test sensitivity of methods; we expect that a simpler, more practical plot design would be used for implementation of these methods in an assessment or monitoring program. We did not have the resources to address our objectives on all types of linear disturbances that occur on rangelands or on multiple ecological sites in each region (US Department of Agriculture [USDA]-NRCS 2003). Therefore, we limited our research to one ecological site per region, and to disturbance types that were of concern to land managers and that posed the most difficulty in adapting existing assessment and monitoring techniques: unpaved, fairly narrow, linear roads, trails, and pipelines (Tables 1 and 2).

Study Locations

A study area was selected within each region where road development and/or off-road vehicle activity was a substantial concern of local BLM and where a variety of road types was present (Table 1). The Wyoming study area was located in the Powder River Basin, which is underlain by vast energy reserves and has been the focus of recent intense coal bed natural gas exploration and well development. The Utah study area has been the subject of repeated seismic exploration, has several active natural gas wells, and is the focus of intense recreational off-road vehicle activity. The New Mexico study area is bisected by natural gas pipelines and has extensive networks of unregulated recreational off-road vehicle trails.

Site and Plot Selection

To select sites within study areas, we used a random sampling design stratified by qualitatively assessed road impact determined using recent high-resolution aerial imagery. From our observations, it appears that the most severe road impacts are often spatially concentrated and not evenly distributed across a road network. This stratification approach was used to ensure that half the study sites included problem road segments. To select areas for high-resolution aerial photography acquisition (three 2.4-km by 1.5-km rectangles in each study area, size, and number determined by width of aerial image footprint and cost limitations), we surveyed existing road, ownership, imagery, and soil maps to find locations on public land that maximized the length of linear features of interest on the chosen ecological site. We acquired color and color infrared aerial photos (1:8 000) of each study area prior to field work (August 2007 in Wyoming and October 2007 in Utah and New Mexico). Photos were scanned at a 10-cm ground sampling distance (10-cm pixels), georeferenced, and orthorectified (see Fig. S1, available at http://dx.doi.org/10.2111/REM-D-09-00176.sf1).

Within the aerial image of each study area, we created a stratified-random sample of road sites by manually digitizing roads on recent Digital Orthophoto Quarter-Quadrangle imagery (DOQQ, 1:12 000; 2006 in Wyoming and Utah, and 2005 in New Mexico), classifying them by road type (Table 2), dividing them into 30-m segments, and assigning a random number to each segment. DOQQ imagery was used instead of the recent higher-resolution photos for road digitizing to ensure that the roads in our sample were at least 1 yr old. Road

Table 1. Study area locations; ecological sites; climate, vegetation, and disturbance characteristics; and road types investigated.

	Wyoming	Utah	New Mexico
Ecoregion[1]	Dry steppe	Semi-desert and desert	Shrub and semi-shrub, semi-desert and desert
MLRA[2]	Northern High Plains (58.2)	Colorado Plateau (35)	Chihuahaun Desert (42.2)
Ecological site[3]	Loamy (058BY122WY)	Semi-desert shallow sandy loam (035XY236UT)	Gravelly (R042XB010NM)
Latitude, longitude	−106°10 43′E, 44°2.48′N	−109°47.88E, 38°34.09′N	−106°40.90E, 32°11.19N
Precipitation (inches)[4]	10–14 (25.4–35.6 cm)	10–20 (25.4–50.8 cm)	8–10 (20.3–25.4 cm)
Historic climax plant community[4,5]	Cool season midstature grassland with patches of big sagebrush (*Artemisia tridentata* Nutt.)	Mixed community co-dominated by trees (*Juniperus osteosperma* Torr and *Pinus edulis* Engelm.) and shrubs (*Coleogyne ramosissima* Torr.) with strong biological soil crust development	Mixed community co-dominated by warm season grasses, shrubs, and half-shrubs (primarily *Larrea tridentata* DC. and *Parthenium incanum* Kunth)
Dominant disturbances	Natural gas wells and infrastructure	Recreation and natural gas exploration	Recreational off-road vehicles and pipeline infrastructure
Road types investigated[6]	1) Crown and Ditch 2) Crown and Ditch with pipeline 3) Two Track 4) Two Track with pipeline	1) Crown and Ditch 2) Bladed 3) Two Track 4) Intensive Use Areas	1) Bladed 2) Bladed with pipeline 3) Two Track 4) Intensive Use Areas

[1]Bailey (1993).
[2]Major Land Resource Areas (US Department of Agriculture, Natural Resources Conservation Service [USDA-NRCS] 2002).
[3]USDA-NRCS (2003).
[4]From ecological site description
[5]Approximately equivalent to reference condition for Interpreting Indicators of Rangeland Health evaluations
[6]Table 2

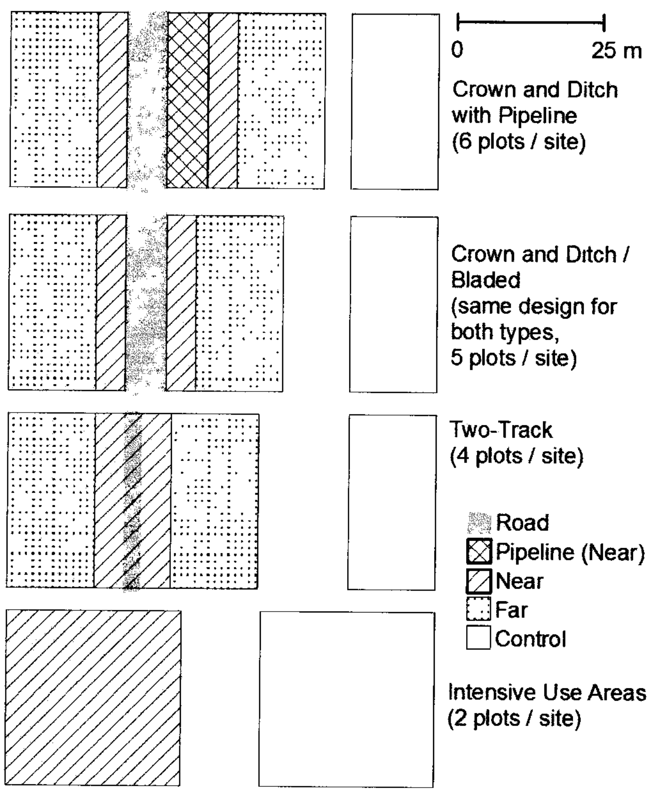

Figure 2. Layout of the disturbance (Near, < 5 m; and Far, 5–20 m) and paired control plots (> 40 m) for the four road types studied. Roads (gray boxes) in Crown and Ditch and Bladed roads were not measured. Distance between control and disturbance plots not to scale.

classification was validated by field visits to several segments of each road type. Road classes were chosen to represent typical construction designs and to differentiate road types that likely differ in the degree of impact to ecosystem functions based on the amount of disturbance and engineering involved (Brooks and Lair 2005). We overlaid randomly sorted segment sample populations on the 1:8 000 photos in a geographic information system using ArcMap® version 9.1 (Environmental Systems Research Institute, Redlands, CA, USA). We visually classified segments into "high" or "low" indirect impacts by comparing patterns of vegetation, bare ground, and erosional features located within 20–30 m of the road to areas of similar topography and ecological site located at least 50 m from roads, trails, and pipelines (Table 3).

In the field, several plots were established at varying distances from the road at each site to test our ability to discern the extent of road impacts with IIRH (Figs. 2 and S1 [available at http://dx.doi.org/10.2111/REM-D-09-00176.sf1]). Road sites were divided into plots near (< 5 m) and far from the linear feature (5–20 m). For two-track roads and two-track roads on top of pipelines, near plots were lumped with the disturbance (road or road plus pipeline) to create one continuous plot that included the disturbance plus ~5 m on either side. For road types with more significant surface disturbance (Bladed and Crown and Ditch), the travel way was excluded from the IIRH evaluations and near plots on each side evaluated separately. For sites with pipelines along Bladed or Crown and Ditch roads, pipelines were evaluated separately.

A similar approach was used to create a stratified-random sample of sites with concentrated off-road and off-trail driving activity (Intensive Use Areas; Table 2). The 1:8 000 photos were used because off-road vehicle tracks are often difficult to

Table 2. Decision tree for classifying disturbances. This process was applied to stretches of road longer than the plots, generally on the order of several hundred meters. We limited our sample population to relatively narrow linear features that included a nonpaved road and were not planned parking areas, developed campgrounds, watering points for livestock, well pads, and very wide pipelines (> ~20 m; this occurred only in New Mexico).

1. Does the road have a discernable[1] crown and ditch (raised in the center > 30 cm with a ditch on the side > 30 cm deep, relative to berm on side)? Yes, then Crown and Ditch. No, then:
2. Does the road have < 30% of total foliar cover (rooted within the road) of that in adjacent areas *and* have evidence of blading[1] (berm > ~30 cm)? Yes, then Bladed. No, then:
3. Is the segment within an area that has at least 75 m of vehicle tracks within a 30 × 30 m square? Yes, then Intensive Use Area. No, then:
4. Two Track

[1]Evidence of past maintenance needed to be discernable in the field on the majority of the road stretch to be counted.

discern on 1:12 000 DOQQs. Intensive Use Areas had at least 75 m of tracks within a 30-m square. This corresponds to approximately 25% cover of vehicle tracks with a standard sized sport utility vehicle (including areas between tires), a percent cover of tracks similar to that within near plots for Two-Track road type (Figs. 2 and S1 [available at http://dx.doi.org/10.2111/REM-D-09-00176.sf1]). A sample population of Intensive Use Areas was identified using a hierarchical sampling approach. First, areas that appeared to have enough off-road vehicle activity were roughly delineated with large polygons. Then, a grid of points spaced at 10-m intervals was established within those polygons, and a layer of overlapping 30-m squares centered on each point created. Squares were evaluated in random order to determine if the amount of vehicle impacts within was sufficient to meet the minimum criteria for an Intensive Use Area plot (Table 2), and, if so, then qualitatively evaluated for impact (Table 3). Those plots that met the minimum qualifications for an Intensive Use Area plot but did not meet the qualifications for a high-impact Intensive Use Area plot were classified as low impact. Because roads and trails within Intensive Use Areas are not necessarily linear nor do they have an easily distinguished edge, we did not subdivide those sites by distance from disturbance and established only one 30 × 30 m plot within the disturbed area (Fig. 2).

Paired control plots were established that were > 40 m from any vehicle-related disturbances for both road and Intensive Use Area plots to determine whether impacts detected in areas on or adjacent to roads were due to the disturbance of interest or other factors. Control plots matched disturbance plots as much as possible in all aspects, including soil series, soil surface texture, aspect, slope, slope shape, and dominant vegetation community (excluding changes in vegetation near the road). To the extent possible, control plots were not placed down slope of roads. For road sites, controls were a 15 × 30 m rectangle (Fig. 2). For Intensive Use Area sites, controls were a 30 × 30 m square (Fig. 2). Controls were oriented the same direction as road plots, except where slopes were > 3% and aspect differed between control and road plots, in which case slope orientation of control was matched with that of the disturbance plots.

Table 3. Qualitative imagery interpretation criteria for high ecological impact.

Site type	Criteria for high impact
Roads and roads with pipelines	Increase or decrease in vegetation or bare ground of > ~30% or any observable increased frequency in erosional features that extended greater than 5 m off the road or pipeline[1]
Intensive Use Areas	> ~60% ground not covered by litter, vegetation, or biological soil crusts[2] and/or > 60% covered with vehicle tracks[2] (for four-wheeled vehicles, area between tires was included in track cover)

[1]Along 30-m road segment.
[2]Within 30 × 30 m plot

Qualitative Assessments

Qualitative assessments were conducted on each of 208 plots following the IIRH protocol, version 4 (Pellant et al. 2005). IIRH uses the ecological site concept (Herrick et al. 2006a) in combination with expert knowledge of soils and vegetation properties in a conceptual reference state. In the field, IIRH is conducted by an interdisciplinary team that evaluates the relative departure of 17 indicators of rangeland health (Table 4) against a description of the reference range of variation for each indicator using a five-category qualitative scale of departures (none-to-slight, slight-to-moderate, moderate, moderate-to-extreme, or extreme-to-total). Once all indicators have been evaluated, three attributes of rangeland health (Soil and Site Stability, Hydrologic Function, and Biotic Integrity; Pellant et al. 2005) are evaluated by synthesizing the five-category scale of departure ratings for the relevant indicators for each attribute (Table 4). The existing reference sheets for the ecological sites required updating. For each state, we updated reference sheets by reviewing available literature and unpublished data, and consulting with a group of local experts. Ecological site-specific reference matrices were developed based on these reference sheets (Pellant et al. 2005).

Field work was conducted in September 2007 in Wyoming, November and December 2007 in New Mexico, and March 2008 in Utah. An interdisciplinary three-person team (range scientist, botanist, and soil scientist), each of whom had received at least two 1-wk formal IIRH trainings, conducted independent evaluations, which were then followed by a consensus evaluation. Bare ground and litter cover, which is necessary for IIRH, was estimated with 100 points collected by the step-point technique (Evans and Love 1957). Soil stability values (collected as part of the quantitative measures; see next section) and step-point litter and bare ground cover were shared among observers for individual and consensus evaluations.

Quantitative Measures

Quantitative measures were completed within 1–14 d after qualitative measures. Five transects were strung across plots, perpendicular to roads and pipelines (if present) and oriented parallel to one square side for Intensive Use Area sites (Fig. S1 [available at http://dx.doi.org/10.2111/REM-D-09-00176.sf1]). Transects in the control were oriented in the same direction as in the disturbance plots. A line-point intercept (LPI) with a point spacing of 30 cm was used to collect vegetation cover and

Exhibit K-6

Table 4. Interpreting Indicators of Rangeland Health indicator numbers, description, attributes with which indicators are associated (dots), and Friedman's test results comparing the distribution of the indicator departure rating in the Near, Far, and Control plots (Fig. 2) in each study area. Adapted from Pellant et al. (2005).

Qualitative indicators		Attribute[1]			Friedman's test[2]		
No.	Description	SSS	HF	BI	WY	UT	NM
1	Number and extent of rills	•	•		**		
2	Presence of water flow patterns	•	•		**		
3	Number and height of erosional pedestals or terracettes	•	•				*
4	Bare ground	•	•		**	**	**
5	Number of gullies and erosion associated with gullies	•	•				
6	Extent of wind scoured, blowouts, and/or depositional areas	•				**	
7	Amount of litter movement	•			**	**	
8	Soil surface (top few mm) resistance to erosion	•	•	•	**	**	
9	Soil surface structure and soil organic matter content	•	•	•	**	**	**
10	Effect of plant community composition and spatial distribution on infiltration and runoff		•		**	**	
11	Presence and thickness of compaction layer	•	•	•	**	**	*
12	Functional/structural groups			•		**	
13	Amount of plant mortality and decadence			•			
14	Average percent litter cover		•	•			*
15	Expected annual production			•	**		
16	Potential invasive (including noxious) species (native and non-native)			•			
17	Perennial plant reproductive capability			•			

[1]SSS indicates Soil and Site Stability, HF, Hydrologic Function, BI, Biotic Integrity

[2]Nonparametric ANOVA testing if the indicator departure rating distributions differed between Near, Far, or Control plots (Fig 2) in Wyoming, Utah, and New Mexico. * indicates Friedman's significant at the 0 05 probability level, ** indicates Friedman's significant at the 0.01 probability level.

composition, basal cover, and ground cover data (Herrick et al. 2005). The 30-cm spacing interval was chosen to ensure that at least 80 points were collected in the narrowest plots (5 m). In addition to vegetation and soil surface cover data collected with LPI, we also recorded vegetation height every 150 cm and recorded dead or decadent plants by recording all hits where the whole plant or plant part intersected was either dead or decadent. To evaluate the susceptibility of sites to wind erosion and weed invasion, size of gaps between perennial plant canopies were measured along the same transects (Herrick et al. 2005).

Soil aggregate stability samples were collected from each plot and analyzed using a soil stability field kit (Herrick et al. 2001, 2005). This method has been shown to be highly sensitive to changes in soil surface structure in New Mexico (Bird et al. 2007), Utah (Chaudhary et al. 2009), and Wyoming (Herrick et al. 2006b). Eighteen samples were collected from each plot in Utah and New Mexico. Only nine samples were collected from each plot in Wyoming because of time and staff limitations. Approximately half of the samples were collected from underneath perennial plant canopies and half outside of these canopies using a stratified (by canopy) random sampling design. Plot averages were generated with weighted strata averages using transect cover data.

To provide a quantitative estimate of rill and gully formation in plots independent of IIRH, depth and width of rill and gully features were measured along continuous transects within each plot by a person not involved in IIRH assessments. For road plots, rill and gully transects were walked approximately up the center of the road and pipeline (if present) and approximately 2.5 m and 12.5 m out from the road edge and parallel to the road on either side. Additionally, two evenly spaced transects were walked across all plots perpendicular to roads. For Intensive Use Area sites, two sets of two intersecting transects were walked. Transects were evenly spaced, parallel to plot edges, and measured as above.

Statistical Analysis

To assess the sensitivity of IIRH attributes and indicators to impacts caused by roads (objective 1) in each study area, we used a nonparametric randomized block analysis of variance (ANOVA, Friedman's test blocking on site, PROC FREQ; SAS 2001) to test the null hypothesis that the distribution of departure classes in Near and Far plots was not different than in the Controls. At the attribute level, this was done separately for Near and Far for each study area, and for each road type in each study area. Although it is generally not recommended to emphasize individual IIRH indicators (Pellant et al. 2005), we were interested in determining the relative sensitivity of different IIRH indicators to linear disturbances. Therefore we also conducted the nonparametric randomized block ANOVA as above at the indicator level in each study area but tested only the hypothesis that at least one of the set of plots (Near, Far, or Control) was from a different distribution, and we did not conduct the analysis for the different road types separately.

To test if the level of agreement among observers conducting IIRH evaluations along roads or in vehicle-disturbed areas was significantly less than in nondisturbed areas and thus possibly limit IIRH applicability in such situations (objective 2), we calculated the range in attribute ratings for the three observers in each plot (0 = all observers had same departure rating, 1 = observers differed by one departure class, 2 = observers differed by two departure classes, and 3 = observers differed by three departure classes). The frequency of attribute departure rating ranges (0, 1, 2, and 3) was then calculated for each group of plots (Near, Far, and Control) for each IIRH attribute. A chi-square test of homogeneity was used to test if the observers experienced a similar amount of agreement in the three groups of plots (Near, Far, and Control) for each IIRH attribute. Although IIRH ratings (either at the indicator or attribute level) are not necessarily evenly spaced in a conceptual ecological process space (i.e., the distance between none-to-slight and slight-to-moderate is not necessarily the same as the distance between moderate-to-extreme and extreme-to-total), this approach does allow us to compare levels of agreement among observers without treating ratings as a continuous variable.

To assess the extent to which trends in IIRH attribute departure ratings were correlated with quantitative indicators (objective 3), we compared the ratings with both individual quantitative indicators and attribute-specific quantitative indices. LPI, canopy gap, soil stability, and rill and gully quantitative data were summarized for each plot to create three sets of quantitative indicators corresponding to the three IIRH qualitative attributes (Pyke et al. 2002; Pellant et al. 2005). These three sets of indicators were then used to generate a quantitative indicator index for each attribute based on the axis score of an ordination of the values of the quantitative variables on all plots. Nonmetric Multidimensional Scaling with Sorensen distance measure and limiting the final dimensionality to one axis (PC-ORD; McCune and Mefford 2006) was used to create the quantitative indicator index. Spearman's rank correlations were then used to compare both the individual quantitative indicators and the quantitative indicator indices with the three attributes (PROC CORR; SAS Institute 2001).

RESULTS

Sensitivity of IIRH to Road Impacts

Attribute Level. Significant differences in qualitative attribute rating distributions ($P < 0.05$) were detected among the three distance classes (Near, < 5 m; Far, 5–10 m; and Control, > 40 m) with greater plot attribute departure from reference condition near disturbances (Fig. 3, open bars) across most attributes and each study area. In all three study areas, the differences between Control and disturbed plots (Near and Far) attribute rating departures were generally greater in Soil and Site Stability and Hydrologic Function than in Biotic Integrity (Fig. 3). There was no significant difference in Biotic Integrity distributions among distance classes in New Mexico, and significant differences detected in Wyoming and Utah were primarily driven by differences in the Near but not the Far plots. Results indicate that the stratified random plot selection process used was successful in obtaining a wide range in IIRH attribute ratings among road and control plots in all states and attributes except for Hydrologic Function and Biotic Integrity in New Mexico, where > 85% of plots were within one departure class (either slight-to-moderate or moderate; Fig. 3).

Examination of IIRH assessment results within road types indicates that changes in the rangeland health of the sites studied (relative to Controls, > 40 m from roads) appears to be limited to < 5 m off the road (Near plots) in most instances. For the ecological sites investigated, detectable impacts to rangeland health (with differences in departure distributions significantly different, $\alpha = 0.05$) extend farther than 5 m (to negatively impact Far plots) only in Hydrologic Function for Two Track with Pipelines in Wyoming ($P = 0.046$; see Fig. S2, available at http://dx.doi.org/10.2111/REM-D-09-00176.sf2), Soil and Site stability for Crown and Ditch in Utah ($P = 0.041$; see Fig. S3, available at http://dx.doi.org/10.2111/REM-D-09-00176.sf3), and Hydrologic Function for Bladed in New Mexico ($P = 0.041$; see Fig. S4, available at http://dx.doi.org/10.2111/REM-D-09-00176.sf4). Crown and Ditch (with or without pipelines) types investigated in Wyoming and Utah consistently had a significant impact on all attributes. For Bladed roads, no differences in attribute departure rating distributions were detected among distance classes (Near, Far, and Control) in Utah, and differences were detected in New Mexico only in Hydrologic Function ($P = 0.041$ for both Near and Far). Similarly, there were very few differences detected in Two Tracks (without pipelines) except for in Hydrologic Function of Near plots in Utah ($P = 0.046$). Differences in all attributes of IIRH were detected for the Utah Intensive Use Areas, but no differences were detected in New Mexico.

Indicator Level. Analysis of the 17 IIRH indicators found that only 3 of the 17 were significantly different among plots at different distances from roads (Near, < 5 m; Far, 5–20 m; and Control, > 40 m) in all three study locations (Table 4): the amount and distribution of bare ground (indicator 4), soil surface loss or degradation (indicator 9), and presence and thickness of a compaction layer (indicator 11). An additional three indicators were significantly different in Wyoming and Utah but not New Mexico: amount of litter movement (indicator 7), soil surface resistance to erosion (indicator 8), and the effect of plant community composition and spatial distribution on infiltration and runoff (indicator 10). There were far fewer indicators that showed significant differences among plots in New Mexico (total of five) than in Utah or Wyoming (total of eight to nine).

Variability Among IIRH Observers

Analysis of the distribution of the range in attribute departure ratings (Fig. 4) indicates that the amount of agreement among observers in the three distance classes (Near, < 5 m; Far, 5–20 m; and Control, > 40 m) was only significantly different ($P < 0.05$) for Soil and Site Stability in Wyoming. This difference detected in Wyoming was partially due to the very high level of agreement in Soil and Site Stability in the Wyoming Controls (same attribute rating among three observers at 75% of the control plots). Otherwise, observers appeared to agree to a similar extent among the groups of plots.

Correlations of Quantitative and IIRH Attributes

Individual Quantitative Indicators. The strength of correlations between quantitative and qualitative indicators provides insight into which quantitative measures are important for capturing the variability present along roads (Tables 5–7). The amount of bare ground and the connectivity of the bare ground (bare ground in gaps > 100 cm) were strongly correlated with both Soil and Site Stability and Hydrologic Function in all three study areas. Other quantitative measures, such as the amount of rill and gully

Exhibit K-8

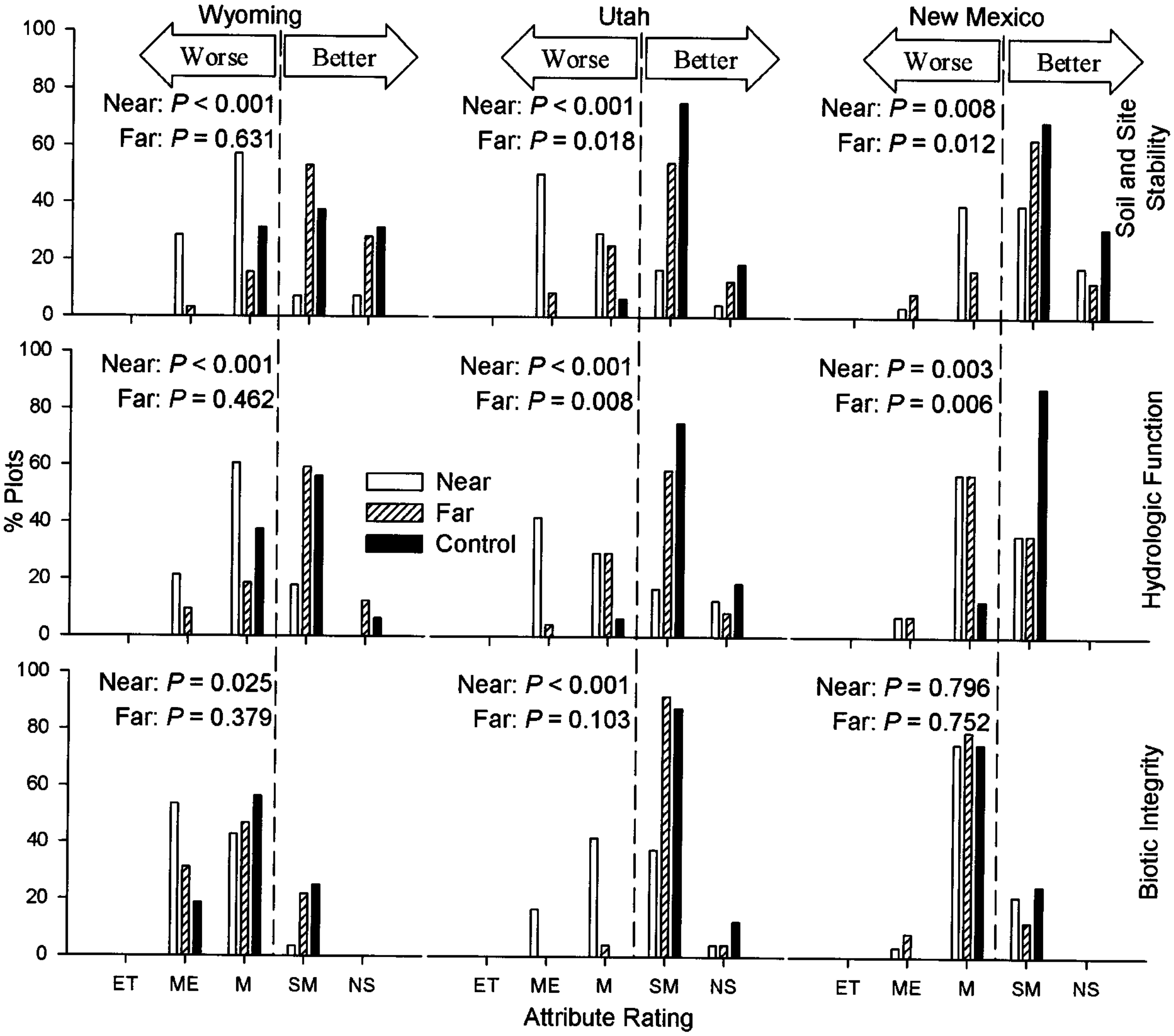

Figure 3. Interpreting Indicators of Rangeland Health (IIRH) attribute ratings for plots at different distances from the disturbance in each study area (Wyoming, Utah, and New Mexico) and for each IIRH attribute (Soil and Site Stability, Hydrologic Function, and Biotic Integrity). "Better" and "Worse" arrows and vertical dashed line between M and SM are provided to help interpret which distance classes are predominately closer to reference condition (NS, none-to-slight; or SM, slight-to-moderate) versus farther from reference condition (M, moderate; ME, moderate-to-extreme; or ET, extreme-to-total). Near plots include areas < 5 m from disturbances (including areas on two-track roads, pipelines, and Intensive Use Areas). Far plots are areas are between 5 m and 20 m of the disturbance. Controls are at least 40 m away from the disturbance (Fig. 2). *P* values are from Friedman's tests comparing the distribution of the Near vs. Control ("Near") and Far vs. Control ("Far") class attribute departure ratings.

development, were strongly correlated with Soil and Site Stability and Hydrologic Function in Wyoming and New Mexico but not in Utah. Conversely, plot average as well as protected and unprotected strata soil aggregate stability were highly correlated with all three attributes in Utah, but correlations were not as strong or consistent in Wyoming or New Mexico. Cover of all plant canopies, cover of plant species that were described in the reference sheet as being important for water capture, and litter cover were all correlated with Hydrologic Function in Wyoming. In Utah, litter and biological crust cover were correlated with Hydrologic Function but not plant cover measures. Similarly, plant community composition measures (functional/structural groups and cover of invasives) were highly correlated with Biotic Integrity in Wyoming but not in Utah or New Mexico.

Quantitative Indicator Indices. Trends in the multivariate quantitative indices followed the same trends as the qualitative attributes in most instances (Table 8). Except for Biotic Integrity in Utah and New Mexico, all correlations were significant ($P < 0.05$).

DISCUSSION

Results of this study indicate that IIRH is both sensitive to impacts and correlated to quantitative measures across many types of road-related disturbances and a broad range of ecosystems, although the severity of impacts detected varied. IIRH attribute ratings indicate that hydrologic function and soil and site stability are the primary ecosystem processes negatively

Exhibit K-9

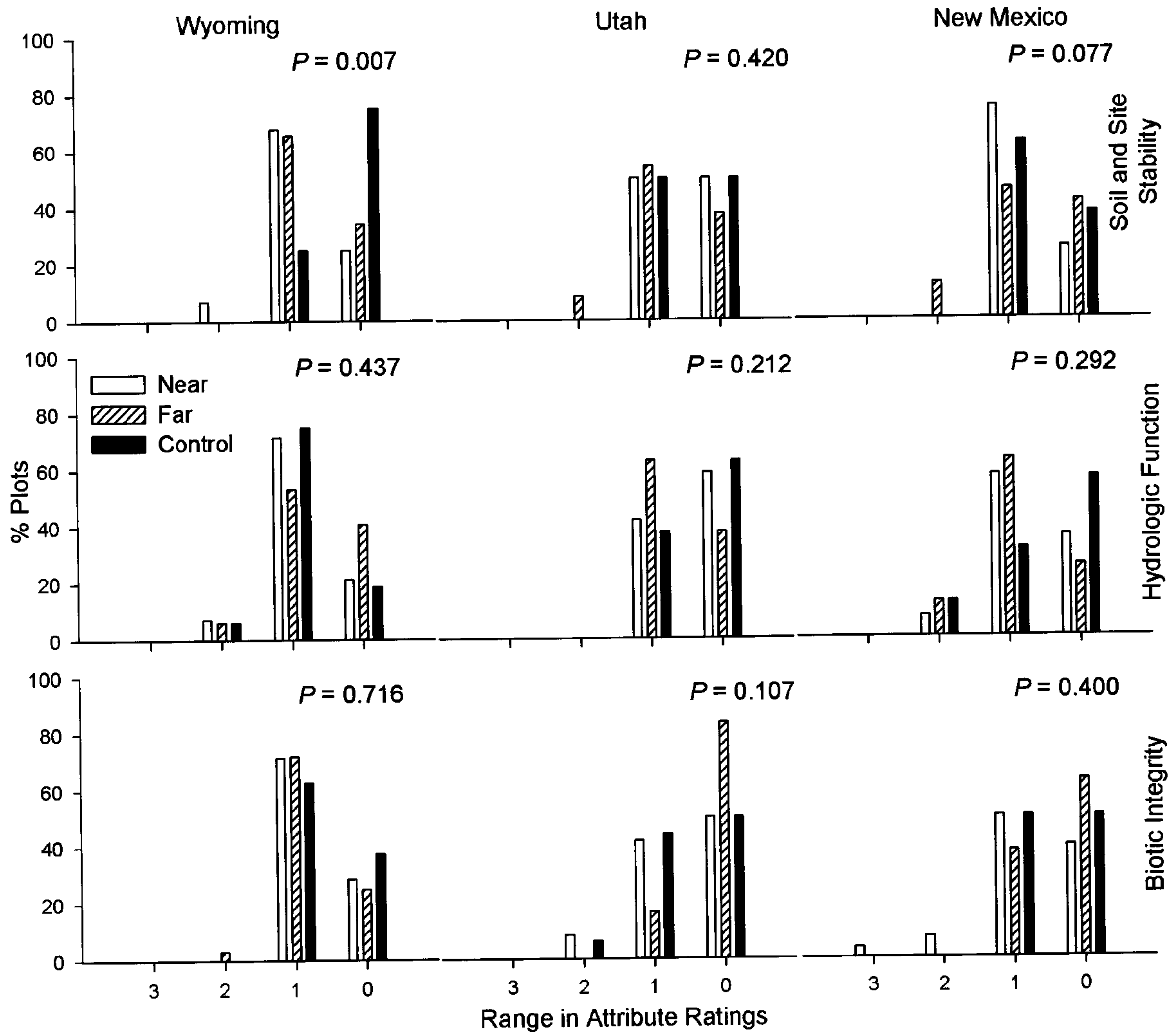

Figure 4. Range in Interpreting Indicators of Rangeland Health (IIRH) attribute ratings among the three observers (0 = all observers had same departure rating, 3 = observers differed by three departure classes) within plots and frequency of occurrence in each distance class in each study area (Wyoming, Utah, and New Mexico) and for each IIRH attribute (Soil and Site Stability, Hydrologic Function, and Biotic Integrity). Near plots include areas < 5 m from disturbances (including areas on two-track roads, pipelines, and Intensive Use Areas). Far plots are areas are between 5 m and 20 m of the disturbances. Controls are at least 40 m away from the disturbance. *P* values indicate probability that the distribution of agreement among observers is the same among distance classes (within attribute and study area).

impacted by road, trail, and pipeline development across all three ecological sites studied. Analysis of coupled qualitative-quantitative measures indicates that commonly applied quantitative techniques capture some of the same information on ecosystem processes as captured by IIRH. For effective monitoring of road-related disturbance, however, other quantitative methods are needed that are sensitive to inter-rill erosion and soil degradation.

Sensitivity of IIRH Attributes to Disturbances

The differences in the range of IIRH attribute ratings among study areas were likely due to a combination of factors, including the severity of the disturbance associated with the linear features investigated, historical disturbance regimes, resilience of the chosen ecological sites to road disturbances, resultant ecological states, and power of the qualitative methods to detect change. Many of the nonroad, control plots studied in Wyoming were in a degraded state relative to their potential, particularly the biotic components (Fig. 3). Although the area evolved with periodic grazing by native ungulates (antelope and bison; Mack and Thompson 1982), there have been periods of overgrazing by domesticated livestock (sheep and cattle) in historical times (Fleischner 1994). According to the ecological site description, the historical climax plant community is a cool-season perennial grassland with some sagebrush (*Artemisia tridentata* Nutt.). However, almost all Wyoming Control sites studied were either heavily invaded by cheatgrass (*Bromus tectorum* L.), dominated by sagebrush with few perennial grasses, or both, resulting in frequent departures from the reference condition (moderate and some moderate-to-extreme attribute ratings; Fig. 3). Disturbances caused by road and pipeline developments impacted the ecological function of

Table 5. Relationship between quantitative measures and Interpreting Indicators of Rangeland Health Soil and Site Stability attribute ratings in the three study areas (based on Spearman's Rank correlation).[1]

Quantitative measure	Pred.[2]	Wyoming ($n = 76$) ρ	Wyoming ($n = 76$) P	Utah ($n = 64$) ρ	Utah ($n = 64$) P	New Mexico ($n = 68$) ρ	New Mexico ($n = 68$) P
Rills and gullies[3]	+	0.31	0.007**	−0.07	0.570	0.41	0.000**
Basal cover	−	−0.26	0.022*	−0.19	0.12	−0 11	0.367
Gaps > 100 cm	+	0 16	0.158	0.22	0.08	0.13	0.273
Bare ground	+	0.73	0 000**	0 70	0.00**	0.33	0 006**
Bare ground in gaps > 100 cm	+	0.68	0.000**	0.63	0.00**	0 34	0.004**
Interspace litter	+/−	−0.68	0.000**	−0.39	0.00**	−0.05	0.713
Ratio canopy/interspace litter	−	−0 47	0.000**	0.00	0 98	−0.27	0.024*
Average soil stability	−	−0.61	0 000**	−0 83	0.00**	−0.09	0.462
Protected soil stability	−	−0.23	0.043*	−0.35	0.00**	0.02	0.864
Unprotected soil stability	−	−0.67	0.000**	−0.83	0.00**	0.07	0.576

[1]* indicates correlation significant at the 0.05 probability level, ** indicates correlation significant at the 0.01 probability level

[2]Predicted direction of relationship ("+", positive; "−," negative, "+/−," positive or negative) between measure value and attribute departure from expected (1 = none-to-slight, 5 = extreme-to-total).

[3]Natural log of Σ(D × W) rills and gullies, where D = depth and W = width of rill or gully feature.

these sites such that differences were detected by IIRH (Near plots; Fig. 3). In addition to the three IIRH indicators that showed significant variability among distance classes in all study locations (bare ground, soil surface loss and degradation, and presence and thickness of a compaction layer; Table 4), significant differences in several other IIRH indicators suggests that changes in overland flow and water retention are important on this fine-textured ecological site (number of rills, presence of waterflow patterns, and amount of litter movement).

In the Shallow Sandy Loam ecological site investigated in Utah, the Controls were in a slightly degraded state (very few Controls with attribute departures worse than slight-to-moderate; Fig. 3). Road and trail development on these shallow sandy soils with strong biological crust development appears to impact ecological processes such that impacts are readily detected by IIRH. Impacts to Biotic Integrity appear to be limited to areas directly impacted or immediately adjacent to roads (Near) but impacts to Soil and Site Stability and Hydrologic Function included areas > 5 m from the roads (Near and Far; Fig. 3). The IIRH indicators related to overland flow that were important in Wyoming (number and extent of rills and presence of water flow patterns) were not as important in Utah but effects of wind erosion and deposition were important (Table 4). This difference is likely related to the contrasting soil textures of the two sites investigated. Changes to site ecohydrologic properties are likely less important in the sandy site investigated in Utah than the finer textured (loamy) site investigated in Wyoming. Conversely, the sandy site in Utah would likely be much more sensitive to changes in susceptibility to wind erosion (such as breaking up of biological soil crusts and loss of vegetative cover) than the Loamy site in Wyoming.

The Gravelly ecological site studied in New Mexico was primarily in a shrubland state, dominated by creosote bush

Table 6. Relationship between quantitative measures and Interpreting Indicators of Rangeland Health Hydrologic Function attribute ratings at the three pilot areas (based on Spearman's Rank correlation).[1]

Quantitative measure	Pred.[2]	Wyoming ($n = 76$) ρ	Wyoming ($n = 76$) P	Utah ($n = 64$) ρ	Utah ($n = 64$) P	New Mexico ($n = 68$) ρ	New Mexico ($n = 68$) P
Rills and gullies[3]	+	0.37	0.001**	−0 05	0 716	0.55	0.000**
Basal cover	−	−0.19	0.097	−0.18	0.161	−0 32	0 009**
Gaps > 100 cm	+	0.26	0.025*	0.30	0.016*	0.16	0.195
Bare ground	+	0 77	0.000**	0.60	0.000**	0 28	0.019*
Bare ground in gaps > 100 cm	+	0.73	0.000**	0 58	0.000**	0.32	0.009**
Average soil stability	−	−0.54	0.000**	−0.77	0.000**	−0 26	0.031*
Protected soil stability	−	−0.21	0 067	−0.48	0.000**	−0.19	0.128
Unprotected soil stability	−	−0.58	0.000**	−0.75	0.000**	−0.10	0.398
All points with biological soil crust	−	NA	NA	−0.76	0.000**	NA	NA
Canopy cover	−	−0.32	0.004**	−0.14	0 287	−0.14	0.240
High infiltration/capture species[4]	−	−0 73	0.000**	0.23	0.064	−0.23	0 065
Litter cover	+/−	−0.75	0.000**	−0.31	0.013*	−0.12	0 313

[1]NA indicates measurement not applicable * indicates correlation significant at the 0.05 probability level, ** indicates correlation significant at the 0.01 probability level.

[2]Predicted direction of relationship ("+," positive; "−," negative, "+/−," positive or negative) between measure value and attribute departure from expected (1 = none-to-slight, 5 = extreme-to-total).

[3]Natural log of Σ(D × W) rills and gullies, where D = depth and W = width of rill or gully feature

[4]Cover of plant species that should improve site water capture and infiltration as described in the reference sheet.

Table 7. Relationship between quantitative measures and Interpreting Indicators of Rangeland Health Biotic Integrity attribute ratings at the three study areas (based on Spearman's Rank correlation).[1]

		Wyoming ($n = 76$)		Utah ($n = 64$)		New Mexico ($n = 68$)	
Quantitative measure	Pred.[2]	ρ	P	ρ	P	ρ	P
Average soil stability	–	−0.15	0.199	−0.75	0.000**	−0.22	0.073
Protected soil stability	–	−0.18	0.117	−0.51	0.000**	−0.06	0.636
Unprotected soil stability	–	−0.06	0.613	−0.72	0.000**	−0.17	0.174
No. dominants[3]	–	−0.11	0.359	−0.32	0.010**	−0.21	0.080
% dominant[4]	–	−0.46	0.000**	−0.21	0.090	−0.02	0.841
% subdominant[4]	–	−0.32	0.005**	0.02	0.891	−0.03	0.820
% other[4]	+/–	0.67	0.000**	−0.20	0.113	0.08	0.535
Biological soil crust cover[5]	–	—	—	−0.77	0.000**	NA	NA
Ratio dead/live	+	−0.02	0.886	−0.18	0.151	−0.03	0.820
Litter cover	+/–	0.16	0.177	−0.38	0.002**	−0.17	0.170
Live vascular hits	–	−0.14	0.214	−0.29	0.020*	−0.22	0.073
Vegetation height	–	−0.13	0.247	−0.11	0.383	0.11	0.378
Live invasive cover	+	0.49	0.000**	NA	NA	0.19	0.116

[1]NA indicates measurement not applicable * indicates correlation significant at the 0.05 probability level, ** indicates correlation significant at the 0.01 probability level.
[2]Predicted direction of relationship ("+," positive, "–," negative, "+/– ," positive or negative) between measure value and attribute departure from expected (1 = none-to-slight, 5 = extreme-to-total)
[3]Number of species in the Dominant Functional Structural (F/S) group
[4]Percent composition of F/S group (live hits only)
[5]Percentage of available soil surface habitat, excluding exposed bedrock and areas covered by rocks, litter, and plant basal.

(*Larrea tridentata* DC). According to the Ecological Site Description (USDA-NRCS 2003), this is a degraded ecological state due to a variety of factors including historical grazing, fire suppression, and drought (many Control plots with moderate attribute ratings; Fig. 3). Although Biotic Integrity attribute ratings of disturbed plots (Near and Far) were not significantly different than the Controls (Fig. 3), the disturbances investigated in New Mexico did alter the ecological processes of these sites such that significant differences were detected in Soil and Site Stability and Hydrologic Function. The indicators that were responsible for the difference in attribute ratings among plots included severity and frequency of formation of pedestals and terracettes around plants and rocks (indicator 3), amount and distribution of bare ground (indicator 4), and loss or degradation of soil surface (indicator 9; Table 4). This indicates that most of the impacts associated with roads in the Gravelly ecological site in New Mexico are related to soil degradation and inter-rill erosion. None of the indicators relating to plant community cover and composition appeared to be important for detecting road impacts in this ecological site.

Which Indicators to Use for Monitoring of Linear Features?

Although IIRH is very effective for assessments, the greater precision provided by quantitative indicators is almost always required for rangeland monitoring, including monitoring impacts due to the presence and use of linear features. For the ecological sites investigated, changes to hydrologic function and soil and site stability appear to be more important than changes to biotic integrity, indicating that a successful monitoring plan should include quantitative indicators that can capture important changes to hydrology and soils. Paired IIRH assessments of areas near roads and trails and areas far from vehicle disturbances can help guide selection of quantitative indicators for monitoring and will also likely help provide context for changes observed in monitoring programs. Results from this study indicate line-point intercept and canopy gap measures should be included. These data can be summarized to capture information related to six of the 13 indicators (Pellant et al. 2005, p. 112) that were significantly different among road and nonroad plots in at least one study location (Table 4). Additionally, soil aggregate stability measures (Herrick et al. 2001) and (though not included in this study because of the presence of buried pipelines) measures of compaction (Herrick and Jones 2002) should also be included to capture information related to two additional IIRH indicators that appear to be important for detecting road impacts (Table 4).

Notably absent from the list in Pellant et al. (2005, p. 112) and Pyke et al. (2002) are any standard monitoring protocols

Table 8. Relationship between ordination of quantitative indicators and Interpreting Indicators of Rangeland Health attribute departure ratings at the three study areas (based on Spearman's Rank correlation).[1]

	Wyoming ($n = 76$)		Utah ($n = 64$)		New Mexico ($n = 68$)	
Attribute	ρ	P	ρ	P	ρ	P
Soil and Site Stability	−0.73	< 0.001**	0.70	< 0.001**	0.32	0.008**
Hydrologic Function	−0.79	< 0.001**	0.60	< 0.001**	−0.28	0.023*
Biotic Integrity	0.32	0.005**	−0.08	0.514	0.00	0.995

[1]* indicates correlation significant at the 0.05 probability level, ** indicates correlation significant at the 0.01 probability level.

Exhibit K-12

for measuring the number and extent of rills or the extent of wind erosion and deposition, both of which appear to be important for detecting road impacts. If they can be applied efficiently and consistently, the transect techniques used in this study for measuring the extent of rill and gully development could help to fill this information gap. Furthermore, the quantitative indicators available for assessing surface loss or degradation (subsurface soil aggregate stability) does not measure the thickness of the A horizon and might not be able to detect subtle but important changes in soil structure. Similarly, the suggested methods for measuring the amount of water flow patterns (basal cover and gaps) are not likely to detect important changes in water flow patterns associated with disturbance in communities with naturally low basal cover and large basal gaps (e.g., shrub community in New Mexico). The lack of quantitative indicators for some IIRH indicators and possibly low sensitivity of others suggest that new quantitative measures sensitive to abiotic changes associated with rill and inter-rill erosion should be developed.

Application of IIRH for Assessment of Linear Features

To differentiate impacts of roads, off-highway vehicle trails, and energy development from other stressors such as grazing and climate with IIRH, it is necessary to conduct IIRH assessments both in areas impacted by activity of concern and in areas not impacted by activity of concern (control area). This could be accomplished using a paired approach, as was done in this study, or as a separate random selection of plots. However, because ecological sites often include some variability in soils and landscape positions, if the latter (nonpaired control) approach is used, it is important that the IIRH assessments account for within ecological site variability that influence ecological potential (e.g., slope, aspect, and soil texture). Creating or obtaining a detailed reference sheet that accounts for within ecological site variation can help. Also, when conducting IIRH assessments in a very heterogeneous area, such as along a road margin, we found using a site-specific evaluation matrix (Pellant et al. 2005, p. 24) that explicitly accounted for spatial variability in the indicators to be very helpful. Observers likely would have experienced less agreement in rating attributes for the disturbed plots without the ecological site-specific evaluation matrices (Fig. 4).

IMPLICATIONS

Results from this study indicate that IIRH is well suited and can be consistently applied for detecting areas adversely impacted by multiple stressors, including off-highway vehicle use and energy development, and has the potential to provide information on cumulative impacts. Because IIRH assessments are potentially a low-precision measurement (low repeatability over time with a variety of observers), they should not be used for monitoring. However, the integration of multiple observational indicators often allows IIRH to more accurately define the current status of the system, especially in aspects that are hard to measure quantitatively such as soil degradation and erosion. To address cumulative effects, it is likely necessary to extrapolate plot measures to landscape scales using both qualitative and quantitative imagery analysis. Satellite- and airborne-based measurements show promise for tracking changes in extent of transportation networks (Wei et al. 2008; Wang et al. 2009; Fang et al. 2010) and detecting changes in important indicators of ecosystem function such as bare ground (Gill and Phinn 2009) and other biophysical indicators (Zhang and Guo 2008). The qualitative imagery interpretation used in this study was important for finding highly impacted areas that would not have been found using strictly random selection. To scale up measures from plots selected using such qualitative techniques, plot data could be used to train and test qualified individuals' ability to consistently detect problem areas with qualitative imagery interpretation. Quantitative plot data could also be used to validate results of remote sensing imagery analysis. Qualitative and quantitative image analysis, coupled with a landscape scale field sampling design, could then be used to provide information to land managers on the cumulative impacts of linear disturbances on ecological function.

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