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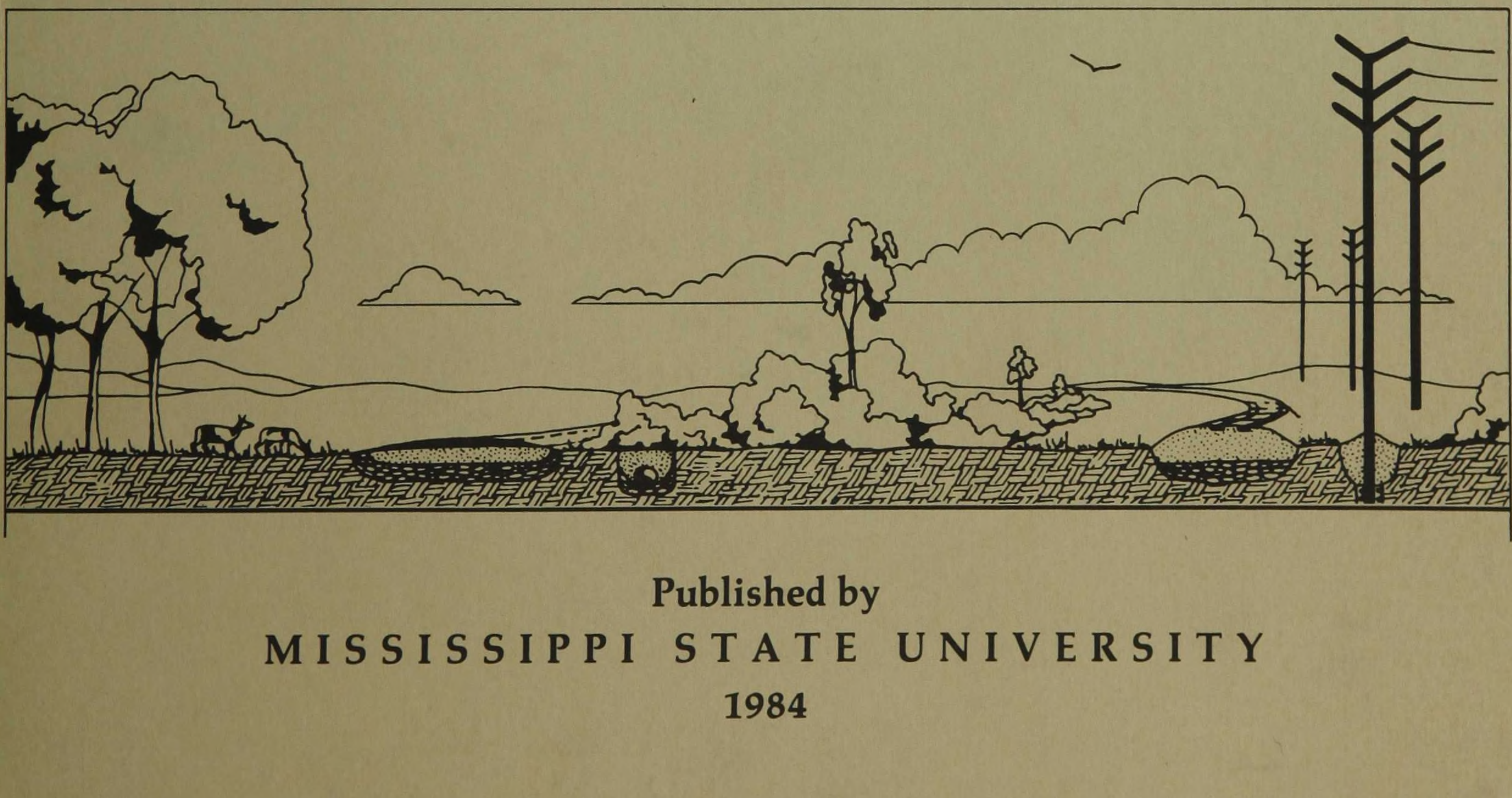
PROCEEDINGS
of the
THIRD INTERNATIONAL SYMPOSIUM
on
ENVIRONMENTAL CONCERNS IN RIGHTS-OF-WAY MANAGEMENT

February 15-18, 1982
San Diego, California



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Edited by Allen F. Crabtree

Symposium Chairmen, Edward W. Colson and Robert E. Tillman

Program Chairman, Allen F. Crabtree

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FOREWARD

The Third Symposium on Environmental Concerns in Rights-of-Way Management was held February 15-18, 1982, at the Hyatt Islandia Hotel in San Diego, California. Close to 400 attendees from the electric power, pipeline and highway industries, academia, government agencies, and consulting firms attended the conference. The primary goal set forth by the Steering Committee was to provide a forum for the exchange of information on current scientific research and state-of-the-art engineering techniques and regulations in rights-of-way management. An additional goal was to publish the Proceedings of the Symposium. We provided an acceptable forum for the exchange of ideas and depending on your perspective, we published the Proceedings in about a year.

In preparing my discussion herein, I reviewed the Proceedings from the previous two symposia held in Mississippi (1976) and Michigan (1979). In the Proceedings of the First National Symposium on Environmental Concerns in Rights-of-Way Management, Dr. John Gill, raised four important questions. These questions are still relevant. I wish to reiterate them and show how we have progressed from that first symposium.

1. "Was a national symposium needed?"

There was and still remains a need to continue having periodic symposia on environmental concerns in rights-of-way management for many of the same reasons. While there has been a general economic slowdown resulting in fewer large pipeline, highway, and electric power facilities, linear projects are still being proposed to link different transportation, pipeline, and power grids across the nation. In addition, many state and local interest groups are playing a key role in decisions that affect environmental concerns. The Administration has shown itself committed to improve this nation's economic strength by opening up federal lands to exploration and development, which may involve more energy projects involving roads, pipelines, and electric corridors. Mr. G. Ray Arnett, Assistant Secretary of the Interior for Fish, Wildlife and Parks, in his keynote address spoke of accelerated development of energy resources, by expanding transportation facilities, including power lines, gas, oil, slurry pipelines, aquaducts, railroads, and road systems. He emphasized the "Spirit of Cooperation" that has developed between those in the federal, state and private sectors to work on environmental concerns. Our conference offered the necessary forum for cooperative and constructive discussions.

2. "What were the symposium's shortcomings?"

Our conference also had its shortcomings, if only a few. While we did incorporate more papers on pipelines and transportation corridors, the balance was not even. And, it may never be, as the number of abstracts submitted in our "call for papers" favored powerline rights-of-ways. We were able to garner a fair representation of attendees from all over the contiguous U.S., Alaska, and Canada. According to the questionnaires we distributed to all attendees, the content and presentations of some of the papers could have been better. There were few innovative ideas on rights-of-way management according to several respondents. Too few papers discussed technical difficulties in the field and maintenance of rights-of-way. Several respondents criticized poor slides and the need for more speaker rehearsal. These are areas where we can make improvements for the next symposium.

3. "What were the symposium's accomplishments?"

We brought to the Third Symposium two prominent individuals purported to share opposite views on the environment. The Assistant Secretary of the Interior, Mr. G. Ray Arnett, represented the present Administration which has been criticized for its uncaring attitude and its controversial approach to stewardship of our natural resources. However, Mr. Arnett's keynote address emphasized the spirit of cooperation that has emerged in the '80's between government, developer, and conservationist. He cited many specific examples of government and industry cooperating in efforts to plan and develop needed facilities while carefully providing mitigation and compensation for unavoidable resource losses. Our second keynote speaker, Mr. Michael McCloskey, Executive Director of the Sierra Club, took exception to Mr. James Watt's philosophy as custodian of our nation's resources and gave many examples of government actions that seem to be contrary to preserving our national treasurers. The '80's is a period of discussion, compromise, and mutual pacts that show that we can all work together for the common good of our precious resources.

Another accomplishment is that close to 400 people with common interests and challenges were able to get together in San Diego for a captivating four days of stimulating and thought-provoking discourse. Approximately 82 papers were presented in technical sessions, discussion panels, and a poster session. The sessions covered planning and routing, wildlife management, vegetative management, aquatic impacts, endangered species, extra high voltage transmission, health, and safety.

4. "Are subsequent symposia needed?"

I sincerely believe the answer is yes. While we do not see as many large projects nationwide as we saw in the late '60's and '70's, we are seeing a trend for many smaller projects. So, the question that is often asked, "What are the cumulative impacts of many small developments on the environment?" While we have often been able to characterize and quantify what specific impacts are occurring for a given linear project, we seldom consider the cumulative impacts to a given region. The next symposium on environmental concerns of rights-of-way management should address this concern along with others. We still receive frequent calls asking when the next symposium will be held. Unfortunately, we must plan symposia at least two to three years apart to insure proper planning and to present new material generated in the field.

Edward W. Colson
Symposium Chairman

ACKNOWLEDGEMENTS

In looking back at three Rights-of-Way Symposia as reflected both in the papers in the proceedings and in the informal exchanges that I saw occur between participants, I strongly believe that the managing of environmental concerns in rights-of-way has come of age. As a group, we have progressed from being primarily researchers in the life sciences who had occasional contact with these linear habitats called rights-of-way, through the stage where we knew what should be done but couldn't seem to get anyone to listen to us, to the present. I saw at the 1982 Symposium a group of energetic, practical, and effective resource managers and researchers who had an effective voice in planning, designing, and managing the rights-of-way of Canada and the United States not just for economic or technical considerations, but for environmental concerns as well. We are no longer "hand-wringers"; we are now "doers."

This "coming of age" is reflected in the papers of this proceedings, and I want to sincerely thank the authors of the more than 90 manuscripts that were submitted for editing and proofreading. Without your input, your record of the work being done in your areas of expertise, we would have had neither a Third Symposium nor these Proceedings.

A special thanks is offered to Bess Bragg and Julie Grubb who labored tirelessly over many tasks of the Symposium. As in the previous two symposia, Dr. Dale Arner, Bess Bragg, Julia Arner, and the Department of Wildlife and Fisheries at Mississippi State University provided a great deal of support in the final typing and proofing of all the manuscripts, and most importantly, deciphering my sometimes obscure and confusing editing marks.

The Third Symposium could not have happened without the assistance and support from an excellent Steering Committee. They made it happen:

- Edward Colson, Symposium Chairman, Pacific Gas and Electric Company
- Dr. Gus Tillman, Symposium Co-chairman, The Cary Arboretum of the New York Botanical Garden
- Allen Crabtree, Program Chairman, Michigan Department of Natural Resources
- Dr. Dale Arner, Mississippi State University
- Dr. Donald Gartman, Columbia Gas System
- Dr. John Huckabee, Electric Power Research Institute
- Al Rodney, Public Service Company of New Mexico
- James Roseberry, Bureau of Land Management
- Dr. R. Kent Schreiber, Eastern Energy and Land Use Team, U.S. Fish and Wildlife Service
- Douglas Smith, Federal Highway Administration
- Bess D. Bragg, CPS, Coordinator, Mississippi State University
- Julie Grubb, Coordinator, Pacific Gas and Electric Company

The Symposium could not have occurred without the monetary support of the following contributors:

Electric Power Research Institute, Palo Alto, CA.
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Western Ecological Services Company, San Rafael, CA.
Wildlife Management Institute, Washington, DC.
New York State Power Pool, New York, NY.

On behalf of the Third ROW Symposium and the entire Steering Committee, I want to thank our contributors for their generous support.

Finally, Ed Colson and I want to especially thank our bosses, the Pacific Gas and Electric Company and the Michigan Department of Natural Resources, respectively, for supporting our interest in working on this conference. Without their understanding and support it would not have been possible for Ed and me to take the time from our other duties to spend the time necessary for the conference. A special thanks goes to the PG&E Department of Engineering Research's and the Geological Survey Division's clerical staff.

I look forward to seeing all of you at the next Symposium.

Allen F. Crabtree
Program Chairman

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RIGHTS-OF-WAY AND WILDLIFE MANAGEMENT: COMING OF AGE

G. Ray Arnett[1]

Mister chairman, distinguished panel members, ladies and gentlemen . . . It is a great pleasure for me to address this Third Symposium on Environmental Concerns in Rights-of-Way Management. In looking at the agenda, anyone could be impressed with the variety of topics being presented and at the representation of research and management expertise from the federal, state, and private sector. It demonstrates a true spirit of cooperation among a wide variety of groups managing land in the best interest of our national heritage of fish and wildlife resources. In my remarks this morning, allow me to focus on this spirit of cooperation.

At the outset, it's important to emphasize clearly and unequivocally that the Reagan Administration is committed to the economic revitalization of this country. It is the firm belief of this Administration that there can be, and will be, economic growth and development with appropriate and reasonable environmental safeguards. The President and his Cabinet, including the Secretary of the Interior, recognize that sound stewardship of our resources involves use as well as preservation, and wise stewardship must encourage, rather than hinder, the private enterprise system.

This Administration is committed to development of our natural resources to strengthen national security and to create jobs for Americans. In our efforts to reduce our dependency on foreign energy supplies, we are making a concerted effort to increase the use of coal, to expand exploration for domestic natural gas and oil, and to develop other resources such as oil shale, tar sands, and geothermal. This raises some legitimate concerns about the environmental consequences of on-site as well as off-site development. Accelerated development of our energy resources also means expanding transportation facilities, including powerlines, gas, oil, and slurry pipelines, railroads, and road systems. It also means expansion of water use and, in some cases, the construction of aqueducts which also contribute to the rights-of-way networks.

In the early days of environmental assessments for such projects, the available information for addressing the concerns raised by such demands on land and water resources was pretty limited. As a consequence, much of the early legislation was directed at a broad assessment of the known and potential environmental problems. It is interesting to look at the evolution of the environmental assessment process. It occurs in three general steps: The first is an awareness and early definition of the problem or potential problem. Secondly, there is a period of data collection and information transfer. And finally, there is the step of developing the appropriate management action based on this information.

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1 Assistant Secretary of the Interior for Fish and Wildlife and Parks.

The first step, an awareness and growing concern of the problem or potential problem, includes an attempt to define the issue as accurately as current information permits, and to place some limits or boundary on it.

In the case of powerline rights-of-way, early definitions of the problem included, among others, the potential effects of electric fields, noise, bird collisions, raptor electrocutions, habitat disruption and loss, and herbicide contamination. Information on these subjects at this time of early concern was fragmented and incomplete. Nevertheless, it suggested a real need to change policy or to pass new legislation. Public participation often focused attention on specific, although not always significant, issues.

The second step, intensive data collection and information development, is something of a repetitive step. Our knowledge reaches a threshold that permits detailed reviews of impacts and may also show the need to revise the initial legislation. For example, in the case of NEPA, (National Environmental Policy Act), the 1969 law was reevaluated and the 1978 amendments incorporated a mandatory "scoping" process. Although scoping (or, setting appropriate limits on the sphere of investigation) was often an informal aspect of the EIS (Environmental Impact Statement) procedure, its inclusion in NEPA demonstrated the continuing refinement of the regulation and the opportunity for changes as our experience and information increased.

The scoping process has been developed for electric power generation and transmission by federal, state, and utility representatives. The process compares cost and environmental factors to locate facilities in a manner intended to minimize environmental impacts and maximize economic efficiencies (Asplundh Environmental Services 1978; Eagles et al. 1979).

The final step of the assessment process is management action in response to regulations. The success of this activity depends on the data base available for planning and the effectiveness of the information transfer to the decisionmaker. Management options must weigh social, economic, and environmental costs of the activity.

The preceding is, of course, the synthesis of the assessment process. And, I admit, it is not only abbreviated; it is perhaps idealistic. I know that none of you are wide-eyed rookies in the field, and thus you realize (as I do) that a few of the real world steps have been overlooked . . . such as the "let's hammer 'em in the press" stage or the "let's withhold our data and make 'em beg" stage.

Still, the case of rights-of-way, this three-step process has evolved to the extent that most management plans now routinely integrate the interests and concerns of federal, state, and private groups.

A lot of the adversary relationships have been displaced by cooperative efforts (e.g., see Urban Wildlife Research Center 1980). Up in Wyoming, for example, in developing the Overthrust Belt, development interests created the Overthrust Industrial Committee. Through this committee, they have donated nearly a million dollars to study the effects of Overthrust Belt development on wildlife, including such high valued species as elk.

In other words, rights-of-way management has made a good start at reaching maturity and we are now pretty well down to the business of productive cooperation . . . getting on with the task of resource development and management. That wasn't always the case. No doubt quite a few of you can recall some projects you've worked on that would have all the makings of a good horror novel. And we can each learn, in our own way, from these "horror stories," but it's more beneficial right now to trace the trail of positive efforts.

The history of rights-of-way management offers many examples to illustrate the process in coordination between diverse interest groups.

In the case of information development, the U.S. Fish and Wildlife Service and others have initiated numerous research projects and cooperative studies on rights-of-way problems. Concerns expressed in the early stages of the regulatory process and management response included potential problems with avian mortality because of collisions with transmission lines and towers. To develop better insight into these problems, a number of workshops (e.g., Avery 1978) and research programs were initiated in the mid-1970's. The results of these efforts are evident in the increase in cooperative planning in routing and location of rights-of-way.

For example, the Service is currently involved with the Bonneville Power Administration (BPA) in a study of a transmission line crossing the Umatilla National Wildlife Refuge. The Refuge borders the Columbia River along Oregon and Washington. At issue is the potential for waterfowl collisions with the line and structures, and possible interference with waterfowl use of habitat near the lines. A study by BPA, in cooperation with FWS (Fish and Wildlife Service), is now monitoring the impacts of this line. An interesting result of this study to date is the development of a new sensory system to indicate bird strikes with the wires.

This type of study increases both our ability to define the problem and to determine the true extent of the impacts. Based on the final report from this study, certain mitigation or compensation measures may be required. Although differences of interpretations of collected data may still exist in the final resolution of the issue, such cooperative studies demonstrate our determination to make final management decisions using the best scientific information.

Government/industry cooperation in rights-of-way management is now new. In 1960, the Potomac Electric Power Company (PEPCO) requested the routing of a 230 kV powerline across a segment of the Patuxent Wildlife Research Center, near Washington, D.C. An agreement was reached on the placement of the corridor, the area was graded and the line constructed. For the first eight years, management of the vegetation was minimal and the right-of-way was essentially allowed to revegetate and grow with little interference. In 1969 a selective basal spraying program was started and continues to the present on a 3-4 year cycle.

The spraying program favors the growth of small trees and bushes and provides a shrubby habitat in an otherwise forested environment. Through close cooperation of the PEPCO personnel and Patuxent biologists, this project has developed as a showcase for ROW management. The 250 foot wide, 2 mile long ROW has created 70 acres of unique habitat to enhance the wildlife diversity of the area. The methods employed have been adapted to other ROW situations and provide an excellent example of industry serving a public need, in tandem with effective wildlife resource management. This example also illustrates the commitment of the private sector to a long-term vegetation management program that benefits wildlife.

To further encourage this type of cooperation, a technical assistance manual on the management of transmission line rights-of-way for fish and wildlife was published by the Service in 1979. It was described at the ROW symposium held that same year (U.S. Fish and Wildlife Service 1979). In the federal government this manual is being used by Bureau of Land Management, the Forest Service, and the National Park Service. Utility company biologists also make frequent use of the information, as do state planning commissions, fish and game agencies, and consultants.

The success of these cooperative efforts has been considerable. For example, results from pilot studies, based on this manual and demonstrating the effectiveness of several treatment programs in Mississippi, will be presented later in this symposium.

The full circle of concern, confrontation, and cooperation might be best illustrated by the situation of raptor electrocutions occurring on powerlines. This issue was an early concern, particularly in the Western States. As many as 90% of the electrocution victims were golden eagles. As many of you in the audience know, a very successful research program was designed to bring together the expertise and experience of state and federal agencies, utilities, and other interest groups. Assisted by the Edison Electric Institute, a workshop was convened to discuss the problem. The outgrowth of this interaction was studied that culminated in several important research reports (e.g., Raptor Research Foundation 1975; Steenhof 1978). These reports outlined suggested practices for raptor protection on powerlines, using modifications of the tower structures and configurations of the wires. The success of these designs has been significant in reducing electrocutions. Construction of nesting platforms and artificial perches on powerline poles helped turn a negative factor into a positive step toward mitigation.

The problem of bird collisions with transmission lines has been addressed in recent meetings (e.g., Avery 1978) and reports (e.g., Avery 1980; Beaulaurier 1981), and you will hear more on the current progress in this area later in this symposium.

The opportunities for cooperation bridge other areas of the energy picture. In the Rocky Mountain Region where development of coal resources poses new environmental challenges, the spirit of cooperation is further exemplified. Both public and private interests are working together to determine that best placement of coal slurry pipelines and conveyor transport systems. The careful use of limited water resources, and appropriate protection of riparian communities are critical factors to be considered. An example of the result of such cooperative planning and studies is the proposed 1800 mile Energy Transportation Systems Inc. (ETSI) coal slurry pipeline from Wyoming to Louisiana. Switching from the use of water in the Madison Formation aquifer in northwest Wyoming to the Oahe Reservoir in South Dakota will prevent a 20% reduction in the dewatering of streams in the Black Hills, eliminating the potential impacts to aquatic habitats of that area. This solution was reached through interaction of state government and private interests, with only minimal federal involvement.

Not only do we see a more consistent "common-sense" approach, if you will, to ROW's, we're seeing some creative and rather novel concepts as well.

New ideas are being tested in New England to compensate for habitat losses. Unavoidable losses in wetland habitats can be addressed by the concept of "wetland banks." As you know, wetlands are vital to migratory birds and a host of resident wildife. In this situation, new wetlands can be developed in advance by the states and held in reserve until habitat losses from rights-of-way construction are charged against the account. A point system based on habitat units allows compensation by replacement of losses with wetlands of equal or higher value.

These examples point to a pattern of cooperation and conflict resolution. It would be good to say that all the environmental problems in rights-of-way management are solved, but of course you know that is not the case. However, there is a continuing and expanding effort to jointly resolve problems early in the regulatory/management process. This is bound to lessen the adversary role being taken by any of the players in the process.

Whether a relatively small ROW project is involved, such as when the Bison State Telephone Company placed a 2,200 foot underground cable across Park Service lands at Jewel Cave National Monument in South Dakota . . . or a large project, such as the Mid-America Pipeline Company, or MAPCO, working with the Bureau of Land Management on a 1,200 mile pipeline ROW from Wyoming to Texas . . . I think the point is clear: that the Department of the Interior can be cooperative and can be responsive.

The Reagan Administration has pledged itself to work with the states and with the private sector to advance sound, orderly development; to work for balanced growth that will be environmentally acceptable and will yield lasting benefits to the American people. We are going to be good neighbors.

As I mentioned at the beginning, Interior Secretary Watt has repeatedly stated that being a good steward involves decisions on the use of resources as well as the preservation of resources (Watt 1982). The current efforts of the land managers in government, industry, and the private sector dealing with ROW management reinforce this goal. Rights-of-way management provides an excellent example of the "Good Neighbor Policy" at work.

The growth in our degree of sophistication and understanding of the biological evaluation of rights-of-way impacts is evidenced by this symposium. For example, total presentations at the first ROW symposium numbered 31, compared to the 88 of this meeting. Sponsorship and planning of the meeting have also grown to include a wide diversity of representatives from government, industry, academia, environmental organizations, and conservation groups.

As information develops, so do our definition and understanding of the problems. In the 1976 ROW symposium, it was estimated that as many as 13 million acres of land would be in ROW use by the year 2000. By the 1979 meeting, this number has been revised to 5.2 million acres.

We have seen an evolution as well in the thinking and perception of the problems and in their resolution. Our focus has gone from broad concerns to more refined and manageable problems. Together, have developed techniques and options that reduce or eliminate many of the impacts found in early ROW management situations. Formal and informal ways of cooperatively solving ROW environmental issues have been established.

Through the use of national scale information bases, such as the National Wetland Inventory (Montanari and Townsend 1980), potential problems can be more quickly and accurately defined and early resolution can begin.

The Reagan Administration is committed to further streamlining the environmental review process by reducing any unnecessary regulations impeding the spirit of cooperation or placing unnecessary and costly restrictions on resource management. As an example, the Fish and Wildlife Service has placed a high priority on facilitating the sensible and orderly development of energy and minerals transportation systems. This will be aided by providing timely information about fish and wildlife resources in potential development areas. The Service's management-by-objectives (MBO) planning currently includes major tasks for this support.

Aldo Leopold, in his Sand County Almanac (Leopold 1949), described railroad rights-of-way as "linear reservations" in the prairie, acting as conservators of the native prairie flora. Today, over 30 years later, our fish and wildlife continue to benefit from the proper management of these linear reservations. The spirit of cooperation and the development of better management tools give us the opportunity to carry forth and expand that involvement.

AN UNPRECEDENTED CHALLENGE

Michael McCloskey[1]

I really am impressed with your program and the detailed attention that you have given to so many environmental problems. It's a very impressive record you have built through these various symposia that you have had, and I can see that many of you have become quite expert in dealing with the various environmental questions affecting the management and development of rights-of-ways. I know that you are directing your attention to those long lists of environmental questions which need your attention as good managers.

I would just add a word or two about the concerns that I have observed environmental groups having over the years in this particular area. Four have come to my attention most often: (1) the improper use of herbicides, particularly dangerous ones; (2) the impact upon endangered species; (3) disruptions in the productive use of farm, forest, and rangelands; and (4) the aesthetic impact of swaths cut through forests for transmission lines, or the vision of such lines marching across wide-open spaces. Without belaboring this whole area, I will only add that questions of the health impacts of herbicides, such as 2,4-D, strike me as posing the most serious questions. Controversies, of course, continue to swirl over whether dioxin is found in 2,4-D and whether it causes cancer, as well as birth defects, miscarriages and illness. Those controversies are really part of a larger debate over widespread use of such herbicides and are not peculiar to applications on rights-of-way.

But I am not here today to deal with environmental questions in this specialized area. I want to talk about environmental questions in a very large context. I am impressed with the degree of concern that you have with environmental questions, and anybody having such depth of concern must be interested in the broader question of where the debate over environmental questions is heading today.

The environmental movement in North America has come a long way over the last 10 or 15 years. There are hundreds of programs underway to protect the environment, particularly at the Federal level, with tens of thousands of people at work, and billions of dollars being spent. We thought those programs and their directions were well established and that the debate was principally over the question of the pace of pursuing them and questions at the margin, of matters of degree, and so forth.

Unfortunately since the Presidential election of 1980, the debate has taken quite a different turn. It has become polarized in a fashion that I have never seen before--more polorized, in a way, than even ten years ago

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1 Executive Director, Sierra Club.

at the time of Earth Day. This polarization is really hard to understand in any rational sense. It is not at all what we expected would be the context for looking at questions in the 1980's. Let me begin by briefly sketching what we had expected the rational context for addressing such questions would be.

We are dealing with questions of trade-offs today; of increasing complexity--such questions as the CO_2 effect on the world atmosphere and climatic patterns, and weather; and complex problems such as acid precipitation, the safety of nuclear power, and what will happen to the wastes from nuclear power plants. We understand that the context is one of complexity, trade-offs, and working at the margin.

We also had expected that the context would deal with certain "new realities," as I will call them, for assessing the interface between economics and development on one hand and questions of protecting the environment on the other. One of the new realities is that demand for basic commodities is soft. It is being reduced in many ways. The market for timber, for instance, is increasingly soft because of a depressed housing market and high interest rates. Rather than expecting that that's going to turn around any day, I think people ought to come to terms with the fact that this probably is a situation that is going to be here for many years. There is 25% unemployment right now, for instance, in the Western timber industry. In the field of oil, we now have a world-wide glut of oil. The demand last year for oil went down by 7%. In the area of electricity for utilities, we have vast over-capacity nationally which exceeds 40%, with many utilities having over-built, and many of them are now in grave financial straits. Who wants to build nuclear power plants any more? Hardly anybody wants to put money into them. We've just seen the abandonment of a whole clutch of them up in Washington State, sending shock waves through the whole web of utilities in the Pacific Northwest states. It is a radically different climate in terms of economic development in the 1980's than there was in the 1960's. In the 1970's much of the debate was confused because on the economic side people were still expecting the heady days of the 60's to somehow recur. I submit that those days are gone forever.

Another new reality is that capital for new enterprises is in short supply. Many of the proposals for huge, new construction projects are floundering today for lack of capital. Does anyone really think that 50 billion dollars is going to be pulled together for the gigantic gas pipeline from Alaska? Projects that started out costing $10 billion, then were projected to cost $20 billion, $30 billion; some of these projects alone could use up a good share of the total amount of the capital available for new plants and construction throughout the entire economy. I think they're just not likely to move much anymore.

Increasingly, basic commodities coming from the land are no longer what I would call high-grade resources. They are resources of declining quality. The high-grade, old-growth timber is increasingly a vanishing commodity. High-grade ores are increasingly hard to find and are not going to be found here anymore. Going to seek oil in increasingly hostile climates and places, and in deeper and deeper places offshore, really amounts to a kind of low-grade resource: a resource that takes larger and larger inputs of energy to extract a usable resource. Even farmland, burdened by the highest rates of erosion since the dustbowls of the 1930's really can be considered to be moving toward the direction of being a lower and lower grade resource as its productivity declines, requiring greater inputs of fertilizer and soil amendments per bushel of crop produced.

Another new reality is that the deployment of high technology on a massive scale is slowing as it is burdened by more and more problems (and not just problems of amassing the necessary capital) but problems in terms of environmental impact. Those with impacts that ramify broadly throughout society are increasingly in trouble. We see that certainly with nuclear power. Synthetic fuel development is having trouble for a variety of reasons, not the least of which are all of the problems attending the environmental impacts connected with it. We see it with problems of hazardous wastes and toxic substances in a chemically-laden environment. While the Reagan Administration doesn't accept this premise, it does seem to us, and I think to most of society, that regulation has to be accepted as the price of living in an extremely complex age and of living with the amounts of high technology that we do have. I might add that studies in the United States have suggested that these regulations are worth the cost. Study after study has suggested that in a large sense, the benefits do exceed the costs, and the benefits are considerable. If air pollution would be controlled as it is supposed to be under the Clean Air Act, the annual benefits could exceed $58 billion a year. Cleaning up air pollution means more than dollars: it means good health; it means lives saved. As many as 40,000 to 50,000 lives per year could be saved if the promise of the Clear Air Act is realized. In the field of water pollution, the benefits could exceed $10 billion a year.

And finally, a new reality is that conservation is here to stay. Conservation really means getting more out of the resources that we have, with greater efficiencies and greater care in their use. We are seeing it really pay off now in the field of energy where energy growth rates have come steadily down. They used to exceed 4% annually (compounded), now they are down near 1-½%. It has been estimated that the improvements in auto fuel economy alone can save as much as one trillion dollars by the year 2000. Conservation is no longer some unproven theory off in the future. It is here today, and it's going to be even more important with every passing day.

Now these are the new realities that we expected that any administration would have to address in framing options in the arena of public policy. Do we see them reflected, however, in the program of the Reagan Administration? No, we don't. Instead, we see them acting as if demand were still strong for all of these commodities and as if more production were somehow going to be the answer. I don't know how you are going to get people to buy more timber when the market isn't there. I might add that there is an absolutely stupendous backlog of sold, but unlogged timber, for instance in the National forests. We see an administration acting as if they were ignorant of the declining quality of our natural resources--as if we were still in a frontier society. We see an administration taking simplistic attitudes toward the issues of the day, of placing its faith in an almost naive way in high technology, as if nothing had been learned, and we see an ingrained hostility toward regulation as if it were a proven evil. A recent Roper poll suggested that 75% of the people in the United States believe that the EPA is on the right course with the level of regulation it has been pursuing. It does not show that the public has turned on EPA. We seen an administration that is failing to deal with the questions of capital shortage, of recognizing that all these projects can't be built, and in many cases nobody wants to build them any more.

The one place where we had hoped that they might respond to the new realities is in the field of subsidies for all sorts of developmental projects because this field is consistent with their conservative philosophy. We believe that the time has come when we can no longer afford to be handing out subsidies to the timber industry, to the grazing industry, to the energy industry for nuclear power, for water projects, for depletion allowances for the energy industry. They talk a great free market line, but American industry, particularly that part of it dealing with natural resources, has been propped up by a whole panoply of subsidies. Truly this is a time to begin to come to grips with the lack of justification for subsidies. While this administration is looking at some of the questions in the area of inland waterway development, by and large it is failing to live up even to its own philosophy in that regard.

Now, we knew the Reagan Administration was a conservative Republican administration, and we were prepared for what we might expect from such an administration. We didn't anticipate that they would address all of these new realities in the way that we would have had them addressed, but the surprise is that this administration is not a normal, conservation Republican administration. It is a radical, extreme right-wing regime, bringing policies into existence that bear no relationship whatsoever to what the American people want. Let me elaborate on that theme.

Let's look at the question of the development of commodities. We had expected that this administration would favor increasing the allowable cut of the national forests of the country, that it would favor more energy development, more push for oil leasing, and more coal leasing. But look at what they are proposing--they are promoting not just increases, but absolutely incredible increases. Let's look at a couple of instances here: offshore oil drilling. Interior has been leasing 1-2 million acres offshore each year. We had a big debate during the Ford Administration about a goal that they sought of stepping that up to 10 million acres a year. What a heady percentage increase; and some of the wildest people in the oil industry spoke of 50 million acres a year to be leased. What does James Watt speak of? Two hundred million acres a year--a figure which is absolutely, physically impossible. It bears no relationship to reality whatsoever. In five years, he would have virtually the whole offshore area leased. There is no physical way that it can be done. It can't be pushed through the bureaucracy; it can't be pushed through the physical environment itself. It's absolutely an Alice-in-Wonderland-type figure.

Look at the national forests. John Crowell, Assistant Secretary of Agriculture, came from Louisiana Pacific. The timber industry in the past has wanted the allowable cut increased. It's now at about 12 billion board feet a year. The Forest Service has been pushed toward projecting it ultimately, if all sorts of investments were made in sound stewardship, to potentially as high as 17 billion board feet. Some of the wildest people in the timber industry have talked of 22 billion board feet as an outer limit figure that they would lobby for as their heart's desire. What does Crowell ask for? 35 billion board feet, a figure that's the equivalent of Watt's 200 million acres. It is a figure that has no basis in reality, let alone reason. What would happen to balance in the national forests with that? They would become the equivalent of nothing but the most simplified kinds of monoculture. In fact, it would be absolutely "cut and get out."

Let's take coal leasing. They want to drastically step up that at a time when there are some 28 billion tons of coal already leased on federal lands, and largely undeveloped, with only about 700 million tons a year in toto, mined. So, even if some of those areas are not best adapted to development, even leaving them aside, there's a huge backlog of coal already leased, but undeveloped; they are really talking about speculation here.

Let's turn to the question of pollution control. We expected this administration to go more slowly in dealing with the problem of air and water pollution and toxic substances. We did not expect that they would try to destroy the Environmental Protection Agency. That Agency is being eviscerated. Its staff has been cut already by about 25%. With the kinds of cuts that they would like to pursue, and if you take the ravages of inflation and the devalued dollar into account, EPA would be left with a staff (if they got their way) which would be about half the size that it has been, with a workload which has been doubled in recent years, as EPA has been given jobs of cleaning up hazardous waste dumps, and dealing with toxic substances. Both programs have lagged badly. EPA needs more staffing to move them along.

Basically, the Administration is afraid to say directly what it really intends to do. It is trying through the back-door-of-the-budget process--and Watt admits it--to destroy an agency. It is trying to destroy programs passed by Congress after Congress, passed by Republicans as well as Democrats, developed in a bipartisan way, programs supported by Republican administrations as well as Democratic administrations.

Let's look at the field of parks. We had expected that they might favor a slow-down in acquisitions for new national parks and further authorizations of new units in the national park system. We did not expect them to try to bring an absolute halt, as they have, to the acquisition of any more acres of land for the national park systems. Here I am talking about units already authorized by the Congress for acquisition, about new legislation. I am talking about completing what the Congress has directed the President of the United States to do.

We certainly expected that they would not look with too much favor on expanding the public domain; we did not expect them to favor massive disposals of the public domain. The President's Council of Economic Advisors is right now hatching a plot to sell to private corporations as much as 100 million acres of the public domain: BLM lands and national forests. There is legislation already introduced in the Congress to do that--an absolutely incredible scheme. If they had some notion of helping to retire the Federal debt by selling these lands, they surely aren't going to do it by unloading these lands all at once on the market. These are lands that millions and millions of Americans use for hunting and fishing. They would then be behind private fences saying "no trespassing."

Let's finally look at the question of nature sanctuaries: sanctuaries for wilderness and other such things. We certainly expected that they might not look with great favor on making major additions to the National Wilderness Preservation System, but we did not expect that they would have the temerity to propose that these sanctuaries be violated. James Watt has proposed leasing for oil and gas development within the established, statutory wilderness areas of the United States in hundreds of cases in the Rocky Mountains and the so-called "Overthrust Belt." He doesn't see what's wrong with having roads and fields of oil derricks pumping away in areas which are supposed to be nature sanctuaries, where they are characterized, by law, as areas where the marks of man are absent, areas where nature prevails and man is a visitor--with oil derricks, roads, buildings, pumping stations-in wilderness areas? That's what he stands for. He has asked for a 20-year extension of the loophole that the mineral industry got in the Wilderness Act of 1964. Under a key compromise, the mineral industry was given 20 more years to search out whatever they could find, and in 1984, that nightmare would be over. Watt now wants 20 more years of that nightmare.* He is not content with curbing the expansion of the National Wilderness System, the national recreation areas, or the national park system. He is pushing oil development; he is pushing gas development; hard-rock mining, and the same in national wildlife refuges, the same in marine sanctuaries (set aside in offshore areas for marine mammals and other such creatures).

I submit that this is a program that is so extreme that it will not only severely compromise the environment of the United States, it will bring us into international disgrace. I was at the conference of the International Union for the Conservation of Nature last October in New Zealand, and people all over the world knew about Watt and his policies, and they can't believe them. They say, "In the United States, are you back-tracking? What's happening?" They just can't understand it.

I don't think the American public can understand it either, but you might well ask, why was Reagan elected? Isn't that what the people wanted? Well, let's discuss that subject for a moment. Let me begin by backing up a little bit and saying that something very interesting happened in the 1970's with respect to public attitudes toward the environment. The environmental movement began in 1970, growing out of the old conservation movement, and was pretty much a reflection of upper middle-class attitudes. But some recent studies of public opinion shifts have shown that as the 1970's went along, a very interesting thing happened. What those studies show is that basically, commitments to the protection of the environment, and strong measures toward that end, became a commitment of

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*Note: This speech was given before Watt proposed that the time for more oil and gas leasing be after the year 2000.

all sectors of public opinion in the United States. That view spread to virtually all income groups, to virtually all levels of education and people, black as well as white, with no essential differences. The basic pattern that emerged was that about two-thirds of the public was strongly committed to these programs, and about one-third had some questions about whether they had gone too far. This is sort of an over-simplification, but that is the general pattern that emerged.

Now, obviously, Ronald Reagan was elected President, and he was elected by a fairly handy margin in the electoral college. But let us remember as a point of departure, that his popular vote was only 51%, and it was one of the most lightly-attended elections in history. If you look at what percentage of the adult population actually voted for him, it was about 16%, hardly a great mandate of public opinion. And I think it is clear that the issue that did turn the election was the issue of the economy. I think the public was desperate for an answer to inflation, and rightly so, but questions of environmental protection were not a principal issue in the campaign. They were hardly talked about at all. So the public did not vote with this question, really, foremost in its minds.

So let's turn to the question of what the public wants now. There have been a number of public opinion surveys since the election, and they confirm completely the general pattern that emerged throughout the 1970's, and it has solidified. Most of these polls deal with the Clean Air Act and pollution controls, a sort of cutting edge where these questions impinge upon the economy. Let me quickly give you the results of a number of polls in 1980 and 1981 because I think they are instructive about where the public mind is. One poll showed a margin of 2 to 1 for the proposition that environmental protection is more important than economic growth. That's a fairly tough proposition--2 to 1 support for that, and there was no increase in the percentage believing that environmental standards should be relaxed to achieve economic growth. The same question was asked in 1977, and again in 1980, to the effect: "Do pollution controls cost more than they are worth?" The percentage believing that actually declined from 19% to 13% over that period. In fact, in 1980, a CBS-New York Times Poll actually found a plurality favoring the toughest of all propositions (which is not one we advocate, incidentally) and that proposition is this: "Protecting the environment is so important that requirements and standards cannot be too high, and continuing environmental improvements must be made regardless of costs." A CBS-New York Times poll last October showed again a 2 to 1 margin for the proposition that air pollution laws should be kept tough even if some factories might have to close.

The most famous of these recent polls is one that Louis Harris did last October, and it is interesting for another reason. It showed that the margin of public support is even greater for keeping the Clean Air Act strict--80% of the public said they wanted it kept as strict as it now is, or made more strict. But the interesting thing is how that broke down in terms of demographic profiles. As you might expect, those who have a more liberal profile were strongly supportive of that proposition. These included big-city residents, young people, people with lower income levels, professionals, union members, Democrats, liberals, and so forth; they often supported that proposition by 80% of more. But supporting it by margins nearly as great were people with high income brackets, people who voted for Reagan, Republicans, conservatives, people in rural areas; generally their margins were 75% or more.

In fact, another public opinion survey suggested almost no difference between the commitment to environmental protection of those who considered themselves political liberals and those who considered themselves political conservatives-something like 66% of the political liberal and 64% of the political conservatives. The point is that this is not a partisan issue. It is not an issue that correlates with political philosophy; it has become basically a broad, public commitment.

These polls suggest that only about 5-10% of the public is actively hostile to environmental programs and really wants to roll them back. It is that 5-10% that this Administration is responding to, which is one of the most astonishing turns of events in American political history. Is this being reflected yet in what the public thinks of the job the Administration is doing? Just a couple of months ago there was a poll in the Rocky Mountain region, which is Watt's home ground. For those who had an opinion (43% did have an opinion), 56% were unfavorable to Watt. He had majority support in only three of the Rocky Mountain states. Another poll dealt with what they thought of how the Reagan Administration was handling the environmental issue. Only 30% thought that Reagan was doing a good job in protecting the environment. In just the last two months, polls have been taken dealing with the question of which of the two political parties in the United States they would trust to do a better job in protecting the environment. Well, in December there was a margin of 56-22% for the Democrats; by January, a poll in the Rocky Mountains suggested 56% for the Democrats, 9% for the Republicans, and the rest didn't know. Something incredible is beginning to happen here.

What I submit is happening is an environmental rebellion. I think it is the equivalent in its political origins, in a certain sense, of the "Sagebrush Rebellion." What happened there, at the beginning of the Carter Administration, was that the Secretary of the Interior, Cecil Andrus, on questions of water projects, and to a certain extent of the questions affecting grazing rights, acted as if those adversely affected were political nonentities. He acted as if those interests basically didn't exist; he acted as if no accommodation had to be made whatsoever to their presence in the American scene. The same thing is happening to the environmental community under the Reagan Administration. We are being treated as if we were nonexistent; as if all of these polls didn't exist; as if public opinion weren't well-established on the question; as if that 5-10% were the majority, and that was the reason they were elected. It is absolutely incredible.

As I conclude, let's just look for a moment at what is ahead. The Administration is clearly doing its best to pursue these policies. Some that it didn't lay on the table the first year are being brought out in the second year, which are even more extreme, as with the disposal of 100 million acres of public lands. But I think it is also clear that the Administration isn't going to get away with it. They are not getting very far. Congress is moving in response to public opinion; the Administration is being check-mated. They tried to vastly increase the amount of leasing off the California Coast, and in sensitive areas that the prior administration had turned down. They were check-mated in court. Almost all of the officer holders, Republicans and Democrats alike up and down the California coast, told them: "Don't do it, the public doesn't want it; they won't stand for it." Even the Republican Chairman of the State called the Administration and told them it was "political murder."

The same thing is happening in the "Overthrust Belt" of the Rocky Mountains. It's not the Democrats who are standing in their way; it's the Republicans-the Republicans from the Rocky Mountain States in Congress. It was conservative Republican Manuel Lujan in New Mexico who blew the whistle on trying to lease in the Capitan Wilderness for oil development; he created a tremendous furor. Republican Senators from the state of Wyoming, and the Congressmen from that state were telling them: don't lease for oil in the Washakie Wilderness and other wilderness areas in Wyoming; people won't stand for it. It is they who convinced the Administration to back off until after the election on more oil development there.

I don't think they are learning from this, but I think there is a fair chance that most of these extreme policies can and will be check-mated, although the worst crisis is with EPA, where the demoralization in the Agency is so severe that people are leaving in droves.

One might expect that with this kind of outcry (I might add that there has been an absolutely unprecedented amount of press on Jim Watt--more critical editorials, more critical cartoons than on any one Cabinet officer in memory), the Administration might have been expected to start to moderate its policies. With the head of the National Wildlife Federation and the National Audubon Society, I was in the White House to talk to Edwin Meese, the President's counselor, two weeks ago. We spent 45 minutes with him. I think it was clear that if he had a painless way of dampening the furor he would have loved to do so, but we saw no willingness whatsoever to moderate the substance of their policies. He has absolutely unreconstructed. I think the only way that they are going to get the message is if the electorate sends them a message in the 1982 Congressional elections--when they become convinced that they no longer have some sort of a mandate to pursue policies of this sort.

I might add that the extremity of their positions is forcing the environmental movement to take unprecedented action. For the first time, on a substantial scale, you will begin to see it moving into the electoral process. As part of a historic evolution, we learned in the 1960's that education wasn't enough; you had to lobby to influence public policy. In the 1970's we learned that it wasn't good enough to lobby, you had to be able to go into court to preserve your gains against wayward bureaucrats. And in the 1980's, we are learning it isn't enough to be good lobbyists or good litigators, you have to know how to work in the electoral process to keep your friends in office. The Sierra Club has decided to jump with full force into the electoral arena this year. We have organized a political action committee; we are going to endorse candidates; we endorsed the first one in Chicago this weekend, and more are coming. The environmental movement is revying up. We can never match the corporate political action committees in terms of millions of dollars, but we have millions of people behind us, and we are going to be mobilizing those people to hit the streets to start walking precincts soon.

A parting thought for you. Many of you, I understand, work for industry. We are not opposed to industry's legitimate aims; we have no basic quarrel with constructing pipelines, or constructing highways, or constructing utility rights-of-way. We may argue at times about whether each project is needed and whether the best route has been found, but I think there is a larger issue that I hope you will address. That is that the instabilities that are affecting our economy, and indeed, the economies of so many countries in the world, are going to produce continuing instability in political life. I think we are going to see a lot of revolving-door situations with people coming into office for a couple of years and then they will be leaving. Policies tend to swing drastically back and forth.

Industry often says they want predictability and stability in the system; they want to know what the ground rules are, and they want steady courses to be pursued so they can plan for them. I would submit that you are not going to get them with the kind of politics reigning in Washington today, and I really think that industry and the environmental movement should begin talking more about things they have in common. I think they are closer together on what are reasonable standards than the Administration is. I think it is not to industry's interest to see EPA eviscerated, to have a whole panoply of varying standards in the states without any uniform national standards. I don't think it is in their interest to see enforcement fall to such a low level that there is nothing but mass confusion, with a mass of lawsuits brought by environmental groups, and states pursuing all sorts of inconsistent policies.

We are close to hammering out some pretty reasonable directions for the future; industry has done far better than a lot of other sectors in society in meeting those standards. I would hope that you would assume the responsibility individually of working with people in your comapnies to address these questions. I think the times are changing, that our posture increasingly is going to be a less adversarial one with industry, and be more one of trying to inject some sort of stability into the political system. I hope we can work together toward that end. Thank you.

PLANNING AND ROUTING

Al Rodney, Session Chairman

NEW YORK'S NATURAL GAS PIPELINES: A ONE-STOP SHOPPING PROCESS

Richard H. Powell[1]

ABSTRACT.--In ten years, New York has seen a sharp increase in gas exploration, well drilling, and pipeline construction. The prospect is good for further exploration throughout southwestern New York, the Eastern Overthrust Belt, and Lake Erie. Conflicts between environmental concerns and publicly-perceived problems, regulatory lag, and the routing, construction, and maintenance of gas transmission facilities can delay prompt returns on investments and facilities. One solution is a streamlined one-stop regulatory siting and permit-approval process. This paper reviews New York's experience in gas transmission facility certification, including routing analysis, applicable State laws, rules and standards, construction plan implementation and regulatory oversight.

BACKGROUND

In 1970, a commission investigated the impact of major public utility facilities in New York State and the consequences of construction delays in those projects. A number of electric and gas transmission facilities ran the risk of delay in securing the necessary local permits. The temporary commission urged legislation for a statewide, comprehensive "one-stop" siting law, assuring the timely construction of needed transmission facilities and minimized adverse environmental impact, while balancing costs and considering available technology.

The Public Service Commission (PSC) was designated as the implementing agency. Since then applications have been filed and processed for approximately 48 electric and 20 gas projects. Based on these recommendations, Article VII of New York's Public Service Law took effect on July 1, 1970.

An opportunity for public participation was provided by filing copies of the application with local and state agencies and public notice requirements. Also included was the override of any local ordinance, including zoning, shown to be unduly restrictive, and the prohibition of other state or local agencies requiring any approval, permit, or other conditions for construction or operation of a certified facility.

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Article VII provides one-stop approval for fuel-gas transmission facilities longer than one thousand feet and operating at pressures of 125 psi and above. Article VII requires the Commission, in approving a project, to apply all applicable state standards or exercise waivers in the relevant laws or regulations, but no local permit approvals need be secured--only the certificate. Local and municipal ordinances can be waived if found unreasonably restrictive by the PSC.

If the applicant is a public benefit corporation as defined in the New York Transportation Law, Article VII certification is automatically a finding of need for exercising the right of eminent domain or property condemnation, which then requires only a monetary property value determination.

The Commission is the final arbiter on substantive issues. Any appeal of a Commission Article VII decision is directed to the State Appellate Court on an expedited basis. Both of these legal changes are time-savers in any proceedings brought against the Commission and/or the applicant.

ROUTING ANALYSIS AND PROJECT REVIEW

Once an application is filed with the Commission, a Public Service staff project review team begins their review. The team includes an attorney, a gas engineer, and a transmission (environmental) analyst. Each member contributes a particular skill to the review. The environmental analysis typically covers land use, visual, ecosystem and cultural factors, and noise.

<u>Land-Use</u> - Land use plans, existing land use, zoning and related controls, major proposed developments, agricultural, and flood-prone areas, etc.

<u>Ecosystem</u> - Watercourses, wetlands, flora, fauna, wildlife, and endangered species.

<u>Cultural</u> - Archaeologic remains, and historic and landmark features.

<u>Visual Impacts</u> - Response of proposed siting to major and lesser landscape features, the color and location of pipeline markers, valves, meter skids, launchers, compressor and regulator stations.

<u>Noise</u> - Construction and operating sound levels related to present or future receptors.

Effectively, this team leads to a review of the proposed pipeline construction methods, including but not limited to, surveying, clearing, grubbing, grading, trenching, erosion control, hydrostatic testing, vegetation restoration, and right-of-way maintenance plans.

RECENT AMENDMENTS TO THE PUBLIC SERVICE LAW, ARTICLE VII

Due largely to the incentive of sharply rising energy prices and transportation costs, natural gas exploration in the Appalachian Basin, especially in New York, has increased markedly in the past five years. The prospect is very good for further gas development within the next ten years. With this in mind, New York State's first Energy Master Plan (1980) urged modification of the Public Service Law to focus the State's oversight of the gas industry on increased drilling, quicker authorization, and supply expansion into new service areas.

On July 15, 1981, Governor Hugh Carey signed amendments to Article VII which provide for an "acceleration" of the expedited review process. The law streamlines the public notice procedures, reduces the information required in an application, eliminates the public hearing requirement in some cases, and directs the Commission to make its determination within 30 days. However, the Commission can require a more extensive review if it determines that the proposed line may have substantial public interest. While the regulated facilities remain as before (over 1000 feet operating at 125 psi or more), pipelines located wholly within highway right-of-way are exempted, and the definition of appurtenant facilities is slightly altered. The amended law now sets up a classification system for pipeline review which depends mostly upon the length and diameter of the pipe but allows for some flexibility depending on the degree of environmental and public concern.

A Tier 1 pipeline (less than five miles long and six inches in diameter or less) requires a Notice of Intent (NOI) to be filed with the Commission and the municipality in which it will be located, stating the date for starting construction and describing the location of the facility. Construcion must follow the approved Environmental Management and Construction Standards and Practices which must be on file with the Commission. The Commission must notify the applicant of any application deficiencies within 14 days, and must act within 30 days of its receipt unless it finds more intensive review needed (Tier 1A). If the Commission fails to act within the 30 days, the application is automatically approved.

A Tier 1A process is followed when the Commission finds within 30 days that a substantial public interest requires fuller review. Further notice is given on the project and more information collected. The Commission must make a decision within 60 days of the NOI filing except where it sets the case for hearings--which extends the 60-day timetable. The Commission's findings must specifically relate to construction and be aimed to minimize or avoid environmental impacts to the minimum extent practical. No alternate routes are considered.

Tier 2 review includes any none-Tier 1 or 1A lines up to ten miles long. An application must contain information on the right-of-way location, facility description, need justification, and related information, as well as a description of the land use, ecosystem, visual, and cultural resources to be affected, and identify the construction practices to be followed at particularly important sites.

Tier 2 applications must be served on New York's Department of Environmental Conservation, Agriculture and Markets, and local government. The Commission may serve the application on anyone else it thinks appropriate. It still is required to notify the applicant within 14 days if the application is incomplete, informing them how to comply. As with Tier 1A, the Commission must act within 60 days of filing. Where hearings are required, the 60-day limit may be extended. The Commission findings in a

Tier 2 case are limited to minimizing or avoiding adverse environmental impacts to the maximum extent practicable.

The Tier 3 gas pipeline cases follow the usual procedure for Article VII electric power lines. This deals with large projects that may generate considerable interest, or actively involve diverse parties.

STATE LAWS, RULES, AND STANDARDS

Each of the following state laws, rules, or standards are applied where appropriate.

Coastal Zone Management

Pipeline routing and construction within New York's Coastal Zone requires consistency to the maximum extent practicable with the New York State Waterfront Revitalization and Coastal Resources Law. Also, The Shoreowner's Protection Act, New York Environmental Conservation Law, Article 34, requires activities development or other actions in coastal erosion hazard areas to minimize property damage and prevent the exacerbation of erosion hazards. These areas include the shoreline and inland (as defined on maps available with the New York State Department of Environmental Conservation and local county clerks' offices) on Long Island, along the Hudson River (from the Atlantic Ocean upstream to the Troy dam), Lake Ontario, Lake Erie, and the Niagara River.

Agricultural Districts

The State Legislature authorized creation of agricultural districts to protect the State's agricultural lands from development pressures and afford farm owners property tax relief. To protect agricultural use within a district, there are restrictions on any entity with power of condemnation which intends to acquire farmland. Alternatives must be considered before taking good farmland. The underlying concern is to continue agriculture where it is an existing land use and avoid reduction of land available for that activity.

State Highway and Barge Canal Crossings

The New York State Department of Transportation (DOT) oversees the state highway and Barge Canal system. An applicant could be required by DOT to obtain individual permits for each state road crossing; negotiate for the accommodation of its line on state highway property (NYS Highway Law §§ 10, 52, 103, 230, 249, 250, and NYCRR Title 17 Transportation Part 131, Accommodation of Utilities Within State Highway Right-of-Way); and obtain a revocable permit under Canal Law, §100 for any crossing of the New York State Barge Canal.

Environmental Conservation

The Environmental Conservation Law (ECL) Articles 15, 17, 24, and 70, as well as 6 NYCRR Parts 608, 617, 663, 664, 700-704, and 750-757 can apply to Public Service Law Article VII certified transmission facilities, where protection of water, wetlands, groundwater, or issuance of State Pollutant Discharge Elimination System permit is involved.

Cultural Resources

The New York State Historical Preservation Act was enacted in 1980. The law established a statewide historic preservation program; a state register of historic places; an inventory of historic property; and a statewide comprehensive historic preservation plan. The law requires each state agency to consider the effect of any state agency action upon cultural resources, allowing comments on the project's effects by the State Historic Preservation officer. Essentially, the law codifies what has been the Commission policy for several years.

Department of Public Service staff have encouraged applicants to contact the State Archaeologist and Historic Preservation Officer for information about their project's effect upon cultural resources. Dependent upon the knowledge or lack thereof about the cultural sensitivity of the routing, a basic literature survey of previous cultural resources reconnaissance reports may be required. Then, based on the knowledge gleaned from the literature search and these recommendations, a cultural resources field survey based upon predictive modeling can be necessary before construction. The main purpose of a survey is to reduce the probability of encountering any resources during construction that may require salvage, possibly stopping or delaying construction. If resources are uncovered during the survey, a decision can be made whether to leave the pipeline location alone, move the pipe or salvage the resource in advance of construction.

Other necessary permanent permits and approvals include New York State Thruway Authority (Thruway crossing permits); individual counties (highway crossing permits of county highways; towns [town highway crossing permits; possible building permit requirements and approvals; zoning ordinance review and conformity; construction permits, including conformity to Federal flood insurance standards for construction in flood-prone areas]).

ADVANTAGES OF THE ONE-STOP SHOPPING SYSTEM

The Article VII process has encouraged the incorporation of environmental concerns into the normal routing, engineering, and cost decision-making process. It saves time and money acting as an early alert to property owners, state agencies, and local interest groups who may be concerned with these projects and wish to participate in the project review process. For most applicants one-stop siting is the most distinct advantage--a reduction of multiagency permits and approvals to one "permit" and a shortened time period before certification.

Each Commission order includes provision for expedient approval of minor changes to the construction plans for anything that is not controversial or of major significance during the proceedings.

The project review is accomplished by staff that are experienced in pipeline environmental impact, engineering and cost analysis, as opposed to staff members in a regulatory agency that may review an occasional pipeline application. Thus, applicants can look for a basic consistency in policy and project review from working with experienced regulatory personnel.

THE PAST AND THE FUTURE

Article VII has evolved, based on staff and Commission experience, with the reality of gas line construction. In most instances, <u>how</u> it was built was more determinative of adverse environmental impact than <u>where</u>. DPS staff are presently developing a model EM&CS&P. This will include basic (and recommended) practices for cultural resource protection, vegetation clearing and disposal, grading, erosion control, revegetation, pavement protection and replacement, and stream and wetland crossing. If accepted by an individual utility, the agreement to comply will be filed with the Commission. We expect that smaller gas-producer companies will adopt these, while most major utilities will submit their own. DPS staff will continue to assure compliance with these standards and practices as approved by the Commission.

HIDDEN BENEFITS OF THE COUNCIL ON ENVIRONMENTAL QUALITY REGULATIONS: PREPARATION PLANS, THE THIRD PARTY EIS PROCESS AND BCM

Janice R. Hutton[1] and Donald J. Miller[1]

ABSTRACT.--The Council of Environmental Quality regulations, which went into effect in July, 1979, has made a significant contribution to unsnarling regulatory duplicity, thereby greatly expediting environmental review in the federal permitting process. Provisions in the regulations have created several avenues for managing the environmental review process. This paper examines procedures used by Federal Agencies to prepare Environmental Impact Statements (EISs) and related documents within reasonable timeframes.

INTRODUCTION

In November, 1978, the Council on Environmental Quality (CEQ) issued its Final Regulations for implementating the National Environmental Policy Act of 1969 (NEPA). Each federal agency was required to adopt procedures supplementing those regulations by April 1, 1980. The CEQ regulations mandated three major innovations: a reduction in paperwork, a reduction in delay, and an improvement in decision making. Advancements have been made in achieving these mandates, especially in reducing delays in the environmental review process.

Specifically, the regulations state that delays should be reduced by implementing the following procedures and policies: (1) placing time limits on complying with NEPA; (2) integrating environmental impact statements (EIS) with other environmental review procedures; (3) integrating NEPA compliance into early project planning processes; (4) emphasizing that interagency cooperation begin before the devleopment of a Draft EIS; (5) determining lead agency early in the process; (6) initiating litigation, if any, after completion of NEPA compliance rather than during it; (7) accelerating procedures used for the environmental analysis of proposed legislation; (8) excluding categorically any actions that would not have a significant effect on the human environment; and (9) issuing a finding of no significant impact when appropriate, thereby eliminating the need for an EIS. This paper examines the application of this guidance by the Bureau of Land Management, particular, over the three years since the CEQ Regulations were implemented.

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NEPA AND AGENCY PLANNING

In response to Section 1501 (NEPA and Agency Planning) of the CEQ regulations, many Federal agencies have established certain requirements to ensure and document compliance with the overall regulations and with the provisions of this section. Various modes of operation have evolved to carry out the planning for preparation of an EIS. Sources of potential delay during preparation are greatly reduced when a thorough effort is made to advance plan the EIS process. Many of these also apply, although less formally, to the preparation of Environmental Assessments (EAs). Several of these modes of operation are not yet highly formalized, although threads of each appear in various BLM "Instruction Memoranda."

Soon after receiving a right-of-way application, the agency must determine the level of environmental analysis that is needed prior to deciding whether to issue a grant of right-of-way. The agency may seek advice from other offices of its agency, from other agencies, and from the public in making this decision (see CEQ, Sections 1501.3 and 1503.4). If the applicant's proposal is determined to constitute a "major federal action," it is likely that an EIS would be needed. There are, however, certain instances in which an EA would suffice, depending on the recency of other relevant environmental documents for the area that would be affected by the proposal.

PREPARATION PLAN

A Preparation Plan, approved in writing by the BLM, must be prepared before beginning the EIS. Generally, this Preparation Plan is written in consultation with the ROW applicant. The Plan describes the primary issues that must be considered in the EIS: the decisions made regarding alternatives to the applicant's proposed action; the review process participants, authority structure, and schedule; and the overall content, outline, and schedule for the EIS itself.

The Preparation Plan is a working document that has taken the form of three reports: Draft Preliminary Preparation Plan, Preliminary Preparation Plan (to be signed by the Authorized Officer), and the Final Preparation Plan (also signed by the Authorized Officer). In series, each report contains more and more accurate detail regarding the project description, agencies and personnel involved in various reviews, issues and alternatives to be analyzed, the schedule, and opportunity for public involvement.

The Preparation Plan represents a negotiated commitment within the lead agency and with other potentially affected agencies about staffing availability. More than anything else, the Final Preparation Plan provides documentation of decisions and coordination efforts.

Major items in the Preparation Plan are (1) a brief description of the proposed action and its purpose; (2) a statement of the level of analysis that will be needed in the EIS or EA; (3) a description of meetings comprising the scoping process; (4) identification of all alternatives to the proposed action (specification of alternatives selected for detailed analysis is made in the final preparation plan); (5) a determination of the areal extent of the affected environment, based on discussions of potential impacts and their significance; (6) potentially involved agencies, identified in terms of authority or jurisdiction, expertise, or interest; (7) detailed list of agreed-upon authority and organizational structures, including names of compliance and technical reviewers, as well as the means for resolving differences of opinion. The role of the contractor is also described; (8) an outline of the EIS or EA, in annotated form; (9) a very detailed schedule, providing specific dates for the beginning and close of review periods and a description of the sequencing of activities by the various participants involved in the EIS process; and (10) the plan for public involvement, including scoping meetings, public hearings, and public review and comment period.

Effective iterations of the planning process depend on the knowledge and commitment of involved personnel from the BLM, the applicant, and the contractor. Communication of knowledge of the project description and its potential environmental consequences, the project area and associated agency jurisdictions and resource values, and of the compliance process itself all serve as the basis for a solid beginning point for the planning process. These alone can provide the material for a first Draft Preliminary Preparation Plan. Subsequent iterations depend on a thorough "scoping process;" that is, early contacts with potentially affected lead agency offices, other agencies, and the public.

The Role of the Applicant

In addition to open participation in communication, four major contributions to the Preparation Plan can be made by the applicant to facilitate initiation of the lead agency's planning process. In addition to specifying a schedule for receiving a grant of right-of-way, the four types of information needed are (1) a concise statement of the purpose of and need for the proposed project; (2) a detailed description of the proposed project. (Basically, this consists of definitions of project components in terms of location, construction and operation methods and workforce, and schedules. The level of detail and specification needed is a function of the stage of preparation for the EIS or EA); (3) preliminary identification of agencies potentially involved with the project, based on interest, jurisdiction, or authority. (Such agencies may be federal, regional, state, or local); and (4) preliminary identification of issues associated with the project and potential environmental problem areas.

The Role of the Scoping Process

According to CEQ regulations, the BLM is obligated early in the EIS process to invite participation in the scoping process by representatives from potentially affected federal, state, and local agencies; Indian tribes; the applicant; and other parties potentially interested in the project. The scoping process, which is a major means by which the Preparation Plan is developed, involves informal and formal contacts with knowledgeable people and with agencies having jurisdiction in the project area. Meetings with the public are likely to be scheduled for most projects.

The scoping meetings are recorded in detail in project files and are summarized in the EIS. They are also abbreviated in the Preparation Plan as a basis for determining the scope and level of analyses for the EIS.

Utility of the Final Preparation Plan

In its final and signed version, the Preparation Plan provides documentation of the many decisions made during initial preparation for developing the EIS or EA. Before signature, the Preparation Plan is scrutinized by cooperating agencies, other officials of the BLM, and other agencies having review responsibilities. Memoranda stating concurrence with the topical approach and schedule are solicited from these other important participants in the process. Thus, the plan is agreed to and can be used effectively as a basis for supporting subsequent decisions.

As long as the project description or environmental effects remain essentially the same as those stated in the Final Preparation Plan, the lead agency can refer to the plan and to previous concurrence with it as a basis for supporting efforts to maintain the EIS or EA schedule.

The plans already have been used to deny requests that would result in delays, such as the following: adding alternatives at mid-stages of EIS preparation; extending agency comment periods; including detailed analyses of unimportant issues or resource values; and extending public comment periods.

It is therefore extremely important that the lead agency, the applicant, and the contractor cooperate fully in providing information for use in the Preparation Plan.

THIRD-PARTY ENVIRONMENTAL IMPACT STATEMENTS

CEQ regulations provide that a contractor may develop and complete an EIS if the designated lead agency selects the contractor and the contractor works under lead agency direction. Although the regulations do not specify the means of contractor selection, the lead agency must participate in developing the selection criteria. In order to properly assess the benefits of this provision, one must understand procedures used prior to the implementation of these regulations. Briefly, the following general sequential steps were undertaken: (1) An applicant, in the case of an industry proposal, developed an environmental report assessing the effects of a particular project. (This report could be prepared by the applicant's staff, but usually it was done by a contractor); (2) The applicant provided the lead agency with the environmental report and the required application(s); and (3) The lead agency or its selected contractor would then prepare an EIS based on the applicant's report. If a contractor was to prepare the EIS, a formal procedure was used: advertisement in the Commerce Business Daily; submittal of formal qualifications and technical and cost proposals; and interviews with potential contractors. All of this was accomplished without applicant participation and took about six months. The amount of applicant-prepared information used in the EIS would depend on its level of documentation, ease of verificiation, and its adherence to procedures.

The use of an applicant-developed report, whether prepared by the applicant or a contractor, meant that a minimum of two documents assessing the effects of a project must be completed, at a significant expense of time and money to the applicant.

The Bureau of Land Management (BLM) has interpreted CEQ regulations for third-party EIS in a manner that significantly reduces the time required for NEPA compliance for energy-related projects. The BLM, in accordance with CEQ and its own Instruction Memorandum No. 80-5, has eliminated the duplication of documents and eliminated time-consuming contractor selection procedures by permiting the applicant to participate in the selection of the contractor from a BLM-approved list, using a BLM-approved means of selection. In all cases, however, the BLM solely selects the contractor.

The selected contractor, while under contract to the applicant, performs under the complete direction of the BLM. The separation of contractor from the applicant ensures the objectivity and defensibility of the lead agency document. This is further ensured by a Memorandum of Agreement between the BLM and the applicant and/or the applicant's formal agreement with the contractor. This separation is confined to technical analyses of potential effects due to project implementation. The contractor has free access to the applicant regarding project design. For example, the contractor and the applicant can develop a project description that incorporates mitigation measures to reduce the potential for adverse impacts, thus minimizing subsequent analyses by the contractor and lead agency.

Several aspects of the third-party EIS process contribute to the reduction in delays. The most important are the elimination of duplication and the improved avenues of communication. Rather than the sequential preparation of applicant-developed and lead agency-developed documents, there is only one document culminating in a Final EIS. This simple change can reduce NEPA compliance schedules by one-half.

A recent major pipeline project illustrates this reduction in time. A natural gas liquids pipeline from southeastern Wyoming to west Texas went into operation in December, 1980, 20 months after the application filing and 17 months from initiation of NEPA compliance using the third-party process. Other pipeline and energy-related projects in various stages of NEPA compliance using the third-party process indicate similar reductions in delay. Energy-related projects that have already experienced this reduction in delay include pipelines in Colorado, Wyoming, Utah, Arizona, New Mexico, Texas, Kansas, Nebraska, Arkansas, Oklahoma, and Louisiana; a coal-fired power plant in New Mexico, oil and gas exploration, development, and operation in Montana; and a synthetic fuels plan in Wyoming. All of these projects were undertaken since the CEQ Regulations were implemented by Federal agencies.

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IMPACT ANALYSIS METHODS: A COMPARATIVE REVIEW

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ABSTRACT.--This paper describes and evaluates methodologies used to locate and evaluate transmission line facilities and related linear land uses by closely examining 15 recent case studies that employ a variety of impact analysis methods and by developing and applying criteria to measure effectiveness and applicability of each method. Criteria include legal and policy considerations, analytical factors, and technical and economic factors.

This review, along with recommendations for adapting methods to suit individual needs, should aid the planner in tailoring a systematic approach to specific linear location problems and to consequent environmental assessment and documentation.

INTRODUCTION

Environmental impact analysis is the study of various social, economic, and biophysical characteristics of the environment as they may be changed by an action. Depending on the action's scope and complexity, the method used to assess its impacts may range from a single technique to a complicated sequence of systematic procedures.

An environmental assessment method should be integrated with the planning process; be an open process; focus on the most consequential environmental factors; help document decisions; and be based on professional and scientific integrity. An appropriate method is necessary to insure the systematic, timely, comprehensive analysis required to comply with the spirit and letter of environmental rules and regulations.

This paper comparatively evaluates 15 environmental analysis methods as a step towards perfecting methods for effectively locating and evaluating transmission facilities. The conclusions are intended to provide a framework for choosing and adapting a method appropriate for the analyst's particular needs.

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STUDY METHODS

Taken from recent case studies, environmental documents, methodology manuals, and technical bulletins published by environmental consultants, utilities, and government agencies, these 15 methods represent the state of the art. The projects to which they have been applied are located in a number of geographic settings, although there is a decided emphasis on the Pacific Northwest. Generally, the projects chosen involve complex issues or technical choices, although some less complicated projects were also included to reflect possible ranges of application. The case studies are summarized in Table 1. Depending on its general approach to impact assessment, each method was assigned to one of six broad, slightly overlapping categories for comparison purposes. Table 2 describes the categories in order of increasing complexity.

The framework for the review and comparison was adopted from earlier studies performed by Warner and Preston (1974). Each method was assessed in terms of three major areas: (1) how thoroughly it addresses federal, state, or agency procedural requirements (Legal and Policy Considerations); (2) how adequately and reliably it identifies, measures, and interprets impacts (Analytical Factors); and (3) how readily it can be adapted to a particular set of needs (Technical and Economic Factors). A total of 24 review criteria was developed to address these three major areas of concern (Table 3). Subjective ratings were made for each of the 24 criteria for each method and interrelated in matrix form (Table 4).

MATRIX: INTERPRETATION AND DISCUSSION

Working column by column across the matrix, the following discussion makes comparisons and draws conclusions for each set of criteria.

Legal and Policy Considerations

The first four criteria focus on how "open" a method is and how well it is integrated with the planning process. They are of paramount importance from a procedural standpoint. The first criterion (#1) assesses the usefulness of a method and resulting documents in the decision process, a significant focus of the CEQ regulations. Decision-oriented studies (12 in all) were considered to satisfy this criterion. For criterion #2, three approaches to public involvement were used in the case studies. Of these, the direct or contributory is by far the most effective in insuring integrated and open planning, yet only three case studies used this comprehensive approach. Six of the studies failed to document clearly a consistent means for NEPA compliance (criterion #3) or for compliance with other rules (#4). The next three criteria (#5-key issues, #6-summary format, and #7-agency planning) describe a method's utility and are particularly important considerations for decisionmaking. Yet only half of the decision-oriented case studies (6 of 12) rated highly in all three areas. Overall, the case studies which rated best for legal and policy considerations were Murray et al., Pacific General Electric, Montana-DNRC, and Montana DNRC and USFS.

Table 1. Environmental Analysis Method Report Summary.

Name	Description
Blair et al. (1978)	A transmission line case study; overlay approach.
Commonwealth Associates (1974)	Report on a project-specific transmission method; combination of computer analysis, manual overlay; uses public involvement techniques.
Coe (1971)	Report on utility siting "Environmental Guidelines"; an ad hoc collection of suggestions; a planning outline.
Federal Colstrip Corridor Study Team	Environmental report, impact statement, and methodology documents; analytical approach--a combination of overlay and matrix techniques.
Giles et al. (1976): POWER	Report on corridor location methodology; computer assisted approach; uses analytical models, networks, and matrices.
Holberger et al. (1975): RALI	Compendium of utility siting considerations; not a set of procedures; characteristics of an annotated checklist.
Landscapes Limited (1974): PERMITS	Methodology report and documentation; a computer-assisted corridor location and environmental assessment procedure.
Leopold et al. (1971)	Procedure for evaluating environmental impact; an open-cell matrix approach.
Montana DNRC (1976)	A transmission line case study with methodology documentation; comprehensive set of studies; uses a computer-assisted approach.
Montana DNRC & U.S. Forest Service (1978)	A transmission line case study; general approach uses map evaluation (overlay) to determine and then evaluate locations.
Simutis and Johnson (1974)	A description of a method used in a case study; a composite computer-assisted approach; uses suitability models to locate utility corridors and electrical generating stations.
Murray et al. (1979)	Environmental report, impact statement and methodology documents; uses a variety of matrix and overlay analysis techniques; a composite approach.
U.S. Department of Energy (1979)	A transmission line case study; somewhere between an ad hoc and a checklist approach.
Pacific Gas & Electric Co. (1979)	A transmission line case study; uses a checklist presentation.
Wirth Associates (1975)	A transmission line case study; a matrix approach; also uses overlay techniques.

Table 2. Environmental Analysis Method Categories.

Name	Description
Ad Hoc	Generally focus on identifying broad areas of possible impacts (e.g., impacts upon flora and fauna; impacts on lakes, forests), rather than defining specific parameters to be investitated.
Overlays	Use sets of maps of a project area's environmental characteristics (physical, social, ecological, aesthetic) which are overlaid to characterize the regional environment and identify impacts upon it.
Checklists	Involve specifically listing environmental parameters to be investigated for possible impacts. Do not require establishing direct cause-effect links to project activities. May or may not include guidelines about how parameter data are to be measured and interpreted.
Matrices	List project activities against potentially affected environmental characteristics in matrix form to identify cause-effect relationships. May either specify which actions have impact on which environmental characteristics, or simply list the range of possible actions and characteristics in an open matrix to be completed by the analysts.
Networks	Establish cause-condition-effect relationships among project activities. Attempt to recognize that a series of impacts may be triggered by a project action. Approach is generally to define possible networks and to allow the user to identify impacts by selecting and tracing out the appropriate project actions.
Combination	Combine matrices, networks, analytical models to (a) identify project activities, (b) identify environmental impacts through each phase of project development, (c) suggest abatement and mitigation techniques, (d) model cause-effect relationships and quantitatively determine potential impacts; and (e) devise methodology to use analysis results in preparing environmental documents.

Table 3 - Review Criteria Used to Evaluate Method Adequacy

Criterion	Description
	LEGAL AND POLICY CONSIDERATIONS
1. Use	Whether the method is directed towards making a decision or compiling information. *
2. Public Involvement	Sought actively, early and directly incorporated? (direct and contributory)? Achieved only through public hearings? (reactive) Consists solely of contacts with bodies considered to represent the public? (indirect or representative)
3. NEPA Compliance	Summarizes the analysis specifically in terms of NEPA and CEQ regulations?
4. Compliance with Other Rules	Complies with special consultation, review or permit requirements?
5. Key Issues	Highlights significant issues and impacts at an early stage?
6. Summary Format	Summarizes results of the analysis?
7. Agency Planning	Integrates the NEPA process into early planning?
	ANALYTICAL FACTORS
Impact Identification	
8. Comprehensiveness	Addresses the full range of impacts?
9. Specificity	Identifies specific impact parameters to examine?
10. Timing/Duration	Discusses impact timing (when occurs) and duration (how long)?
11. Data Sources	Discloses the data sources used to identify impacts?
Impact Measurement	
12. Explicit Indicators	Uses measurable indicators to quantify impacts?
13. Magnitude	Distinguishes between impact magnitude and impact intensity?
14. Objectivity	Emphasizes objective rather than subjective impact measurements?
Impact Interpretation	
15. Significance	Assesses impact significance in terms of context (ie - local regional, national scale) and intensity?
16. Explicit Criteria	Discloses criteria and assumptions employed to determine impact significance?
17. Uncertainty	Assesses degree of certainty for impact projections?
18. Risk	Identifies probability of occurrence of impacts?
19. Alternatives Comparison	Specifically compares both fundamentally and incrementally different alternatives, including the "No Action" Alternative?
20. Aggregation	Aggregates impact indicators into a net total as composite estimate?
	TECHNICAL AND ECONOMIC FACTORS
21. Location Facilitation	Uses environmental data to determine most suitable routes and/or sites?
22. Resource Requirements	Overall "costs" of resources (ie-data availability, retrieval, skill needs, learning time, cost use of technologies) are reasonable in terms of method's scope?
23. Replicability	Will different analysts using the method produce comparable results?
24. Flexibility	Applicable to projects of widely different scales or to situations other than those for which it was designed?

*A decision document is integral to determining the best course of action; an information document functions primarily to reveal the implications of a single, clearly best choice. Analysis for a decision document will generally emphasize identification of key issues, quantification, and direct comparison of alternatives. Analysis for an information document is more comprehensive and concentrates on interpreting the significance of a broader spectrum of possible impacts.

Table 4—Method Review Summary

CASE STUDY	TYPE/CATEGORY	1. Use	2. Public Involvement	3. NEPA Compliance	4. Compliance with Other Rules	5. Key Issues	6. Summary Format	7. Agency Planning	8. Comprehensiveness	9. Specificity	10. Timing and Duration	11. Data Sources	12. Explicit Indicators	13. Magnitude	14. Objectivity	15. Significance	16. Explicit Criteria	17. Uncertainty	18. Risk	19. Alternative's Comparison	20. Aggregation	21. Facilitates Facility Location	22. Resource Requirements	23. Replicability	24. Flexibility
		LEGAL/POLICY							ANALYTICAL													TECHNICAL/ ECONOMIC			
									IMPACT IDENTIFICATION				IMPACT MEASUREMENT			IMPACT INTERPRETATION									
1. Blair et al (1978)	O	D	DC	○	○	■	■	▲	▲	■	▲	■	■	■	■	▲	▲	○	○	▲	○	■	■	▲	■
2. Commonwealth Associates (1974)	Co	D	DC	○	○	■	○	■	■	▲	○	■	▲	○	▲	○	■	▲	○	▲	▲	■	■	▲	■
3. Coe (1971)	A	I	R	○	○	○	○	○	▲	○	○	○	○	○	○	○	○	○	▲	○	–	▲	■	○	○
4. Federal Colstrip Corridor Study Team (1978)	Co	D	IR	■	▲	▲	■	▲	■	▲	▲	■	■	▲	▲	▲	■	▲	○	■	■	■	■	▲	■
5. Giles et al (1976): POWER	Co	D	IR	○	▲	■	■	■	■	▲	■	■	■	▲	▲	▲	■	■	○	■	■	■	■	■	■
6. Holberger et al (1975): RALI Study	C	D	–	■	▲	■	○	■	■	■	▲	■	■	■	▲	■	■	▲	▲	○	▲	■	■	■	■
7. PERMITS (1974)	Co	D	IR	▲	○	■	■	■	■	■	○	■	▲	▲	▲	■	■	○	○	■	■	■	■	▲	■
8. Leopold et al (1971)	M	I	IR	▲	○	■	■	○	▲	■	▲	○	○	■	○	▲	▲	○	○	■	–	○	■	○	■
9. Montana DNRC (1976)	Co	D	R	■	○	■	■	■	■	■	○	■	■	▲	▲	▲	■	▲	○	■	■	■	■	▲	■
10. Montana DNRC & U.S. Forest Service (1978)	O	D	R	■	○	■	■	■	■	■	▲	■	■	▲	▲	▲	■	■	○	■	▲	■	■	▲	■
11. Simutis and Johnson (1974)	Co	D	IR	▲	○	▲	▲	▲	▲	▲	○	■	▲	▲	▲	▲	■	■	○	○	▲	■	■	■	■
12. Murray et al (1979)	Co	D	DC	■	■	■	■	■	■	■	▲	■	■	■	▲	▲	■	■	○	■	■	■	■	▲	■
13. U.S. Department of Energy (1979)	C	I	R	■	■	○	▲	▲	■	■	○	■	■	▲	▲	○	○	○	○	▲	▲	○	■	○	■
14. Pacific Gas & Electric Co. (1979)	C	D	IR	■	▲	■	■	■	■	▲	○	▲	○	○	▲	■	○	○	○	○	■	■	■	▲	■
15. Wirth Associates (1975)	M	D	IR	▲	○	■	▲	▲	■	■	▲	■	■	■	▲	▲	■	○	○	■	■	■	■	■	■

A = Ad Hoc
O = Overlay
C = Checklist
M = Matrix
N = Network
Co = Combination
D = Decision
I = Information
IR = Indirect or Representative
R = Reactive
DC = Direct or Contributory

■ = Substantial Compliance; Low Resource Needs; or Few Replicability - Flexibility Limitations

▲ = Partial Compliance; Moderate Resource Needs; or Moderate Limitations

○ = No or Minimal Compliance; High Resource Needs; or Major Limitations

Source: Criteria and format adapted after Warner and Preston, 1974.

Analytical Factors

Three interdependent actions (impact identification, impact measurement, and impact interpretation) represent the normal sequence an analysis follows. Under Impact Identification, four criteria evaluate how well a method defines and delimits impacts. Adequate identification of impacts is important because it forms the foundation for subsequent analysis and documentation. All 15 studies addressed a comprehensive set of topics (criterion #8). On balance, the majority of methods specifically defined the impact categories to be examined (criterion #9) and did a good job of disclosing data sources (criterion #11). However, for criterion # 10, only one method (Giles, et al.) clearly identified the timing and duration of impacts, small but nevertheless significant parts of the total picture.

Impact Measurement. These criteria provide a basis for judging the quality and professional accountability of the analysis framework: how logical, explicit, and free from bias the terms and parameters of the analysis are. Most (9 of 15) methods used measurable indicators such as wildlife species or land use type to quantify impacts (criterion #12). However, only one approach (Blair, et al.) was judged to have satisfied fully the goal of using objective indicators (#14). How these indicators were actually used to delimit the amount of impact (criterion #13) was also handled less than ideally. In only one-third of the studies was the amount of impact fully quantified. However, most (10) methods were successful in disclosing the criteria and assumptions (criterion #16) of the study. Since the analytical process is comprised of both objective and subjective elements, a traceable rationale for all judgmental factors must be provided for a method to be deemed adequate.

It is one thing to identify and measure the potential impacts of a project. It can be quite another to assign meaning to this impact information so that the nature and level of the project's probable consequences can be understood. Criteria under the category of Impact Interpretation measure how successfully a method meets this goal. The concept of impact significance (criterion #15) combines determinations about an action's setting (context) and the severity of its impact (intensity). Because significance is a powerful overall indicator of the nature and extent of impact, how effectively it is analyzed and described largely determines a method's value. Nearly all the methods reviewed could substantially strengthen their treatment of this key issue. Following the new CEQ regulations (i.e., Section 1508) should guarantee more adequate treatment in the future.

Knowledge about the elements of uncertainty (criterion #17) and risk (criterion #18) is clearly important in making realistic impact predictions. Yet only four studies adequately discussed the certainty of their predictions of impact, and none of the studies systematically dealt with the likelihood of an impact occurring. Comparing alternatives (criterion #19)--ones that differ fundamentally as well as incrementally--and aggregating impact measurements into a summary factor (criterion #20) are essential attributes of a decision-oriented method. About 50% of the studies substantially satisfied these related requirements. However, none of the methods meaningfully compared the "no-action" alternative, a serious shortcoming.

In summary, few case studies performed strongly in all three sets of analysis criteria. It is evident that current methodological approaches could improve substantially in this regard. The approach used by Murray (1979) ranked highest overall. Six other studies also ranked highly (Federal Colstrip Corridor Study Team, 1978; POWER, 1976; RALI Study, 1975; Montana DNRC, 1976; Montana DNRC and USFS, 1978; and Wirth Associates, 1975).

Technical and Economic Considerations

Taken together, these criteria can be used to rate the practical factors of cost and applicability; these greatly influence the selection of a method. Unfortunately, information needed to rate these criteria is often either unavailable or too general to allow definitive comparisons.

The first criterion in this category (#21) assesses whether the environmental data used for impact assessment and documentation are also used to guide the location process. Using the data to place facilities is a significant mitigative technique and indicates an integrated planning approach. A method that performs all three functions can be a valuable tool. It is noteworthy that all but three of the methods reviewed applied the data in this manner. In a less positive vein, worthwhile conclusions about resource needs (criterion #22) were difficult to make because definitive information about them was almost uniformly unavailable for review. Nevertheless, it appears that there is much latitude in most of the methods to scale the resource requirements to the scope of the project. The degree of replicability (criterion #23) was also difficult to assess simply from review. As a general conclusion, however, those methods which most adequately satisfy the analysis criteria--particularly the ones which emphasize specific and explicit disclosure of the study framework--would probably yield similar results over repeated applications. Finally, for criterion #24, virtually all methods (14 of 15) were deemed to be applicable to different situations or to different scales.

CONCLUSIONS AND OBSERVATIONS

Warner and Preston (1974) state that there is no single best methodology for environmental impact assessment, a conclusion which implies that some approaches are more appropriate than others, depending on the application. Regardless of the application, however, any approach needs to respond to the major requirements for legal compliance, analytical adequacy, and integration of environmental concerns with planning and decisionmaking. The matrix (Table 4) reveals that efforts by Murray et al., Wirth Associates, Federal Colstrip Corridor Study Team, Montana DNRC and Montana DNRC and U.S. Forest Service, Holberger et al., and Giles et al. have made significant progress in addressing these major concerns. But the matrix also discloses that none of the 15 studies fully satisfies all of the review criteria, underscoring a need for significant improvement as analysis methodology continues to evolve.

In this paper we have highlighted directions to proceed in method development that should lead to adequate, effective analysis methods. In the review criteria (Table 3), we have offered a framework for choosing or designing a method to suit particular needs. Finally, we offer several caveats on the implementation of a methodology. First, design of an assessment method must stem from use. Because false expectations are often placed on the capabilities of a methodology and since technical problems are usually larger than the designers imagine, the user must be directly involved in its design, development, and implementation. In other words, a good system cannot be built in a vacuum. This methodology must be designed with its purpose clearly in mind as well, so that the approach matches the scale of the decisionmaking. And, finally, the user should consider the audience, their needs, and their levels of perception and understanding. No methodology can be considered successful which frustrates or confuses the communication of its findings.

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HIGHWAY NOISE AND RESIDENTIAL PROPERTY VALUES

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ABSTRACT.--This paper reports on a study which was designed to ascertain if residential properties subjected to highway noise levels in excess of Federal Highway Administration Guidelines experienced a diminution in value. Both single family homes and apartments in close proximity to Interstate highways, and fronting on major arterial collector roads were compared to similar units in the same vicinity not exposed to the same high noise levels. Properties in cities with populations of approximately 30,000, 350,000 and 1,100,000 were studied. Apartments were compared as to rental rates, percentage of occupancy and move-back requests. Homes were compared as to prices obtained, percentage of value increases and frequency of sales. Results were developed, both unadjusted and adjusted. The results clearly indicate that apartment rentals are, except in one unusual instance, similar and that the occupancy rates are as high for units with living rooms facing the Interstate highway, as those in the nonimpact zone of the complexes. Also, there is a total lack of requests to move away from the highway. Single family homes show a difference in market value between those abutting the highway and those remote of as much as plus or minus 9%, with the average prices of home abutting the highway selling for about the same price as those in the more remote part of the same subdivision at the same time. The sales price variances, since they were both higher and lower for homes with high noise levels, are attributed to imperfections in the market.

INTRODUCTION

This paper is the result of a major research effort conducted by the New Orleans appraisal firm of Max J. Derbes, Inc. for the Louisiana Department of Transportation and Development (DOTD). The DOTD Office of Highways determined that there was a need for such a study, particularly after several reports were published, Gamble et al. (1974) and Langley (1976), which established a dollar value on the basic unit of noise, the decibel. This research effort was formulated in response to these papers and had a twofold aim. First, to determine, by use of accurate, acceptable practices, the effect, if any, of highway noise on adjacent residential

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property values, and second, to provide a set of procedures which can be followed in any situation to give an accurate, fair measure of the effect of noise on property value. The results were provided in a format that might be implemented by the DOTD engineers and appraisers in planning for future highways, evaluating rights-of-way, and testimony in litigation proceedings.

PROCEDURE

The general method used to determine market effect of noise was the following five step process.

(1) Preliminary noise level measurements were taken in selected areas to determine if noise was above acceptable levels according to the Federal Aid Highway Program Manual, Volume 7, Chapter 7, Section 3 (FHPM 7-7-3). Three areas of Louisiana were surveyed: a major metropolitan city (New Orleans), an urban area (Baton Rouge), and a suburban area (Slidell).

(2) Sales and rental data were analyzed to determine if there was a sufficient volume of data available for comparison of properties close to the noise source and away from it, in order to determine market value effects.

(3) Each potential area was then examined to determine whether or not it would meet the following selection criteria: (a) Areas near other sources of high noise levels, such as airports, were eliminated. (b) Areas must be susceptible to comparison; i.e., in the case of residences, there must be sufficient sales of similar properties over an area large enough to distinguish affected and unaffected properties. (c) Areas under the influence of socio-economic change were eliminated. (d) Areas near or with any of the following were avoided: elevated highways, canals, individually built homes, acute subsidence problems, and mixed commercial and residential properties.

(4) After the compilation of initial data and inspection of an area or subdivision verified that it would meet all the criteria, a more in-depth noise study was made to determine the noise environment.

(5) Sales and rentals of similar properties close to and away from the noise source were compared. Where additional information was needed to assure valid comparisons, interviews were conducted with owners of the houses to ascertain the condition of the home at the time of sale, or a particular circumstance of the sale.

METHOD OF COMPARISON

Single Family Homes

Three basic comparisons were made between houses subject to above average noise levels and those not affected. These were individual comparison of sales prices of similar homes, yearly resale percentage increases of similar homes, and frequency of resales.

Where a subdivision being studied contained virtually identical house models, the sales were separated by models for comparison purposes. All sales of a matching model for a year before and after a subject sale near the highway were used for comparison. The only adjustments made were for lot size differential and for time-using the average monthly resale increase figure for that model.

Owners of all subject houses, with the exception of a few who could not be contacted, were interviewed to obtain basic information about the house. Such information as number of rooms, special features, condition at time of sale, renovations, etc. constitute vital data in order to perform accurate comparisons. If, after time and lot size adjustments were made, any comparison sale was more than a samll percentage above or below the subject sale, a visual field inspection was made. When there was no apparent difference, the owner of the comparison home was interviewed.

A different approach was taken in subdivisions which were developed with homes having substantial variation in design, model, etc. Homes close to and away from the highway which sold for similar prices at about the same time were evaluated. All homeowners were interviewed with this procedure, and all homes were measured in order to make a comparison on a square foot basis. This method of comparison was used to avoid making many adjustments to price for individual differences which could affect the objectivity of the study.

Where there was more than one sale of a subject house over the time period studied, the resale increase of the subject was compared with those of matching homes away from the highway. Likewise, the frequency of these resales were compared. The number of sales on a street was divided by the number of developed lots on that street to determine the rate of turnover. The rates of turnover for noise affected and unaffected areas were then compared.

Apartments

Any financial loss in apartments due to noise levels must be reflected in either the unit rental rates or occupancy of those apartments near the highway when compared to similar units away from the highway. The study analyzed these two indicators and additionally checked to determine the number of noise-related requests for moving from one apartment to another. Due to the scarcity of apartment units in New Orleans and Baton Rouge (there were none in Slidell), many of the apartment complexes which front on interstate highways had such a high occupancy rate that they could only be surveyed from the standpoint of rent levels and move-back requests. Only one unit was found, meeting the selection criteria, which had a sufficient vacancy rate to study the occupancy distribution. However, the evidence from units with high occupancy levels was still considered valid from the standpoint of rent levels and particularly move-back requests.

Noise Measurements

Noise levels in each area studied were taken during morning peak traffic, evening peak traffic, early night and late night hours. This generally corresponded to 7:00-9:15 AM, 4:00-6:15 PM, 8:00-8:15 PM and 11:00-11:15 PM. All noise levels were measured using the L_{10} system developed by the Federal Highway Administration (FHWA) which expresses noise as a function of time by recording the level of noise exceeded 10% of the time. This method accounts for the fluctuating noise levels generated by constantly moving traffic. Since the time of the study the FHWA has adopted another system called the Equivalent Noise Level (Leq); however, since all of the work was done along heavily travelled highways, the differences between the two systems are not significant.

Three sites were monitored simultaneously for each area studied. Eleven separate L_{10} meaurements were recorded at each site during the times mentioned above. Site 1 was located at the side of the row of buildings facing the highway. These readings, therefore, represented the peak levels experienced by the residents of the subject property. The sound level meter used at Site 1 was a precision meter, with recorder, which was capable of recording noise levels to be analyzed later for frequency. The subsequent frequency analysis was inconclusive except that time of day seemed to be the most significant variable. Whenever possible, traffic was counted at Site 1 during the recording period.

Site 2 was located either at the back side (side away from the highway) of the first row of buildings, or at the front of the second row, depending upon the particular geography of the area. This site was monitored with an A.N.S.I Type II General Purpose meter from which manual readings were taken. Neighborhood noises were eliminated from this set of readings as much as possible to get a true picture of the drop off rate of noise from the highway being studied.

The readings in each area at Site 3 represent almost exclusively neighborhood noises. This site was selected to record background, subdivision traffic, and general noises in each area, as well as, to a minor extent, the background contribution from the highway. The equipment used at this site was also a Type II meter; however, it had the capabilities of automatic recording of the noise level.

Traffic data were obtained for the time period corresponding to the period of sales being studied, 1973-1978. These historic data were used to calculate probable noise levels for past years where actual noise measurements were not available. By using the traffic figures actually counted during noise monitoring, the FHWA traffic noise prediction method was calibrated for each site to insure that the historic noise levels calculated were consistent with the noise levels actually measured. Because of this, there was a high degree of reliability for the calculated noise levels used in the study.

DISCUSSION

Six subdivisions, three along interstate highways and three along major arterials, and one apartment complex were studied in detail. In addition, numerous other areas were surveyed before being eliminated by the selection criteria. These criteria were established to reduce the number of variables which might affect property values to a point where any difference between the price of a subject and a comparison house must be attributable to highway noise. In all, over 2,000 individual sales transactions were studied in detail during the research effort. The subdivisions along interstates were Willowdale--in Metairie (New Orleans area), Vineland--

also in Metairie, and Slidell Country Club Estates. Those studied along major arterials were Holiday Drive--New Orleans' West Bank, Terrytown--also on the West Bank and Sherwood Forest--Baton Rouge. The apartment complex studied in depth was the Lake Kenilworth Apartments along I-10 in New Orleans.

Willowdale

This was an ideal subdivision for the purposes of the study due to the age, similarity of models and large number of sales of the houses. While 11 of the sales on the highway indicated that the houses in the interior sold for 5.43% more than the houses on the highway, 7 other sales indicated they were worth 6.92% less, after adjustment for time and lot size. Thus, the evidence does not support a diminution in value due to noise. In addition, the houses near the highway resold at a frequency rate of 1.99% less than that of the houses away from the highway noise.

The overall percentage of value increase per annum is lower by 1.61% for houses near the highway. However, since extreme fluctuations were eliminated, two inflated sales which would have changed the annual percentage to a plus 1.7% were not considered by the study. Since only 8 houses near the highway were used in the calculation, this is not considered conclusive.

Vineland

This subdivision had a limited number of comparables and the study indicated that the houses near the interstate sold for 2.83% less than the interior houses. Smaller lots near the highway account for this percentage decrease. Five houses near the interstate showed an average annual increase due to resale 3.18% higher than five houses off the highway, being 16.39% and 13.21% annually, respectively.

Slidell Country Club Estates

In this subdivision of non-standardized homes, an average value per square foot was used for comparison. The houses near the interstate sold for an average of $28.45 per square foot, while the homes away from the interstate sold for $26.64, or 6.8% less. The average resale price was 11.1% per annum for houses near I-12, while for the interior houses, it was 9.8%, or 12% less. The frequencies of resale were about equal.

Terrytown

In this new subdivision, all houses within one style or model were sold for the same price by the builder. However, there were no indications of buyer reluctance concerning the houses fronting on the major arterial. The one resale on the major street showed a 13.63% annual increase compared to the average of four interior resales at 12.79%.

Holiday Drive

The houses on Holiday Drive were found to sell for from 1.5% to 2.1% less than those on the interior of the subdivision. The resale percentage increase was likewise somewhat higher by 0.24% for the interior. The frequency of resales on Holiday Drive was less, however, 10.83% compared to 11.4%. The selection criteria broke down somewhat in this area in that the houses on Holiday Drive were very close to the street and other factors than noise were considered to have influence on the market; e.g., safety of children.

Sherwood Forest

Eight houses on Sherwood Forest Boulevard were studied. Five of these houses showed sales 6.5% higher than interior comparables on a square foot basis. The three others sold for 3.0% less than their interior comparables. There appears to be no appreciable variance in sales price between the two areas. During the time period being studied, the resale frequency was so small that this means of comparison was not used in the subdivision.

Lake Kenilworth Apartments

This complex was studied because of all the apartments with high noise levels, it was operating with less than 100% occupancy. Also, at the beginning of the study, it had a small rent concession to those apartments with balconies which were near the interstate; in effect, not charging for the balconies. Shortly after the start of the study, this concession, $17.00 per month, was removed. During the remainder of the study, the situation was monitored, and no occupants changed apartments due to the increase.

The occupancy rate was equal to the average for the entire complex, and was only exceeded by those units in choice locations such as interior courtyards or facing the lake. No occupant preference due to noise was observed in this complex.

CONCLUSIONS

The evidence gathered in this study gives no indication of a diminution in property value due to noise. Selected groups of houses near highway noise do sell for less; however, other groups sell for more. The variance in both groups can adequately be accounted for by normal fluctuation within the market.

The study has limitations, particularly in regard to geography. Evidence from other studies indicate that noise awareness varies according to geographic location within the United States. Therefore, this study may not apply to the northeastern and western parts of the country in particular. Also, the data for this study were collected prior to recent economic changes. This may not have a significant influence on the results since it is still essentially a "seller's market." The study was also deliberately limited by the selection criteria to avoid the introduction of variables other than noise which would alter the market. The exact influence of these other variables was not determined.

ACKNOWLEDGMENTS

We thank the staffs of Max J. Derbes, Inc., the Louisiana DOTD and the local Traffic Departments. Without their work this effort would have been impossible. Specifically, the contributions of Ms. Pamela Gibson, Ernestine Olliges, and Donna McFarland were invaluable.

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COMPUTER ASSISTED ROUTE SELECTION

Steven J. Kangisser[1]

ABSTRACT.--Permitting a right-of-way is a complex process, particularly when many jurisdictional areas become involved, each with its attendant environmental licensing concerns. An important step in the licensing process is initial route selection. The selection process must be designed so as to demonstrate that all relevant variables have been examined. The applicant must also show that a reasonable number of alternatives have been considered. The manner in which the initial route selection is conducted, therefore, has serious implications for the licensing process. Computer assisted geographic information systems can be a valuable aid in storing, manipulating, and analyzing the large amounts of data associated with meeting these requirements. These systems provide increased flexibility, speed, and result in a well documented process.

INTRODUCTION

Routing and permitting a right-of-way (ROW) entails examination of a wide range of topics. These topics can include terrestrial, aquatic, hydrologic, land use, sociological, and cultural resource parameters. Numerous states, including California, Florida, Minnesota, Maryland, Michigan, New York, Ohio, and Pennsylvania, have exerted strict regulatory control over the ROW licensing process. Licensing requirements often include justification of the ROW based upon a review of viable alternatives.

As a result of this regulatory climate, it is advisable to follow a thorough, reproducible methodology when examining alternative corridors and selecting the preferred route. Various manual and computer assisted methodologies have been developed for corridor and site selection studies. The choice between a manual or computer assisted approach is largely determined by the length of the ROW, number of environmental variables and issues within the study area, regulatory requirements, availability of computer hardware and software to the study team, and the adequacy of the existing data base. Larger study areas and greater degrees of environmental variability dictate more sophisticated modes of data storage, manipulation, and display. Recent developments in geographic data management hardware and software have made investment in a Computerized Geographic Information System (GIS) more economical and, therefore, more available to users with limited resources.

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DISCUSSION

Utilization of a GIS provides a number of advantages over manual techniques including greater flexibility in manipulating large numbers of variables; reduced time and cost when altering the ROW selection methodology to accommodate unexpected events; enhanced communication among study team members; and improved quality control. Each of the many currently available GIS's offers additional specific advantages for ROW selection. Some computer systems are designed to store and display data without capacity for data manipulation. Data storage may occur as grids or more flexibly as polygons. These systems produce graphical displays which can be black-and-white, full color, two-dimensional, or three-dimensional. Output can be via a line printer, pen plotter, or photographs taken off a CRT display.

A more advanced system is capable of manipulating, as well as storing and retrieving, data. These systems may provide for overlaying of individual parameter maps, combining individual parameters to form new ones, correlating socioeconomic and environmental factors, or even determining engineering cost penalties. These systems may, however, stop short of actually designating alternative corridors. The user must therefore examine the data and manually designate the corridor.

Advancements in computer software have made it possible for the GIS to select alternative corridors and to compare alternatives. Alternatives are selected by indicating environmental conditions which are to be avoided and those which are to be minimized. Minimum path selection algorithms are then used to designate the alternatives. Each of the environmental parameters is assigned a value indicative of its condition within the specific grid cell or polygon. A weight is then assigned to each parameter and applied throughout the study area. Alternatively, the weight may differ from one area to another. Crop lands may be considered highly valuable in the rural portion of a study area but far less valuable in an urbanized portion of the study area. In this case, parameters may be assigned weights specific to each grid cell or polygon. Weights may be determined by the study team or in cooperation with the regulatory authorities. The GIS may then be instructed on the selection of alternative corridors by designating parameters to be minimized or maximized. For example, the study team may wish to minimize crossing of wetlands, placing of towers in navigable rivers, crossing of major highways, interference with highly urbanized nodes, and grids or polygons with significant slope. Construction costs also may be minimized as may operation costs including line loss. Selection parameters should also consider system reliability.

Once alternative corridors are selected, the study team can take advantage of the flexibility of a computerized system by conducting sensitivity analyses. Weights assigned to each value can be readjusted and the resultant preferences between alternatives identified. Changes in regulatory requirements can be anticipated by adding or deleting selection parameters. The quick response time of a GIS allows the sensitivity analysis to proceed interactively. Often this analysis is conducted within the framework of a structured route selection meeting at which representatives of each discipline are present. Each time a preferred ROW is selected the environmental and economic cost penalties are indicated. The final selection, therefore, remains in the hands of the study team, as results of each scenario must be considered.

Each route selection task carries individual system requirements. No GIS can be expected to meet all needs. Recent developments, however, have made available some useful specialized capabilities. Included is integration of DIME file socioeconomic data, Landsat imagery, and computerized aesthetic analysis. A number of software packages are commercially available which incorporate one or more of these capabilities.

Systems are available which are capable of integrating various grid and polygon statistics including DIME file information. Geographic Base Files (GBF) were developed for use in the 1970 Census for assigning geographic classifications to respondent mailing addresses. This made the mail out-mail back self-enumeration census technique possible. The GBF/DIME-File was used to code addresses to specific census blocks, tracts, enumeration districts, and such other areas needed by the Census Bureau to produce geographically classified statistics. DIME File capabilities permit the classification and display of local address referenced data for standard metropolitan statistical areas (SMSA's). DIME File information can be merged with more conventional GIS data to more fully incorporate the socioeconomic analysis. In this manner detailed analysis of ROW impacts on urbanized areas can be performed.

A very useful capability of a GIS is merger of satellite imagery. The Landsat satellites, first launched by NASA in the early 1970's, are continually taking "electronic pictures" of 1.1 acre (0.4 ha) grids for most of the earth's surface. Repeat coverage of the same area occurs on an 18-day basis, providing an entirely new picture of the surface land cover.

An example of utilizing Landsat data is where the unprocessed Landsat data is displayed to simulate an infrared photograph. A portion of the area can then be electronically enlarged using zoom capability to better show the 1.1 acre (0.4 ha) detail. A box, or "training sample," can be drawn around a specific condition of interest. An area representative of a land cover condition is thereby isolated, and the computer system is "trained" to recognize this condition. Statistical analyses can be automatically performed to ensure a good sample has been selected. Once the computer system has been trained for a specific condition on a relatively small area (approximately 40 acres (16 ha) is an average size), an automatic mapping of each 1.1 acre (0.4 ha) grid is possible for the entire study area, based on the training samples chosen. Acreage statistics can accompany the mapped results.

Many systems also have the capability of producing scale mapped products with acreage statistics for specific areas contained within the larger region covered by a Landsat frame. A corridor can be mapped showing land cover conditions and acreage totals provided for each category. This provides a strong basis for ROW land use impact analysis.

Perhaps the most effective uses of Landsat data are realized when this information is merged in a geographic data base with other data such as soils, topography, geology, and cultural resource information. Data base

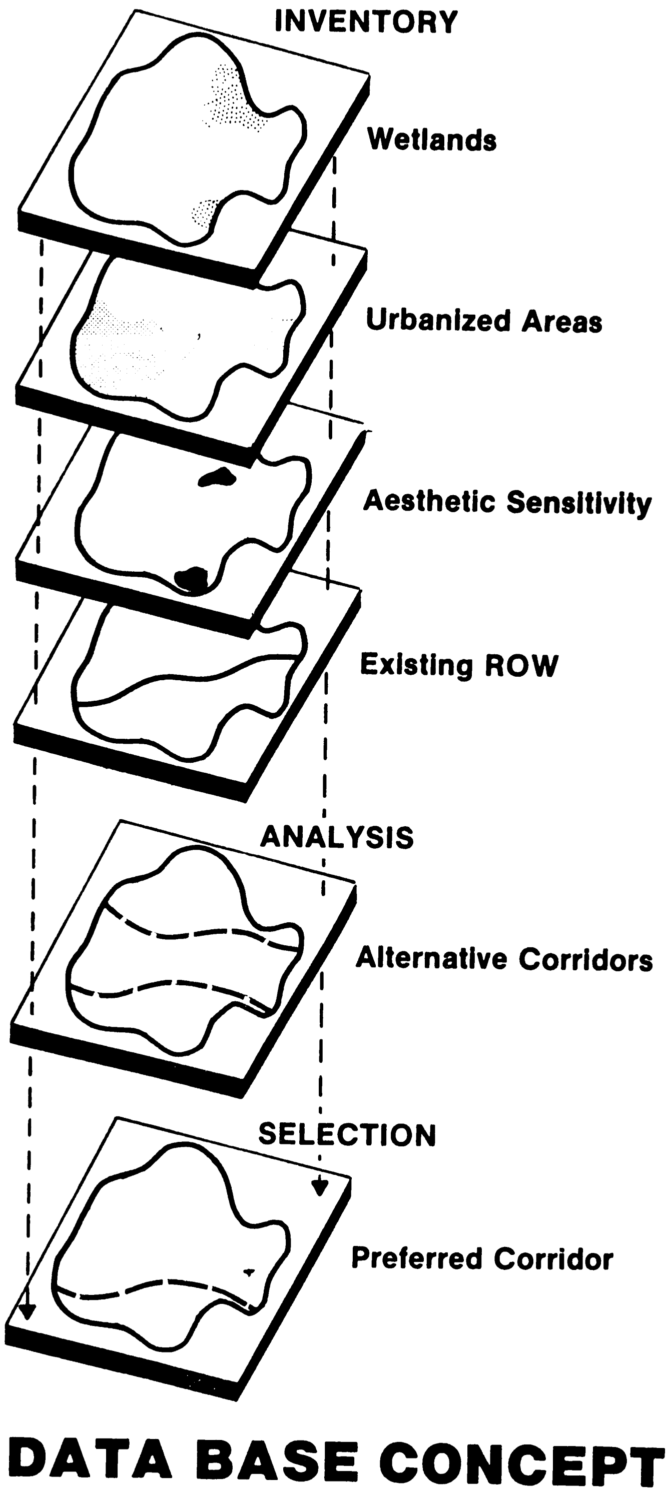

Figure 1. Data base concept.

software packages allow efficient and accurate rectification and merger of Landsat data into a data base structure. Computerized GIS's allow flexibility to quickly overlay manually encoded data with satellite imagery. Correlation can then be made among various environmental factors. Figure 1 illustrates the data base concept. This concept is highly valuable when minimim path selection algorithms are used to select alternative corridors.

An additional potential use of a computerized GIS is aesthetic analysis. Key indicators such as slope and land cover can be employed to identify sensitive view points of a ROW cut or structures such as transmission towers. Topographic data are normally digitized from US Geographic Survey topographic sheets while land cover can be obtained from ground surveys, aerial photographs, or satellite imagery. The exact location of ground clearing and dimensions of all structures are manually programmed. It is then possible for the GIS to display a three-dimensional simulation of the aesthetic impact of the ROW. This display can be a black-and-white line image or a colored picture taken off a CRT. Black-and-white line images normally require enhancement by an artist. Color computer images allow greater flexibility in simulation display. The ROW can be easily viewed at simulations of different daylight conditions, and angles of view. Effects of various landscape plantings can be evaluated with ease. High quality exhibits are then available for presentation to regulatory authorities and the public.

CONCLUSION

These are but a few of the capabilities of computerized geographic information systems. Site selection has always been an imperfect process. Use of a geographic information system does not change this fact. Flexibility and speed in storing, manipulating, and retrieving data is greatly enhanced by utilizing computer capabilities. Geographic information systems provide for a well documented right-of-way selection process, useful when preparing licensing reports. Allowance should still be made for professional judgement, particularly when differentiating between alternatives.

A NEW APPROACH - ENVIRONMENTAL FEASIBILITY STUDIES

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ABSTRACT--The unprecedented growth of mining in Northern Saskatchewan has given the province the opportunity to investigate the feasibility of supplying and/or augmenting electrical power via transmission lines to both the new mines and the established communities which would otherwise utilize diesel generation in the north. Accompanying this need and opportunity for expanded electrical service was the desire to route transmission lines based upon sound environmental and social considerations, as well as the usual technical and economic considerations. Therefore, an extensive study program was developed in order to determine the routine of the proposed transmission grid.

INTRODUCTION

The unprecedented growth of mineral exploration in northern Saskatchewan during the past decade has led to new uranium mines and the potential for even more development. These projects, however, need large supplies of electrical power; the present source being high-priced diesel-fueled generating units. The recent and potential developments have given the Province of Saskatchewan the opportunity to economically supply and/or augment electrical power via transmission lines to both the new mines and the established communities of the north.

The Saskatchewan Power Corporation, a Crown Corporation, has realized that (1) existing and future mines would provide load centers large enough to make a transmission line economically feasible; (2) demand in already serviced northern communities is expected to exceed supply by 1985; and (3) other communities presently on diesel power could now be serviced by a transmission line.

From these realizations came the proposal of a Northern GRID; a transmission line grid serving existing and potential mines as well as northern communities. The proposal included lines ranging from 25 kV to 230 kV.

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3 Eldorado Nuclear Ltd., Ottawa, Ontario.

Two power generating sources are available--the hydroelectric dam at Island Falls on the Churchill River and the dam on the Saskatchewan River at Squaw Rapids. By using either one, or both sources, seven possible grid configurations could service the proposed load centers (Figure 1). Based upon these seven configurations, a broad (50 to 90 km wide) corridor concept was developed with which to locate the final transmission line right-of-way. This decision was based upon several factors, including (1) the need to service several communities and mine sites; all of which were widely dispersed over a tremendously large, sparsely populated study area including all corners of northern Saskatchewan; (2) the use of one or even two power sources; and (3) the desire to connect the northern grid with the existing grid serving the more densely populated southern Saskatchewan.

The objective of the study was to compare the seven possible corridor configurations and to determine which was environmentally and socio-economically preferred. Later, within the recommended corridor, possible transmission line rights-of-way could be located and following a detailed environmental impact assessment, a right-of-way might be chosen which would supply the load centers requiring power.

METHODOLOGY

The size and location of the study area presented a unique problem in choosing a corridor, for environmental baseline information on northern Saskatchewan is very deficient. Only site-specific areas (e.g., mines, roads) have been studied, leaving a vast area with only sparse environmental information available.

Realizing these data deficiencies, several standard study methodologies were considered including the "Ad Hoc Committee" method, the "Map Overlay" method, the "Impact Checklist" method and "Systems Analysis" methods. All, however, were designed for comparison of potential impacts on selected, site-specific rights-of-way within a corridor. As this study was of a broad, regional nature, a modified evaluative technique evolved.

To compare corridor configurations, the study area was divided into ten "sectors," labelled from A to J (Figure I). Four of these sectors, A, B, C, and G were common to all seven possible configurations. It was therefore apparent that at the regional level of comparison these common sectors were of little importance; the final decision being dependent upon the noncommon sectors.

As the seven corridor alternatives were created by varying combinations of sectors, the evaluation study became a comparison of the non-common sectors. This approach assumed that the corridor consisting of those combinations of sectors most favored for environmental and socio-economic reasons would be the preferred corridor in which to locate a transmission line.

An "issues identification" methodology evolved in which to evaluate the non-common sectors. This approach may be viewed as three distinct steps.

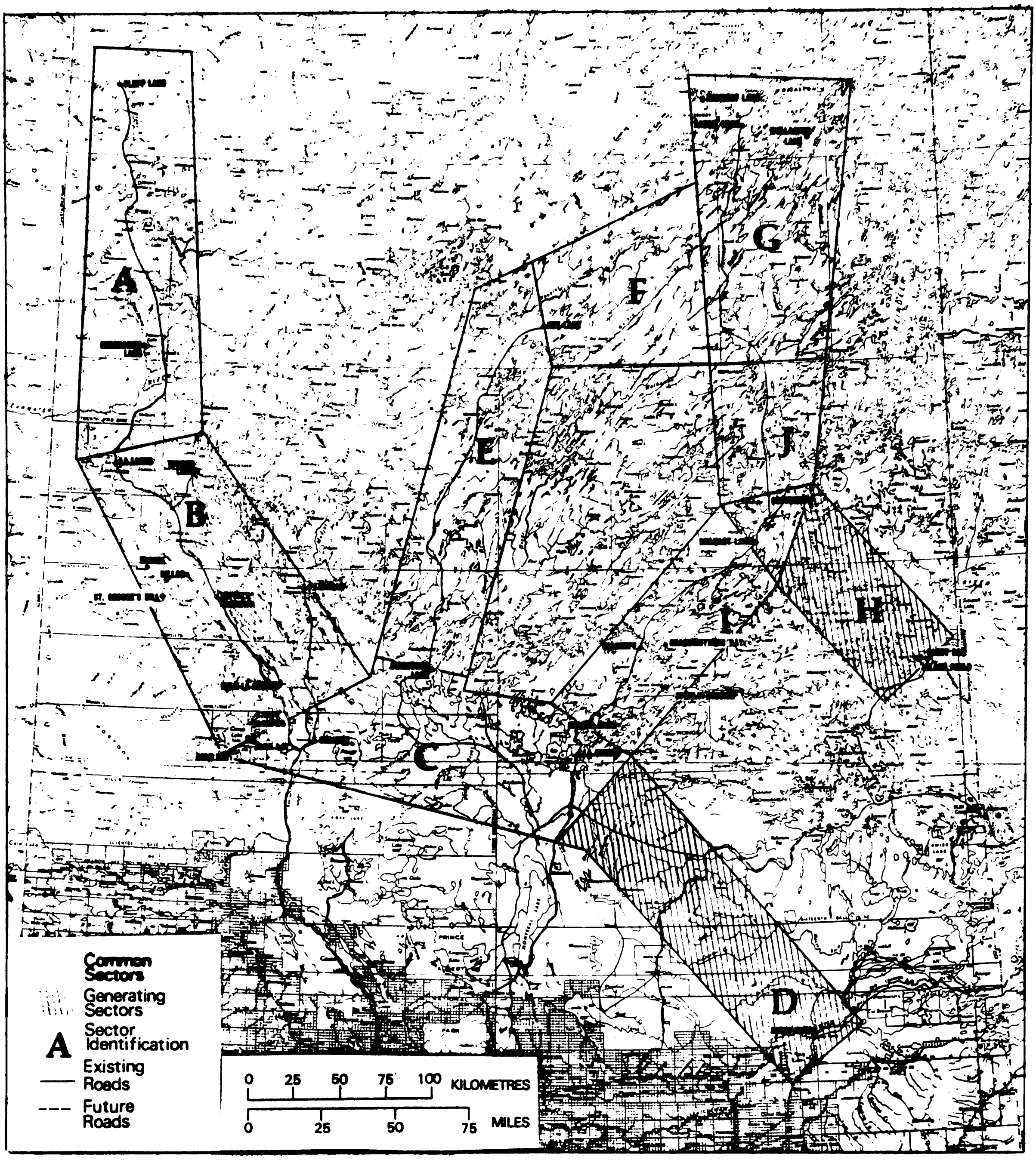

Figure 1. Definition of study area in northern Saskatchewan, Canada

Step One - Identification of Issues and Concerns and Baseline Data Collection

A public participation program played an important role in this stage of the study. This program was a new approach to involve the concerned public in the decision making process. The program, conducted by the Saskatchewan Power Corporation over a period of 10 months, was an intense effort informing the northern people of the nature of the Northern Grid and obtaining their feedback.

Open houses and meetings with local administrative councils, the appropriate Indian bands and other northern organizations were held in 30 communities. All communities were visited two or three times throughout the program. In addition, periodic press releases kept the public informed. Over the ten-month period, several issues and concerns were identified which were useful in making corridor evaluations and planning decisions.

The study team, using the identified issues and concerns gleaned from the public involvement process, combined with concerns raised by regulatory and government agencies and, from an extensive literature review, defined several issues useful at a regional scale with which to compare the resources within the non-common sectors.

Step Two - Defining the Evaluative Measurements and Measuring Relative Impacts

Six major regional issues were refined. These included: (1) wildlife and wildlife habitat; (2) traditional resource use; (3) forestry; (4) recreational lands; (5) land use; and (6) regional economic development potential. From each of these issues a measure could be determined to evaluate non-common sectors using a relative impact rank of High, Medium or Low. For example:

Issue/Concern - Potential adverse effects of the transmission line, its construction and/or right-of-way clearing on traditional land users such as fur trappers.

Evaluative Measures - Total number of active trappers per sector.

Relative Impact Rank - High, Medium, or Low.

As little detailed environmental and socio-economic information was available for northern Saskatchewan, evaluative measurements were, by necessity, very subjective. Without the time or financial ability to conduct detailed baseline inventories of such a large area, the existing information was used to its fullest extent. From this information evaluative measurements evolved and are presented in Table 1.

The objective in the example above would be to compare sector components on the basis of the number of active trappers within each sector. If a particular sector was assigned a Low rank, that sector would have fewer trappers than a sector with a Medium or High rank; the assumption being that the fewer the active trappers present in a sector, the lower the degree of impact from a transmission line and its right-of-way on the traditional resource user.

Table 1. Evaluative measurements.

	Issue	Evaluative Measure for Each Non-common Sector
1.	Wildlife and wildlife habitat	Relative ungulate density
2.	Traditional resource use	Number of trappers
3.	Forestry	Area of productive forest
4.	Recreational lands	Number of designated canoe routes and outfitting camps
5.	Land Use	Areal extent of Provincial Parks, potential recreation sites, and candidate ecological reserves
6.	Regional economic development potential	Area of mineral claims

The relative impact scale is determined following the suggestion of Fredin and Larder as quoted by Reimers et al. (1955).

$$\frac{10(x-y)}{z-y} = \text{Range Value}$$

where x is the given value for a sector (e.g., 78 trappers)
y is the minimum value for all sectors (e.g., 34 trappers)
z is the maximum value for all sectors (e.g., 105 trappers)

Range values determined by this formula are then grouped into the following categories:

Range Value	Relative Impact Rank
0.0-3.3	LOW
3.4-6.6	MEDIUM
6.7-10.0	HIGH

Examples are presented in Tables 2 and 3.

Table 2. Number of trappers per corridor sector.

Non-Common Sector	Trappers	Relative Impact Potential
D	105	High
E	78	Medium
F	34	Low
H	65	Medium
I	105	High
J	41	Low

Table 3. Area of productive forest per sector.

Non-Common Sector	Area (sq km)	Relative Impact Potential
D	4183	High
E	1031	Medium
F	0	Low
H	572	Medium
I	1466	Medium
J	0	Low

Step Three - Evaluate Sectors and Select A Recommended Corridor

In order to evaluate sectors and corridors, the High, Medium, and Low rankings were assigned numerical equivalents of 4, 2, and 1, respectively. After each non-common sector has been ranked using each evaluative measure, the numerical values are summed, thereby giving a final numerical appraisal of each sector (Table 4).

Upon summing the total impact values of the appropriate sectors, a potential impact value is obtained for each corridor (Table 5). That configuration with the lowest potential impact value represents the preferred corridor in which a transmission line might be routed when used in combination with the common sectors.

Table 5. Corridor evaluation.

Corridor Alternative	Sectors Components	Total Relative Impact Potential
1	F+J+D+I	56
2	F+J+H+I	50
3	E+J+H+I	53
4	E+J+D+I	59
5	E+F+D+I	54
6	E+J+H+D	52
7	F+J+H+D	49*

*Alternative 7 has the lowest total Relative Impact Potential based upon the six evaluative measurements. Therefore, the non-common sectors represented by corridor 7 are the preferred sectors in which to locate the transmission line right-of-way, in combination with the common sectors.

REVIEW PANELS

The evaluative process and the study team's decisions were tested with the assistance of two panels. First, a Technical Review Panel consisting of individuals having recognized environmental expertise in northern

Table 4
Relative ranking of corridor sectors[a]

Non-Common Sector	Wildlife	Forest Land	Traditional Resource Use	Land Use[b]	Recreational Resources[c]	Regional Economics[d]	Total Relative Impact Potential
D	H (4)	H (4)	H (4)	M (2)	L (1)	H (4)	19
E	L (1)	M (2)	M (2)	L (1)	L (1)	M (2)	9
F	L (1)	L (1)	L (1)	L (1)	L (1)	L (1)	6
H	M (2)	M (2)	M (2)	L (1)	M (2)	H (4)	13
I	M (2)	M (2)	H (4)	H (4)	H (4)	H (4)	20
J	M (2)	L (1)	L (1)	L (1)	M (2)	H (4)	11

[a]The higher the ranked number, the greater the potential of undesirable impacts.

[b]Provincial parks, IBP sites and potential recreation areas.

[c]Canoe routes and non-accessed outfitters.

[d]Regional economic development (mineral claims) differs from the norm. A High (H) value indicates little opportunity for a transmission line to serve potential mine sites. A Low (L) value indicates that the presence of a transmission line may be beneficial to future regional developments.

Saskatchewan reviewed the process during the early stages of issues refinement. From this review, recommendations were made concerning the choice of evaluative measures. The panel also served as an information source, providing input into the study team's subsequent reevaluation.

Secondly, a Northern Public Panel, consisting of representatives from communities, native groups, and northern interest groups, reviewed the study team's evaluation. This was conducted several weeks after the Technical Panel meeting and after a refinement of the process.

The corridor chosen by the study team on the basis of non-common sector evaluation, met with the approval of both panels, and was recommended to the Saskatchewan Power Corporation as the preferred route in which to locate a transmission line.

DISCUSSION

As discussed, these issues and the evaluative measures were obtained from extensive public involvement programs, literature reviews and the use of a technical panel of experts. The issues identification approach did provide an acceptable means of making decisions based upon sketchy baseline information; however, improvements to the methodology might simplify the process and provide a more significant environmental evaluation. Two improvements are (1) The refining of an objective voting procedure used by the review panel and (2) The use of Landsat imagery for the computer mapping of environmental information.

First, a procedure should be developed which presents the available information to a review panel enabling the group to objectively vote for a preferred corridor. A procedure which presents the potential environmental impacts and environmental trade-offs is necessary which allows the panel to decide on the hierarchical importance of each.

Secondly, the use of Landsat imagery, although expensive, will provide environmental information appropriate to certain evaluative measures.

Landsat imagery, when analyzed by computer, provides information which can be mapped at a reasonably large scale (e.g., 1:50,000). For example, a variety of vegetation communities are easily mapped using this technique. Some ground-truthing is required to refine the mapping procedure.

By utilizing these computer-based maps, the pattern of vegetation communities can be examined with respect to their potential as wildlife habitat. In our case for example, ungulate densities were used as an evaluative measurement although this information was based on a few, widely dispersed population studies. If, however, Landsat-based potential habitat maps, in association with known population densities, were used, a more accurate representation of actual conditions would be possible. When this method is used evaluations with respect to a transmission line right-of-way are more accurate.

CONCLUSION

In our study, we were faced with the problem of supplying power to several widely dispersed load centers in northern Saskatchewan. This vast, sparsely populated region, provided a problem due to its size and the lack of any detailed environmental information.

Due to the lack of detailed information, it was decided that the usual methods of selecting two or three possible rights-of-way and then conducting an environmental impact analysis was not appropriate. As several possible configurations were possible and, in an attempt to use public input at an early stage, an "issues identification" approach was devised.

This methodology was based upon issues and concerns expressed by the public who were to be affected by a new transmission line. The approach allowed the public to express these concerns at a time when route planning was still at a broad, regional scale.

It appears to be a reasonably acceptable procedure where the outcome will be a transmission line right-of-way which is acceptable for both environmental and socio-economic reasons. The methodology would be applicable to any large scale utility corridor although the better the existing environmental information, the more valid the outcome. With the increased use of Landsat imagery and computer mapping, the issues identification approach would become useful in many remote regions.

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ENVIRONMENTAL PROTECTION PLANNING FOR A CANADIAN SEGMENT OF THE ALASKA HIGHWAY GAS PIPELINE

Doris M. Morris[1]

ABSTRACT.--Westcoast Transmission Company Limited of Vancouver, British Columbia, as 50% partner in the Canadian portion of the Alaska Highway Gas Pipeline Project, has had the responsibility for developing environmental protection plans for the 716 km section of the pipeline which will pass through northeastern British Columbia. Following the guidelines of the Northern Pipeline Agency, a federal regulatory body set up to expedite the project in Canada, Westcoast has carried out extensive studies of fisheries, wildlife, vegetation, terrain and archaeological resources in 1980 and 1981. Provincial environmental requirements must also be met.

INTRODUCTION

The large-diameter gas pipeline which will deliver Alaskan gas to markets in California and the midwestern states will be constructed along a right-of-way parallel to and, in most cases, close to the Alaska Highway through Canada's Yukon Territory, but south of 60°N latitude, where the pipeline route crosses the province of British Columbia, the meandering highway, constructed as a wartime supply road, is not an efficient pipeline corridor. A more direct pipeline route across the province has therefore been under study, and considerable field investigation has been undertaken to define an environmentally-sound and cost-effective pipeline corridor.

BASELINE SURVEYS

Much of the field work has been baseline surveys to describe the wildlife, fisheries, and heritage resources of the region since little previous information for the remote area is available. Survey crews have worked primarily by helicopter because ground access along the pipeline corridor is extremely limited. The cost of helicopter support for ten study teams of biologists and archaeologists has accounted for 40% of an environmental studies budget in excess of one million dollars.

At the conclusion of the 1981 field season in October, wildlife specialists had compiled detailed observations of moose, elk, and woodland

1 Environmental Coordinator, Westcoast Transmission Company Limited, Vancouver, British Columbia, Canada.

caribou populations along a 6 mi (10 km) wide corridor. Furbearers and furbearer habitat was examined and related to the fur trapping industry on registered traplines along the corridor. An assessment of habitat suitable for cliff-nesting raptors was made, as well as a study of the many small lakes and wetlands which support waterfowl. An inventory of the fisheries potential of some 250 rivers and streams scheduled to be crossed by the pipeline has been a significant part of the program. One representative stream was continuously monitored from break-up in April to freeze-up in October to obtain data on fish life histories and characteristics patterns of fish migration in northern streams. A search for archaeological remains located a small number of prehistoric and historic sites of past human occupation of the area. Further field study of the heritage sites will be carried out in 1982 to determine their significance.

CONCLUSION

Environmental studies along the pipeline corridor have contributed significantly to the siting and design of the pipeline, and to the scheduling of construction. Environmental protection plans for various phases of the project, based on the field data collected, are now being prepared for submission to the government regulatory agencies and for public review. Depending on overall project financing, construction of the Yukon and north British Columbia segments of the pipeline is scheduled to begin in 1984.

SINGLE REGULATORY PROCESS FOR ELECTRIC TRANSMISSION LINES

Donald G. Beamer[1]

ABSTRACT.--The Alberta Energy Resources Conservation Board (ERCB) uses a unique, single regulatory process for approval of electric transmission lines. This paper addresses the legislation under which electric transmission lines are approved, the responsibility and authority of the ERCB, the process followed by electric utilities in gaining approval, including public disclosure of proposed lines, public participation in planning routes, information included with the application for approval, public hearing process, decision, and the inclusion of other government departments that have the authority under separate legislation to deal with resource development within the regulatory process.

INTRODUCTION

The Alberta Energy Resources Conservation Board (ERC) is a quasi-judicial agency charged with the regulation and management of developing Alberta's energy resources--oil, gas, oil sands, hydro, coal, and energy transport systems such as pipelines and electric transmission lines. Some of the regulations and management functions are the appraisal of reserves, the regulation of exploration; the approval of construction and operation of power plants, electric transmission lines and pipelines; prevention of waste; protection of correlative rights; appraisal of productive capacities of Alberta's requirements and of markets outside Alberta; recording and publishing statistics; and advice to the Provincial Government on energy-related matters.

To perform these functions, the ERCB administers various pieces of legislation. Through the Hydro and Electric Energy Act, the ERCB is responsible for economic development in the public interest of electrical energy and transmission in Alberta. Under the Act, anyone generating, transmitting, or distributing electric energy must obtain approval by formal application for hydroelectric developments, thermal power plants, transmission lines, service areas, and interconnections.

The ERCB is presently made up of six board members supported by a technical and clerical staff of 675 persons. It has nine technical departments:

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1 Energy Resources Conservation Board, Calgary, Alberta, Canada T2P 3G4.

Coal, Development, Gas, Geology, Hydro and Electric, Oil, Oil Sands, Pipelines and Environmental Protection and five service departments: Administrative Services, Data Processing, Economics, Employee Relations and Legal.

The following discussion outlines the Board's methods and procedures used in approving electric transmission lines.

ALBERTA ELECTRIC SYSTEM

A combination of private investor-owned companies and municipally-owned utilities generate, transmit and distribute Alberta's electric energy. The present net generating capacity is 5170 MW; 4000 MW is private investor-owned and 1170 MW is municipally-owned. There are about 1800 circuit kilometers of 240-kV transmission lines and 3500 circuit kilometers of 138-kV transmission lines. About 350 circuit kilometers of 500 kV transmission lines have recently been approved for construction.

There is some overlapping legislation for the approval of electric transmission lines. Alberta Environment, Alberta Energy and Natural Resources, and Alberta Culture--all provincial government departments--have legislative responsibilities regarding the environment, particularly Alberta Environment under the Land Surface Conservation and Reclamation Act. Under this Act, Alberta Environment has the authority to prepare transmission line construction. Alberta Energy and Natural Resources administers all public lands and has environmental responsibilities over these lands.

Under the Hydro and Electric Energy Act, the ERCB is required to obtain Ministerial Approval from Alberta Environment and Alberta Energy and Natural Resources for all environmental matters regarding transmission lines. This requirement is the main vehicle which allows the single regulatory process to work. Through this requirement and other procedures established by the ERCB and the departments, which both government departments believe they are able to discharge their responsibilities regarding environmental matters, and therefore, have chosen not to develop other parallel processes to meet their own legislative requirements.

PRELIMINARY REFERRAL

In the preliminary referral stage, the first process in the overall procedure the utility submits a summary of the proposed transmission line project to Alberta Environment, which is coordinator of this stage. This summary includes a description of the proposed development and of the study area, a regional route identification and evaluation, and a selection of alternative and preferred routes.

Alberta Environment, forwards the summary for review to other interested government departments (Alberta Culture, Alberta Recreation, Parks and Wildlife, Alberta Agriculture, Alberta Energy and Natural Resources, and Alberta Municipal Affairs) who then forward the comments and concerns received to the utility.

Alberta Environment, along with the ERCB, determines whether, and how extensive, an environmental impact assessment (EIA) is required. EIAs are required by Alberta Environment for major energy-related projects pursuant to the Land Surface Conservation and Reclamation Act, which it administers. As a general rule, high voltage transmission lines of significant length require a detailed EIA, although such requirements are judged on a project-by-project basis. If an EIA is required, it will be filed by the utility as part of the formal application to the ERCB for the project.

The utilities are encouraged to disclose their initial project concept to the public as early as possible. So, during this stage, the utilities also mail information packages to anyone who may be affected by the transmission line. Public information meetings are also held throughout the area of the proposed line.

PROCESSING OF APPLICATIONS

Applications

The ERCB, under the Hydro and Electric Energy Act, requires application for all new substations, for alterations to existing substations, and for all new and alterations to transmission lines from 69 kV to 500 kV. The application will generally consist of four sections: project description, technical and environmental information, and an economic assessment. Details of the information required in an application are outlined in the ERCB's Guide G-22 entitled, "Guidelines Respecting an Application to Construct or Alter an Electric Transmission Line."

These guidelines were developed jointly by the ERCB and Alberta Environment to meet the requirements of both agencies and to enable the utilities to identify early in their planning the specific type of information expected to be filed with the application. These requirements are summarized below:

The project description includes a discussion of the need for and any alternatives to the proposed facility; maps and drawings showing the preferred and/or alternative routes; and maps and/or air photomosaics showing the major land-use and resource features.

Technical information includes the design capacity and operating voltage of the transmission line; a description of the proposed structures; a construction schedule; and a list of major equipment to be installed.

Environmental information includes a description of the study area; a comparison of major land-use features; a discussion of each route's impact on major land use and resource features; environment trade-offs and costs associated with the alternative routes; and methods for rights-of-way clearing, reclamation, and maintenance.

The economic assessment includes land costs; capital investment; annual operating and maintenance costs, including those associated with transmission losses; and identifiable costs associated with unavoidable environmental impacts.

Review and Disposition of Applications

Upon receipt of an application, the ERCB's Hydro and Electric Department reviews the application to ensure that the technical, environmental, and economic information is sufficient for a proper assessment of the proposed transmission line. The application is also forwarded to Alberta Environment and Alberta Energy and Natural Resources for review and comments regarding the environmental information within the application. The procedure of directing the application and all information related to it through the ERCB ensures that all the information is contained in one document and is directed to all those concerned at this stage of the processing.

Once all the necessary information has been received, the application is classified into one of two categories, major or minor. Major applications have substantial impact and therefore, require a notice for objection or a public hearing. Minor applications may be approved without notice or hearing.

Where public notice for objection is required, the notice is mailed to all landowners and/or occupants within one-half mile of all the proposed routes. The notice is also placed in the local newspapers and sent to all government departments. If no objections are received and the ERCB is satisfied that the transmission line is required, the application is approved.

If objections are received, they are reviewed by the ERCB and might be discussed with the utility to see if the objections can be resolved. If the objections cannot be resolved, or if there are numerous objections, a public hearing is normally scheduled. Depending upon the type and extent of the objections, the public hearing could be restricted in nature; i.e., the ERCB could approve a portion of the line and hear the remaining portion.

The notice of hearing is advertised in the same manner as the public notice. The hearing is usually held in a location near the project area.

The utility provides copies of the application to those parties who may request them.

Submissions by Interveners

Persons or landowners who have received notice of the Board's public hearing and who may be adversely affected by the proposed transmission line and who wish to be heard are required by the Board to provide written submissions (interventions) filed prior to the hearing. Copies of the submission must also be filed with the utility.

The Board expects the interveners to outline their position in their written submissions, including their concerns and reasons for them. Submission should indicate the interest of the interveners, the nature of the interest to be affected or a description of the affected land, and how the intervener views the adverse effects of the project. The submission may also make reference to matters the intervener considers relevant and appropriate.

Provincial government departments or agencies may also appear as interveners at the hearing and participate in the same manner as the other interveners. However, if they wish not to appear, a special provision of the regualtions allows them to submit a statement to the Board and supply a copy of it to the utility and other interveners. The Board may then accept the statement as evidence, without the need for cross-examination.

Hearing

The utility presents its application at the hearing and is then questioned by all interested parties, ERCB staff, and the panel members. The interveners then present their submission and are, in turn, questioned. The interveners and the utility conclude with summary statements.

The ERCB staff may request the assistance of the Alberta Environment staff, particularly when the application heard involves environmental issues. Similarly, the Board may appoint an acting member with specific expertise and background experience to the examining panel.

Jurisdiction and Scope of Hearing

In all cases, the ERCB is constrained by its legislative authority. For example, adequate and reasonable compensation for the use of an intervener's land may be an extremely important concern to a landowner. The ERCB, however, does not have jurisdiction to determine what constitutes adequate and reasonable compensation for purposes of making an award of compensation. Such matters are to be dealt with by other tribunals, usually the Alberta Surface Rights Board. For purposes, however, of deciding whether a project should be allowed to proceed, the ERCB may evaluate the project on the basis of the financial magnitude of the adverse impact on lands. The ERCB's jurisdiction encompasses matters of the environment and of the public interest as well as conservation and orderly development. If the ERCB decides the project should proceed, its jurisdiction does not extend to resolving the environmental or public interest concerns beyond conditioning the manner in which the project is developed. This does not necessarily mean such environmental or public interest issues will go unresolved. When the ERCB hears environmental or public interest concerns which it has no authority to resolve, its written decision brings such matters to the attention of the government or the appropriate government department or agency that might address those problems.

The Decision

After the completion of the hearing, the examining panel will recognize the issues which have emerged (e.g., need for the proposed facilities, route of the line, specific issues related to the specific project). It may call on the ERCB and Alberta Environment staffs to assist in reviewing the hearing's evidence and data. The Board's decision is presented in a report which is released to the public. Appropriate permits and licenses for facility construction and operation are then issued.

SUMMARY

This single regulatory process provides several benefits:

1. It does not impose several parallel approval processes on the electric industry and the public.

2. It allows all parties, particularly those government departments with environmental responsibilties, to obtain adequate information to ensure full consideration of environmental concerns.

3. It contributes to a shorter regulatory process for obtaining approvals necessary to proceed with construction of the facilities.

The Board realizes that transmission lines are seldom popular with the general public. The regulatory process attempts to accommodate invididual interest while at the same time ensure economic, orderly, and efficient development of facilities in the public interest. Delays and costs associated with lengthy public hearings tend to find their way back to the consumer in the form of higher utility rates. It is thus in the interest of all parties to have a fair but efficient process for the approval of transmission lines. Therefore, the Board has attempted, and will continue to streamline its regulatory process so that the time involved in approving an electric transmission line is as reasonable as possible.

EFFECTIVE MANAGEMENT AND DISPOSAL OF ELECTRIC UTILITY COMPANY RECREATIONAL LAND

W. L. Reid[1]

ABSTRACT.--Utility companies have vast holdings of land. They have a duty not only to manage them while owning them, but to endeavor to assure their management and development, following sale, in a manner compatible with sound land use and environmental principles. This paper discusses how one utility company accomplished this for over half a century of ownership, management, and recent sale with some 100,000 acres (40,500 ha) of undeveloped recreation land.

INTRODUCTION

Consumers Power Company in the period following the turn of the last century acquired over 100,000 acres (40,500 ha) of land on the AuSable and Manistee Rivers in northern lower Michigan. Most of the property was acquired from small predecessor utilities and from lumbering interests. Eight dams and hydroelectric generating stations were built with the remaining land being held for construction of future dams. However, the future dams were never built because the development of larger fossil fuel plants closer to the Company's load centers made them unnecessary.

Over the years most of the lands were held in their natural state and the public was welcomed and encouraged to use them in day use recreational pursuits. Some lands were leased to the Michigan Department of Natural Resources (MDNR) and to local governmental units for campgrounds and more formal recreation pursuits. Other lands were leased to individuals for cabin site and recreational purposes. There had been some 300 of these private cabin site leases.

LAND MANAGEMENT

The Company operates eight hydro plants and associated lands totalling about 30,000 acres (12,150 ha) in Michigan. They are and will remain under Federal Energy Regulatory Commission (FERC) license. The remaining 100,000 acres are surpluse to the Company's needs for utility purposes.

While the Company enjoyed substantial public relations benefits from its ownership and management of the non-licensed lands, its financial

1 Consumers Power, Jackson, Michigan.

condition, like that of so many utilities, worsened as the need for large amounts of capital increased. Escalating taxes and other land management costs together with the increasing difficulty of controlling public usage, litter, and squatters became the more dominant concerns. Thus, it was determined in 1975 that the Company should attempt to sell all of the non-licensed lands.

Certain of the lands (approximately 28,000 acres (11,340 ha)) were located within the boundaries of two national forests and were offered to the United States Forest Service (USFS). Other lands within or near boundaries of various state forests fish and game areas (35,000 acres (14,175 ha)) were offered to the Michigan Department of Natural Resources (MDNR). It was also determined that all existing lessees, be they private individuals or public agencies, would be offered the opportunity to acquire their leaseholds and protect their investment in one of three ways. These were outright purchase, a 30-year lease at a much higher rent than at present, or a year-to-year lease at the current rent.

Many of the lessees as well as the governmental agencies were concerned that restrictions be included in the sales to prevent overdevelopment and undesirable development by the lessees and new owners. A list of these restrictions is shown in Table 1. It was also essential that all lease sites be surveyed and their boundaries adjusted so that each was at least 10 acres in size. Otherwise, the entire project would become subject to the Michigan Plat Act. Road (or trail) access also had to be assured. Because the Company provides both electric and gas service, it was also important to protect its interests by retaining all minerals (gas, oil and hydrocarbons) and to protect all existing, and to the degree possible, future electric and gas facilities by retaining easements and/or fee strips.

The most difficult problem probably was that of securing government appropriations to match negotiated purchase price from government agencies. This required lengthy and detailed negotiations with the government agencies who were purchasing. Considerable conversation with Congressmen, state legislators and their aides was another essential ingredient.

CURRENT STATUS OF THE PROJECT

A total of 19,000 acres (7,689 ha) have been sold to the Michigan Department of Natural Resources in three separate transactions for a total of $8.5 million. Sale of remaining lands held for the State (approximately 15,000 acres (6,075 ha)) are under discussion at the present time with no specific sales expected before late 1983. In a large purchase completed just at the end of 1980, the USFS acquired 25,700 acres (10,408 ha) for a total of $13.5 million. There are only about 2,000 acres (809 ha) held for later sale to the USFS. An attempt will be made to secure appropriations to proceed with this in fiscal 1983. Approximately one-half of the private leases have been disposed of with 70% of these purchasing their leasehold and 30% continuing to lease, most on the basis of the 30-year unbreakable lease. This will be a continuing operation for the next 18-24 months. More than $3.25 million has been thus far committed for the purchase of leaseholds.

SUMMARY

The public has benefited from the sale of these acreages of land going into public ownership and being held for the recreational pursuit of future generations. The Company has benefited by converting the unneeded assets of land into very much needed capital dollars, and the Company rate-payers have benefited because the cash generated reduces future interest payments for money that would otherwise have to be borrowed. The government has benefited by acquiring these major holdings in a relatively small number of purchases and from the Company's commitment to hold the lands for them for a reasonable time. The Company's lesses benefit by being given a variety of options by which they can acquire their leasehold and protect their investment in cabins and other facilities. The main disadvantage is the loss of real estate tax revenue to the various governmental units involved. While both the State of Michigan or the USFS make payments in lieu of taxes on lands they own, these payments are substantially less than ad valorem taxes.

Table 1. Declaration of restrictions.

T75-150A

DECLARATION OF RESTRICTIONS

WHEREAS, Consumers Power Company, a Michigan corporation, with its principal office at 212 West Michigan Avenue, Jackson, Michigan, (herein referred to as "Consumers"), is the owner of certain lands in the County of Crawford, Michigan, as described in Exhibit A which is attached hereto and made a part hereof, and

WHEREAS, in connection with the proposed sale of some or all of said lands, Consumers desires to make said lands subject to certain use restrictions for the purpose of maintaining the present natural beauty and open space character of said lands.

NOW, THEREFORE, Consumers, as owner of all of the lands described in Exhibit A, does, for itself, its successors and assigns, hereby declare that said lands described in Exhibit A are subject to the following use restrictions:

1. Said lands shall be used for single family residential purposes and for recreational purposes, including all uses necessarily or customarily incidental to said purposes. No commercial or business activity of any kind shall be conducted on said lands.

2. Not more than one permanent single family residential structure with appurtenant buildings shall be constructed or placed on each parcel of land described in Exhibit A.

3. No buildings or other structures hereafter erected on said lands shall be located within 200 feet of the edge of the Au Sable River.

4. No trees, except trees that are dead, diseased or unsafe, will be cut or removed within the area lying between the edge of the Au Sable River and line drawn 100 feet upland from and parallel with the edge of said river.

5. No billboards or commercial outdoor advertising structures of any nature shall be located on said lands.

6. Anything in paragraphs numbered 1 through 5 to the contrary notwithstanding these use restrictions shall not prevent (i) the use of said lands for roadways, (ii) the use of said lands for utility lines, (iii) the commercial cutting of trees, (iv) the exercise by Consumers of all rights in connection with its ownership of oil, gas and other hydrocarbons, (v) the replacement of or an addition to any single family residential structure and appurtenant buildings existing on a parcel of land on the date of this Declaration of Restrictions and (vi) the replacement of or an addition to a building or other structure located within the area described in paragraph numbered 3 on the date of this Declaration of Restrictions.

7. Anything in paragraphs 1 through 5 to the contrary notwithstanding these use restrictions shall not prevent nor shall they be construed to preclude the acquisition of the lands herein described by any agency of federal, state, or local government, and the provision and development thereon by such agencies of facilities and services for public outdoor recreation.

The foregoing use restrictions are intended to cover the lands described in Exhibit A only, and are not to be extended or deemed applicable to any other property of Consumers by implication, inference, or otherwise, unless by a like declaration in writing and duly recorded.

IN WITNESS WHEREOF, this Declaration of Restrictions has been executed by Consumers this 10th day of March, 1980.

Witnesses:

W L Reid

Carol J. Kielar

CONSUMERS POWER COMPANY

By G. L. Heins

G L Heins
Vice President

CONSUMERS POWER COMPANY LEGAL DEPARTMENT

wlk

STATE OF MICHIGAN)
) SS.
COUNTY OF JACKSON)

The foregoing instrument was acknowledged before me this 10th day of March, 1980, by G L Heins, Vice President of Consumers Power Company, a Michigan corporation, on behalf of the corporation.

Carol J. Kielar
Carol J Kielar
Notary Public, Jackson County, Michigan
My Commission Expires 12/22/81

PREPARED BY B. E. HAGEN
CONSUMERS POWER COMPANY
212 WEST MICHIGAN AVENUE
JACKSON, MICHIGAN

APPLICATIONS OF AERIAL PHOTOGRAPHY IN TRANSMISSION LINE NATURAL FEATURES STUDIES

Nancy L. Van Dyke and Allen C. Cassaday[1]

ABSTRACT.--At Pennsylvania Power and Light, a detailed map depicting all "natural features" (e.g., vegetation cover types, aquatic resources) of the study area is prepared during the initial steps of the transmission line siting process. This map, along with a report describing the study area environment, becomes an integral part of the line route selection analysis. Accuracy is important, and existing maps often do not supply up-to-date or sufficiently detailed information.

Aerial photography and field reconnaissance are used to collect this information. Several applications of aerial photo prints and different types of photography for natural features studies have proven extremely useful during field studies and in mapping, including large scale photography, contact print blowups, orthophotos with additional information (e.g., contour lines) superimposed, and color infrared slides.

The discussion includes a brief description of the various techniques and applications, and also describes how they help in identifying natural features and in supporting the line route selection process at public hearings.

INTRODUCTION

Knowledge of an area's vegetation cover types, streams, wetlands, and other "natural features" plays a key role in selecting a preferred transmission line route and in predicting impacts, costs, and mitigative measures. Often these features are not only environmentally sensitive areas, but also involve major construction or cost constraints. Therefore, a natural features inventory should be one of the first steps in any successful transmission line siting process.

The inventory must be accurate to be useful and defendable. In many cases, maps or photography which are out-of-date or of insufficient working detail present major roadblocks to achieving the accuracy needed. For example, USGS maps are generally not current, provide little detail, may miss or incorrectly locate small streams and wetlands, and do not differentiate between different vegetation cover types. Photography available

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from company files or from public agencies is also often outdated or of extremely small scale, or lacks corresponding stereoscopic contact prints. Furthermore, where data is old, lacking or doubtful, ground truthing is often not possible, due to inaccessibility or legal problems.

Most of the transmission line projects at Pennsylvania Power & Light Company (PP&L) involve 138 kV lines, 4 to 5 miles (6.48 km) long, with study areas of 15 to 30 square miles. The purpose of the siting studies done for these projects is to select alternate line routes, not just broad corridors. Every alternate route selected must be acceptable from environmental, engineering, and economic standpoints. Because the end product is a line route, and because the study areas are relatively small, one cannot afford to miss detailed information. Several aerial photography techniques have been extremely helpful in obtaining the accuracy needed. Although these techniques are not necessarily new ideas, they are sometimes overlooked by people not familiar with their availability, ease of use, and cost effectiveness.

AERIAL PHOTOGRAPHY TECHNIQUES AND APPLICATIONS

Large Scale Aerial Photography

A primary source of natural features information is recently flown panchromatic black-and-white aerial photography ordered at scales of 1" = 800' or greater. This large scale greatly helps in aerial photo interpretation of vegetation types and aquatic features, and also in pinpointing land use details. For small study areas, it is only slightly more expensive than 1" = 2000' scale prints (e.g., $100-$200 more for 16 square miles).

In addition to contact prints, an orthophotograph of the study area is ordered at the larger scale. In orthophotography, distortions due to camera tilt and topographic relief are removed. Therefore, the photograph becomes a "photomap." In cases of relatively long lines (e.g., 10 miles (16 km)), a mosaic is used instead of an orthophoto in order to keep costs down. A mosaic is made by splicing the individual contact prints together, without correcting for distortion. In all cases, photography is specified for leaf-, snow-, and cloud-free conditions, if at all possible.

Information Superimposed on the Photomap

Information can also be added to the photomap by producing a print of the orthophoto with other information enlarged or reduced to the same scale. This additional information can be soil survey data, a USGS topographic quad map, or contour lines.

Adding contour lines to the orthophotograph produces an extremely useful photomap. This type of map is the basic tool used in interpreting natural features and other inventory information from contact prints and field notes. The ability to simultaneously view the vegetational cover, aquatic features and topography is a major advantage and eliminates constantly crosschecking more than one map. The contour information aids in pointing out wetlands (e.g., depressions, low slope areas near streams, headwaters), vegetation cover types (topography used as a clue to probable species composition), streams, and drainage swales (see Figure 1). This type of map is also valuable in interpreting soil survey maps, which are often difficult to enlarge to a correct scale, in land use interpretations, in impact analysis, and in habitat surveys.

A different photomap can be produced by superimposing the entire USGS topographic map onto the aerial orthophoto. This map is also quite useful, especially during field surveys since the location information from the topo map is readily seen along with the vegetational cover (Figure 2). This photomap is used during the final placement of alternative routes when alignments are field checked and all final adjustments are made.

Although use of these types of photomaps is not a new technique, it is often overlooked. The cost of producing such maps is relatively minimal. USGS map or contour line information can be added to the orthophoto by first making a reproducible mylar enlargement of the contours (taken from USGS contour plates--approximately $22 each) or of the USGS topographic maps (approximately $2 each). The enlargement is then duplicated simultaneously with the aerial photo reproducible obtained from the photographic contractor. A mylar reproducible for a 16 square mile study area costs about $45. It is also possible to make a composite map, in which the USGS or contour information is superimposed directly onto the orthophoto reproducible. This process costs approximately $135 for a similar size study area.

Contact Print Blowups

Contact print enlargements, or "blowups," involve enlarging an individual contact print (normally 9" x 9" (23 x 23 cm)) to a print 36" x 36" (91 x 91 cm).

Blowups are used to point out details to audiences, to focus in on one area (e.g., a sensitive natural area), to provide greater interpretive ability, and to display or develop the specific mitigative measures needed in sensitive areas. Enlargements are obtainable from the aerial photographic contactor at a cost of approximately $30 (paper print) to $45 (reproducible).

Color Infrared Aerial Photography

Color infrared photography is particularly useful in natural features studies. Infrared film differs from the normal panchromatic film in its sensitivity to different wavelengths of light. Features are recorded similarly, but appear with "false" colors. The film is especially good for distinguishing different vegetation cover types and wet areas.

Vegetation texture is much more emphasized than in the black-and-white photography. Different types of vegetation and successional stage can be more readily distinguished. Although leaf-free black-and-white photography usually picks up the contrast between deciduous and coniferous growth more distinctly, color infrared film makes this distinction even when the trees are in leaf. This eliminates the time constraint involved in limiting flying to leaf-free seasons only. The infrared film is also helpful in identifying and determining the extent of water-related

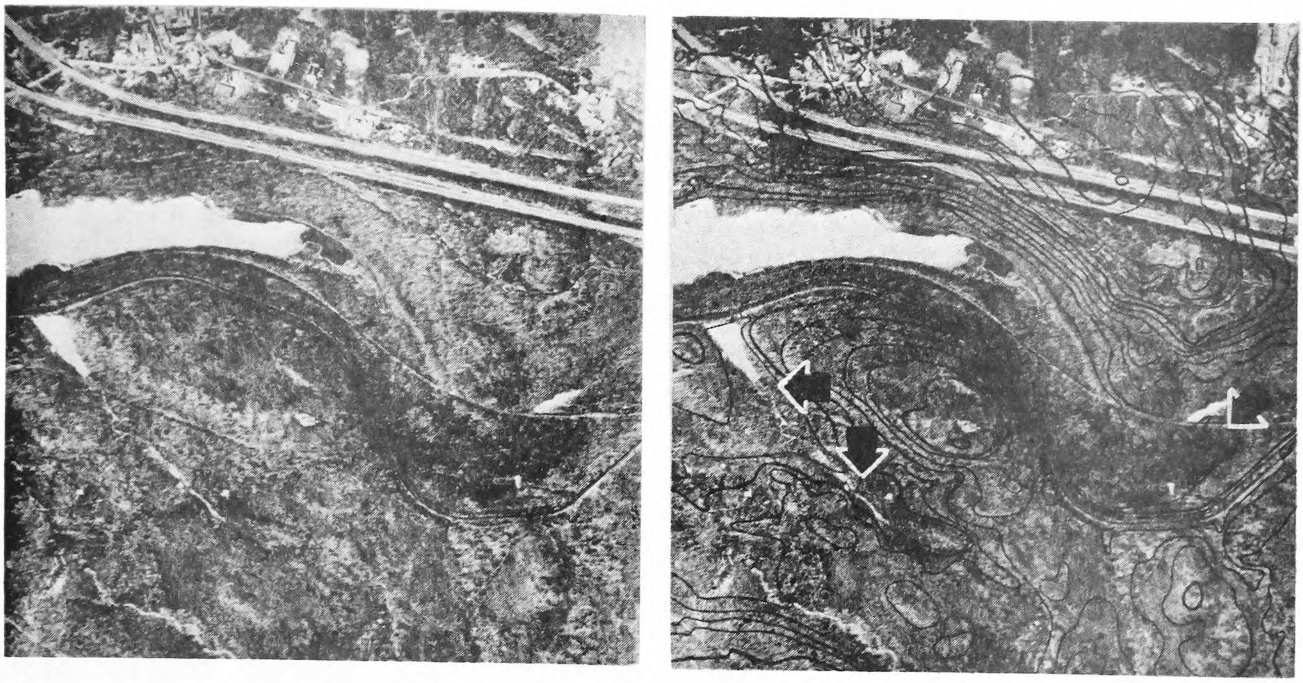

Figure 1. The addition of contours to the orthophoto helps to locate streams, ponds, and wetland boundaries (see arrows).

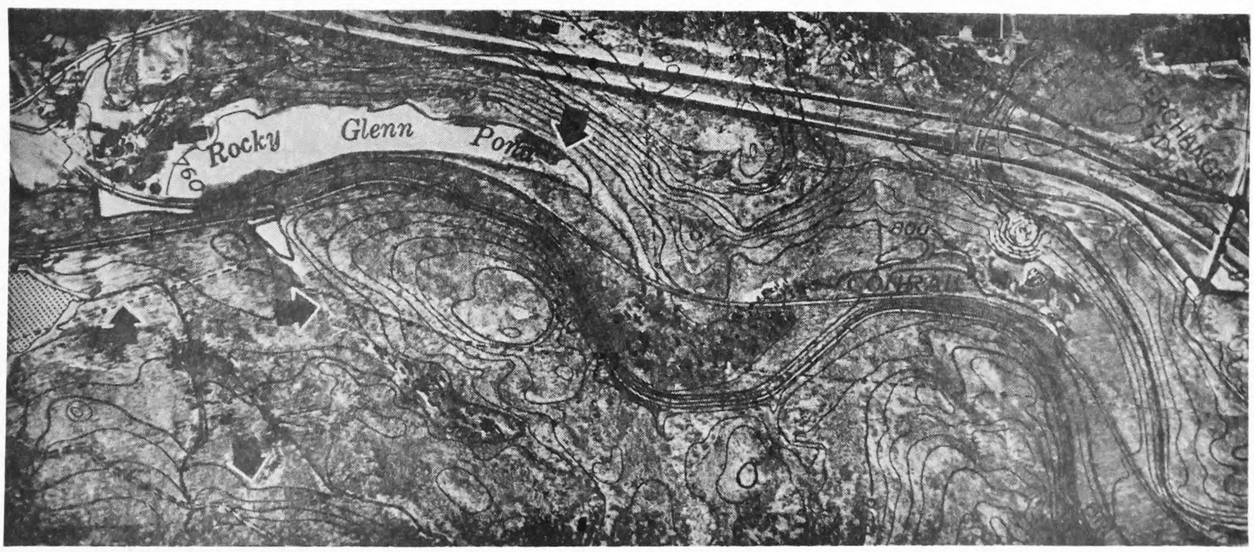

Figure 2. The USGS map information pinpoints useful field access points such as roads, railroads, and utility lines, as well as water bodies, towns, etc. Note that the USGS map misses such features as wetlands and small stream courses (see arrows).

features--wetlands, streams, drainage swales, and water bodies. All these photograph as bright blue to blue-green features or as darkened areas on the infrared film, and they stand out against the normally red vegetation.

Color infrared slides or more expensive paper prints can be used. The slides can be projected onto a screen adjusted for maximum enlargement and interpretative ease, or set so that a particular scale is obtained. In addition, they can be projected onto a paper print base map to make mapping data easier. Such slides are very inexpensive, relative to other aerial photography costs (e.g., slides for up to an 80 square mile study area were provided for approximately $700). Price depends mainly on flying time and will, therefore, vary with the location of the aerial photo contractor. Unlike the other techniques discussed, this application has great potential for very large study areas, since large areas can be covered at a relatively small cost.

CONCLUSIONS

It should be recognized that the type and scale of photography used to support specific projects depends on the size of the study area and the level of detail required. Because the cost and size of large scale orthophotography can be prohibitive for large study areas, many of the techniques discussed have the greatest application for smaller transmission line projects. However, they can be applied to certain portions of larger jobs, especially after a preferred route has been selected, or in sensitive "high priority" areas, where more detailed investigation is required. Many of these techniques are also very valuable in supporting other inventory stages of transmission line siting, especially land use and visual analyses.

ACKNOWLEDGEMENTS

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TOWARD OBJECTIVE VISUAL IMPACT ASSESSMENT: PHOTO-SIMULATION AND AN ALASKAN CASE STUDY

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ABSTRACT.--The role of color photosimulations in assessing potential visual impacts is discussed. Particular reference is made to the application of color photosimulation technology in the environmental assessment process for a proposed 345 kV transmission facility between Anchorage and Fairbanks, Alaska.

Visibility variables, technology selection criteria, and the photosimulation process are discussed within the context of the Alaskan case.

INTRODUCTION

The Alaska Power Authority is currently studying numerous power grids and primary electrical generation sources in the State. A feasibility study for one such project, the first electrical interconnection between Fairbanks and Anchorage, has recently been completed and route planning is proceeding (Commonwealth Assoc. 1981).

The primary purposes of the proposed interconnection have to do with potential benefits of economy interchange and reserve sharing. Studies for the interconnection have been framed by the potential need of 160 miles of new transmission facilities and additionally, to coordinate any new plans with the long-standing proposal to construct the Susitna Hydro Project. This 1200 megawatt generation facility would be located approximately halfway between Anchorage and Fairbanks. Current thinking is that it will come on line prior to 1995 and possibly utilize the corridor selected for the subject interconnection.

Feasible corridor choices for the interconnection were essentially limited to three. The new transmission facilities can parallel either the existing Parks Highway or the Alaska Railroad corridors or be partially built within each with occasional cross over sections between them. Each of these choices has its own set of problems related to geography, ecology, construction cost, and perceived social costs.

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The task of sorting out the problems and recommending the best corridor or combination was awarded to Commonwealth Associates, a Jackson, Michigan, firm of engineers, consultants, and planners. That firm's Environmental Systems division was also charged with conducting an environment assessment of the potential impacts associated with the construction of alternative transmission alignments, and the choices of tower and conductor designs and materials.

Visual impact was one of the dominant concerns voiced by public officials and private citizens in the area to be influenced. As part of the environmental assessment the degree of visual impact or change to be created by a select number of favored alignment alternatives was to be determined through photosimulation (Scheele 1981).

METHODS

Primary Visability Variables

The degree to which proposed transmission facilities can be seen is dependent on the interplay of certain variables which fit under the headings of social, temporal, and physical phenomena.

Social. The expectations, values, perceptions, and observation positions of the types of potential viewers must be identified. Included are considerations of current versus future viewers, tourists versus permanent residents, land managers versus land users, and ground level viewers versus those in aircraft.

An analysis was conducted from selected points adjacent to the Parks Highway and from the top of Curry Ridge. This addressed concern for the view of users traveling this highly scenic road corridor and using Denali State Park.

Temporal. The ability to perceive visual change is strongly influenced by season of the year, time of day, and ambient light conditions (Litton 1972). To conduct a study of the predicted visual consequences of change, field work should be conducted at various times of the year under variable conditions of light and climate.

Physical. Factors related to landscape scale (figure-ground relationship), land cover, relative topographic relief, patterns of color, distance between viewer and object, and the mass, color, form, and material of the object being viewed are the primary conditioners.

The landscape surrounding the various alignment alternatives studied are large scale relative to the proposed transmission towers. The topographic relief is highly variable within a range of 4000 feet. The predominant land cover is coniferous vegetation in the overstory and deciduous shrubs low to the ground. Predominant land cover colors were classified as 5.0GY 4.0/8.0, 5.0GY 7.0/10.1, and 4.7Y 9.0/4.0 on the Munsell scale in the season of field analysis (Munsell 1977).

Additional physical variables of great importance include distance and the characteristics of the principal objects being planned; i.e., the transmission towers. Distances between proposed alignment alternatives and viewers ranged between 700' and 21,000'. Transmission towers were designed to be between 85' and 105' high and single pole or 'X' type (Figure 1). The proposed tower material was Cor-Ten steel. Thus, the towers would appear rust colored in the foreground and gradually appear to shade toward flat black as the distance from the viewer increased.

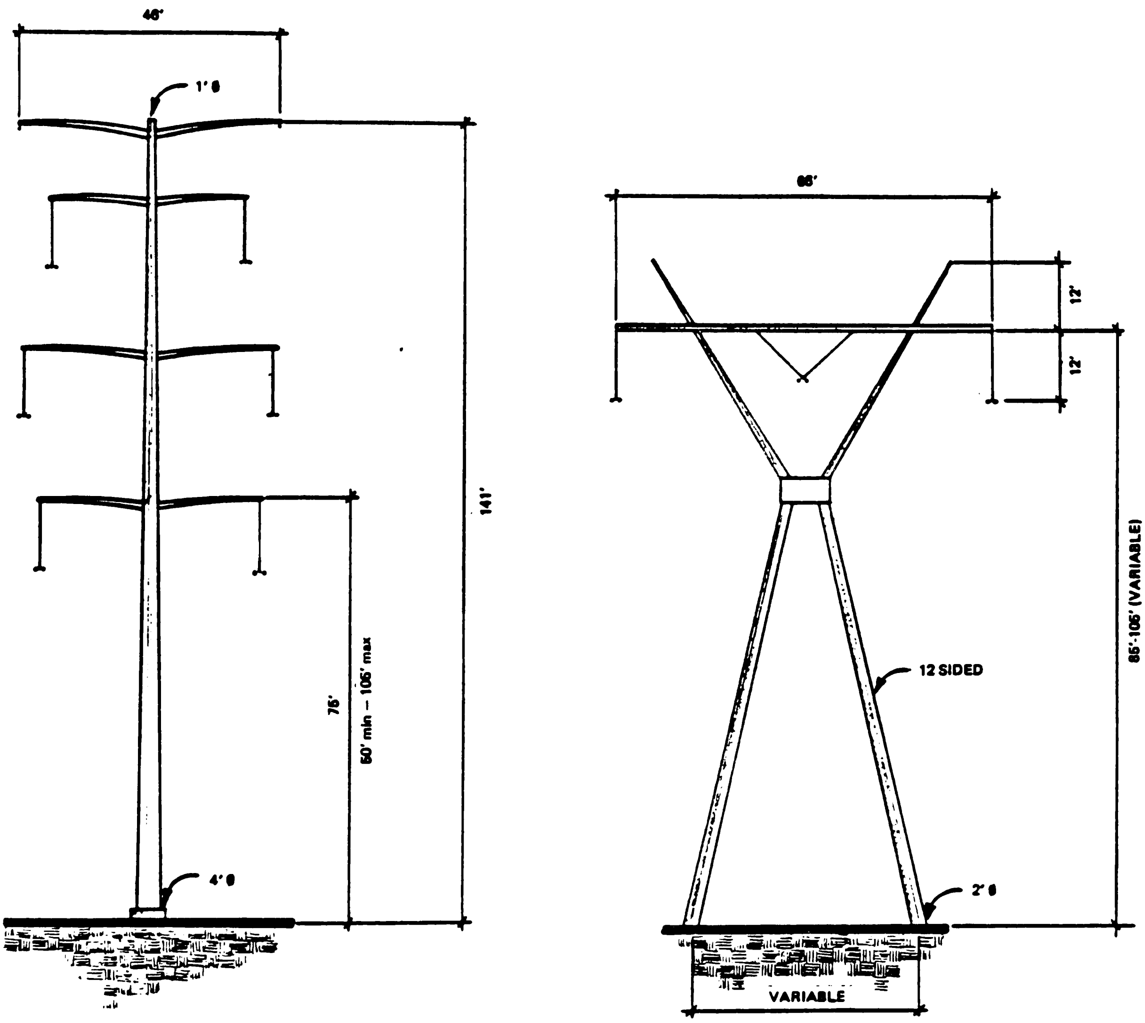

Fig. 1. Transmission tower types.

PHOTOSIMULATIONS

There are a number of visual simulation evaluation technologies which might have been chosen for the task at hand. Appleyard (1976), Ady et al. (1979), Baird et al. (1979), Scheele and Sullivan (1979), Roundy (1979), Howlett (1979), U.S.D.I. Bureau of Land Mangement (1980), Berg (1981), and Nickerson (1981) among others have experimented with various techniques. They rely on photographic, video, or computer generated imagery as the base for visual simualtions which in turn, yield varying degrees of realism.

Photosimulations based on color photographic prints as base material most closely match the project requirements. Color slides and black-and-white prints were chosen as the desired products. This range of photographic media best satisfied the additional project requirement for presentation of study results to large on-site live audiences and duplication in project reports.

The photosimulation process involves the photographic superimposition of a film image of the object to be built onto a film image of the landscape in which it is to be built. Double, and sometimes triple, exposure of images are made onto the same film frame.

Murray and Niemann (1979) underscored the need for accurate and thorough analysis and field documentation requirements when addressing visual issues thought to be contentious and subject to possible scrutiny by the courts. Accordingly, a complete log which records the particulars of each viewpoint chosen for photographic simulation was kept. This included the location of the viewpoint by known reference point, the corrected compass direction of the view enclosed in each photographic frame, the film type, frame number, shutter speed, aperture openings, time of day, location of sun in sky vault, ambient light as measured in foot candles, and the extant weather conditions.

The steps involved in accurate photosimulation construction are depicted in Figure 2. Scaling and creating object images are two critical steps.

The USDI Bureau of Land Management has identified a series of scaling procedures which can be used to construct the object(s) to be simulated into the base photograph (BLM 1980). Two of these, the Project and Scaled Equation Techniques, proved useful. The use of either technique requires knowledge of the location of the subject alignment on a scale plan, the expected distance between towers, the height of the towers, and the length of the alignment which would be captured in the base photography. The Scaled Equation Technique further requires the measurement of an object of known dimensions in the base photograph to use as a guide when proportionately reducing or enlarging images of the object to be simulated. A transparent, to-scale view-cone template also proved invaluable in determining the length of alignment which would appear in each simulated setting (Scheele 1981; Shipman 1977).

Object/transmission tower imagery can be created for use in simulations through the use of photographs of existing built projects which match the details of the proposed development or by use of perspective drawings. Particular attention to line weights is necessary for drawn objects to be located in the middle ground or background of a view. The object can appear too sharp and bold in the setting if the line weights are too heavy.

Ortho contact negatives and positives are created as masks after the object imagery is drawn to correct scale and perspective. When the masks are created the photographic superimposition process can begin.

Photographic superimposition is the final step in the photosimulation process and involves exposing the base color photograph with the Ortho positive overlay onto one film frame. For color photosimulations the

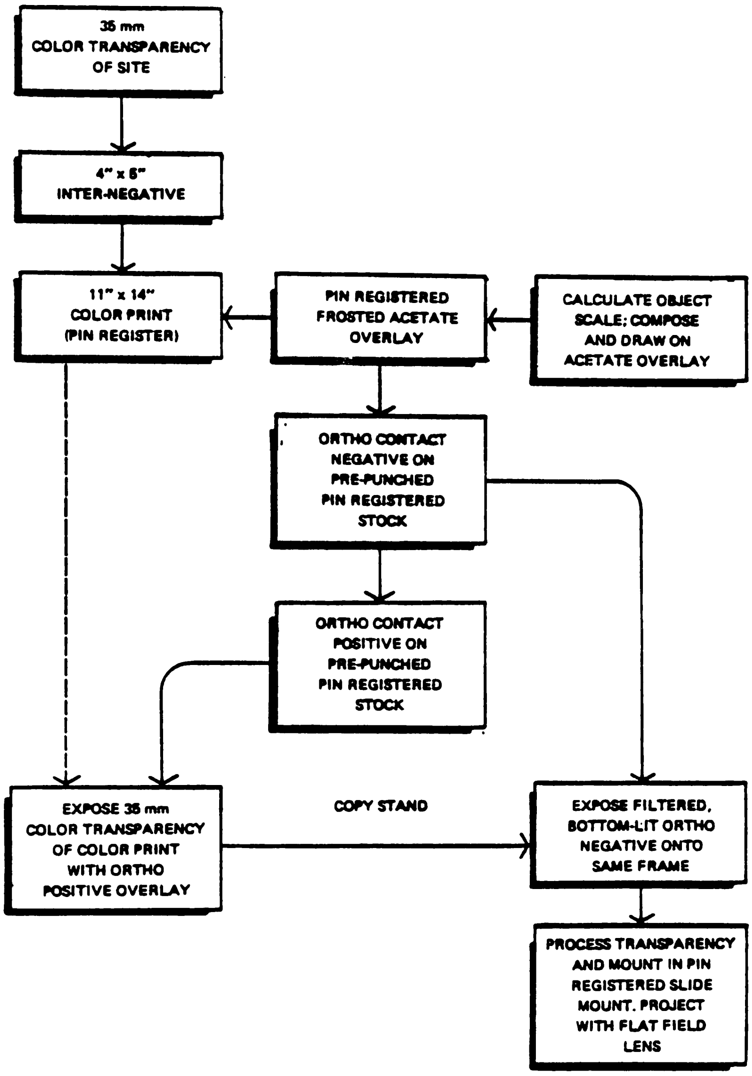

Fig. 2. Photosimulation construction process.

backlighted Ortho object negative is then double exposed onto the same frame through the color gel filter combination which most closely matches the actual color of the object in its setting. Choice of the color gel filter combination requires informed judgment and experimentation. This judgment is aided through study and understanding of the effects of the ambient light and direction of solar radiation depicted in the base photograph and the proposed color of the object in similar settings.

The entire photosimulation construction process requires use of a pin registry system. Base drawings and the Ortho masks are created over pin bars, and photographic superimposition requires use of a pin registered camera if accuracy tolerances are to be maintained. The Oxberry Pro Copy F2 System proved a particularly efficient and useful piece of pin registry technology for photosimulation construction purposes (Oxberry 1979).

SUMMARY

The use of photosimulations can be an extremely useful means of judging visual impacts of alternative transmission alignments during project planning and design. The process of photosimulation creation requires close attention to, and understanding of, visibility variables and rigorous adherence to applying a detailed methodology. Complete field records, accurate object scaling and construction technique, and skillful use of photographic equipment can yield highly realistic imagery prior to project construction. Thus, those involved in management decision making in rights-of-way, whether public or private bodies, have access to a powerful means of visually testing alternative corridor/alignment proposals before the fact. Color photosimulations yield realistic imagery of proposed projects in the proposed location and also provide the benefits of easy transportability, reproducability and low cost.

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THE MANDAN PROJECT - AN INTERNATIONAL PERSPECTIVE ON EHV TRANSMISSION LINE SITING

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ABSTRACT.--The MANDAN Project proposed by Manitoba Hydro and Nebraska Public Power District is a 600-mile (966 km) international, interstate EHV Transmission facility from Winnipeg, Manitoba to Hoskins, Nebraska. The facility will consist of a 500 kV AC transmission line with terminals in Manitoba and Nebraska and substations in North Dakota and South Dakota. The project is designed to provide for seasonal diversity exchanges of energy and power between winter and summer peaking utilities with capacity also available for other transactions. Coordination and consultation between three state governments, one provincial government and the Federal Governments of Canada and the United States dictate the necessity of developing a process that would balance international, regional, and state concerns, provide adequate coordination between the participants in Canada and the United States, and identify routing preferences acceptable to the wide range of environmental regulatory requirements.

INTRODUCTION

The MANDAN Project transmission facility will consist of a nominal 500 kV, AC single circuit, electric transmission line with terminals in Winnipeg, Manitoba, and Hoskins, Nebraska, and substations in North Dakota and South Dakota. The line will be capable of carrying 1000 megawatts between the Canadian and North Dakota substations, and 1200 megawatts between the North Dakota, South Dakota, and Nebraska substations. The transmission line will be approximately 600 miles (966 km) long, and will interconnect the transmission systems of Nebraska, South Dakota, and North Dakota with the transmission system in Manitoba.

The major purpose of the MANDAN Project is to provide for seasonal diversity exchanges of electric power and energy between winter and summer peaking electric utilities with transmission capacity also available for other types of transactions. The Project will also transfer economy energy, emergency energy, scheduled outage energy, storage of energy,

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adverse hydro replacement energy, participation power and energy, and firm power and energy.

The MANDAN Project has been in development since 1974 through a series of discussions, a memorandum of understanding, feasibility reports, and detailed economic and technical studies. In June of 1980, a Letter of Intent was signed by Manitoba Hydro Electric Board (MHEB) and Nebraska Public Power District (NPPD) as the basis for developing a formal, definitive agreement.

NPPD is coordinating the United States portion of the project. It is acting on behalf of itself and other utilities in the United States which may become participants in the project. MHEB is the Canadian utility responsible for planning and constructing the Canadian portion of the project.

UNITED STATES REGULATORY REQUIREMENTS

Federal

Two United States Federal Agencies that will have regulatory responsibility for the MANDAN Project are the Economic Regulatory Administration (ERA) of the Department of Energy (DOE) and the U.S. Army Corps of Engineers (COE). The ERA is the lead Federal agency and will develop the Environmental Impact Statement (EIS) for the Project. A Presidential Permit is also required to construct, maintain, and connect facilities for the transmission of electrical energy at the boundary between the United States and Canada (Executive Order No. 10485, Part 32, of the Regulations of the U.S. Department of Energy, Economic Regulatory Administration), and an order must be secured from the ERA Pursuant to Section 202(e) of Part II of the Federal Power Act for the transmission of electrical energy from the United States. Section 10 of the Rivers and Harbors Act of 1899 requires a permit for crossing the Missouri River. In addition, a portion of the Missouri River is designated a recreational river under the Wild and Scenic Rivers Act. Other Federal agencies will become involved by way of Executive Orders concerning wetlands, floodplains, and historical preservation, and in the review of the Federal EIS.

An Environmental Report (ER) is being prepared by NPPD for submission to the Economic Regulatory Administration for input to the EIS. Draft portions of the ER are being submitted and the final ER will be submitted after state applications are completed. An application for a Presidential Permit is pending but no action will be taken until after the EIS has been completed.

State

State regulatory bodies will play the major role in the certification and siting of the MANDAN Project. Public hearings on the project are required by the North Dakota Public Service Commission (PSC), the South Dakota Public Utilities Commission (PUC), and the Nebraska Power Review Board (PRB). Following certification by these agencies, other specific and local agency approvals may be required.

North Dakota

The North Dakota PSC requires a Certification of Corridor Compatibility (corridor permit) and a Transmission Facility Permit (route permit) under the Energy Conversion and Transmission Facility Siting Act. The state siting act requires that no route shall be designated which violates the rules of any state agency or violates local land use, zoning, or building rule, regulations, or ordinances. A permit for the construction of a transmission facility may supersede and preempt any local land use, zoning, or building rules, regulations, or ordinances, as applied to the proposed route that are unreasonably restrictive in view of existing technology, factors of costs or economics, or needs of consumers regardless of location.

The North Dakota Public Service Commission requires that both the Certificate of Corridor Compatibility and the Route Permit for a transmission facility comply with designated criteria of exclusion and avoidance areas, and selection and policy criteria. Exclusion areas (which cannot be crossed by a transmission facility) include factors such as designated or registered parks, historic sites, wilderness areas, archeological sites; and areas critical to threatened, endangered, or rare plant or animal species. Avoidance areas (which cannot be considered for routing unless the applicant shows that there is no reasonable alternative) include designated or registered wildlife refuges; wildlife, forestry and grassland management areas; wild, scenic, or recreational rivers; areas which are geologically unstable; reservoirs and water supplies; areas within 500 ft (152 m) of occupied residences; and irrigated land.

The applicant must also demonstrate there will be no significant adverse effects to selection criteria such as agricultural production, irrigable land, extractive resources, and human or animal health and safety. The Commission will give preference to applications that maximize policy criteria such as training and utilization of local labor, commitment of a portion of the transmission product within the state, and utilization of existing rights-of-way.

A corridor application was filed in North Dakota in September 1980, and a certificate of Corridor Compatibility was issued by the North Dakota PSC in July 1981 after extensive hearings on the possible impacts of facility construction and operation. A route application will be filed in North Dakota in early 1982.

South Dakota

The South Dakota Energy Facility Permit Act requires a permit from the South Dakota PUC for a specific route for the transmission line. In addition to four burdens of proof on the siting of the proposed facility, recent legislation enacted by the South Dakota Legislature added a fifth burden of proof that any trans-state facility is necessary and satisfied the public need, convenience, and necessity. A 1980 Legislative Act defined a "trans-state transmission facility" as an electric transmission line and its associated facilities which originates outside the State of South Dakota, crosses this state and terminates outside the State of South Dakota; and which transmission line and associated facilities delivers electric power and energy of 25% or less of the design capacity of such line and facilities for use in the State of South Dakota. The legislation further states that, in addition to the route permit required by the South Dakota PUC, no utility shall begin construction of a "trans-state transmission facility" within the state without having first obtained approval by an Act of the South Dakota Legislature. The South Dakota Siting Act further has provision for the preparation of an Enviornmental Impact Statement, but this requirement could be waived if an EIS is required to be prepared pursuant to the requirements of NEPA. Subsequent rulings by the SDPUC determined that the state would prepare their own EIS on the MANDAN Project. As in North Dakota, the South Dakota Siting Act calls for compliance with all state and local ordinances but provides that a permit may supersede or preempt any county or municipal land-use, zoning, or building rules, regulations, or ordinances upon a finding by the Commission.

Transmission lines in South Dakota must conform to the Energy Facility Siting Rules of the Public Utilities Commission. A permit for the construction and operation may be granted after the applicant has met the following burdens of proof: (1) the proposed facility will comply with all applicable laws and rules; (2) the proposed facility will not pose a threat of serious injury to the environment nor to the social and economic condition of inhabitants or expected inhabitants in the siting area; (3) the facility will not substantially impair the health, safety, or welfare of the inhabitants; and (4) the facility will not unduly interfere with the orderly development of the region with due consideration having been given the views of governing bodies of affected local units of government.

Factors which the South Dakota PUC require to be considered in the siting process include geological features, economic deposits, hydrology, terrestrial fauna and flora, aquatic fauna and flora, land use, cultural resources, recreational facilities, transportation facilities, public facilities, and rural residences and farmsteads.

An application was submitted to the South Dakota Public Utilities Commission for a route permit in January 1981. Evidentiary hearings were conducted in November 1981; a decision by the South Dakota PUC is required by law before 14 January 1982. Legislative consideration will follow approval by the South Dakota PUC.

Nebraska

In Nebraska, the PRB is responsible for the coordination of power supplied to the state from various suppliers. An application must be filed with the board before any transmission lines or related facilities carrying more than 700 volts are constructed. The Nebraska PRB sets service areas for utilities within the state and conducts hearings on proposed facilities, giving consideration to (1) the supplier best able to supply the load required; (2) the most logical future supplier of the area; (3) the desires of the supplier with respect to loads and service areas it wishes to serve; (4) the ability to provide service at costs comparable to other suppliers in the service area; and (5) the ability of the supplier to cope with the problems of expanding loads and increased cost. A constrution permit for transmission lines is required from the Nebraska Public

Service Commission (PSC) which rules on the safety of design, construction, and operation of lines as regards the public, other utilities, and airports and landing fields. The proposed facility in Nebraska must meet the requirements of various state and local agencies.

The State of Nebraska has no siting criteria for the routing of transmission lines.

Application has been made to the Nebraska PRB for construction and operation of the portion of the facility in the state of Nebraska. Application will be submitted to the Nebraska PSC after surveying is completed and the exact centerline has been determined.

CANADIAN REGULATORY REQUIREMENTS

The Federal Government of Canada through the National Energy Board (NEB) must reivew, hold a public hearing, and approve all facets of the MANDAN energy agreement as well as the location of the transmission line route. In general, the NEB affords an opportunity for potentially affected parties to participate in the public hearing process and insures that the energy agreement is in the best interests of the country. The NEB has established a set of transmission line environmental guidelines which must be addressed by all applicants. Recent Manitoba Hydro experience with international transmission lines suggests there is more emphasis by the NEB in seeing that a reasonable planning process has been followed by the provincial environmental review agencies than in strict adherence to details of transmission line environmental guidelines.

In 1974, the provincial cabinet established the Manitoba Environmental Assessment and Review Agengy (MEARA). This agency requires all public undertakings that may have a significant impact on the environment must follow the Environmental Assessment Review Process (EARP) in determining the scope of the environmental study to be prepared. To date, the focus of this process has centered on air-water-soil aspects of the proposed project. All transmission lines of 230 kV level and higher must follow the EARP process. In 1976, the Manitoba Planning Act was passed by the provincial legislature to guide the orderly growth of land use development in the province. The administrative arm of the Planning Act is the Interdepartmental Planning Board (IPB) which has Deputy Minister level representation from 10 different government departments and crown corporations, and who answers to a Cabinet committee known as the Provincial Land Use Commission (PLUC).

The IPB and PLUC are primarily involved in approving municipal and district land use planning schemes. Since a transmission line project could apply equally to the requirements of the two review processes described above, IBP/MEARA officials have agreed to employ a single review process with the main focus on the IPB procedures. This is consistent with Manitoba Hydro policy which places considerable emphasis on the involvement of local government in the siting process. After involvement of government departments, local governments, landowners, and interested environmental groups, Manitoba Hydro makes a recommendation to IPB/MEARA for approval. Public hearings may be called at the discretion of the province; however, to date no hearing has been held under the IPB/MEARA procedures. IPB/

MEARA can approve the recommendation, modify it, or choose a different corridor/route depending on its own review priorities. Manitoba Hydro then accepts the decision and the application to the NEB is initiated.

In the fall of 1980, provincial government departments, local governments, and environmental interest groups reviewed the alternative corridors for the Project and Manitoba Hydro's recommended corridor was generally supported. In the spring of 1981 Manitoba Hydro slowed down its site selection program awaiting siting decisions to be made in North Dakota. The site selection process in Manitoba was reactivated in December 1981.

UNITED STATES ROUTE SELECTION PROCESS

The United States route selection process was developed to balance international, regional, and state concerns, to provide adequate coordination between Canadian and American participants, and to identify routing preferences acceptable to the wide range of regulatory requirements. The process was designed to accomplish the following objectives: (1) identify a site where the MANDAN transmission facility could be constructed, operated, and maintained so as to minimize overall adverse effects on the environment and land use, consistent with economic and technological considerations; (2) encourage public input throughout the selection process; (3) provide for the analyses of reasonable alternative locations; and (4) provide the flexibility to fulfill all applicable Federal, state, and local regulatory requirements.

Siting the MANDAN transmission facility involved designation of a study area from which a preferred corridor and, finally, a proposed line route and associated substation sites were selected. Siting guidelines for the MANDAN transmission facility (Table 1) were developed to comply with applicable Federal and state regulations. In addition, input was sought from experts, representatives of government agencies, and the general public to identify factors relevant to siting the MANDAN Facility.

Public input has been an integral part of the siting program since its inception. The public input program was designed to receive information on how the project would affect the orderly development of the region through which it would pass, to identify possible environmental impacts, and to obtain any other relevant information that might influence facility siting. Two sets of public meetings, one for corridors, one for routes, have been held in each of the three states. Meetings were held in each county for the convenience of the public, and wide notice of the meetings was given through local newspapers and the electronic media. An "open house" format was used to allow individuals to move from one interest area to another and to carry on a one-on-one conversation with project representatives. The public information and public input program will continue throughout the project.

A combination of constraint mapping and network analysis techniques was used to analyze siting data during corridor and route selection designed to systematically eliminate from consideration those areas less desirable for transmission line routing, until only one preferred corridor and, ultimately, one line route with associated substation sites remained.

Table 1. MANDAN transmission facility siting guidelines for North Dakota, South Dakota, and Nebraska.

Provide mechanisms for public input during the selection process.
Route along section lines, quarter-section lines, or property lines to minimize interference with agricultural practices.
Route on range or uncultivated land rather than cropland to minimize economic impact on and effects on agricultural practices.
Avoid diagonal crossing of cultivated cropland to minimize interference with farming practices.
Avoid interference with established airspace.
Avoid close proximity to farmhouses, rural residences, and places of business.
Minimize interference with irrigation.
Minimize effects on prime farmlands.
Avoid designated or registered recreational, historic, archeological, or other culturally significant areas.
Minimize disturbance of shelterbelts, woodlands, and wooded areas.
Avoid disturbance of unique or rare species of plants and animals.
Avoid interference with designated or registered areas of conservation or ecological importance.
Minimize interference with existing surface water drainage patterns.
Avoid interference with facilities such as defense installations and fixed commercial communication systems.
Avoid interference with public facilities such as reservoirs and municipal water sources.
Minimize interference with extraction of economic resources.
Minimize engineering, construction, and maintenance hazards.
Minimize total line length to reduce overall impacts and cost.
Maximize use of existing rights-of-way.

Study area boundaries were established after consultation with Manitoba Hydro and state officials in North Dakota, South Dakota, and Nebraska (Figure 1). Corridor selection consisted of study area data collection, constraint mapping, candidate corridor analysis, alternate corridor analysis, and preferred corridor selection. Approximately 300, 6-mile-wide "candidate" corridor options which best achieved the siting guidelines were identified. These corridors occupied approximately half the study area, yet they excluded almost three-fourths of the siting constraints.

Alternate corridors were selected from this set of candidate corridors using the selection factors listed in Table 2. The quantity and spatial arrangement of these selection factors were used to select 39 alternate corridors which eliminated an additional one-third of the remaining siting constraints within the candidate corridors.

A composite ranking was assigned to each of the 39 alternate corridors for the general environmental categories (Table 2) and for engineering based on the average rank for all factors within each category. The highest ranking corridor overall was selected as the preferred corridor, which was then slightly modified to reduce potential for adverse environmental effects (Figure 1).

The same general siting methodology was applied in the route selection process; however, a number of additional selection factors, consistent with the siting guidelines, were included (Table 3). The route selection process started with an evaluation of all quarter-section line routing opportunities in the preferred corridor and proceeded through a series of candidate and alternate routes to one proposed route in each state. As in corridor selection, several meetings, open to the public and government officials, were held to review the candidate routes.

CANADIAN ROUTE SELECTION PROCESS

The objectives of the site selection program in Manitoba are to (1) address the requirements of the National Energy Board and the Province through IPB/MEARA, (2) ensure that local governments and landowners are actively involved in the siting and decision making process, and (3) achieve a reasonable balance of trade-offs associated with engineering/economic criteria vs. resource issues.

The siting program addressed three major regional issues: agricultural resources, biotic resources, and human resources. Each of these factors was treated as having equal significance in the assessment and, accordingly, all were given equal weighting. Any "trade-offs" that may eventually be required between the factors will be determined by the IPB/MEARA process. Engineering and economic considerations were evaluated as a fourth major area of interest but not within the same scheme of developing data to represent potential impact.

A phased site selection program was used because of (1) the size of the study area, (2) the need for a methodology and schedule that would be compatible with the United States, and (3) the need to identify early on those regional options and resource trade-offs that will have to be resolved through the various governmental planning process.

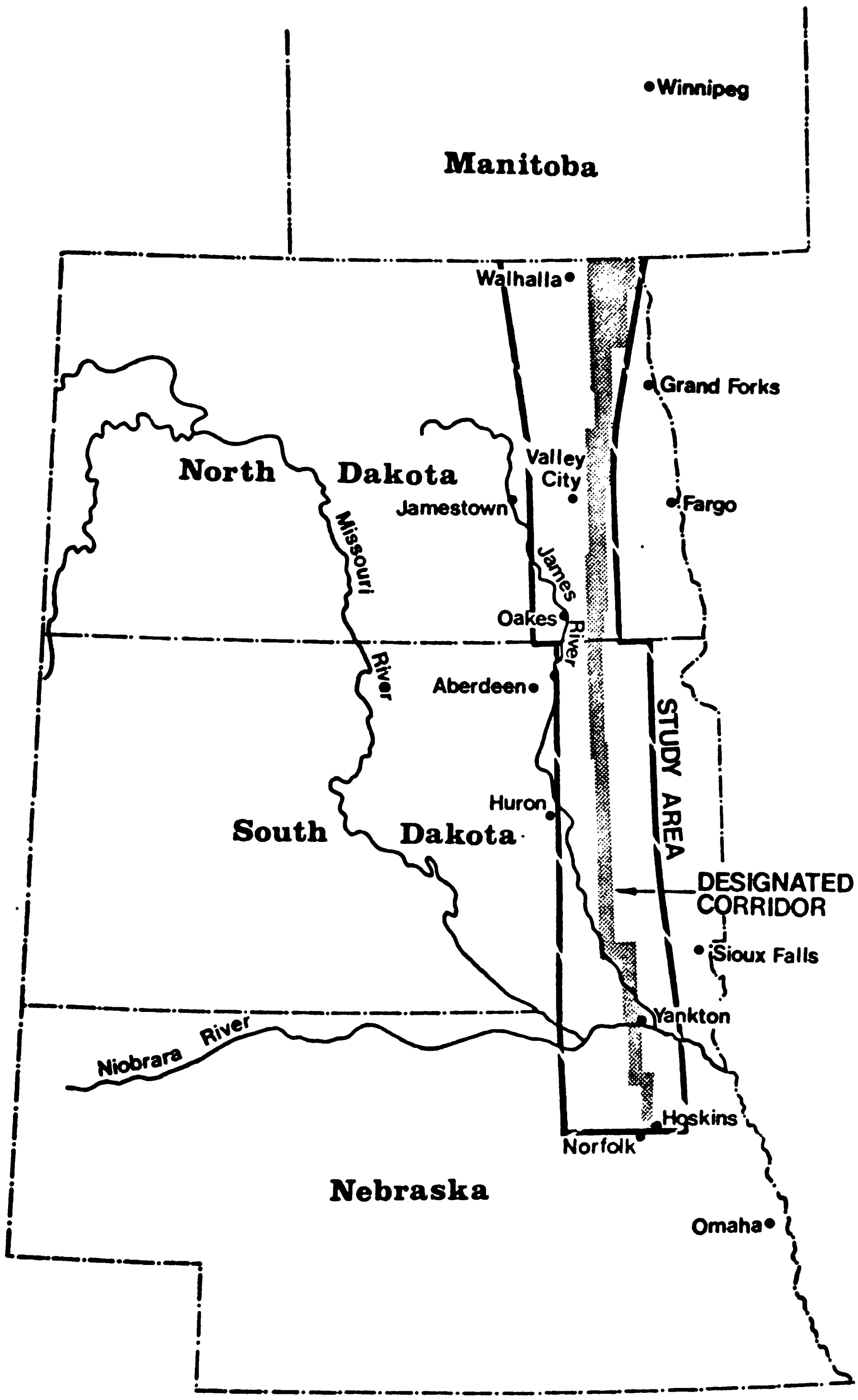

Figure 1. MANDAN study area and designated corridor in the United States.

Table 2. Corridor selection factors for the MANDAN Project in North Dakota, South Dakota, and Nebraska.

General Category	Selection Factor
Agriculture	Prime Farmland
	Suitability for Irrigation
	Irrigation Permits
	Cropland
	Rangeland
	East-west Shelterbelts
	Rural Buildings
Cultural and Recreational Facilities	Cultural Sites
	Registered Cultural Sites
	Recreational Rivers
	State Parks & Recreation Areas (State Parks)
	County Parks & Recreation Areas
	Areas of Recreational Significance
	Public Campgrounds
	Public Access
Public Facilities	Urban Centers
	Rural Cemeteries
	Rural Churches
	Rural Schools
Transportation and Utilities	Airports
	Missile Sites
	State and Federal Highways
	Active Railroads
	Abandoned Railroads
	Communication Towers
	Pipelines
	High Voltage Transmission Lines
Physical Features	Rivers and Streams
	Water
	Wetlands
Natural and Conservation Areas	Major Fish-bearing Rivers
	Proposed Natural Areas
	Waterfowl Production Areas
	National Wildlife Refuges
	State Conservation Areas
	Wooded Areas
	Wetland Easements
Engineering Requirements	Equivalent Miles

Table 3. Route selection factors for the MANDAN Project in North Dakota, South Dakota, and Nebraska.

Agriculture

Irrigation Permits Crossed
Irrigation Permit Bordered
Irrigation Crossed
Irrigation Bordered
Cropland Crossed
Cropland Crossed Diagonally
Rangeland Crossed
Shelterbelts Crossed
Shelterbelts Paralleled
Properties Crossed
Occupied Residences (500 ft.)
Occupied Residences (500-1000 ft.)
Unoccupied Residences (500 ft.)
Unoccupied Residences (500-1000 ft.)
Rural Buildings (500 ft.)
Stockponds (500 ft.)
Wells and Windmills (500 ft.)

Public Facilities

Urban areas (1 mile)
Residential Developments (.5 mile)
Active Schools (500 ft.)
Active Schools (500-1000 ft.)
Active Churches (500 ft.)
Active Churches (500-1000 ft.)
Cemeteries (500 ft.)
Cemeteries (500-1000 ft.)
Public Water Supplies (1000 ft.)
Sewage Treatment Facilities (1000 ft.)
Rural Commercial Development (.5 mile)

Physical

Rivers Crossed
Rivers Paralleled (500 ft.)
Lakes (500 ft.)
Lakes (500-1000 ft.)
Wetlands (500 ft.)
Wetlands (500-1000 ft.)
Gravel Pits (1000 ft.)

Engineering

Equivalent Miles

Cultural and Recreational

Historic Sites (500 ft.)
Historic Sites (500-1000 ft.)
Archeological Sites (500 ft.)
Archeological Sites (500-1000 ft.)
State Park and Recreation Areas (1 mile)
County Parks and Recreation Areas (1 mile)
Public Campgrounds (500 ft.)
Public Campgrounds (500-1000 ft.)
Wayside Areas (500 ft.)
Wayside Areas (500-1000 ft.)
Public Access Areas (500 ft.)
Public Access Areas (500-1000 ft.)

Transportation

Airport Zone
Highways Crossed
Highways Paralleled (1 mile)
Paved Roads Crossed
Paved Roads Paralleled (1 mile)
Active Railroads Crossed
Active Railroads Paralleled (500 ft.)
Communication Towers (1000 ft.)
Pipelines Crossed
Pipelines Paralleled (500 ft.)
Power Lines Crossed
Power Lines Paralleled (500 ft.)

Natural and Wildlife

Fishing Rivers Crossed
Waterfowl Production Areas (500 ft.)
Waterfowl Production Areas (500-1000 ft.)
State Conservation Lands (500 ft.)
State Conservation Lands (500-1000 ft.)
Woodlands Crossed
Wetland Easements (500 ft.)
Wetland Easements (500-1000 ft.)

The major determinants of study area boundaries in Manitoba included (1) the location of the existing Doresey converter station, (2) the western limits of the City of Winnipeg, (3) the desire to establish a multi-line corridor west from Dorsey, and (4) the mutual desire of MHEB and NPPD to insure that the international boarder crossing area was broad enough to contain a number of viable corridor alternatives.

The MANDAN study area in Manitoba crossed three major physiographic regions. The eastern portion is in the Red River Valley which supports diverse and specialized agricultural operations. The western edge coincides with the Second Prairie Level and is predominately used for agriculture. The third region, a transition zone between the other two, is dominated by the Manitoba Escarpment (Pembina Hills) which contains smaller agricultural operations in association with a considerable mix of recreation, wildlife, and waterfowl resource uses. This clear differential of resource uses in the study area made it evident that a distinct choice of agricultural resources vs. wildlife-waterfowl-recreation resources would likely be the main focus of early locational decision.

A public information and public input program consisting of ongoing contacts with provincial government departments and input from local municipal councils, potentially affected landowners, and environmental interest groups has been closely tied to key decision points in the project schedule.

The siting methodology consisted of a map overlay technique. For each land unit, the highest impact rating assigned to any of the individual data series was displayed on Factor maps. Through the "maximizing rule," each Factor map presents the highest level of impact that may accrue to any land unit from a transmission line. This "maximizing rule" was repeated in the production of the final "Composite" impact map, thus showing the levels of impact across the entire study area.

Alternative corridors seven miles wide were delineated. Each corridor was evaluated for viable routing possibilities, using airphoto interpretation and field studies.

On the basis of a regional assessment which included evaluation of agricultural, biotic, and human resources, and engineering/economic criteria of the alternative corridors, Manitoba Hydro recommended Corridor 4 as the preferred choice (Figure 2). In the fall of 1980, provincial government departments, local governments, and environmental interest groups reviewed the alternative corridors, and it was tentatively concluded that Corridor 4 was the preferred choice.

The route selection program will consist of a site-specific analysis within the preferred corridor to identify and evaluate alternative routes and, finally, one preferred route. Again, involvement of provincial government departments, local units of governments, landowners, and interested environmental groups will be of critical importance for a credible route selection process.

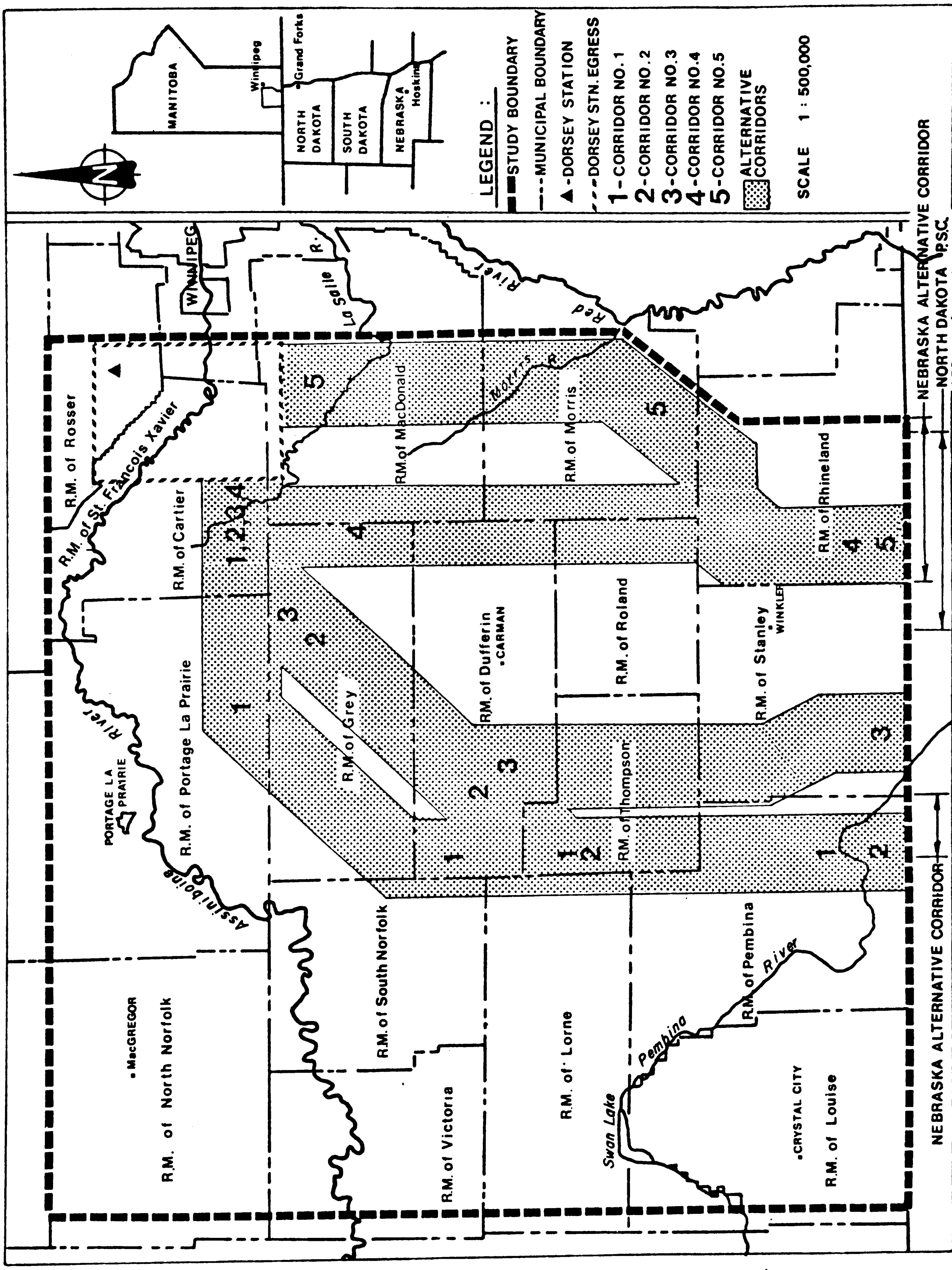

Figure 2. MANDAN study area in alternative corridors in Canada.

CONCLUSIONS

Two distinctly different approaches to siting regulations exist in Manitoba and the United States. Manitoba Hydro works closely with the environmental review agencies in the province throughout the siting process. The Province of Manitoba through IPB/MEARA makes the final siting decisions. These decisions will reflect current provincial priorities regarding environmental trade-offs.

The participation of the regulatory authorities in decision-making with the utility throughout the siting process is in distinct contrast to the legislated siting requirements in North Dakota. Specific siting criteria are clearly defined for the applicant in the North Dakota Siting Act, and the Public Service Commission rules on applications which are the result of decisions made by the applicant throughout the siting process.

Effective coordination and communication between the utilities involved in a project the magnitude of MANDAN are always of extreme importance. Both NPPD and Manitoba Hydro were sensitive to the issue of either party making siting decisions before the other, since this could raise the issue of one jurisdiction having undue influence on the other. The difference in regulatory processes between Manitoba and North Dakota have made coordination between the two major participants all the more important in order to arrive at a mutually acceptable corridor and route at the international border.

In regard to the initial activity of defining corridor preference at the border, the time lags associated with approvals via policy (Manitoba, vs. legislation North Dakota) became very evident. Corridor preference of the two utilities was established in September/October 1980 and in North Dakota in July 1981. This difference in timing reinforced the need for continued dialogue not only between MHEB and NPPD but between the environmental review authorities in Manitoba and North Dakota. It is anticipated that this issue will become more critical when the matter of preferred routes are reviewed in Manitoba and North Dakota.

The siting process in North Dakota is well defined. It requires the Public Service Commission to act on a corridor application or route application within 3 months or 6 months respectively from the time the application has been determined complete. These times can, however, be extended for just cause. NPPD filed a corridor application with the North Dakota PSC on 30 September 1980. The application was deemed complete on 13 October 1980 and public hearings were scheduled for 2 December 1980. At these hearings substantial public concerns were expressed on need for the project, benefit to North Dakota, health and safety, and location of the corridor in agriculture lands to avoid wooded areas. These hearings were continued until 2 March 1981 and a Certificate of Corridor Compatibility was received on 6 July 1981, approximately 6 months later than projected. The Public Service Commission designated a corridor which was approximately 70% larger than the proposed corridor to provide additional routing opportunities in wooded areas. This change in emphasis was continued by the PSC on 9 September 1981 when they held public hearings to change the designation of woodlands from avoidance areas to selection criteria.

The siting process and licensing schedule in South Dakota have been difficult to determine due to a relatively new siting act which had not been tested on a major transmission project and several pieces of new legislation enacted since the project started. For example, legislation added an additional burden of proof to the siting act, defined trans-state transmission facilities, and required legislative approval of the project. Although the PUC is required by law to reach a decision within 1 year of an application, legislative approval in South Dakota has no such constraint and can, in fact, only be received during the annual legislative session.

Intervention in Nebraska has lengthened the hearing and approval process well beyond that required for any other project in our experience.

The overall siting program developed for the MANDAN Project has been effective in meeting the requirements of the regulatory agencies of the three states involved. Because of the extensive program of agency contact and public input, few specific siting concerns have been identified during the hearing process. The issue of agriculture land vs. woodlands raised during the North Dakota corridor hearings essentially became a debate on the siting criteria established by the North Dakota PSC and resulted in the proposed changes to the PSC Rules and Regulations.

The majority of the public comments expressed at public meetings and hearings have centered on three general issues: need, benefit, and health and safety.

Finally, the overall schedule in the United States was designed to take into account the time historically required by regulatory bodies to accomplish their review and action on permit applications. Overall project scheduling for the United States portion of the project was based on submitting information and applications at the state level before submissions at the Federal level. Therefore, the schedule on the Federal level is largely dependent upon the schedules at the state level and any change in the state schedules will change the Federal schedule. The timing of state agency actions on the MANDAN Project have generally exceeded our original estimates. Based on our experience, any project which requires the involvement of a variety of Federal and state agencies must recognize the inevitability and the consequences of these agencies acting independently and should schedule projects accordingly.

THE COMPLEXITIES OF ROUTING A HIGH VOLTAGE TRANSMISSION LINE THROUGH FEDERAL LAND: A CASE STUDY

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J. P. Thomas[2], and Charles von Herrmann[3]

ABSTRACT.--Major issues involved in routing transmission lines through federal lands in South Carolina revolve around the key concepts of multiple use and biotic diversity. Not only are these concepts important to environmental planners, ecologists, and others, but they have taken on additional meaning with the promulgation of such regulations as the Endangered Species Act, the Fish and Wildlife Coordination Act, and the National Forest Management Act. Energy transport rights-of-way are considered acceptable as one of the multiple uses of federal land; however, routing studies must be prepared in accordance with the National Environmental Policy Act and other pertinent regulations. This paper presents a case study detailing the problems and solutions of routing a transmission line across U.S. Forest Service Land. These include the advantages and disadvantages of sharing right-of-way with a gas pipeline, the presence of several threatened, endangered or provisional plant and animal species, archeological/historical sites, and proposed wilderness areas.

INTRODUCTION

This study examines several issues encountered during the routing of a proposed High Voltage Transmission Line through approximately 27 miles of the Francis Marion National Forest in South Carolina. These included the coordination measures necessary to protect (1) endangered wildlife, (2) endangered plants, (3) historic sites, and (4) aesthetics. Since the proposed route was to traverse National Forest Land, it was necessary to conform to the requirements of the National Environmental Policy Act and the U.S. Forest Service, in order to obtain a permit for crossing the Forest. It was ascertained in the early stages of the line design that the areas of primary interest concerned land use in relation to the concepts of multiple use and biotic diversity.

BACKGROUND

The project is located in eastern South Carolina on the Atlantic Coastal Plain (Fennemann, 1938). Within this physiographic division, the entire

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2 South Carolina Public Service Authority
3 U.S. Forest Service

study area is located in the marine coastal terrace, referred to locally as the "Low Country," a specific geographic division. It is generally described as level to gently undulating and rolling.

Soils in the area are composed of gray sands and sandy loams, except in swamp areas where peat and muck cover the sand. Major forest types (U.S. Forest Service, 1977) include gum and cypress which are located in the swampy areas. Loblolly and longleaf pine and oak are associated with the dry sites.

The project entailed linking the South Carolina Public Service Authority (Santee Cooper) Winyah Generation Station and Charity Substation with a 230 kV transmission line approximately 39 miles in length. Approximately 37 miles of the transmission line parallels an existing natural gas pipeline right-of-way. Approximately 27 miles traverse the Francis Marion National Forest managed by the U.S. Forest Service. Alternate routes were proposed; one route was close to the coast and the other more inland than the final route. Neither of the alternate routes parallel existing right-of-way for significant distances and both have other, more serious environmental and economic problems. The project implemented a resource management plan with U.S. Forest Service to provide management guidelines and requirements for treatment of various areas such as visually sensitive areas, significant archaeological sites, scrub oak areas, windrow areas, river bottoms or wet areas, and grass areas. A study of the response of red-cockaded woodpeckers to cavity tree removal was mutually agreed to as being in the best interest of Santee Cooper and the Forest Service.

Other agencies and groups, in addition to the U.S. Forest Service, became involved in the routing process, due to the proximity of the project to the Atlantic Coast. For example, it was necessary to obtain permits from the South Carolina Water Resources Commission and the U.S. Army Corps of Engineers. Additional agencies were contacted so that each agency's concerns would be addressed before final route selection was recommended. Various local special interest individuals and societies were also contacted in order to ascertain their areas of concern.

PROBLEMS

The unique environmental and historical aspects of the Francis Marion National Forest required consideration of various problem areas. These problems included federally listed endangered and threatened wildlife, various plant species in provisional categories at the state and federal level, disjunct plant communities and archeological/historical sites. The problems which resulted from encountering these unique entities and the solutions to those problems should provide direction for future studies involving federal lands.

Endangered Wildlife

The red-cockaded woodpecker (*Picoides* (*Dendrocopus*) *borealis*) has been listed by U.S. Department of the Interior as an endangered species.

Because woodpecker population levels are high in the project area, avoidance of this species was a major problem. It was determined that the woodpecker would be impacted along any of the route alternatives. Therefore, several options to mitigate those impacts were thoroughly examined. These options included (1) following one of the alternate routes; (2) routing into the forest away from the existing pipeline right-of-way to avoid red-cockaded woodpecker (RCW) cavity trees; and (3) following the pipeline route and removing cavity trees which were in the right-of-way (i.e., seeking a special permit to remove the woodpecker trees).

The first option was rejected because it was felt that the potential impact to other endangered species was greater along both alternate routes. Additionally, with the concentration of identified RCW cavity trees along all routes, the problem would merely be shifted, not resolved. Deflecting the line along the pipeline right-of-way into the forest (option 2) would have created more impact as this option would have necessitated increasing both the ROW length and width. Both options would have required additional clearing with the subsequent loss of timber resources and further altering of the wildlife habitat. There was a high probability of encountering other endangered species in these deflections.

To evaluate option 3, a special study was proposed by the U.S. Forest Service (Hooper, 1980) and a permit was requested from, and approved by, the U.S. Fish and Wildlife Service (Lennartz, M.R., personal communication, 1981) to remove the cavity trees in three red-cockaded woodpecker colonies which the right-of-way will directly involve. At this writing, these studies are underway and no results are available.

Other threatened or endangered wildlife native to the project area included the eastern cougar (*Felis concolor*) listed by the state as endangered, the eastern brown pelican (*Pelicanus occidentalis carolinensis*) and the Bachman's Warbler (*Vermivora bachmanii*), both listed by the U.S. Department of the Interior. None of these species was observed along the proposed route through the National Forest. The pelican was observed along one of the alternate routes.

Endangered Plants

Another problem area included the protection of plants which have been placed in various provisional categories at the state or federal level, as a result of the Endangered Species Act. When the project commenced, the initial effort was aimed at ascertaining which species had been identified in the Federal Register. A review of this publication indicated that the July 1, 1975, list served as a notice of review for 3,187 vascular plants, of which 37 were located in South Carolina; the June 16, 1976 list indicated 1,783 proposed endangered species, of which 10 occur in South Carolina. Final rulings published in the Federal Register identified additional endangered species from South Carolina.

In order to develop a comprehensive list of endangered plants for this project, the Smithsonian Institute (Ayensu and DeFillips, 1978) and an unofficial list for the state of South Carolina were also consulted. Another species not identified in the Federal Register for South

Carolina, but which was under study by a local botanist for the Forest Service (Dr. Richard Porcher), was also included in the study list.

Once the habitats and ranges were documented from texts and herbaria, species were identified which could occur in the study area. Field work located three species in or adjacent to the proposed routes: Fothergilla gardenii, Lindera melissifolia, and Litesa aestivalis.

One shrub, Fothergilla gardenii, was not rare as initially thought, and was located in several places along the existing gas pipeline. Even though the shrub was in a protected category, it was determined that the transmission line and the shrub could coexist, provided modifcations to clearing and maintenance practices were undertaken.

The other two species, which are associates, are found in cypress sinks with Litesa being the more abundant of the two. Steyermark (1975) referred to Lindera melissifolia as one of the rarest shrubs in the United States. Local botanists indicated it grew along the margins of sinks. Extant populations were observed in dry sinks. However, while gathering biogeographical data, it was learned from a botanist in Arkansas that Lindera often grows in the water within a sink. Once the Litesa was discovered, a thorough search of the sink yielded a large concentration of Lindera in the water. This is the only sink in which Lindera occurred along the right-of-way. Fortunately, the proposed route is located north of the gasoline right-of-way and these plants are located in a sink south of the right-of-way.

Also located within the project area were disjunct stands of the Appalachian Forest, with American Beech (Fagus grandifolia) being the primary indicator. This somewhat unique local vegetation community created no problems since stands were located along one of the alternate routes.

In general, threatened or endangered plant species were not adversely affected. In actual fact, the right-of-way should be beneficial to species requiring early successional type habitat and/or "edge" effects.

Historic Sites

Although the preferred route did not cross properties of known National Register significance, the region, "the South Carolina Low Country," is one of the most historically significant regions in the United States. Among the historic aspects of the area are the Revolutionary War activities of Francis Marion, the "Swamp Fox." It was for him the National Forest was named.

Eighteen sites of archeological/historical significance were found along the preferred route. Several sites were prehistoric, classified as either Late Archaic or Woodland Age.

The Plan Profile for the proposed line was plotted such that no structure would be located within any of the archeological/historical sites. After the line structures were staked, archeological/historical sites were located and flagged to ensure that none of these sites were disturbed.

Aesthetics

A concern voiced by the Forest Service was that a high voltage transmission line right-of-way may disrupt the park-like atmosphere which prevails throughout much of the Francis Marion Forest. To avoid creating a tunnel-like view of both rights-of-way from the state, county, and Forest Service roads, mitigative measures were proposed. Additionally, views up the right-of-way where the line crossed the Santee River were also of concern.

The mitigation of these visual impacts is discussed in the Resource Management Plan.

RESOURCE MANAGEMENT PLAN

After evaluating the routing options and associated problems, a Resource Management Plan was developed by the U.S. Forest Service and the South Carolina Public Service Authority. The purpose of the plan was to provide coordination requirements to be complied with by uses and management guidelines for the 167 acres of land located along the right-of-way. The plan covers "conditions, restraints, controls, and construction" associated with the six parameters listed in Table 1. (Those parameters comply with regional and NEPA policy requirements).

Table 1. Special management areas as identified by the U.S. Forest Service along the proposed right-of-way.

Visually sensitive areas	Retain natural vegetation screens or use windrows with plantings or plant 100'-200' screen of low growing shrubs.
Archeologically Significant Sites	Hand clearing; no heavy equipment. Remove only taller vegetation.
Scrub Oak Areas	Cut and remove merchantable timber; cut other scrub oak and allow to sprout. Maintain at levels acceptable to safety standards.
Windrow Areas	Cleared and revegetate with grasses; windrows constructed with Bicolor Lespedesa strip plantings.
River Bottoms or Wet Areas	Cut merchantable timber; leave stumps and maintain low growing vegetation. Special equipment needs.
Grass Areas	Cleared and revegetated with specified grasses.

Site specific mitigation included inspection tours to define problem areas and suggest solutions. Study teams included two engineers, one each from

Santee Cooper and Commonwealth, a biologist/forester and a landscape architect from Commonwealth. Forest Service representatives (i.e., Archaeologists, Land Use Specialist, Wildlife Biologist, Landscape Architect, Hydrologist, Foresters, and Soil Scientist) were also present. Each tower structure site was visited to discuss engineering and environmental constraints. If the proposed site was found to be unacceptable, usually because it was located in a wetland, it was relocated to a commonly acceptable location.

In addition, archeologically significant sites were flagged. The approved construction and maintenance procedures dictated avoidance of these sites. Heavy machinery will be re-routed away from these sites and all clearing will be accomplished by hand.

Scrub oak areas were identified by the Forest Service for special maintenance. During construction, only trees greater than ten feet will be cut and removed. Scrub oak and other low growing species are to be cut at the ground level and allowed to sprout from the stump. Trees at tower locations will be allowed to grow somewhat higher than ten feet but must remain within safety requirements. Slash remaining from ROW clearing will be windrowed. Windrow areas will be developed and used in conjunction with grass and bicolor lespedesa strip plantings. The windrows will be 200 feet long with 50-foot breaks. These will provide resting and escape cover for wildlife. Other areas will be revegetated similarly, but will not include windrows.

Included in the Resources Management Plan is a Planting and Seeding Specification. Working with Forest Service personnel, areas identified as "sensitive" were subsequently developed, and a planting plan was developed. These "sensitive" areas, as defined by the Forest Service, are situated where the proposed route crosses state secondary highways 45 and 33. In each case, a plan identifying and illustrating planting materials (i.e., species type, location, and size) was prepared for each side of the highway crossing.

Plant materials selected included species common to the forest which would add aesthetic appeal near the highway, as well as to improve wildlife habitat. Once clearing and construction have been completed, the planting plan will be implemented by a local contractor. As mentioned earlier, seeding will be conducted in identified areas as part of this right-of-way restoration effort.

SUMMARY

Of the three alternate routes proposed to connect the Winyah Generation Station and the Charity Substation, the route which paralleled an existing gas pipeline right-of-way through the Francis Marion National Forest was found to be the best. The removal of vegetation and subsequent altering of wildlife habitat was lessened by sharing that right-of-way. It was found that supposedly insurmountable problems, particularly with endangered species, could be overcome by close coordination with all agencies involved. Disruption of the scenic quality of the forest could be minimized through selective clearing during the construction phase and appropriate plantings following construction. Disturbance of archeological and historical artifacts was avoided by cooperation from clearing and construction crews with agencies responsible for the maintenance of those artifacts.

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COMMUNICATING IMPACTS

Bruce E. Howlett[1]

ABSTRACT.--When a new transmission line is proposed, the public may harbor vague or incorrect ideas about what the line will look like and what its impacts will be. Opposition may result from misconceptions which can be alleviated by providing an accurate understanding of the project. It is important, therefore, to effectively communicate how the line will appear within the environmental setting selected for it, and what effects it will incur. The applicability and effectiveness of communicating siting information using photographs, maps, photo simulations, computer simulations of maps and terrain, computer graphics, reports, public presentations, and other means is presented.

INTRODUCTION

How someone comes to understand a proposed project has a great deal to do with his opinion about it. Providing the public with a clear and accurate understanding of what the project is all about can be one of the most useful things utility representatives and environmentalists can do.

The objectives in any communication program are to (1) describe the project completely and fully; (2) convey accurately what will occur; (3) clear up misunderstandings and misinformation; (4) allay unwarranted misapprehensions and fear; and (5) create understanding, and hopefully confidence and trust in the firm proposing the project.

Depending on the policies and past performance of a particular utility, achieving these objectives can be fairly easy--or extremely difficult. Some utility executives see public communication programs as eyewash--something that will only get people unnecessarily upset. However, today when many institutions are looked at with suspicion, it is better to let people know what the needs of the utility are. The utility's job is to serve people, and letting the public know how this is being done cannot help but serve the utility well in the long run.

A communication program can be looked at in three different ways, depending on the needs and objectives of the utility:

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(1) Public relations, where the utility tells the public what it wants them to hear, with no opportunity for questions or reaction. Some companies feel this is the only way to go, but people often see through this approach and begin to suspect they are being manipulated or are not being told the facts.
(2) Public information, where an effort is made to present facts and information about a project and to answer any questions that arise. There is no "public involvement" as such, only a sincere effort to communicate what a project is all about. There is ample opportunity for the public to learn, but no opportunity to influence the decision as to the need for the project or its location.
(3) Public participation, which involves actively seeking public involvement in the project as it develops. The extent of participation can range from selecting the type of project to assisting in its design and location. Public participation programs are comparatively new. It is sometimes hard to keep a public participation program focused on the project at hand. Broad questions about company policy may arise together with other unrelated issues.

There are two further topics that require attention in the communication program: (1) defining the issues to be addressed and topics to be covered; and (2) deciding on the means and media to be used in communication.

There are several ways to decide which issues need to be addressed and what topics require study, the first being compliance with the law--to provide whatever is required by agency regulations that govern the project. To obtain a permit to construct a transmission line, state or federal siting regulations and guidelines may be in force, in which case an initial list of features to be studied or topics to be treated can quickly be put together. How data are gathered and presented can be very important in securing prompt review by the staff of those agencies with jurisdiction. Inadequate studies, sloppily prepared and inadequately presented will inevitably result in requests for more--or better--data, all of which can mean delay and higher costs.

Beyond regulatory requirements there may be specific issues that are of keen local interest or concern. Perhaps a particular building, wildlife area, scenic outlook or other feature may be of great importance to local residents. If so, it should be identified and included in the data gathering stage at the outset.

In addition, if the utility has performed a number of routing studies, it will have a body of experience concerning issues that have consistently arisen in the past and therefore are likely to arise in the current case.

Once regulatory requirements are known, local concerns have been identified and general interest issues have been listed, the communication program can begin. First, the communications media must be identified, such as news releases, press briefings, public meetings, workshops, formation of advisory groups or committees, public information meetings, preparation of information pamphlets, establishing a "hot line," and other means of getting information across to the public.

The means of communication is most important and includes the spoken word, the written word, and visual communication (maps, graphs, charts, photos, etc.).

Written reports are the first and most obvious means of communication, but too frequently are dull, verbose, and full of jargon. They are often written as if from one professional to another. It is important to write well--to make the topic interesting and exciting to the reader. Second are visual means of communication. A well illustrated report or public presentation can save an enormous amount of time in communicating information. The layman can see just what is of environmental interest by looking at the picture and can find its location by looking at the map or aerial photograph.

Simulations are another means for portraying a new line. Photo simulations can be prepared for a number of typical viewing locations. A most interesting new means for communicating impacts is emerging from the field of computer graphics. There are several programs currently available that can portray an area of land from any perspective and any elevation. Objects such as transmission lines can be introduced into the landscape and their visual impact assessed from any vantage point.

Television may also be used as a communication tool. For example, a project could be packaged as follows: (1) spot advertisements appear in local newspapers and on TV two to three weeks in advance of the program; (2) the program itself runs about one hour and begins with a company executive explaining the need for the line and the firm's commitment to serve the public; (3) a presentation of the routes studied for the line using maps, photos, photo simulations, and movies; (4) a brief description of the environment, the impacts expected and mitigation to be used by key environmental staff or consultants; (5) a discussion of costs and engineering data by the chief engineer; (6) a live discussion of the project by a studio audience; (7) an "open phone" line to accept questions from the TV audience; (8) offers to send out a report on the project to those who write or call in; and (9) an offer to lend a video cassette of the TV program to groups who are interested.

This approach could gain a wide, attentive audience who would hear and see the entire study, rather than learn about it through the brief words of a local newspaper reporter. Although costly, the benefits and ultimate savings could be very high.

THE MINNESOTA DIRECT CURRENT TRANSMISSION LINE: WHAT WENT WRONG AND WHY?

D. McConnon[1]

ABSTRACT.--The Coal Creek Project includes, in part, a ±400 kilovolt direct current transmission line extending from central North Dakota to east central Minnesota for a distance of about 436 miles (700 km). Almost from the time the Project was first announced, the transmission line became the subject of bitter controversy in Minnesota, ultimately resulting in violence and vandalism during line construction in 1978. Even though the transmission line is currently operational, vandalism continues, albeit at a reduced level, and opponents have recently renewed efforts to have the line removed.

Most of the issues raised in the regulatory proceedings were not unique to the direct current line controversy. The public is aware that the energy situation has changed dramatically in this country; "business as usual" approaches may no longer be applicable. The lessons learned in the direct current transmission line controversy may apply in the planning of future large energy projects.

INTRODUCTION

During recent years, it has become increasingly more difficult to plan, construct, and operate large energy facilities in the United States. There are many reasons, including adverse public opinion and stringent regulatory requirements. Consider, for example, the experience of the Diablo Canyon Nuclear Plant in California, the Kaiparowits Project in Utah, and extra high voltage transmission lines in New York. Perhaps the best example of public opinion adversely affecting a project is the Coal Creek Project located in the upper midwest. Almost from the time the Project was first announced, a section of associated transmission line became the subject of bitter controversy in Minnesota, ultimately resulting in violence during construction and in sabotage. This report examines the major issues raised during the Project's history, the causes underlying the controversy, and the lessons learned which may have application for projects planned in the future. The opinions expressed are solely those of the author who was associated with the Project virtually since its inception.

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Project Description

The major components of the Coal Creek Project are shown in Figure 1. The Project as finally designed and constructed consists of a 1,015 megawatt (net) two-unit power plant near Underwood, North Dakota, called the Coal Creek Station; a lignite coal mine adjacent to the plant; a 436-mile (700 km) long ± 400 kilovolt (kV) direct current (dc) powerline extending from the generating station to just west of Minneapolis, Minnesota; three 345 kV alternating current (ac) lines which deliver the power from the dc line into the existing transmission system; and necessary converter and substation facilities. At the present time, the power plant, the mine, the dc transmission line, the converter stations, and two ac lines are fully operational. Although the Project consists of several distinct elements, it is only a small portion of the dc line in Minnesota that has created controversy and is the subject of this report. The only segment of the Project left to complete is the third ac line from the Minnesota terminus of the dc line to a substation near Mankato, Minnesota.

The Project Owners

The Project is owned and operated by two Minnesota-based generation and transmission cooperatives--Cooperative Power Association (CPA) of Eden Prairie, Minnesota, and United Power Association (UPA) of Elk River, Minnesota. The area served by the Cooperatives is shown in Figure 2.

CPA serves as the wholesale power supplier for 18 distribution cooperatives which provide electrical energy to about 138,000 consumers in southwestern and west central Minnesota. Until the Coak Creek Project, CPA had no generating capacity of its own. However, CPA owns and operates the transmission lines and all substations through which it receives power for its member cooperatives. CPA performs all of its maintenance and construction functions under contract with member systems, other utilities, or independent contractors. CPA owns 56% of the Coak Creek Project.

UPA serves as the wholesale power supplier for 15 member distribution cooperatives. These member cooperatives provide power to 32 counties and over 183,000 consumers in central and northeastern Minnesota and a small area of northwestern Wisconsin. In addition to the Coal Creek Project, UPA owns and operates 216 megawatts (MW) of base load generation to meet normal demands and 87 MW of combustion turbine generation to meet peak demands. The base load generation consists of a 167 MW lignite-fired plant near Stanton, North Dakota, and a 49 MW coal-fired plant at Elk River, Minnesota. UPA owns and operates over 2,700 miles of transmission lines, 191 substations, various maintenance buildings, and dispatching facilities at Elk River. UPA handles all of its own maintenance activities.

PROJECT HISTORY

Planning and Permitting

In mid-1972, CPA and UPA began discussing the possibility of jointly constructing a major generation complex to supply the power requirements of

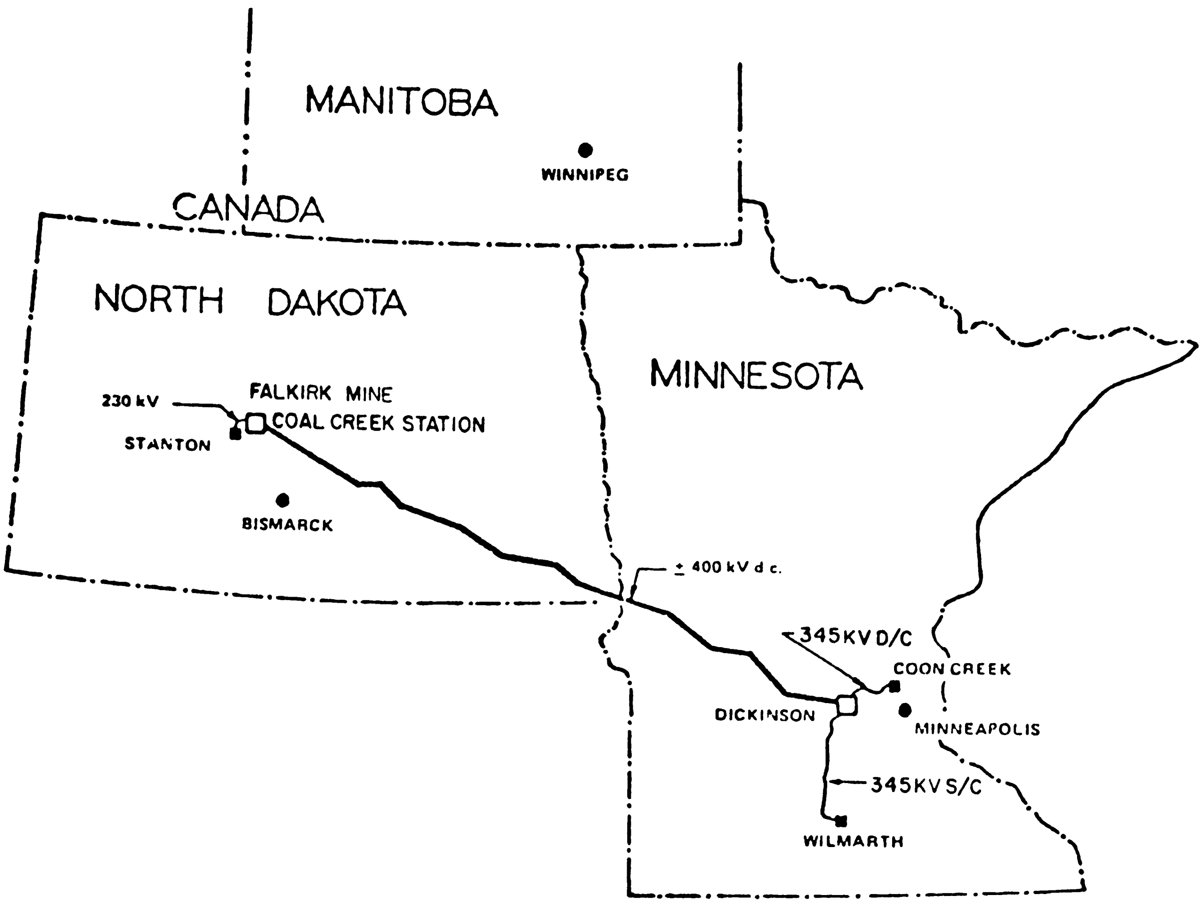

Figure 1. Major project features.

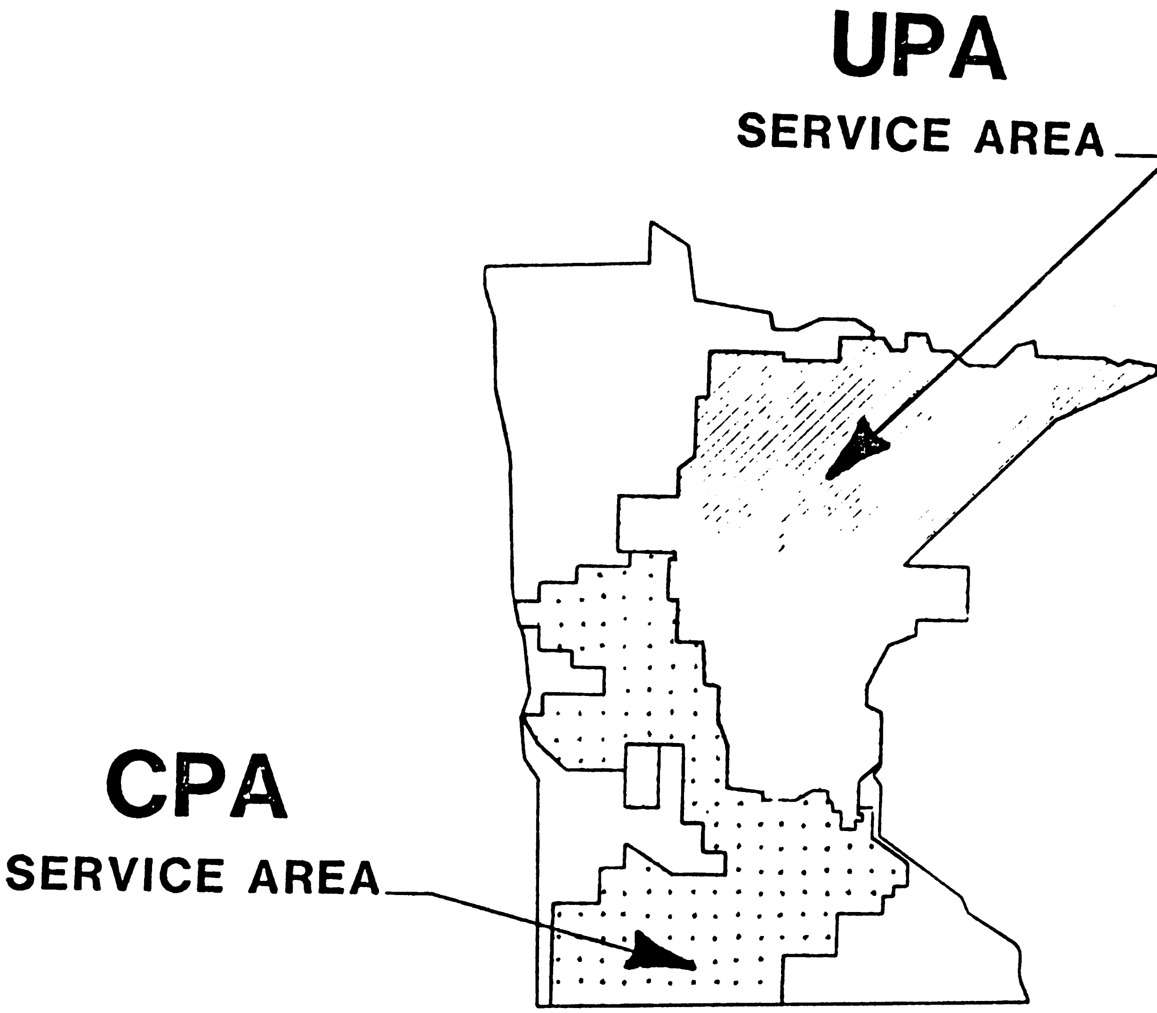

Figure 2. CPA and UPA service areas.

their rural electric distribution cooperatives and to satisfy the combined power deficit projected for the winter of 1978 of an expected 665 MW.

Both Cooperatives recognized the need for a new power source. Other suppliers who were providing power to the Cooperatives in 1972 could not give assurances power would be available in the late 70's and beyond. Also, the cost of purchasing power, even it if were available, was considerably higher than what self-generation costs were expected to be.

The Cooperatives authorized the necessary feasibility and engineering studies, and, following their completion, submitted a loan application to the Rural Electrification Administration (REA) for the necessary funds. In February, 1974, the REA granted initial loan approval and guarantees in the amount of $537 million following the preparation of a federal Environmental Impact Statement in accordance with the National Environmental Policy Act.

By July, 1974, land had been acquired in Minnesota for the converter station and grading had begun. Survey work and planning had progressed substantially. CPA and UPA also began holding public meetings in each of the counties in Minnesota and North Dakota which would be affected by the dc line and acquiring zoning permits where they were required.

During the summer and fall of 1974, opposition to the construction of the dc line developed in Minnesota. Some county planning commissions and county boards opposed a line routed through their counties and recommended the imposition of impossible or illegal conditions to permits. One county attempted to adopt new zoning regulations to exclude transmission lines altogether.

Because of the impossible situation the Cooperatives found themselves in, they elected to have the State of Minnesota determine the route of the transmission line under a new law known as the Power Plant Siting Act of 1973 (Hartman and Simmons, 1979) from which the line was intially exempted. The Cooperatives submitted an application for a corridor* certificate--the first step of the two-step process--in April, 1975. Following a six-month period during which 82 witnesses submitted almost 1,800 pages of testimony and 180 exhibits at public hearings and during which a citizens' corridor selection committee met several times, the state issued the Corridor Certificate in October, 1975.

On October 6, 1975, the Cooperatives filed an application for a Certificate of Need for the powerline and associated facilities in accordance with Minnesota statutes. Public hearings were held during December at which oral testimony from 22 witnesses was heard, including 15 persons from the general public. Sixty-five exhibits were received in evidence and the typewritten testimony covered 1,151 pages. The hearing officer's report was forwarded to the Director of the Energy Agency who reviewed the findings and issued the Certificate of Need on April 2, 1976.

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*Corridor - the general location of a high voltage transmission line up to 30 kilometers in width.

Following the selection of the corridor by the Minnesota Environmental Quality Board (MEQB), CPA and UPA applied for the designation of a route* for the line. A new series of public hearings were held by the state in March and April, 1976. In addition, a new citizens' route evaluation committee was established to study proposals for the final route of the line. The hearing examiner's report, along with that of the citizens' committee, was brought before the MEQB. After review of all the reports and public input, the MEQB issued the route construction permit for the line on June 3, 1976. Before the final decision by the MEQB, the Minnesota Department of Natural Resources completed a draft and final environmental impact statement on the transmission line as required by law.

In total, the Project was reviewed by four separate administrative proceedings in Minnesota. Over 30 public information meetings and 50 public hearings were held; over 340 witnesses introduced 500 exhibits and testified for almost 6,000 pages of transcript. Over 90% of the witnesses were members of the public.

Following the issuance of the certificates and permits for the dc line, there were nine major lawsuits filed challenging state agency decisions. On March 1, 1977, the Minnesota Supreme Court consolidated the lawsuits and appointed a special panel of three District Court judges to hear them. On July 15, 1977, the special three-judge panel unanimously upheld the decisions of the state agencies. On September 30, 1977, the Minnesota Supreme Court upheld the decision of the special three-judge panel and thus, the actions of the state agencies.

Construction

Construction of the transmission line in Minnesota began in October, 1977, and continued for one full year. In addition to construction difficulties imposed by Minnesota's harsh winter weather, further problems were created by those who opposed the Project. They shifted their attention from the regulatory and legal arenas to the field. Wherever construction activites were occurring, a crowd always gathered. The crowd not only often engaged in verbal abuse of the construction workers, but also tried to physically interfere with construction activities. Local law enforcement officials were unable to maintain order and turned to the Governor's office for help. The Governor ordered the Minnesota State Patrol to assist local law enforcement officials where necessary. At times, over 200 members of the State Patrol were on duty in the construction area.

On several occasions, violence broke out resulting in several arrests. The State Patrol used Mace to control the protestors on one occasion. The next day protestors sprayed liquid ammonia fertilizer on the patrolmen.

Violence culminated one night when a private security guard and a sheriff's deputy were shot at by several men at a construction marshalling yard. The men were apparently intent on destroying equipment at the yard

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*Route - the specific location of a high voltage transmission line up to 1 kilometer in width.

when they were surprised by the guard and deputy. Shots fired by the men missed the guard and deputy; however, one was wounded by flying debris and glass from their vehicle. Several arrests were made and one conviction resulted from the incident. The conviction is currently under appeal.

Vandalism and sabotage during construction were extensive. Heavy equipment belonging to the contractor was wrecked and line materials such as insulators and conductor were destroyed in storage yards. Before the line was completed, a lattice-steel tower was pulled down and destroyed by protestors.

Despite the protestors' efforts, the Minnesota portion of the line was completed in October, 1978, almost one year to the day from the start of construction. The North Dakota segment of the line had been completed in 1977 with no significant problems on a normal construction schedule.

Operation

The line was initially energized on October 17, 1978, followed by intermittent operation for testing of the converter facilities over a period of approximately six months. Continuous operation began in May, 1979, and commercial operation began on August 1, 1979, following completion of Unit 1 of the Coal Creek Station.

Even during operation, vandalism and sabotage continued. Through 1981, a total of 15 lattice-steel towers have been destroyed in Minnesota at a replacement cost of approximately $1.4 million. In addition, about 9,700 insulators have been destroyed for a total cost of $650,000. Security costs both during construction and operation have amounted to about $4.8 million, exclusive of those costs incurred by local, state, and federal law enforcement authorities.

Despite its problems, the line has operated well when not hampered by vandalism. In 1981, for example, when vandalism subsided, the line was available for use 98.6% of the time.

Since operation of the line began, most of the issues raised by protestors which will be described later, have faded . . . with the exception of the health issue. It is the health issue which currently keeps the controversy going and accounts for the more recent developments. Protestors have been trying to convince the state to revoke the route construction permit because of "alleged" adverse health effects caused by the line's operation. The state has taken several steps to investigate the health effects claim, but to date no action has been taken with respect to the line permit.

ISSUES RAISED

During the Project's history, several issues and concerns have been raised concerning dc technology, the location of the line, and the need for the Project. Most of these issues and concerns have been resolved by regulatory changes, by information releases by the Cooperatives, or by acceptance of the line by many of those living in the area.

Need for Power

Those who opposed the Project alleged the power to be delivered on the dc line was to be used in the Twin Cities of Minneapolis and St. Paul rather than to satisfy rural demand. Opponents wanted the Cooperatives to aggressively pursue conservation to control electrical growth rather than allow the growth of electrical power to continue unchecked. Opponents questioned whether alternatives to the proposed Project had been adequately considered during the planning phases. Such an alternative as building a generating plant within the Cooperatives' service area was more appealing to them than a mine-mouth plant with a long transmission line. Finally, opponents alleged the cost for the power to be delivered by the Project would be excessive and needlessly high.

Location

Several issues were raised with respect to the routing and location of the dc transmission line. Extensive debate was held during the hearings and at public meetings concerning the advantages and disadvantages of property line routing versus diagonal routing. Opponents questioned why "prime" farmland seemed to be preferred to the exclusion of what they termed "wildlife land." Opponents questioned why more extensive use of existing rights-of-way could not be made.

Further, a dispute arose about the location where the line crossed the border between the states of Minnesota and North Dakota. Opponents felt there was insufficient coordination between the MEQB and the North Dakota Public Service Commission (NDPSC) for the best border crossing point. Finally, opponents were concerned about the impact the presence of the transmission line would have on the value of the land it crossed.

Land Use

Many farmer-landowners potentially impacted by the line raised questions about the inconvenience the line's lattice-steel towers might create for their farming operations. Also questioned was the potential interference by the line of existing and potential irrigation in west central Minnesota. Landowners were also concerned because they felt the line would preclude the use of fixed wing aircraft for various agricultural operations. Further, landowners were concerned because they thought the electric field created by the transmission line might interfere with electronic monitoring equipment such as seeders used near the line (Gustafson et al., 1979). Concern was expressed over the aesthetics of lattice-steel structures not being consistent with the rural or agricultural landscape. Finally, it was suggested by several landowners the transmission line be constructed underground to reduce environmental and aesthetic degradation.

Regulatory Processes

Many people in west central Minnesota felt that the state regulatory process was "fixed" and was too complex for the layman. They thought the process was entirely for the benefit of attorneys and provided little opportunity for meaningful public input. Because of the perceived lack of public input, many strongly felt a total loss of control over the Project. An incident involving an incomplete transcript and additional hearings to correct the record added to the Project's problems during the regulatory process.

Eminent Domain

Many people perceived that the Cooperatives were "taking" farmland without adequate compensation. This feeling persisted despite the results of the condemnation proceedings wherein the average commissioners' award for the transmission line totaled $52,400/mile in Minnesota for a strip of land 160 feet wide.

Health Effects

Most of the issues described previously were responded to or taken care of by some means or another over the history of the Project. Either regulatory or legislative changes have eliminated several of the issues or landowners have come to recognize that the concerns originally expressed were not as severe as first thought. The only significant issue which remains to plague the Project today is health effects. This issue was raised because of concern over ozone that might be generated by the transmission line. The Cooperatives have sponsored an extensive study by the University of Minnesota which showed the transmission line contributes insignificant amounts of ozone to ambient levels (Krupa and Pratt, 1982). Concerns were raised over the biological effects of the electric fields created by the line. Initially, these concerns were raised in the context of studies and reports dealing with ac transmission lines. As the Project evolved, attention was given to dc electric fields and more recently, adverse health effects have been alleged from air ions in the vicinity of the transmission line. Landowner concerns have also been raised over perceived potential health impact of the transmission line on farm animals in the vicinity.

CAUSES

External

As long and as controversial as the Project has been, there is no doubt that many causes have contributed to the Project's problems. Among the major external causes one can identify are as follows:

The Times. The Project was proposed at a time when Watergate and other world events had generally caused a public mistrust of government and business. This country was in the midst of a social revolution in which many established practices and ways of doing business were seriously being questioned. The time was right for a major energy project to be seriously questioned by the public.

The People. The Project coincided with a period in our history in which consumerism was very evident. First, the public wanted a risk-free environment. Secondly, the public demanded more of a say in the conduct of its own affairs and in the direction individuals' lives take. This was particularly evident among the strong-willed people of several ethnic backgrounds who live in west central Minnesota. They generally felt a mistrust of "city people," particularly those from the Minneapolis and St. Paul area where both Cooperatives are located. Farmers felt that this Project was one of several outside influences which were slowly deteriorating their way of life. Landowners who were closely tied to the land felt the powerline an unnecessary intrusion on the land.

Finally, those who opposed the Project were able to find strong leaders to take control. The leadership of the opposition groups changed often during the course of the Project and a new leader always stepped forward to fill any void. Leaders from outside the Project area who had been engaged in various protest movements in the 60's were attracted to the controversy, often playing strong leadership roles.

The Law and Regulations. The last external major cause of the Project's problems can be attributed to the legal and regulatory framework in which the Project was conceived and planned. The Power Plant Siting Law was created in 1973 and the Project was the first to be routed under the law. Deficiencies in the law and regulations were surfaced by the Project as it went through the process for the first time. Among the law's significant problems was its provision for "broad-spectrum citizen participation." Many who opposed the Project misinterpreted this provision to mean "Do as I say," and could not differentiate between participating in a routing decision and making the decision which was the responsibility of the MEQB.

In addition, another utility had proposed large transmission facilities in the area just prior to the time that the Project was first announced which sensitized people and led to the rapid formation of opposition groups.

Internal

There was little doubt that both CPA and UPA were responsible for several of the problems experienced in the Project. Initially, the Cooperatives exhibited a very inflexible position with respect to the location of the transmission line in farmland. In addition, the Cooperatives did not seek to communicate in any meaningful way and solicit input from local units of government and the general public.

Public relations in the initial phases of the Project were very poor because both Cooperatives were inadequately staffed to handle a project of this size. Representatives went in the field with inadequate training and background. Because of lack of appropriate staff and preparation, the Cooperatives made what some might consider to be an inappropriate use of consultants to speak on behalf of the Cooperatives at meetings and forums when Cooperative representatives should have been speaking.

The Cooperatives misjudged the public's mood, maintaining the position that the opposition movement was a transient phenomenon which would eventually fade. The Cooperatives took advantage of a state siting process which provided that no project could be stopped or significantly modified. The only matter to be decided by the siting process was "where" the line should be located, not "whether" it should be built. This situation was misunderstood by the public and created further animosity toward the Project.

The underlying cause for opposition to the project appears to have resulted initially from a perception by those directly affected that the line constituted an unacceptable intrusion upon an existing way of life (Casper and Wellstone, 1981). The Cooperatives did very little to challenge that perception. While the effects of the line were specific to individual landowners, its benefits were general and not perceived to apply directly to landowners in west central Minnesota. The Cooperatives contributed to the Project's problems by rejecting contact with landowners in favor of complete reliance on the state's regulatory processes for routing the line. As the Project progressed, outside dissidents took advantage of this situation and kept the controversy going, not because of any impact the Project had on rural Minnesota and Minnesotans but because, as social revolutionaries, they felt the Project represented the worst aspects of central versus decentralized electric power generation and big business in a capitalistic society and therefore could be used to further other purposes.

NORTH DAKOTA EXPERIENCE

As stated previously, the transmission project extends over two states. Roughly two-thirds of the line is located in North Dakota. All of the problems which have received attention have occurred in Minnesota. The experience in North Dakota was excellent. Better than 98% of the required right-of-way was acquired through voluntary negotiation with landowners. No significant acts of vandalism occurred in North Dakota. No protests were experienced during construction of the transmission line. Why have there been no problems in North Dakota as contrasted to the Minnesota experience? Again, there are several reasons but the three main areas of difference relate to the people we dealt with, the regulatory climate in North Dakota, and changes in the way the Cooperatives handled matters.

With respect to the landowners, they were more "cooperative" minded in North Dakota. Landowners in North Dakota are tied to a cooperative in one form or another. North Dakota is an energy exporting state. Residents are more accustomed to large energy facilities such as generating plants near the lignite fields, large hydroelectric dams, and long high voltage transmission lines. They have come to accept such facilities as necessary for the economy of their state and the good of the region.

North Dakota has a power plant siting law under which the dc transmission line was routed. However, the laws and regulations are significantly different from those in Minnesota. The North Dakota process is concerned only with the acceptability of a route or routes suggested by the utilities or others. In Minnesota, the process is more concerned with finding the "best" route, a concept which is desirable in theory but difficult to achieve in practice. As opposed to the MEQB, the NDPSC is generally pro-industry and reasonably cost-conscious. This is because the NDPSC has the responsibility not only of locating large energy facilities but also of determining an appropriate rate of return to utilities for these facilities. They must be concerned about costs both to the utilities and to consumers.

Finally, because the North Dakota process occurred after the Minnesota process, both CPA and UPA had the opportunity of applying several lessons learned in Minnesota to the North Dakota process. The Cooperatives were much more flexible in their dealings with the regulatory agency and landowners and tried to work more closely with all parties.

CONCLUSIONS AND RECOMMENDATIONS

Anyone connected with the CPA/UPA Project has undoubtedly come away with lessons they have learned because of their experiences. The conclusions to be reached are many and varied and perhaps can best be summarized by a series of statements which generally give the major lessons the author has learned from the Project.

With respect to project need:

There must be a demonstrated need for the facility, and the public and affected landowners must understand how it benefits them. The question of central versus decentralized generation and alternative technologies must be addressed. Also to be addressed are the use of conservation and load management.

With respect to project design:

(1) Expert analysis alone is insufficient since the problem is not solely a technical one.
(2) Energy projects should have human and environmental design as well as technical and economic design.
(3) Technical and economic factors are not absolutes but should be modified to accommodate human and environmental concerns. Project flexibility should be maintained as long as possible.
(4) Agricultural and rural concerns need more recognition. Circumstances unique to a project area require careful evaluation in the planning phases of a project.

With respect to landowners affected and the general public:

(1) Most members of the interested and affected public will cooperate if they believe they are being treated fairly. This requires earlier and more meaningful input to energy decisions and an open and straightforward information program (McConnon, 1979). Substantial public acceptance is essential for a successful project.
(2) Trust and credibility are essential and must be built by the utility with the public and affected landowners.
(3) Public input must be able to influence important choices.
(4) Utility representatives should leave no questions unanswered.
(5) Local authority over a project should be maintained to the maximum extent possible.

Finally, with respect to the regulatory process:

(1) The regulatory process under which a project is routed needs to be streamlined and made predictable.
(2) A regulatory review process is more productive if it is accommodating rather than adversarial in nature.

The public today senses that the energy situation in this country has changed dramatically in the past decade and the "business as usual" approach of many utilities is seriously questioned. It is therefore necessary that utilities respond to this change in public mood. Projects in the future will undoubtedly be done differently than the CPA/UPA Project, hopefully because of several of the lessons which have become apparent from our Project. The issues raised, the problems experienced and their causes are not unique to our Project. They all can be expected in future projects. The burden will be on planners of future projects to review our experiences and decide how to avoid our mistakes and which lessons that we have learned by bitter experience should be applied. Only in this way can successful projects be completed and future electrical energy supplies be assured.

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PUBLIC ISSUES AND EFFICIENCY IN RIGHT-OF-WAY USE: A MINNESOTA APPROACH

Lawrence B. Hartman[1]

ABSTRACT.--A Minnesota Supreme Court ruling (PEER v. MEQB) established the principle of "nonproliferation" by requiring that new transmission lines be placed along existing rights-of-way unless there are extremely compelling reasons for not doing so. In addition, efficient use of rights-of-way has become an important public concern. To specifically address this issue, a "Rights-of-Way Compatibility Analysis" was undertaken, which addressed technical, institutional, and electrical environmental issues associated with paralleling existing rights-of-way (transmission, highway, railroad, pipeline) and of uprating existing transmission facilities. The analysis establishes an objective methodology for rights-of-way evaluation and presents the results.

INTRODUCTION

The routing of transmission lines and their resultant impact has caused considerable public and regulatory interest in minimizing the number of new transmission line rights-of-way. This interest is reinforced by a 1977 Minnesota Supreme Court ruling (PEER v. MEQB) (People for Environmental Enlightenment and Responsibility v. Minnesota Environmental Quality Council, Minn. 266 N.W. 2d. 858 (1978) which established the principle of "nonproliferation" in Minnesota. It requires that new transmission lines be placed along existing rights-of-way unless there are extremely strong reasons for not doing so. Since the PEER decision, the Minnesota Environmental Quality Board (MEQB)--the agency responsible for route selection of transmission lines over 200 kV--has designated three transmission line routes at voltages of 230 kV and 345 kV that parallel or follow existing rights-of-way for all or part of their distance. This does not imply that all existing linear rights-of-way are suitable for use by proposed high voltage transmission lines (HVTLs). Existing rights-of-way may be unsuitable for a wide variety of reasons.

To specifically address some of the questions and issues associated with the compatibility of a new transmission line sharing with existing rights-of-way, a detailed right-of-way analysis was undertaken. It includes the

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information necessary for a better understanding of transmission facility requirements, the effects of transmission lines, and the practicality of transmission line right-of-way sharing with other transmission lines and other linear facilities.

STUDY OVERVIEW

The Transmission Line and Its Environment

This part of the study describes the elements of the power system with emphasis on both the physical and electrical characteristics of transmission lines. Also discussed are the function and considerations in selection of structures, conductors, insulation, and associated hardware; the construction requirements; the operation and maintenance of transmission lines; all of which are fundamental to analyzing right-of-way sharing and the technology of capacity uprating.

Transmission Lines Sharing Rights-of-Way with Nonelectrical Power Facilities

This part details the characteristics of highways, pipelines, railroads, and communication circuits which relate to assessment of sharing those rights-of-way with electric power transmission lines. Whereas transmission lines have much in common with each other and therefore tend to be judged by the same rules and regulations, the nonelectric power facilities have quite different objectives, operating conditions, and physical parameters. Therefore, in addition to electrical effects, a number of institutional and technical considerations and constraints are discussed.

Uprating Transmission Lines for Increased Power Capacity

One of the methods chosen by a number of utilities to transmit more electric power across existing lines is capacity uprating of existing lines. Technical considerations, National Electric Safety Code (NESC) requirements, and the electrical environmental effects of increasing current and voltage are discussed.

Power System Reliability

This part discusses the concept of reliability, the constitutent elements and guidelines for the assessment of reliability, and the needs and methods of obtaining power system reliablity.

Bibliography and Addendum

This part offers an extensive list of references of the various subjects discussed in the report. An addendum to the report contains calculated profiles of electric fields and audible noise and radio noise for all existing and compact transmission line combinations assessed in the study.

TRANSMISSION LINES SHARING COMMON RIGHTS-OF-WAY

The study objectives were to define the considerations (technical, electrical environmental, and institutional) applicable to sharing of linear rights-of-way by electric power transmission lines, to assess the compatibility of such sharing, and to present the results in a manner understandable to a broad audience. The rights-of-way considered were those of existing transmission lines (69 kV, 115 kV, 161 kV, 230 kV, 345 kV, 500 kV, ±250 kV dc, and ±400 kV dc), highways, railraods, pipeline, and communication circuits. Also considered was uprating of existing transmission facilities. The emphasis is on transmission lines as the most logical candidate for right-of-way sharing.

Transmission Line Assessment Considerations and Criteria

Two primary areas which form the basis for right-of-way requirements and which quantifty the effects and compatiblity of sharing right-of-way by more than one transmission line are the National Electric Safety Code (NESC) and the electrical environmental effects. The NESC defines minimum separation distances between transmission lines and other transmission lines, buildings, and other facilities, including railroads and communication circuits to insure both public and worker safety. Electrical environmental effects result from radio noise, television noise, audible noise, and electric and magnetic fields at ground level. The magnitudes and conditions under which these quantities may cause public annoyance or which public safety becomes important can determine the practicality of sharing rights-of-way.

To assess the conditions under which electrical environmental effects and separation requirements can impact both transmission line design and right-of-way sharing, the electrical environmental effects criteria and the NESC criteria were combined. The criteria used for assessment of the electrical environmental effects are derived from Minnesota Environmental Quality Board construction permit electrical performance standards, accepted industry practice and the National Electric Safety Code.

Summary of AC Electrical Environmental Effects Criteria

Radio Noise. The degree of interference with radio reception is a function of the transmission line noise and the radio signal strength. (1) For lines of 161 kV and below the assumed off-the-ROW limit of signal-to-noise ratio is 26 dB or greater for a signal strength of 2 mv/m. (2) For lines of 230 kV and above the assumed off-the-ROW limit of signal-to-noise ratio is 26 dB or greater for signal strength of 5 mV/m. (3) The noise limits of 1 or 2 (above) will define AM radio right-of-way width.

Audible Noise. The criteria are based on past experience, current Minnesota Pollution Control Agency Noise Regulations, and those ambient conditions when noise may occur. (1) If less than 50 dBA (wet conductor conditions) at worst location, the installation meets Minnesota Pollution Control Agency standards. (2) The 50 dBA limit will define the audible noise right-of-way width.

Electric Fields. Electric fields are evaluated in two locations: within the right-of-way the maximum field must not exceed safety levels set by the MEQB; off the right-of-way annoyance and perception levels dominate. The largest vehicle (tractor, trailer, or bus) is used to assess shock hazard in all cases. Therefore, the criteria used for evaluation address limits to maximum induced currents and voltages. (1) For 69 kV through 161 kV: 6.3 kV/m on the right-of-way and 0.95 kV/m off the right-of-way (see No. 3 below). (2) For line voltages of 230 kV and above: 8.0 kV/m or a maximum of 5 mA assuming the largest vehicle expected on the ROW is used on the right-of-way and 1.5 kV/m off the right-of-way (see No. 3 below). (3) Where exposure to the public is significant (e.g., on highway shoulders), there should be no perception even for the largest vehicles. This is 0.23 kV/m.

Magnetic Fields. Induced currents and voltages cannot be quantitatively addressed and are dependent upon specific system and object parameters, nor can they be addressed for the generalized conditions of circuit design and voltage.

DESCRIPTION OF REPRESENTATIVE TRANSMISSION LINES ASSESSED FOR RIGHT-OF-WAY SHARING

Applications of the NESC and electrical environmental effects criteria requires characterization of the transmission lines being considered. These necessary characteristics include line voltages, span lengths, conductor sizes, tensions, and heights above ground (i.e., the mechanical and electrical characteristics of the transmission lines), conductor clearances, and a number of other minor characteristics. Generation and transmission utilities that operate in Minnesota supplied the representative characteristics for evaluation for each voltage level in their transmission system. For single circuit lines, the voltage levels were 69 kV, 115 kV, 161 kV, 230 kV, 345 kV, 500 kV, ±250 kV dc, and ±400 kV dc. For double circuit lines, the voltage levels were 69 kV, 115 kV, 161 kV, and 345 kV.

For single circuit lines, the structure types were single wood pole for 69 kV and 115 kV; H-frame wood pole for 161 kV and 230 kV; and self-supporting steel lattice for 345 kV and 500 kV. The double circuit structures were single wood pole for 69 kV; steel lattice for 115 kV; wood H-frame for 161 kV; and steel single pole for 345 kV.

The application of compact line technology for new circuits sharing rights-of-way with conventional circuits was also investigated. Four compact single circuit lines (115 kV, 230 kV, 345 kV, and 500 kV and three double circuit lines (115 kV, 345 kV, and 500 kV) were selected to illustrate the effect of compaction of new lines on right-of-way sharing.

Using the voltage levels above, minimum right-of-way requirements were established for all individual transmission lines, single circuit lines with other single circuit lines and double circuit lines, double circuit lines with double circuit lines, and compact line design using existing and larger conductors for all single and double circuit combinations.

RESULTS

The rights-of-way calculated are the minimum values for the criteria and assumptions defined. Frequently, practical requirements will dictate that wider rights-of-way be used. Therefore, the rights-of-way calculated and discussed are those that are necessary once a transmission line is constructed and in operation.

Using the NESC and the AC electrical effects criteria for radio noise, audible noise, and electric field strength at ground level, rights-of-way widths were calculated for all the voltage levels and combinations identified for assessment. For purposes of illustration Table 1 presents results for individual transmission lines. Illustrated are a wide variation in requirements for the various criteria and the tendency for the electrical environmental effects to become more important at the higher voltage levels. The minimum right-of-way criteria for each line in Table 1 represents the maximum of the individual limits. These right-of-way requirements can be compared to the right-of-way needed for sharing and the resultant impact assessed to evaluate their overall suitability.

Table 1. Minimum ROW width for individual transmission lines.

	Minimum Width of ROW (feet) for				
System Voltage kV	NESC	Radio Interference	Audible Noise	Electric Fields	Minimum ROW (feet)
69 (1 Ckt)	32	0	0	0	32
115 (1 Ckt)	38	0	0	32	38
161 (1 Ckt)	75	0	0	88	88
230 (1 Ckt)	83	0	0	88	88
345 (1 Ckt)	109	133	0	148	148
500 (1 Ckt)	146	186	0	220	220
±250	90	80	0	--	90
±400	104	136	0	--	136
69 (2 Ckt)	33	0	0	0	33
115 (2 Ckt)	58	0	0	0	58
161 (2 Ckt)	73	0	0	62	73
345 (2 Ckt)	93	84	0	104	104

NOTE: Zero in column denotes limiting criteria not reached.

Constraints for evaluating two transmission lines on a common right-of-way are more complex than for individual circuits since different voltages and different structure designs have different requirements. Figure 1 illustrates, for example structures, the three dimensions, A, B and C, which must be considered. Dimension B is determined by the NESC, while A and C may be determined by either the NESC or the electrical environmental effects performance criteria..

Table 2 illustrates the right-of-way required by each performance criterion for single circuit lines sharing right-of-way. Included in Table 2 is the minimum right-of-way required, which is the sum of dimension B and the maximum requirements of A and C for the NESC or the electrical environmental effects criteria.

Analysis of Table 2 shows that the NESC or the electrical environmental effects or a combination of both may limit right-of-way width. For example, the right-of-way required for a 69 kV line sharing with a 115 kV line is determined by NESC criteria. For a 500 kV line sharing with a 500 kV line, the limit is the electrical environmental effects. In some instances, for example a 69 kV line sharing with a 230 kV line, the limit on one edge is NESC and the other edge is the electrical environmental effects.

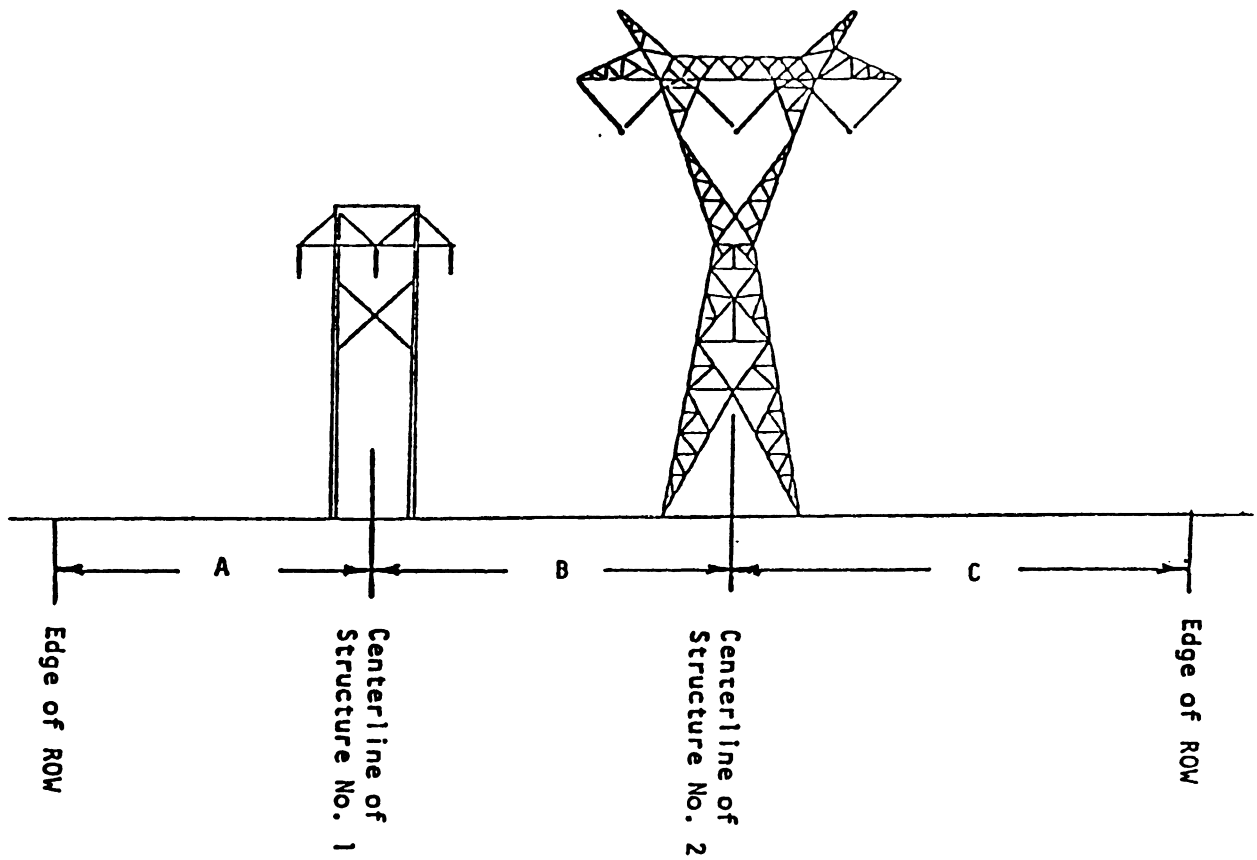

Figure 1. Illustration of right-of-way dimension.

An analysis comparing right-of-way requirements for lines on individual rights-of-way and lines sharing right-of-way illustrate that rights-of-way for sharing are usually wider than individual rights-of-way. However, in some cases, even without modification or mitigation, a second line added to an existing transmission line right-of-way may actually reduce the right-of-way requirement (e.g., an individual 500 kV line versus a 500 kV line with a 115 kV line) or, conversely, may not require additional right-of-way for the same NESC and electrical effects criteria. When this occurs, it is because the limits in both cases are electrical environmental effects and the addition of the circuit reduces the magnitude of the effect. Frequently, when the addition of another circuit on an existing right-of-way requires added right-of-way width, or when the environmental factors become more significant, a degree of mitigation is possible. Increasing the height of conductors above ground, rearranging the phases, and/or increasing the size of the conductors will reduce the electrical environmental effects. Whether such modifications will reduce the electrical environmental effects sufficiently to allow addition of the second circuit is a function of the two voltage levels involved and the original right-of-way width. For example, addition of a 115 kV line,

Table 2. Minimum ROW width for transmission lines sharing ROW.

Line No. 1 Voltage (kV)	Line No. 2 Voltage (kV)	Minimum Width of ROW (feet) for									Minimum ROW Feet
					Radio Interference		Audible Noise		Electric Fields		
		A (Ft)	B (Ft)	C (Ft)	A (Ft)	C (Ft)	A (Ft)	C (Ft)	A (Ft)	C (Ft)	
69	69	16	16	16	0	0	0	0	0	0	48
69	115	16	18	19	0	0	0	0	9	7	53
69	230	16	40	42	0	-	0	0	1	42	98
69	345	16	53	55	9*	63	0	0	11	72	141
69	500	16	71	87	13*	79	0	0	15	100	187
69	±250	16	44	45	80*	38	0	0	0	0	105
69	±400	16	51	52	21*	70	0	0	0	0	137
115	115	19	16	19	0	0	0	0	19	11	54
115	230	19	38	42	0	0	0	0	14	45	102
115	345	19	52	55	22	67	0	0	18	75	149
115	500	19	70	87	19	82	0	0	20	103	193
115	±250	19	42	45	25*	43	0	0	8	27*	106
115	±400	19	49	52	16*	71	0	0	8	33*	139
161	161	38	48	38	0	0	0	0	45	45	138
230	230	42	54	42	9	10	0	0	46	47	147
230	345	42	69	55	44	68	0	0	47	76	192
230	500	42	88	87	45	83	31	18	49	104	320
230	±400	42	67	52	35*	73	0	0	44	30*	184
345	345	55	76	55	71	71	32	80	75	76	227
345	500	55	95	87	71	85	39	100	76	102	273
500	500	87	105	87	86	87	62	126	104	104	313
±250	±250	45	52	45	43	42	0	0	-	-	142
±400	±400	52	71	52	72	72	0	0	-	-	215

NOTES:
Zero in column denotes limiting criteria not reached; * denotes Dimension A is to right of center line of structure 1 or Dimension Cis to left of center line of structure 2; criteria of high voltage line are applied; and electrostatic fields for AC lines only.

either single or double circuit, to an existing 500 kV right-of-way can likely be accomplished with minimum, if any, modification to the existing right-of-way. However, addition of a 500 kV line to an existing 115 kV right-of-way would require a much wider right-of-way unless the original right-of-way was much wider than that required for the NESC and electrical environmental effects.

The limits defined by the NESC are much less subject to mitigation than are the electrical environmental effects or other nonregulatory constraints. While shorter span lengths accompanied by reduced sag may allow some reduction in right-of-way width, it is generally not significant. Also, modification of both span length and conductor height above ground normally come at a significant cost.

Rights-of-way for many, if not most, existing lines, however, are most often wider than the minimum defined by either NESC or electrical environmental effects. Sharing of existing rights-of-way by transmission lines is frequently possible within the constraints of the NESC and acceptable electrical performance when the ability to design a line to minimize the electrical environmental effects is also considered.

CONCLUSION

This study presents Minnesota's approach to providing the public and others with the information necessary to understand many of the questions and issues associated with right-of-way compatiblity. Besides quantifying the technical and institutional requirements necessary to evaluate right-of-way compatibility, it applies the criteria for evaluation to a broad range of existing rights-of-way combinations and presents the results. Other factors not discussed in the report must also be considered when evaluating the practicality of existing rights-of-way for sharing. This includes reliability, terms of the original easement, and perhaps most important, the environmental and human impact of adding a higher voltage line to a poorly routed lower voltage line or other existing rights-of-way which may not be suitable for a new transmission line.

LITERATURE CITED

Electric power transmission lines--an assessment of rights-of-way compatibility, prepared for the Minnesota Environmental Quality Board by Power Technologies, Inc., Schenectady, New York.

CLARITY, CONSULTATION, AND COMMITMENT INGREDIENTS FOR SUCCESSFUL TRANSMISSION LINE ROUTING

Bradford M. Stern[1] and Janis T. Munson[1]

ABSTRACT.--A case study is referenced to illustrate the benefits of incorporating three key principles into transmission line routing projects. These principles--clarity of approach, continual consultation, and commitment to mitigation practices--serve to ensure a route selection effort that is of high quality, facilitates licensing approval, and promotes good relations between the project sponsor and the public.

INTRODUCTION

Transmission line routing is a complex process. A large geographical area must be analyzed to identify and select a linear route, usually 1000-2500 feet (300-750 m) in width, for a proposed transmission line right-of-way. The route selected must be the most suitable location among several alternative routes. The test for suitability is based on the potential for affecting the environment adversely; the costs for designing, constructing, and operating the transmission line; and the likelihood of licensing approval.

A successful transmission line route selection process ultimately will select a route that is acceptable to the project sponsor, the regulatory agencies, and the public, but success also depends on maintaining a schedule and budget. To accomplish this, the selection should incorporate three key principles--clarity, consultation, and commitment.

Clarity of Approach

Suitable routes must be selected by a process that is straightforward and understandable, yet thorough in its evaluation of the complex mix of engineering, economic, and environmental concerns.

Consultation

Working relationships should be established with regulatory agencies and appropriate public participants early in the planning and maintained throughout the selection process. Such consultation will help identify special policies and issues of concern, and provide up-to-date data that

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are critical to the selection process. With this information, potential conflicts will be minimized and subsequent licensing will proceed on schedule.

Commitment to Mitigation

A mitigation program informs the public of the management's support to minimize adverse impacts. It identifies issues that can and cannot be mitigated fully, thus, focusing the route selection on concerns for which feasible mitigation measures cannot be implemented.

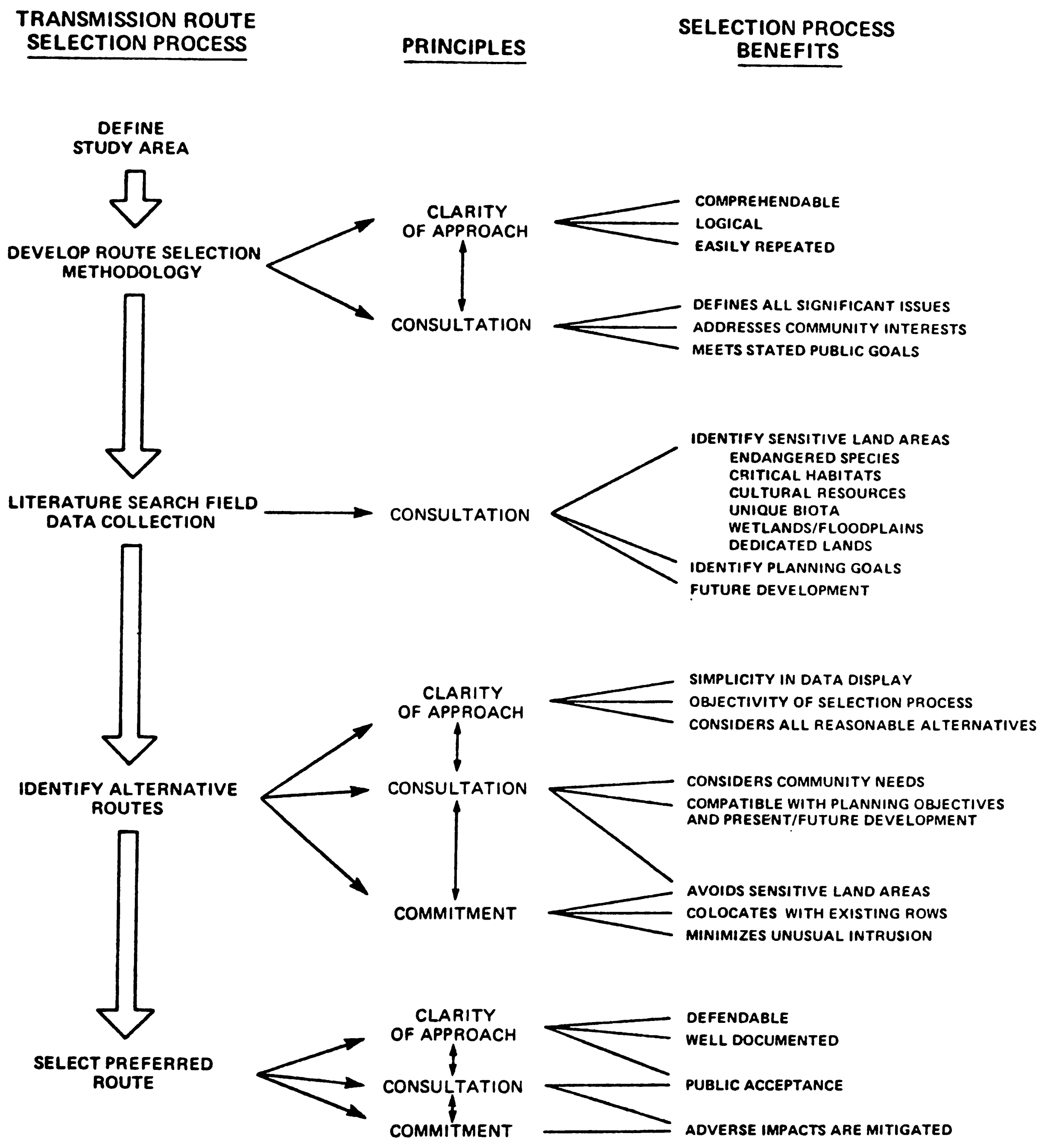
Clarity, consultation, and commitment are interdependent, and the success of a selection process requires that all three principles be incorporated into its development and implementation. For example, the full benefits to be gained from consultation would not be realized if the process were not completely outlined or if it were not understood by the regulators that project management was committed to reduce at least some of the environmental impacts that were unavoidable. The development of a mitigation program is incomplete without consulting regulatory agencies and the public for input into the identification of significant issues. A meaningful program committed to mitigating adverse impacts cannot be designed without defined objectives, hence a defined program. The following diagram (Figure 1) illustrates the relationships and the benefits of these principles in the selection process.

These principles are demonstrated through the route selection study conducted for the transmission lines associated with East Kentucky Power Cooperative's (EKPC) J. K. Smith Power Station.

PROJECT DESCRIPTION

United Engineers performed a study for East Kentucky Power Cooperative (EKPC) to select transmission line routes associated with the J. K. Smith Power Station. The scope comprised selecting and evaluating alternative routes totalling 182 miles (300 km) to eight termination points for 138, 161, and 345 kV lines. The study area, or region of interest, included 19 counties (approximately 3000 square miles (7800 sq km) in eastern Kentucky (Figure 2). The region of interest encompassed many diverse features such as large expanses of prime farmland, wild mountainous terrain, a geologically unique Knobs Region, broad floodplains, urban centers, diverse terrestrial habitat, and significant public land holdings including the Daniel Boone National Forest.

Following completion of the 5-month study, an environmental assessment (EA) was prepared in conformance with the Rural Electrification Administration's (REA) National Environmental Policy Act (NEPA) compliance program (USDA, 1980). The EA was filed with the REA, cooperating federal agencies, and Kentucky Department of Natural Resources. The REA issued a Final Environmental Impact Statement (FEIS) for the J. K. Smith Power Station and the transmission facilities in December 1980, 11 months after the transmission EA submittal.



TRANSMISSION ROUTE SELECTION PROCESS
PRINCIPLES
SELECTION PROCESS BENEFITS
DEFINE STUDY AREA
DEVELOP ROUTE SELECTION METHODOLOGY
CLARITY OF APPROACH
COMPREHENDABLE
LOGICAL
EASILY REPEATED
CONSULTATION
DEFINES ALL SIGNIFICANT ISSUES
ADDRESSES COMMUNITY INTERESTS
MEETS STATED PUBLIC GOALS
LITERATURE SEARCH FIELD DATA COLLECTION
CONSULTATION
IDENTIFY SENSITIVE LAND AREAS
ENDANGERED SPECIES
CRITICAL HABITATS
CULTURAL RESOURCES
UNIQUE BIOTA
WETLANDS/FLOODPLAINS
DEDICATED LANDS
IDENTIFY PLANNING GOALS
FUTURE DEVELOPMENT
IDENTIFY ALTERNATIVE ROUTES
CLARITY OF APPROACH
SIMPLICITY IN DATA DISPLAY
OBJECTIVITY OF SELECTION PROCESS
CONSIDERS ALL REASONABLE ALTERNATIVES
CONSULTATION
CONSIDERS COMMUNITY NEEDS
COMPATIBLE WITH PLANNING OBJECTIVES AND PRESENT/FUTURE DEVELOPMENT
COMMITMENT
AVOIDS SENSITIVE LAND AREAS
COLOCATES WITH EXISTING ROWS
MINIMIZES UNUSUAL INTRUSION
SELECT PREFERRED ROUTE
CLARITY OF APPROACH
CONSULTATION
COMMITMENT
DEFENDABLE
WELL DOCUMENTED
PUBLIC ACCEPTANCE
ADVERSE IMPACTS ARE MITIGATED

Figure 1.

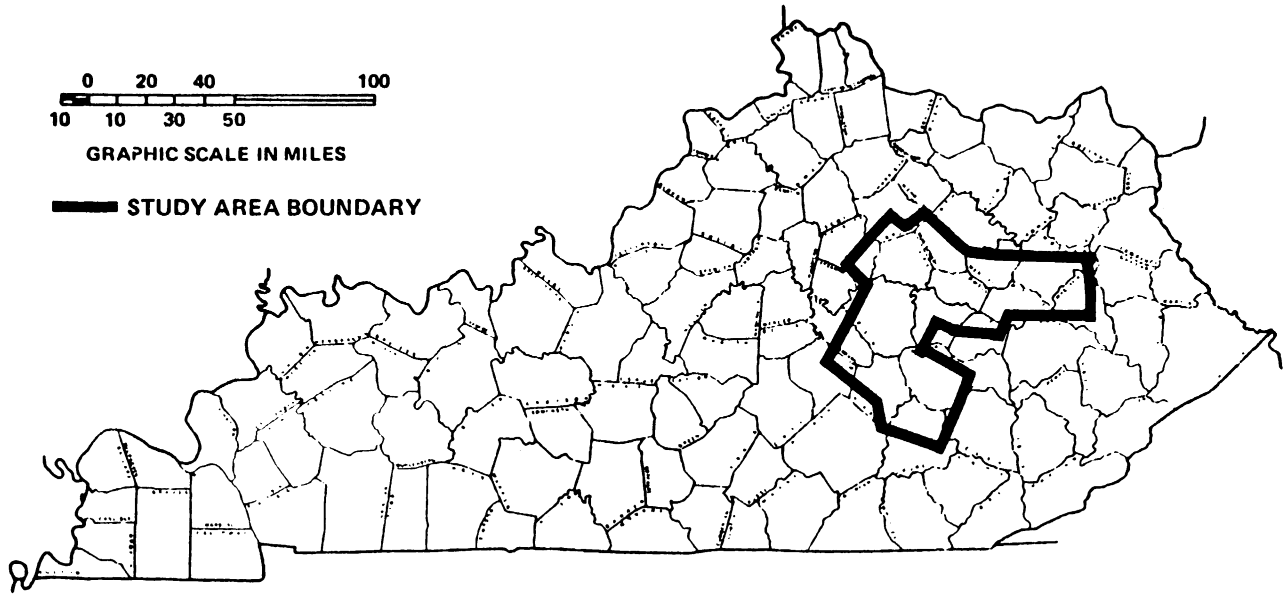


Figure 2. EKPC transmission route study area.

CLARITY OF APPROACH

Overview

The goal of a transmission line route selection study is to identify the most suitable transmission line route. The selection process, that begins with a large geographical area (often termed Region of Interest) and culminates with the identification of the most suitable route, must be straightforward and understandable. When presented to regulatory agencies and the public, the process should produce a defendable case that supports the recommendation of a specific linear route. The achievement of this goal is a direct function of the clarity of the approach to transmission line routing. That is, a clear and logical decision-making process facilitates the understandable presentation of the study results. This in turn facilitates regulatory and public review and acceptance of the route.

Case Study Discussion

The region of interest encompassed a large area with a high level of diversity. The method used in selecting and recommending routes had to synthesize the many complex variables influencing route selection in a systematic and defendable manner, and the selection process had to be understood by all concerned. A four-phase sequential selection process was developed. Each phase reduced the area under investigation successively, while increasing the amount of data and level of analysis The "macro to micro" stepwise approach provided a clear and well documented record of the decision-making process. (Figure 3).

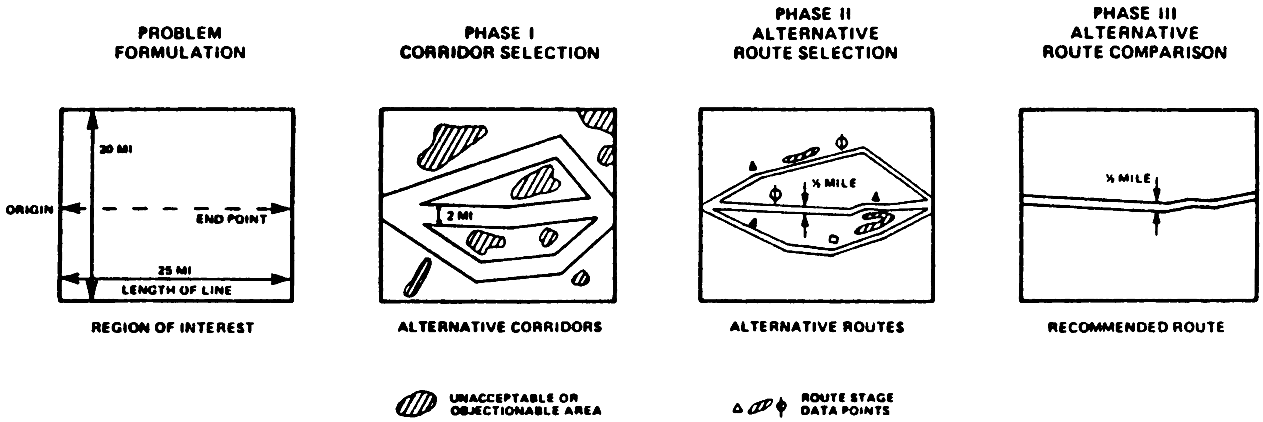


Figure 3.

All phases of analysis were developed from a consistent format to ensure that they would be organized and documented. This consisted of developing specific criteria to define what was being considered, the basis of the criteria, the method of conducting the evaluation, and the method of displaying the results. To ensure that a logical progression toward the recommendations of the most suitable route was made, each of the following phases was developed discretely.

An initial problem formulation phase was conducted.

Phase I screened the region of interest for significant special land areas determined less desirable for transmission line routing and identified two or three 2-mile wide alternative corridors per line termination point.

Phase II screened the alternative corridors for small scale land areas determined to be unsuitable for transmission routing and identified one-half-mile wide routes within each corridor.

Phase III rated the alternative routes for each termination point and selected the route that optimized environmental impacts and engineering costs. This final evaluation was based on quantitatively rating each route's environmental impact potential; this in turn facilitated the comparison of alternatives based on costs and environmental impact by expressing both numerically. Many of the judgments used in selecting routes were standardized, and a clear logic to the decision-making process was provided.

A more detailed outline of the phases of analysis is provided as Figure 4.

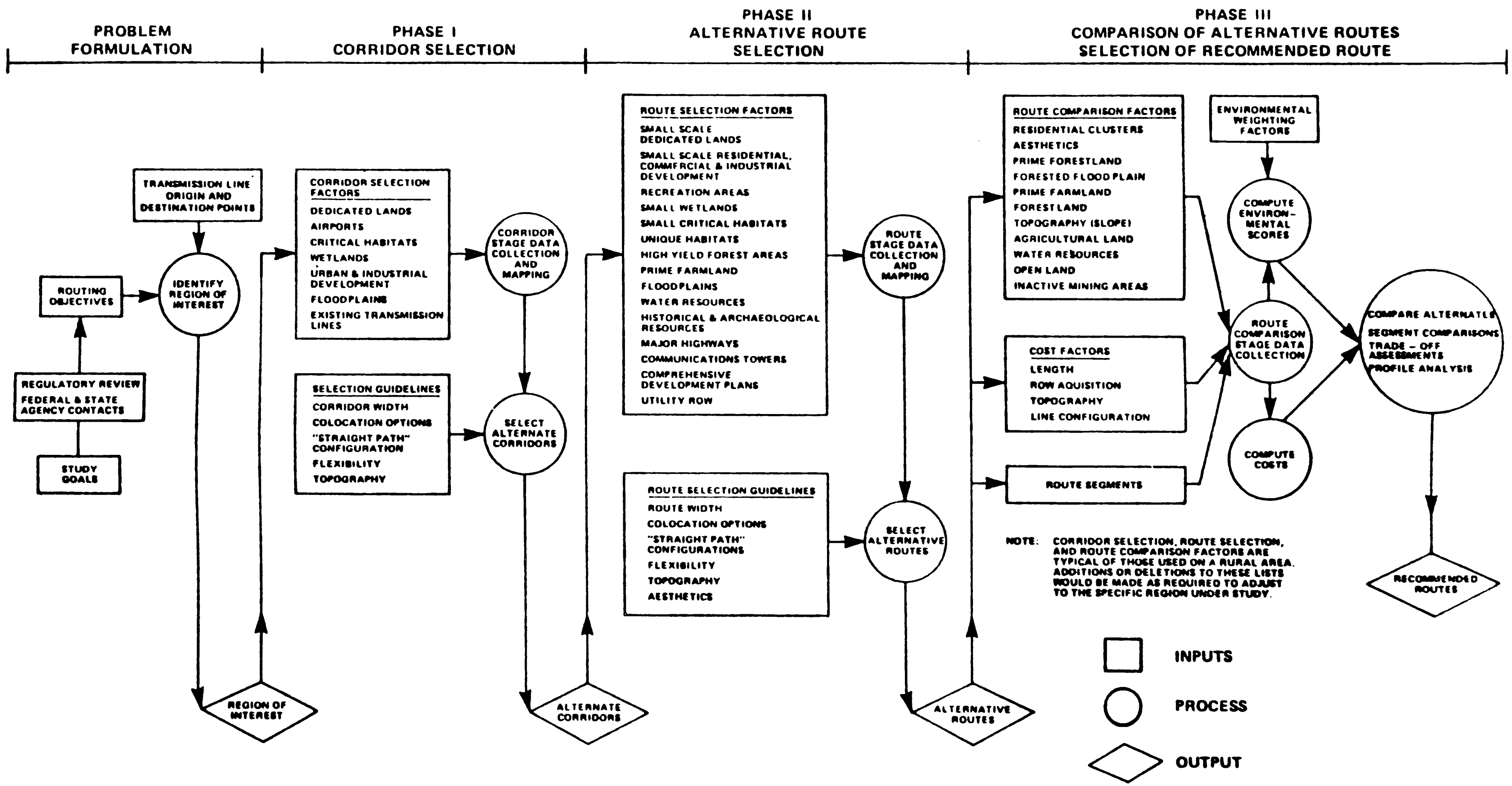


Figure 4. Case study route selection methodology.

By making each phase of analysis discrete, the preliminary results could be presented to regulatory agencies and selected public representatives for their review and comment. The use of a consistent format and quantification of environmental impacts provided a clear explanation to the reviewers of what was evaluated, and this facilitated their contribution to the decision-making process.

Summary

Based on the principle of maintaining clarity of approach, the authors developed a "macro to micro" four-phased procedure. This accurately related to the public the route selection process, indicated the sequencing of analysis, the results of the assessments made, provided the data base needed for documentation, and identified eight one-half-mile wide transmission routes that were acceptable to EKPC, regulatory agencies, and the public.

CONSULTATION

Consultation with regulatory agencies and the public is already a part of the scope of NEPA (and/or state-level equivalent). The extent to which such consultation occurs before formal scoping and review (during front-end studies, such as route selection) is generally left to project management. There are many benefits to be realized by implementing a program of consultation during route selection. For example, regulatory requirements are dynamic. Because the goal of route selection is the identification of a route or routes that will comply with all applicable regulations, it is important at the project outset to use the most recent data available. Consultation provides still another benefit, namely the establishment of working relationships with agencies. Developing working relationships during the initial phase of route selection provides valuable input concerning agencies and public sensitivity to selected issues.

For the EKPC project, public agencies were involved from the beginning. Agency involvement both improved the decision-making process and facilitated the approval of the EIS.

Problem Formulation

This step in the siting process developed the overall standards and criteria that were used in the multi-staged route selection. Rules and regulations identified some of the issues, but there were also factors of non-regulatory concern that were important for obtaining an approved transmission route. For example, several land forms in the Knobs Region were identified by public agencies as unique from the standpoints of geology and terrestrial habitat, and were worthy of preservation.

Data Collection

The EKPC project was based on reconnaissance-level information. If the project had relied strictly on published information, the data base would have been inadequate and any decisions that were made would have been incomplete. Through consultations with agencies and appropriate members of the public, the data base was greatly expanded. Additional input to the initial list of issues refined the methodology, and new issues were introduced to the methodology. These included unpublished mappings of prime farmland, mining locations, boundaries of public and private recreational and resources management areas, archaeological site locations, and future land dvelopment.

Preliminary Results

Agencies were asked to review the results of each stage of the selection study, to ensure that there were no "fatal flaws" with the corridors and routes proposed. This review proved especially valuable for certain aspects of the selection process. Two of the transmission routes, for example, required crossing the Daniel Boone National Forest. Through consultation with regional foresters, the authors were assured that the routes identified did not impact areas that were highly sensitive and incompatible with transmission line facilities. A third route required crossing either U.S. Army property or Kentucky Central Wildlife Management Area. Consultation with responsible individuals at these properties resulted in the identification of a route that would present only minimal impacts to both areas. Information of obvious importance, but nevertheless unavailable in the literature, came from the U.S. Forest Service. They were developing, concurrently with the transmission project, a prime and unique forestland program, but at that time maps delineating prime forestlands were not finished. Through consultation with the regional foresters, a working definition of the lands acceptable to the U.S. Forest Service staff was established, and, consequently, routes were selected that minimized impact to these forestlands.

Summary

The route selection process reflected the concerns of the agencies. This reduced the potential of overlooking significant issues and resulted in the development of a feasible mitigation program to ensure that the routes selected would impact the environment minimally. The authors found the approach to consultation to be conducive to the establishment of the working relationships, the development of the data base, and feedback on issues. Several agencies and members of the public indicated appreciation of the opportunity to have had early inputs to the process. Consequently, the preparation of the environmental assessment and EIS for the transmission routes required few changes, and the approval process was not subject to delays.

COMMITMENT

Overview

It is impossible to avoid all adverse impacts through selection of the route's location, but a meaningful selection process can be achieved by incorporating into it project management's commitment to a mitigation program.

First, feasible measures to reduce impacts can be made by identifying positive features of the study area that serve to mitigate impacts. Colocation with an existing ROW is an example. Second, alternative routes can be compared with the knowledge that, in the collection of all impacts presented by the routes, at least some can be reduced by the application of feasible mitigation measures. Categorizing the collection of impact issues according to the opportunity and commitment to apply the feasible measures provides a realistic appraisal of the relative significance of all impact issues.

Case Study Discussion

In the EKPC project, the initial program of mitigation commitments was developed during the problem formulation phase. The development of the program included consultations with the appropriate public agencies such as the U.S. Forest Service. Their early input facilitated the selection of appropriate mitigation measures that, in turn, made approval of the EIS more likely.

Initial commitments to identify positive features of the study area included routes that would minimize visual impacts of skylining, tunneling effects, incompatible scale, and focal dominance; where colocation with existing ROWs would reduce the potential of impact; that are accessible to existing roads, thus minimizing the need for access road construction; and that provide flexibility for final ROW selection.

Alternative routes could then be identified and compared with the knowledge that additional elements of mitigation would be implemented. For example, avoiding excessively steep slopes and the commitment to cut vegetation along steep slopes selectively reduced the potential of impact from erosion. Comparing routes based on terrain crossed was, therefore, considered a relatively insignificant issue. The number of streams crossed was also considered insignificant because of commitments to maintain a vegetative buffer zone along stream banks and to set back transmission towers a fixed distance from streams.

Summary

Development of a mitigation program during the route selection process provided a meaningful basis for the identification and comparison of alternative routes. The results of the route selection process were a one-half-mile wide route location and formal commitment by EKPC to a program of mitigation activities to be undertaken during ROW location, line construction, and operation. Presentation of both the location and impact reduction measures ensured the regulatory agencies and the public of EKPC's good faith and facilitated the acceptance and the licensing of the proposed routes.

CONCLUSION

A route selection study incorporating the three principles of clarity in approach, continual consultation, and commitments to mitigation is recommended. This methodology establishes the decision-making process and is the basis for the documentation of that process. A clear and understandable methodology for both selecting the route and presenting results is critical.

During the selection process, a program for continual consultation with regulatory agencies and the public greatly enhances the quality of the data base and identifies the significant selection factors. Recognizing that agency and public review will occur during the mandatory hearings and document review, it is beneficial to establish working relationships with these groups early, incorporate significant concerns as route selection factors, and resolve conflicts that may arise during a more flexible period in the project.

The commitment to mitigation measures eventually undertaken during final ROW location and construction should be identified during route selection to the extent that a more precise expectation of impacts and project costs may be made. The tradeoffs made among factors indicative of impact are tempered by this knowledge, and decision-making focuses on these impacts that cannot be avoided. Furthermore, the opportunity to implement mitigation activities in selecting routes, such as for aesthetic issues, needs to be defined during the selection process.

The authors' experience was that adoption of these "three C's"--clarity, consultation, and commitment--during the route selection activity was highly beneficial both to the task at hand and to the subsequent activities of licensing and design.

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SITING CONSIDERATIONS: MULTIPLE-USE VERSUS SINGLE-USE RIGHTS-OF-WAY

J. Michael Steinmaus[1]

ABSTRACT.--This paper presents a perspective on the concepts of multiple-use of utility and transportation rights-of-way. Potential benefits and conflicts of joint development of rights-of-way corridors in urban and rural settings are discused. Compatible nonutility uses of rights-of-way are identified. Utility and regulatory policies are assessed to provide an insight into the circumstances resulting in multiple-use versus single-use rights-of-way.

INTRODUCTION

This paper describes the factors involved in the use of existing rights-of-way corridors or establishment of new rights-of-way, and considers the joint-use of rights-of-way by utility systems (electric transmission lines; pipelines for gases, liquids and slurry; and communication lines) and transportation systems (highways, railroads, and air space). Additional parameters discussed in this paper are nonutility/transportation uses of rights-of-way and policies and guidelines affecting right-of-way selection.

RIGHT-OF-WAY REQUIREMENTS

Representative right-of-way widths for the various systems will vary based upon the policies of the utility, transportation department, or regulatory agency.

Electric Transmission Lines

Right-of-way width requirements for transmission lines are primarily dependent on the voltage and the number of circuits (Berkshire County Regional Planning Commission, 1974). Other factors determining width requirements are side clearance to obstacles such as buildings and vegetation, distances required to minimize radio and TV interference, and maintenance access (U.S. Fish and Wildlife Service, 1979). Typical rights-of-way widths are shown in Table 1.

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Table 1. Typical Right-of-Way Widths.

Line Voltage	Typical ROW Widths (ft)(m)
115/138 (AC)	90-150
230 (AC)	100-150
345 (AC)	150-170
500 (AC)	135-200
765 (AC)	260-280
+400 (DC)	104-150

SOURCE: U.S. Fish and Wildlife Service, 1979.

Pipelines

Pipeline right-of-way requirements can vary significantly depending upon the medium transmitted. Petroleum, gas, hazardous liquids, coal slurry, sewers, and water are common substances transported by pipelines. A common right-of-way width is 60 feet and allows adequate room for access. Most pipelines are buried and sometimes encased to enhance structural protection, especially for pressurized lines and lines used for conveyance of flammable, corrosive, or other potentially hazardous substances. Requirements for the depth of buried and encasement practices vary among the states primarily as a result of differences in engineering opinion and local engineering experience.

Underground and underwater pipelines are susceptible to electrolytic corrosion. To minimize this corrosion, most pressurized lines are protected by cathodic protection, a process by which an electric current is applied to the pipeline, making the pipeline act as a cathode instead of an anode.

Communication Lines

Communication lines and cables require a smaller right-of-way than most other utilities. For example, Northwestern Bell Telephone Company typically obtains a 15-foot easement or land acquisition for distribution cables and toll cables. Right-of-way can vary depending upon whether underground cables or pole lines are used.

Highways and Freeways

The right-of-way for highways and freeways can vary based upon location (urban or rural), topography, operation, safety, and appearance. A right-of-way width of 66 ft is adequate for many low volume roads. High volume roads may require a minimum of 100 ft of right-of-way with 120 ft or more being preferable. A right-of-way width of 150 ft (with 50 ft on each side) is considered desirable for a two-lane highway where the highway may ultimately be widened (American Association of State Highway Officials, 1965).

A desirable divided highway right-of-way width is 210 to 310 ft, depending upon the availability of right-of-way. Where this range cannot be obtained, a right-of-way of 140 to 180 ft should be obtained. These rights-of-way should have a median at least 30 ft wide. An absolute minimum width of right-of-way for a four-lane divided highway is about 92 ft, which provides for a 4-foot median, 24-foot pavements, 8-foot usable shoulders, and 12-foot borders (American Association of State Highway Officials, 1965).

Railroads

As with roadways, railroad rights-of-way vary significantly based upon land acquisition costs through the area traveled. Typical right-of-way widths are 66 ft and 100 ft.

Air Space

The Federal Aviation Administration has established standards for determining obstructions to air navigation. The standards apply to existing and proposed manmade objects, objects of natural growth, and terrain. For instance, civil airport imaginary surfaces are established in relation to the airport and each runway. A manmade object is considered a hazard to air navigation if it extends into the imaginary surface. An approach surface can extend to a maximum of 16,000 ft for precision instrument runways.

MULTIPLE-USE RIGHTS-OF-WAY

Multiple use of rights-of-way is an essential element in land use planning. In maximizing land use compatibility and minimizing conflict, the use of existing rights-of-way often appears as an attractive solution to the routing of new rights-of-way.

The primary benefits of joint-use of rights-of-way is a minimization of existing right-of-way acquisition, since there is usually a reduction in the amount of total right-of-way required. Multiple use corridors can reduce right-of-way clearing, construction of additional access roads, and additional aesthetic impacts.

Effects of multiple use rights-of-way on specific utilities and transportation systems vary according to the combination of systems utilizing a corridor. A brief analysis of the major systems follows.

Electric Utilities

Electric Transmission Corridors--Although close paralleling of power lines is an attractive routing solution from a land use standpoint, this joint use results in a reduction in service reliability and can result in safety problems during maintenance and construction. Aesthetics can also be degraded with additional structures and conductors in a corridor.

The separation between parallel lines depends on voltage, tower height, sag of conductors, and terrain. For example, in heavily populated areas clearances are increased for protection of the public. Typical minimal separation distances are shown in Table 2.

Table 2. Minimal Separation Between Parallel Transmission Lines.

Voltage (kV)	Minimum Separation (ft)(m)
115	50
230	75
345	100
500	130
760	200

SOURCE: Forest Service, 1975.

Joint-use of a corridor by several power lines reduces the reliability of the total electric system. Events external to the transmission system make up nearly 85% of the total failures of electrical systems. Typical causes are lightning, accumulated ice, fallen trees, aircraft, and windstorms.

Parallel high voltage (HV) and extra high voltage (EHV) circuits, as well as parallel distribution circuits on a shared right-of-way with HV and EHV lines can develop high voltages in neutral circuits. These induced currents require that special grounding precautions be taken to improve safety (Eichin, 1976).

Electric Transmission-Communications Corridors--Joint use corridors for power transmission lines and wire communications (including railroad signal systems) are possible but not supported by the utilities because of compatibility problems such as (1) induced and conducted noise, (2) protection of circuit integrity, and (3) public safety (Eichin, 1976). Mitigative measures include improved shielding of communication cables from the HV and EHV circuits and improved grounding practices.

Electric Transmission-Railroad Corridors--Railroad rights-of-way are often jointly used by electric utilities for power transmission since the rights-of-way are usually zoned commercial or industrial and usually connect major load centers. The utility can reduce the number of property owners to obtain an easement or fee title by dealing with the railroad (Berkshire, County Regional Planning Commission, 1974).

In addition to signal system problems, adverse effects include reliability and electrostatically induced currents. A rail mishap or storm conditions could result in a fallen conductor or tower that would block the tracks. Electrostatically induced currents can cause nuisance shocks for workers contacting insulated objects on rail cars. Proper design and adequate grounding can minimize this impact.

Electric Transmission-Pipeline Corridors--Joint-use of electric transmission and pipeline rights-of-way is very compatible. A major problem is that electrical effects of HV ac and HV dc power lines can aggravate existing corrosion situations, resulting in safety hazards to people and equipment. Solutions to this corrosion problem include proper separation, cathodic protection, and pipe insulation (Eichin, 1976).

Electric Transmission-Highway Corridors-Although the potential exists for joint-use of electric transmission and highway rights-of-way, the aesthetic impact can often be significant. The American Association of State Highway and Transportation Officials stated, "New aerial installations should be avoided at such locations where there is a feasible and prudent alternative to the use of such lands by the aerial facility." (American Association of State Highway and Transportation Officials, 1969). Likewise, the U.S. Department of the Interior and U.S. Department of Agriculture suggest, "Long views of transmission lines parallel to existing or proposed highways should generally be avoided. Alternative routes away from highways should be considered. Where ridges or timber areas are adjacent to highways or other areas of public view, overhead lines should be placed beyond the ridges or timber areas." (U.S. Department of the Interior, 1970).

Other impacts are related to reliability and compatibility. A probability of outages due to traffic accidents exists. Proper design and grounding techniques will mitigate electrical shocks from insulated objects.

Electric Transmission-Air Space Corridors-Transmission structures are not compatible with air space requirements near airports. Routings in the vicinity of airports, especially within the imaginary surface, should be avoided. Transmission structures and conductors should be below the imaginary surface and navigation obstruction aids should be considered.

Communication Utilities

Communication Corridors-Communication systems using a common right-of-way are common. Adverse impacts include crosstalk (resulting in the loss of communications), aggravated corrosion and construction damage. Proper shielding, cathodic protection, and care in surveying and construction can mitigate these impacts.

Communication-Pipeline Corridors--This multiple use of rights-of-way for these systems is compatible. Adverse impacts include increased corrosion and construction damage. Proper cathodic protection can reduce the corrosion. Quality surveying and proper trenching techniques reduce the possibility of damaging an existing pipeline or communication cable.

Communication-Transportation Corridor--Joint-use of communication systems with railroad and highway rights-of-way are common. The major adverse impact is the possibility of derailment or vehicle damage to repeater stations or above-ground facilities.

Pipeline Utilities

Pipeline Corridors--Pipeline corridors are common throughout the United States. Adverse factors include decreased reliabilility and increased corrosion potential. A fuel leak could result in the loss of all pipelines in a corridor. Corrosion potential is reduced through proper cathodic protection.

Pipeline-Transportation Corridor--A corridor with pipelines and a transportation system can be compatible. Derailment and vehicle damage to above-ground facilities is the major potential adverse impact.

Transportation Systems

Transportation systems are often expanded to facilitate additional use. This is usually accomplished through constructing additional trackage within a railroad right-of-way and highway widening, usually with additional lanes. Airports often upgrade runways through extensions of existing runways. Additional right-of-way may or may not be necessary with these systems, depending upon the expansion program and width of existing rights-of-way.

Reliability and safety are often impaired with joint-use of railroads. Derailments can block or damage adjacent trackage.

The increased traffic with improved and combined highways can potentially result in increased highway accidents. Combined highways can create more problems in interchange access if proper design is not incorporated into the highways' design.

Increased air traffic also results in a safety problem. However, improvements in air traffic control equipment are usually required along with other airport expansion.

Nonutility Use

Multiple use of rights-of-way does not stop with the joint-uses of utility and transportation systems. Agricultural, industrial, and recreational land use practices may occur within rights-of-way.

Farming is probably the most common agricultural land use on rights-of-way, especially on transmission line and pipeline rights-of-way. In most cases, the right-of-way is leased to the utility by the property owners. The utilities may place restrictions on agricultural uses, such as irrigation, to prevent accidents.

Other compatible agricultural uses are tree nurseries, lawns, and gardens. Christmas tree farms and orchards are also common.

In urban areas, where a scarcity of open land exists, utilities often allow parking lots, material storage yards, and railroad yards within the right-of-way. These agreements for multiple use, primarily with electric utilities having power transmission lines through the proposed area, stipulate that the industrial use would meet safety requirements.

Recreational uses of rights-of-way take several forms: trails, picnic areas, playgrounds, playfields, golf courses, and wildlife sanctuaries. Recreational use is practiced on electric transmission lines, pipelines, highway, and railroad rights-of-way.

Innovative recreational practices have resulted from the conversion of abandoned rights-of-way, especially railroad rights-of-way, into trails with access or linkage to other recreational resources or "clusters" such as county parks. Station houses can offer trail-related support functions including food, lodging, and restroom facilities (Blair, 1977).

SINGLE-USE RIGHTS-OF-WAY

As noted in the discussion of joint uses of rights-of-way, there are often technological and special problems that must be overcome to achieve compatibility of multiple uses. A solution to these problems is to establish a new right-of-way.

Reliability of utility and transportation networks can be enhanced by establishing several systems on alternate corridors. If problems develop on one corridor, the probability exists that alternate systems will continue to serve the system.

Hazardous situations can result from a change of land use and development. If an industry producing or storing explosive materials locates near a utility or transportation right-of-way, the utility may decide to relocate a right-of-way in a relatively safer area.

Often the right-of-way of one utility is not adaptable for use by another. Examples of this situation are the concern of railroads about inductive interference with their communications system by electric utilities and the concern of highway engineers with highly explosive pipelines.

Separation between systems is often the most economical method of achieving compatibility between electric utilities, communications, and pipelines. Bonneville Power Administration has found that a separation distance of 0.5 to 1 mi (08. to 1.6 km) is usually adequate for parallels over 1 mi (1.6 km) of transmission lines and telephone and railroad communication systems (Eichen, 1976).

Expansion of existing rights-of-way can be impractical if the right-of-way has adjacent high value uses. A new right-of-way can prove to be a better economic solution.

Additional clearing or additional structures in a right-of-way may have a significant adverse effect on the aesthetic quality of a region. This is especially true where there exists a high visual perspective, such as open areas along freeways or areas set aside for their scenic quality. Such areas include recreation areas and overlooks.

CONCLUSION

The growth and development of the United States makes the process of rights-of-way selection more difficult each year. It is becoming more and more necessary for utility and transportation agencies to jointly plan integrated systems so that right-of-way duplication is eliminated.

In some instances, a single use right-of-way may best meet the interests of the safety and well-being of the public. However, present technologies offer solutions to many of the compatibility problems of multiple use rights-of-way.

The attitudes and practices today are toward the multiple use of rights-of-way. Joint-use of utility corridors represents a concept of tomorrow's right-of-way.

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RIGHT-OF-WAY SHARING

Bruce E. Howlett[1]

ABSTRACT.--When selecting a location for a new transmission line it is frequently assumed that the location of choice is alongside an existing transmission line, or absent a transmission line alongside a pipeline, railroad, highway, or communication facility. Combining linear features will save land and reduce intrusions on other land uses. Each of these facilities shares the common characteristic of joining origins with destination points by means of a right-of-way over which legal control is obtained to preclude conflicting land uses. They are, however, quite dissimilar in function and respond to different demands. As a consequence, the planning, location, construction, and operation of these facilities differ considerably and the opportunities for mutual sharing of rights-of-way may not be great.

INTRODUCTION

Interest in sharing rights-of-way between transmission lines, pipelines, railroads, highways, and communication facilities is important in long-range land use planning. Implicit in the concept of joint use of rights-of-way is the consolidation of linear features with a reduction in the land area needed. In many instances interest in joint use is shared by each of the industries. Where escalating land costs, rising property taxes, and increased public interest in limiting the proliferation of rights-of-way prevail, the incentives for joint use become more imperative.

There are many examples of joint use rights-of-way, particularly in urban areas where high land costs and extensive development force joint use simply because other alternatives are unavailable. But each system has its own location and operational requirements, each requires a certain amount of land, and preferably each would go its own way to minimize costs and maximize reliability if it were not for overriding social, environmental, and legal constraints that modify theoretically ideal solutions to facility siting and operation.

This paper endeavors to point out how each of three industries-pipelines, highways, and communication facilities--goes about planning and operating

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its facilities so that a fourth industry--high voltage electrical transmission--can determine how to combine rights-of-way with them.

SITING OBJECTIVES FOR LINEAR FEATURES

There is a certain amount of similarity in the procedures followed by all linear features in siting their facilities: they usually join two points some miles apart; they require a right-of-way that excludes other conflicting land uses (some of which can be other linear features); and they must meet certain safety and reliability standards. In the siting process, all of these facilities follow a system planning process to provide a functioning network of service for their particular industry.

In the system planning process, there are certain determinants and parameters that must be identified for each system. The principal aspects that control route location include points of origin and destination, intermediate points of service, and connecting facilities such as switching stations, pump stations, or other supporting facilities. There is seldom any freedom of choice in providing line connections with these points. The parameters vary according to the system involved. Some of the more significant parameters for the various systems include such measures as voltage, current, number of circuits, pipe size, operating pressure, number of lanes, and system capacity.

Typically, there is little coordinated or combined planning for new rights-of-way. Each facility has its own needs to respond to, and these are unrelated to the future needs of other linear facilities.

Frequently, the service area of one facility does not coincide with that of another, so that the jurisdiction or control over facility siting and operation may vary considerably between industries. Each linear facility determines its own future needs and ascertains at what point in time these needs must be met. Usually, these needs do not occur at the same time, so even the opportunity for joint construction periods may not coincide. If times do coincide, construction of one facility may interfere with another when they are located in the same corridor.

Under the joint-use concept, systems are located in close proximity to each other. This usually will allow the combined space requirements to be less than for each individually. It may be possible to jointly utilize a common construction area and share the right-of-way fringe area, for example. Joint use requires these facilities to change some of their present practices, however, which generally discourages sharing rights-of-way.

Some systems may not be at all compatible in close proximity to each other, and it may be necessary to locate a new facility some distance away. Some older systems (e.g., twisted pair communication lines) were built with different standards than those used today and require costly mitigation to be made compatible. The railroad industry generally prefers to have transmission lines sited away from tracks where there is a possibility of future commercial or industrial development alongside the track. Electric transmission lines close to railroads, pipelines, and communications systems can also cause electrical interference problems.

Electric transmission systems are probably the most difficult utility to include in joint rights-of-way with other systems due to the effects of powerline switching surges, fault currents, and electromagnetic and electrostatic fields. If mitigation measures are not maintained, corrosion of pipelines, dielectric breakdown of buried cables, rupture of buried pipelines, failure of protection circuitry for buried cables, hazards to personnel, and malfunctioning of electric control of railroad signaling circuits and communication lines are all possible during construction and operation of power lines. There can also be interference with voice communication circuitry and radio and television reception. The usual way to solve these problems is to obtain adequate separation. Where separations cannot be maintained, mitigation measures such as shielding, undergrounding, or changing the mode of operation are required.

Pipelines

From the standpoint of efficiency the best location for a pipeline is the shortest line between two points. The shortest may not be the best, however, since bends in the pipe and changes in terrain increase pumping costs. Rocky areas are avoided where possible, as are steep canyons, fault zones, and landslide hazardous areas.

Construction requirements usually establish the width of rights-of-way. The area needed for construction is directly related to the diameter of pipe and soil condition--as the diameter of the pipe increases, the right-of-way width increases. Space is also needed for temporary storage of excavated material, access for construction equipment, and space for storage and preparation of the facilities to be installed.

Once in operation, only about half of the pipeline right-of-way is needed for operation and maintenance. The entire width of right-of-way will be retained in the event that pipe replacement becomes necessary.

Electric utility engineers, like pipeline engineers, are greatly concerned with the safety and reliability of the systems they design. When both systems are located together, reductions in safety and reliability can occur. Whereas pipelines are generally compatible with railroads, highways, and communication systems, they are less compatible with electrical transmission lines. Powerlines create particular problems because induced voltages and currents can create shock hazards in construction, operation, and maintenance. Fault currents can damage pipeline facilities, while leaks in natural gas lines could cause fire or explosions.

In addition to safety and reliability constraints, land ownership may pose problems for joint use. The type of property right obtained by the pipeline company for their pipeline may not permit any additional facilities without renegotiation with the property owner. Construction costs in a joint use right-of-way also will sometimes be higher because of the measures needed to avoid damage to adjoining facilities during construction and to maintain their safety and reliability. Additional costs might include special footings for transmission towers, additional angle structures, or additional length required to parallel pipelines.

Communication Facilities

Communication facilities, as the name implies are devices for the transmission of messages. In the past, communication lines could be found parallel to railroads, highways, and electric transmission systems, but with the advent of newer complex, higher capacity communication systems, interference problems with other systems have increased. Higher voltage transmission lines have complicated the interference problem. Because of these difficulties, separation of communication systems from other sources of interference is currently the practice.

A typical communication system requires a right-of-way up to 50 feet in width, depending on system type, terrain, and future need. During construction, a larger area of up to 100 feet in width may also be required for coaxial and waveguide systems. Other components include repeater and terminal facilities, electric power source, and an access road for operation, maintenance, and patrolling.

Reliability is the primary objective in siting communication facilities. Factors considered in reliability are the capacity of the line planned and the capacity of alternate lines to absorb the traffic if a disruption should occur. Safety is also a factor considered in locating communication lines. Where communication lines are located in parallel with transmission facilities, the potential for construction accidents is increased and electrical hazards to personnel become substantially greater. As a consequence, locations alongside transmission lines are generally avoided.

Generally, telephone companies have no set policy opposed to sharing of rights-of-way with transmission lines, but their preference is to avoid this type of joint use because of electrical interference problems. While the extent of problem depends on many variables both in the power line and in the communication system, extended lengths of paralleling are avoided. Where paralleling does occur the preference is to stay as far away from the power line as possible.

Highways

Because few new highways are now being planned, the opportunity to combine a new transmission line with a new highway is quite limited, thus right-of-way sharing will be along existing highways.

The major technical problems associated with the sharing of rights-of-way between highways and electric power lines are safety related. A powerline down on a highway presents a shock and fire hazard to the motorist. In turn, an out-of-control vehicle could seriously damage transmission line support structures that are located within the highway right-of-way. Transmission lines can also cause interference on car radios.

A transmission line parallel to and within a highway right-of-way could also significantly impact the cost of construction. To parallel an existing highway it may be necessary to locate the powerline along a longer, and thus more costly route. The transmission line may also have to change direction more often requiring more structures. Construction activities may also interfere with normal operation of the highway, at least to some degree, perhaps posing a hazard.

In addition to construction and operational problems, incompatibilities may occur between the functions of the two systems. Over the years, growth has inevitably occurred along highways with access afforded directly to them. Thus, a transmission line following an existing highway may have to circumvent strip development, making it impractical to parallel the highway for any extended length. Not only may a right-of-way location be constrained by technical, cost, and functional considerations, it is also limited by legislative and administrative constraints.

One department's administrative rules state that access to utilities for all installation and maintenance purposes must be from off the right-of-way space. Thus, even the chance to avoid duplicating access roads is lost.

<u>Railroads</u>

The 200 foot width of a railroad right-of-way is adequate to accommodate all, or a major portion of the right-of-way that is needed for a transmission line. Functionally, however, there are certain incompatabilities that can create problems from an operational standpoint. When a transmission line is placed alongside a railroad an operational impact to the signal and communications systems can occur--thus safety can be affected. If protection is not provided, a fault from a transmission line could cause a railroad signal system to burn out or malfunction, perhaps causing a serious accident.

From a design perspective, the location of railroads (while relatively flat) often requires many wide curves in order to maintain an adequate grade. To follow the railroad would require the transmission line to be constructed with many angle structures (which are more costly) to follow around the curves. Usually, it is much less costly for the transmission line to follow a straight line (which is shorter than the railroad's curved alignment) where less expensive tangent structures can be used.

An additional major constraint to joint use of railroad rights-of-way by transmission lines is land cost. Without industrial and related users alongside their tracks, the railroad cannot exist, thus the land alongside a railroad right-of-way is considered of great value because of its industrial potential. This is sometimes reflected in the asking price for the railroad land--a price which may seem excessive to an electric utility used to buying lower valued property for transmission lines.

A further constraint to joint use alongside railroads is the presence of existing structures--industries, warehouses, and other structures--in addition to the structures and tracks associated with the railroad itself. The presence of these structures can severely limit the placement of transmission structures, perhaps requiring special designs to overcome the problems encountered.

RIGHTS-OF-WAY MANAGEMENT AND SOCIAL IMPACT ASSESSMENT

Robert C. McManus[1], Franki Craig[1], and Grant A. Ross[1]

ABSTRACT.--Social Impact Assessment (SIA) is an environmental management tool concerned primarily with the identification and mitigation of negative social and economic effects of proposed alternations of the human environment. Over the last decade several methodologies have been developed to assist researchers in assessing these impacts. Accordingly, the accuracy of predicted social impacts and the use of these studies for project planning purposes have increased dramatically.

Impacts associated with rights-of-way developments differ significantly from those which are geographically fixed because of the narrow linear shape of ROW. Consequently, when assessing social impacts of rights-of-way, commonly used SIA methodologies must be modified in order to adapt to a different set of study conditions. The unique characteristics of right-of-way projects are identified and contrasted to the traditional model of Social Impact Assessment. Appropriate methodological changes are suggested to expand SIA to adequately assess the social impacts associated with rights-of-way.

INTRODUCTION

The issues surrounding transmission line development have been documented in various regulatory hearings and received national attention in the news during the violent confrontations surrounding the Minnesota DC transmission line controversy. In Alberta, the protest over a controversial transmission line reached new heights with a dynamite blast which toppled a HUAC tower in a remote farming area.

Managing the social concerns of linear developments has proven to be a particularly difficult task and the presently used social assessment process in inadequate. To more effectively manage the social effects of linear developments such as transmission lines, new techniques for linear planning must be developed.

Planning and Routing For Linear Developments

Historically, route location and corridor planning were done by "experts" working in isolation from the public. Society had entrusted these

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"experts" with the responsibility of making decisions regarding technological development. There existed an aura or mystic about the expert and his activities. Engineers and planners defined the problems; proposed, analyzed, and evaluated the alternatives. These experts then recommended to higher authorities an appropriate course of action.

Recently, the process of technological planning has changed radically. A loss of faith in the professionals' ability to make decisions about technological development coupled with the environmental movement of the 60's and 70's pressured governments to legislate new environmental requirements in resource and energy development planning.

The Government Response

The governmental response to public environmental concerns resulted in the enactment of legislation creating the Environmental Impact Assessment process in the U.S., and its complement in Canada, the Environmental and Assessment Review Process. Since the enactment of NEPA (1970) in the United States, environmental impact assessment has become a common part of the planning process at both the federal and state levels in the U.S., and federal and provincial levels in Canada.

Initially the environmental impact assessment process was concerned primarily with impacts occurring within the biophysical environment. Since the mid-1970's, however, the scope of the EIA process has broadened to include more emphasis on the social and economic features of the environment in addition to its biophysical characteristics. Today, social considerations are being recognized as potentially the critical factor in determining whether a project proceeds or not.

Social Impact Assessment

Social Impact Assessment (SIA) can be defined as a process of identifying and predicting and developing mitigative measures for the negative social impacts of a project or development before they occur. It is utilized both as a planning tool, allowing the developer and/or planning agency to ameliorate negative impacts to whatever degree possible, and as an informational document used by decision makers in the decision making process.

Methods for identifying social impacts have evolved over the last decade, primarily by borrowing from social science theory and methodologies, in association with large scale point developments. In the classical scenario, an SIA would address the question, Given the impacts of society on project x, who stands to benefit or gain and who stands to pay or lose? SIA addresses this basic dilemma inherent in modern industrial developments; that being, that in any development scheme, some will benefit while others will pay.

SIA as an assessment technique has developed considerably in the last 10 decades. For a site specific point development, a properly done SIA provides essential information to planners and decision makers. However, research on electrical transmission line ROW planning suggests that a distinction between development scenarios is needed. For assessing and managing impacts, we must separate the single point development for which SIA is appropriate, from the linear development for which new techniques must be developed.

Defining the Site Specific and the Linear Development

The single point development is defined as a project where development activities are more or less geographically confined to a given state. Illustrative examples of this type of development would include electrical generation plants, mineral mines, and petro chemical plants.

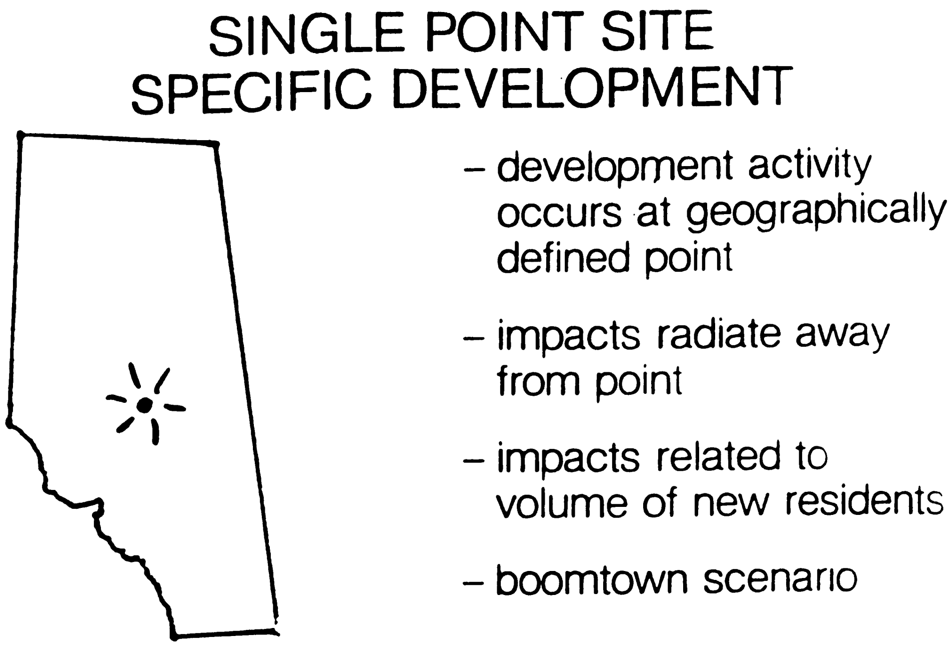

Figure 1.

Social impacts associated with this type of development are directly related to the volume of new people moving into the region surrounding the project. These new people will require homes, schools for their children, hospital beds, expanded sewer and water treatment facilities, etc. They will place escalating demands on existing services such as police, social welfare, and recreational facilities. In many cases, local employers will be forced out of business because they cannot compete with high wages offered by the industrial sector. Boomtowns, plagued with social problems, increases in mental health caseloads, suicides, divorces, family tensions and emotional stress, are created overnight. While this hypothetical scenario all too often becomes a reality, we now know that by identifying the negative social impacts before they occur and carefully managing them by implementing appropriate mitigation agreements, we can have orderly development activities which benefit these communities rather than destroy them.

Linear developments initially appear much less disruptive than single point developments. Transmission lines, pipelines, and highways are generally built by mobile construction crews moving along the right-of-way from one end of the project to the other.

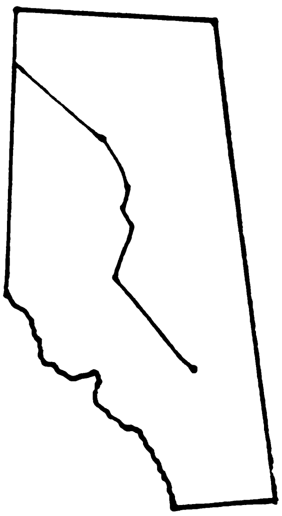

Figure 2.

There are no permanent construction or operations crews, no need for new homes or schools, and boomtowns are not generally created. The concern and organized public opposition generated by these activities, however, tells us that social impacts do indeed exist. Is there a solution to public dissatisfaction with the process of planning and routing linear facilities?

The first step towards more effective management of the social impacts of linear developments is to develop impact assessment and management techniques which address the special characteristics of these projects.

Linear developments often extend for hundreds of miles. The negative impacts of linear developments are usually confined exclusively to the community of individuals living in direct proximity to the right-of-way. The positive benefits accrue, in very small units, almost entirely to the rest of society. This unique shape and scale of community creates some very special problems for those responsible for managing the social concerns of linear development activity:

1. The scale and sahpe of "linear communities" creates practical problems when attempting to organize and involve local citizens in the ROW planning process.

2. The unique shape and large scale of communities affected by linear developments often brings into focus potential land use conflicts between regional interests. Trade-offs must be made as to whether facilities should be routed through farming areas or recreation lands; through rural residential subdivisions or cattle ranches, etc. This often creates destructive community dynamics between local or regional groups protecting their interests.

3. Assessment of social impacts of linear developments tends to focus only on the negatively impacted community in direct proximity to the ROW.

The community bias and limited scale of this process does not include the larger community, who benefits from the development, in the cost/benefit trade-off deliberations.

4. Assessing alternatives - The project level emphasis of SIA techniques can be utilized in comparing proposed alternative routes for linear developments. However, SIA does not address the more important question of assessing appropriate technological alternatives. For example, in electrical planning, the present assessment process compares route A to route B. It does not address the more important question: Is alternative A, large scale centralized electrical generation and distribution, or alternative B, small scale regional generation, or C, energy conservation, the most appropriate technology for meeting the social goals of electrical consumption?

Choosing An Appropriate Assessment Process

In the last decade, there have been several social assessment and forecasting techniques developed and applied in a variety of development situations (Figure 3).

SOCIAL ASSESSMENT AND FORECASTING		
SOCIAL IMPACT ASSESSMENT ENVIRONMENTAL IMPACT ASSESSMENT	TECHNOLOGY ASSESSMENT	FUTURE STUDIES
short ←	TIME HORIZON	→ long
site-specific ←	GEOGRAPHICAL LOCUS	→ wide
limited ←	POLICY FOCUS	→ broad

Figure 3.

Time horizons, geographical locus, and policy focus are three dimensions which differentiate techniques appropriate to identifying effects of interventions in the social environment. Utilizing this framework, social impact assessment can be seen as an appropriate forecasting/ assessment technique for short-term, site-specific developments. At the opposite end of the continuim, future studies are attempts to forecast or generate possible alternate future scenarios. Technology assessment (TA) is "a class of policy studies which systematically examines the effects on society that may occur when a technology is introduced, extended, or modified. It emphasizes those consequences that are unintended, direct, or delayed" TA also concerns itself with assessing the intended and unintended effects resulting from introduction of new technologies and falls somewhere between SIA and future studies.

As the geographical scale or locus of a project increases, social impact assessment as a forecasting technique becomes less and less appropriate. Technology assessment is more appropriate as the geographical scale and time horizon of a project increase. Linear developments generally fall into this classification.

Combining SIA and TA for Linear Assessments

A combination of social impact assessment and technology assessment is potentially a process which could more effectively address the problems of linear development assessments described in the previous section. A combination of assessment procedures would be undertaken at different times and at different levels of analysis for linear developments. A form of Technology Assessment at the regional scale would form a basis for sequential, project related SIA's.

The initial TA, which would be done in 5-10 year intervals, could provide policy guidelines for linear developments at the regional or provincial/ state level. This large geographical scale could address the problem of including the larger impacted communities in the assessment process and include a wider focus for addressing potential conflicts in regional land uses. Public issues and goals could be identified at a broader scale, and the question of appropriate technological alternatives could be addressed. As part of the TA process, a series of public hearings could be undertaken around the region, allowing citizens and interest groups to represent their views and become involved in the development of policies which could guide future development of the technology in question (electrical development, pipelines, transportation plans, etc.). Mitigation and compensation approaches developed at a policy level would be implemented and monitored by subsequent SIA's done on a project by project basis. Information and policies developed and updated occasionally in the technology assessments could streamline the development process by eliminating the need for "initial disclosure" by industry. The SIA process could focus on impact management as opposed to impact assessment, by monitoring mitigation agreements.

Positive benefits from an SIA/TA process might include:

Benefits for Government: filling the gap between regional energy policies and individual projects; serving the function of an "indicative structure plan;" aiding long-range integrated planning for resource development; forming a basis for evaluation of preliminary project proposals; and aiding in identification and monitoring of cumulative and long-term impacts of resource development.

Benefits for Communities: allow for public participation in front-end planning decisions regarding technological development; provide a data base to react to development proposals; could serve as a mechanism to assist community level studies by intervenors; and provide information on proposed and alternate technologies including risk assessment.

Benefits for Industry: reduce the "environment of uncertainty" within which resource development planning is presently done; streamline the development process by providing structured policy and program guidelines regarding resource development; identify government and societal assumptions and values; provide planning guidlines or a basis for discussion of planning guidelines and assumptions; serve as a basis for further EIA/SIA and community interaction; and provide a social data base.

ENVIRONMENTAL PLANNING FOR RIGHTS-OF-WAY IN A RAPIDLY DEVELOPING MULTIPLE RESOURCE SETTING, THE ALBERTA DEEP BASIN

G. H. Passey[1] and D. R. Wooley[2]

ABSTRACT.--Alberta Energy and Natural Resources (ENR) is responsible for administering renewable resources (timber, wildlife, etc.) as well as rich petroleum and natural gas reserves on about 150,000 square miles of Alberta.

Development of a petroleum and natural gas field is a competitive process involving large numbers of seismographic lines, access roads, exploratory wells, production wells, wellsite access roads, collection and transmission pipelines, powerlines, and processing plants complexes.

One large newly discovered field is the Deep Basin, thought to be the second largest gas field in North America. Energy developments in this area have removed as much timber as has been removed by an active forest industry in that area. Populations of moose, woodland caribou, elk, big horn sheep and furbearers, present in this relatively remote forest, are potentially impacted. Unstable terrain and steep slopes cause concern for watershed management and fish populations. The Deep Basis Program is one attempt to examine the effect of such massive and rapid development on renewable resources. This paper details an example of environmental and resource management issues that arise in a resource rich area undergoing heavy development in both renewable and non-renewable sectors. Particular emphasis is placed on linear facilities associated with non-renewable resource developments, these being responsible for the majority of land disturbance on the renewable resource sector.

INTRODUCTION

Western Canada is one of the greatest hydrocarbon areas of the world. Many of the reserves underlie extensive forested lands in the Province of Alberta. The rapidly escalating world price for petroleum caused a ninefold increase in the price of natural gas to producers in the period 1973 to 1977 and touched off a large scale search for gas, which previously had not been economical to recover. The Deep Basin, one of these reserves, is

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a large recently discovered natural gas deposit in a 26,000 sq. mi. (67,600 km^2) area straddling the British Columbia-Alberta border (Fig. 1). Initial estimates suggest recoverable deposits may be as much as 440 TCF (12.5 X 10^{12} cubic meters), compared to the San Juan Basin, second largest in North America at 25 TCF (0.7 X 10^{12} cubic meters).

Approximately 50% of land in Alberta is provincially owned, and to a large extent forested. The development of non-renewable petroleum resources has a considerable impact on the land surface and the management of its renewable resources. This fact has considerable bearing on the planning approach of the resource management agencies.

The Environmental Setting of the Alberta Deep Basin

The Deep Basin lies on the western portion of the province abutting the Rocky Mountains, in the resource rich foothills. The area is relatively remote with only a few populated centers (Fig. 2), and is largely forested with conifers (mainly white spruce, lodgepole pine, black spruce and balsam fir) but with a significant deciduous component (primarily aspen and balsam poplar). This same forest supports a large and important timber industry. The watershed is very important as the area feeds many of the large rivers which cross the Canadian prairies and the Northwest Territories. The terrain has significant relief and where soil and overburden are unstable, terrain sensitivity is a very important issue. The fish and wildlife resources are very rich and include moose, deer, elk, bighorn sheep, the rare woodland caribou, grizzly and a wide variety of furbearers.

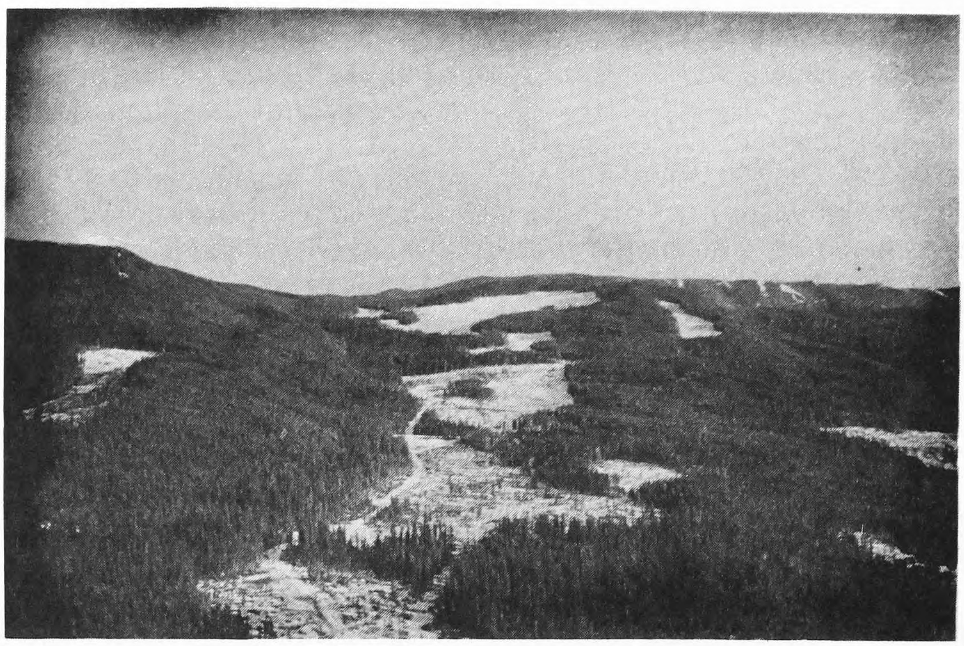

Figure 3. Timber cut block.

FIG. 1

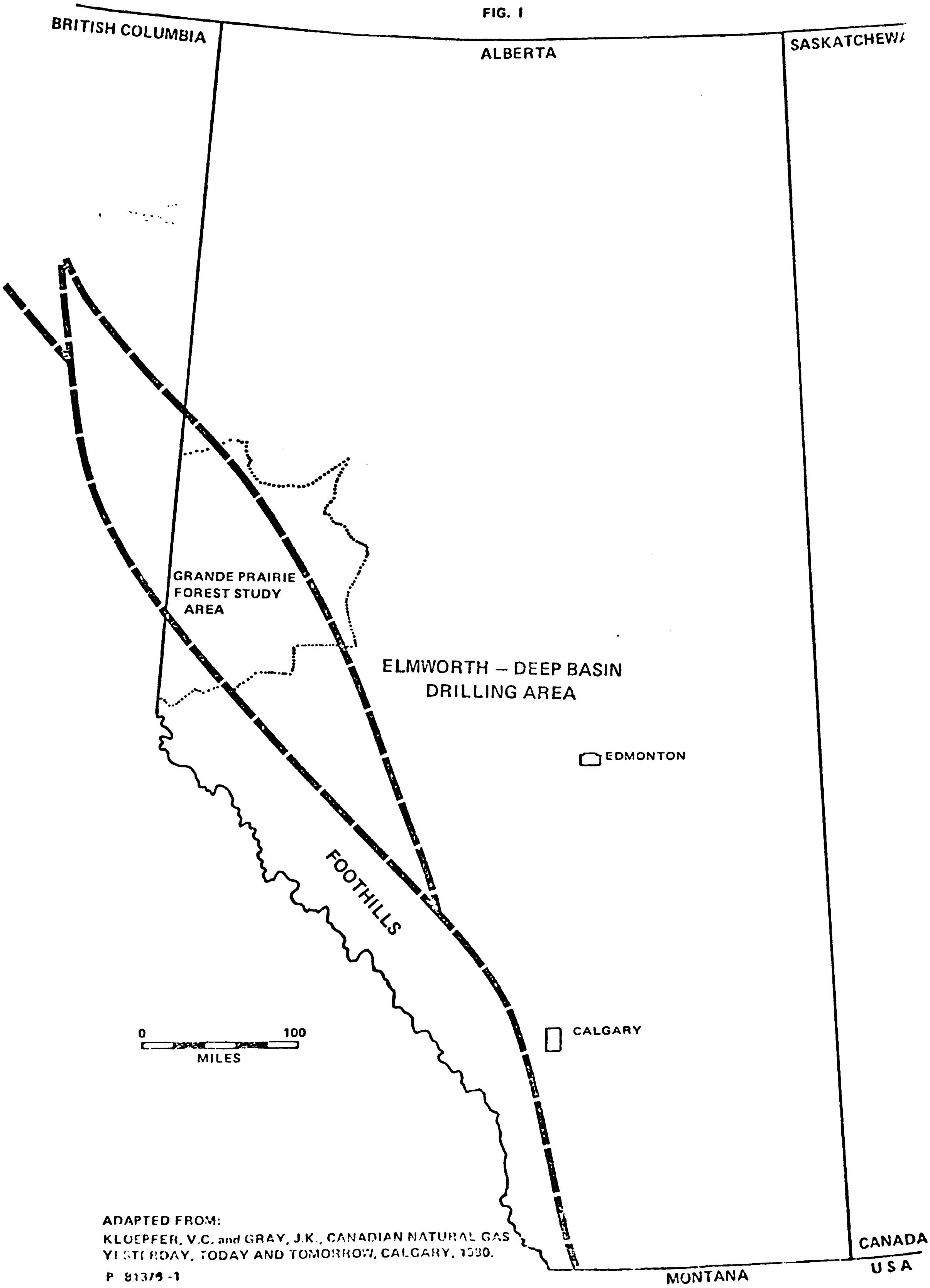

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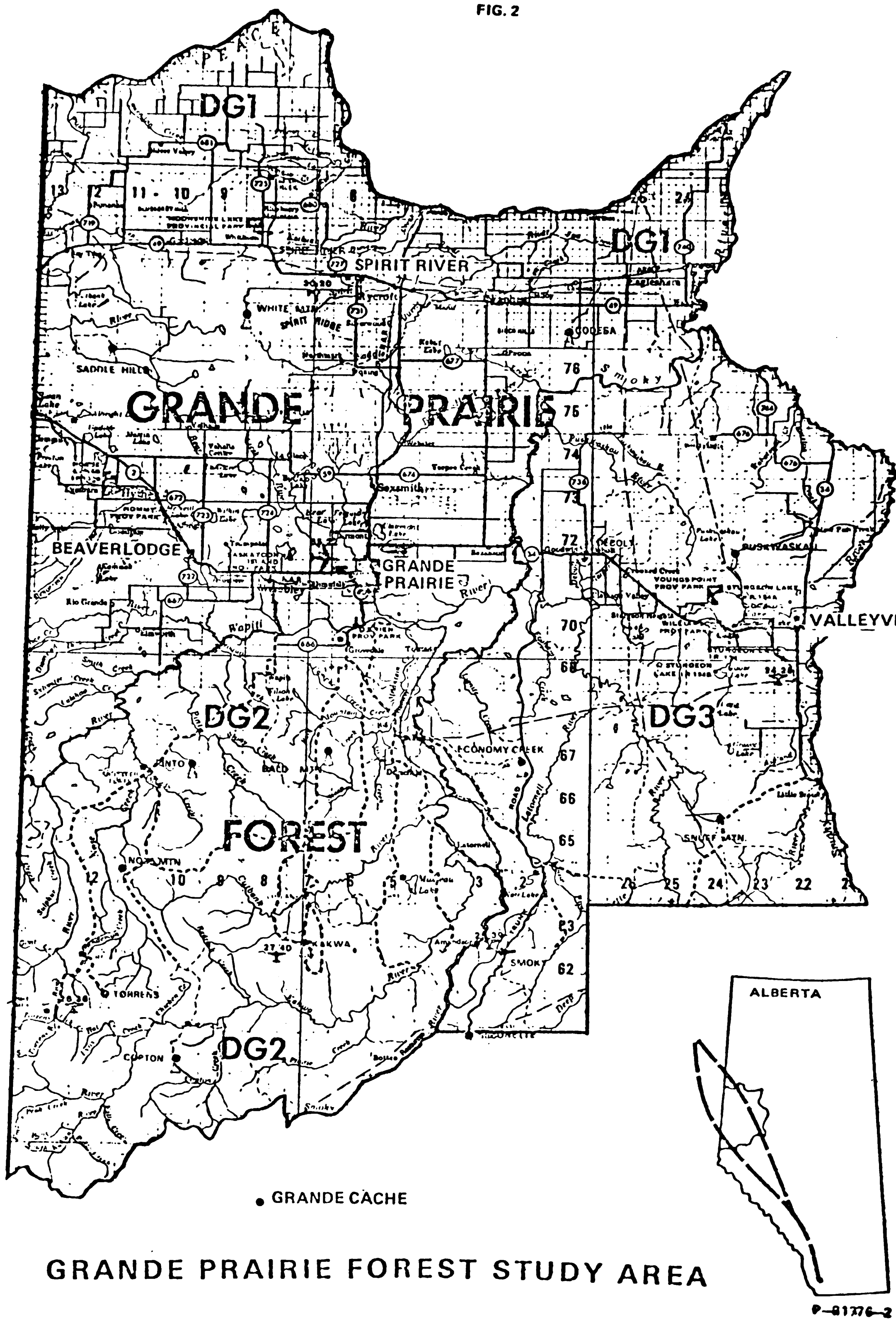
FIG. 2



GRANDE PRAIRIE FOREST STUDY AREA

Due to limited access in many areas until recently, the wildlife populations have not been heavily exploited. This, however, is changing rapidly with the development of road networks by the timber and petroleum and natural gas industries. The area has many deeply incised rivers, waterfalls, and large wilderness areas. A limited amount of grazing occurs in some areas.

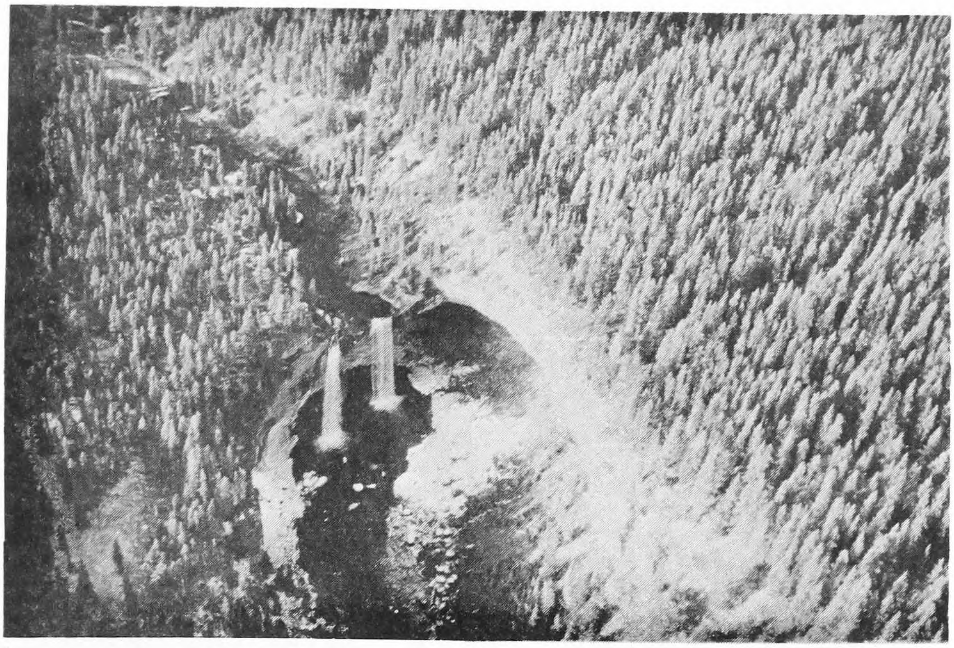


Figure 4. Prime Recreational Land

RIGHTS-OF-WAY AND ASSOCIATED DEVELOPMENTS IN THE STUDY AREA

A recent study (using a 10% stratified random sample) estimated the amount of area physically disturbed by energy related activity, to be 66,576 acres (26,963 ha) for a selective study area encompassing the Grande Prairie Forest, an administrative unit of the Alberta Forest Service (Fig. 2). Table 1 shows average land use disturbance by area for oil and gas related activities.

Seismographic Exploration Lines (SEISMIC)

There were 15,713 miles (25,140 km) of 25 ft (7.6 m) wide seismic lines constructed in the study area, which resulted in disturbance to 47,614 acres (19,283 ha). Seismic activity, the predominant activity in the initial exploration stage, involves removing the forest cover and grading the ground clear. The line may be used only once or it may be used several times. Little deviation from a straight line occurs except to by pass difficult obstacles. In sensitive areas such as steep slopes of alleys, regulations typically call for hand-cut lines which use no surface machinery. Seismic line construction does not preclude subsequent land uses but does have indirect effects on timber rotation, watershed protection and access into significant habitats, etc.

TABLE 1 EXTENT OF LINEAR DEVELOPMENT ESTIMATED FOR STUDY AREA TO DEC. 1979
(TOTAL ACRES) (ALBERTA ENERGY & NATURAL RESOURCES 1981 UNPUBLISHED)

DISTURBANCE TYPE / AREA CLEARED IN ACRES (HECTARES)	PRODUCTIVE FORECAST	POTENTIALLY PRODUCTIVE	NON-PRODUCTIVE	TOTAL	MILEAGE EQUIVALENT	%
SEISMIC	34615 (14019)	2803 (1135)	10196 (4129)	47614 (19283)	15713 * (25140 km)	72%
ROADS AND WELLSITES	2053 (831)	379 (153)	1250 (506)	3683 (1491)	460 (740 km **)	6%
POWERLINES PIPELINES	2889 (1170)	500 (203)	1536 (622)	4925 (1995)	616 (991 km **)	7%
GAS PLANTS	93 (38)	0	0	93 (38)	–	0
MULTI-PURPOSE RIGHT-OF-WAY	8001 (3240)	808 (327)	1252 (507)	10062 (4075)	1258 (2024 km **)	
MISCELLANEOUS OIL AND GAS	156 (63)	40 (16)	0 0	197 (80)	–	0
TOTAL	47809 (19363)	4532 (1835)	14234 (5765)	66576 (26963)	18047 (28875 km)	15%

* SEISMIC LINES ARE STANDARD 25 FT. WIDTH

** AVERAGE WIDTH IS 66'

Figure 5. Typical Seismic Line.

Oil and Gas Roads and Wellsites

Seven percent of the surface activity in the study area was attributable to oil and gas roads and wellsites for a total of 3,683 acres (1,491 ha). Roads are an average of 66 ft (20 m) wide and wellsites are 4 acres (1.6 ha). Limited road infrastructure existed prior to oil and gas exploration, due to forest harvesting activity and forest management activity. This provided a framework for new road development in a portion of the area. From a road use perspective, it created some very serious problems of overuse viz-a-viz grade destruction and locational difficulties in road network expansion. Several energy companies and major forest products companies wanted access to the same general areas. However, their locational timing and capitalization requirements were vastly different. From the government perspective, this led to some very difficult negotiations in the name of coordination of road development.

Currently the government is attempting to put a new major roadway in place across the heart of the study area that will provide the core for road network establishment. As the study area has not advanced far into the development stage, roads, and wellsites will increase in proportion to other disturbances. Those roads and wellsites involved with producing wells eventually form the basis of a network which will exist at least for the life of the field. Wellsites have fairly rigid location requirements and determine the end point of access roads. Such roads are typically route planned during exploration on the basis of the nearest interconnection point and the proposed drill site. During exploration ones does not know which wells will be producers. The common management strategy for access locational analysis is to look at each well road on its own merits.

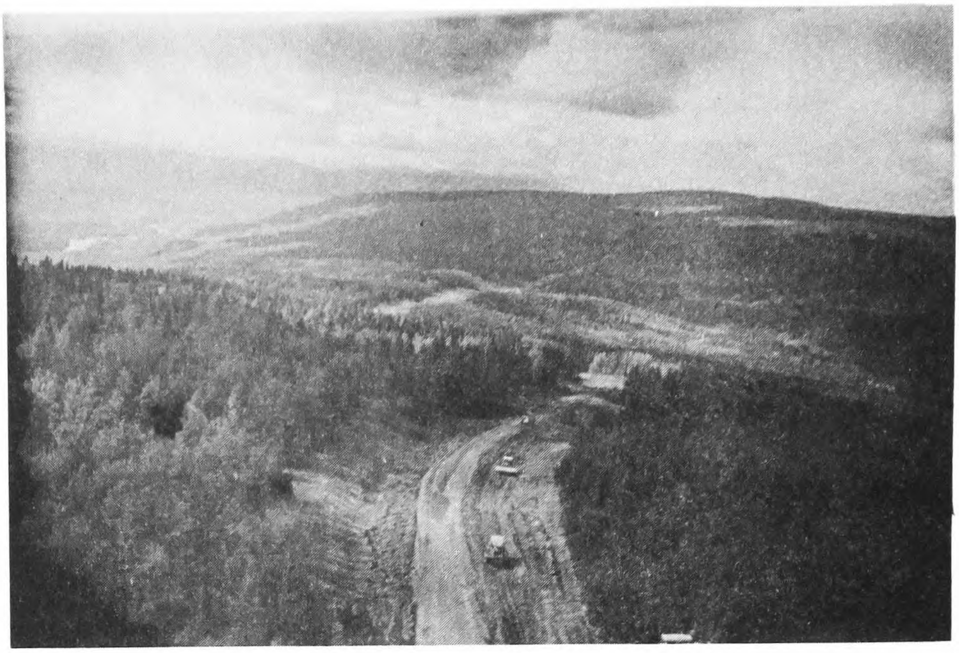


Figure 6. Wellsite Access Road.

Figure 7. Wellsite.

Powerlines and Pipelines

Powerlines and pipelines account for 7% of the undisturbed area for a total of 4,925 acres (1,995 ha) which translates to 616 miles (991 km) of R-O-W 66 ft. (20 m) wide. Land occupied by such facilities is not typically available for other activity uses such as timber production during the life of the facility. For the timber operator the impact on the operating unit can be serious. If the oil and gas developer attempts to follow existing road rights-of-way with production facilities, this may avoid timber operation problems. However, existing rights-of-way many times fail to meet the majority of locational requirements for pipelines and powerlines. In these cases the indirect effects of the oil and gas right-of-way are very disturbing to the timber operator, because the landscape gets heavily dissected, isolating timber stands and making haulage road development very difficult.

From a fish and wildlife perspective, the new R-O-W create edge and browse for wildlife, but also open up the area to hunter access and through the direct effects on fisheries habitat.

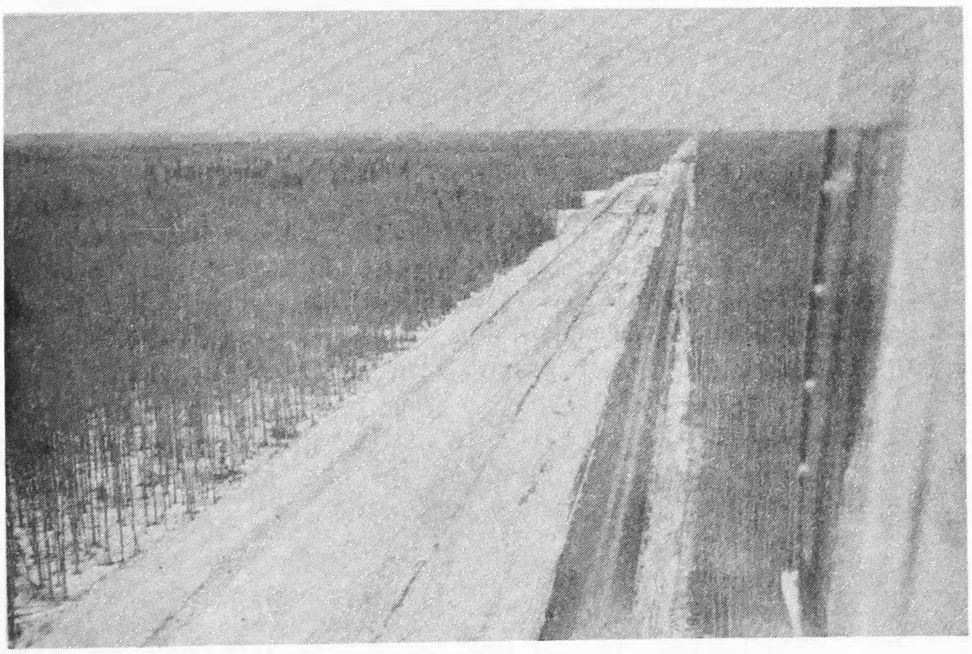


Figure 8. Pipeline Right-of-Way.

Two new major pipelines have already been built to service the expected transportation needs of energy development. Both of these pipelines are located on the basis of "probable" locations of collection and processing facilities. However, they do not reflect a great deal of locational consideration for the indirect effects they will create viz-a-viz secondary interconnection facilities. As of the time of construction the complete development picture was not known. In light of this uncertainty, the pipelines are located in a way that economically minimizes future secondary system development. This approach makes little allowance for future effects on renewable resources.

Figure 9. Gas Plant Construction.

Gas Plants and Batteries

As development increases, gas plants, oil tank batteries, and similar facilities become more prevalent. The location of these nodal features is important because it dictates the overall configuration of field development for flow lines, road power lines, product transmission lines, and railways to and from the plant. From a land use perspective, the location of the plant is critical. In this study area an estimated 93 acres (38 ha) have been directly removed by gas plants to date. The indirect land use effects have yet to be assessed.

Multiple-Facility Rights-of-Way

These facilities contributed to 10,062 acres (4,075 ha) of clearing and accounted for 15% of the total disturbance. These features are quite permanent. Planning for such facilities often take the form of second and third party developers taking advantage of or being regulated to locate in an existing common right-of-way. Rarely will one find a multiple facility right-of-way that has not developed in an ad hoc fashion. As noted previously, use of existing rights-of-way is the most common form of multiple use right-of-way. Thinking and planning of idealized multiple use rights-of-way prior to any development were impossible in the Deep Basin because of the existence of a limited forestry industry road network in place, and because of the scale and rate of new right-of-way requirements. Thus planning and development of multiple use rights-of-way have taken place case by case as proposals for roads and pipelines were received from developers. A number of successes have been achieved for facilities of a similar type to date in the case of roads and separately the case of pipelines. However, as the area develops a much more extensive network of secondary facilities in the future, the amount of landscape dissection is bound to increase. Multiple facility rights-of-way are not always the best solution for reasons of land sterilization, etc. However, it is a major issue requiring careful consideration in cases such as the Deep Basin where many linear facilities are required.

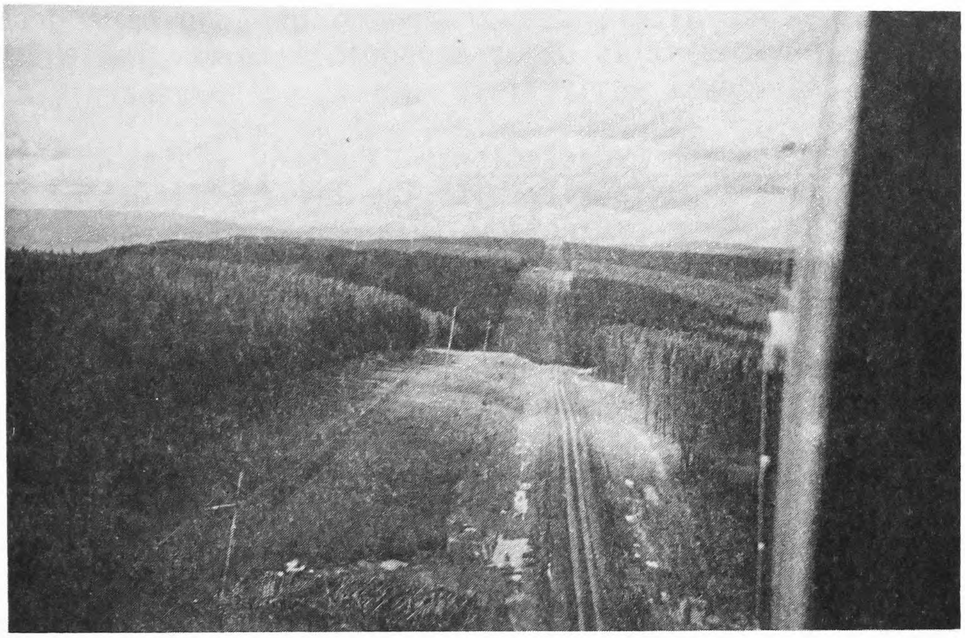


Figure 10. Ad Hoc Multiple-Purpose Right-of-Way.

Miscellaneous Areas By Others

These areas, which include industrial campsites and airstrips, accounted for only 197 acres (80 ha). While the physical area they occupy is small, the extent of activity has consequences beyond the immediate area of the facility. For instance, the numbers and locations of campsites have an effect on road use and wildlife disturbance. Major campsites in the study area are owned and operated by the two major forest products companies. These campsites are used repeatedly, and consequently form significant nodal features for road development.

Resource Management and Linear Developments

The problem facing the resource manager is the planning for heavy initially rapid development in the absence of complete knowledge. At a constant level of petroleum development activity, the resource agency can staff managers to work with companies to plan routes for individual activities with an eye toward overall comprehensive land use and good environmental design. However, when a large and rapidly developing "play" occurs, this system becomes overloaded, time frames for planning become extremely tight and regulation becomes reactive. Existing measures can cope with many of these development problems, as follows:

Existing Measures

Legislation. Legislation works on a permit system, a somewhat reactive approach. Field staff review plans and offer advice, and supervise and inspect and approve project development. Companies are encouraged to carry out preliminary planning with resource managers prior to permit application submissions. In low activity modes this works well but as activity increases and more companies enter the scene, competition shortens planning times further, and coordination by resource managers of short-term developments within teh framework of long-term goals becomes very difficult. In fact, it is often impossible to develop a framework in time to focus on individual activities.

Field Level Cooperation and Expectations. Company engineers, landmen and envrionmentalists work individually with the field officers of the management agency to plan their projects. This works best when the level of activity is low. Companies, however, vary in the extent to which they plan their projects with the agencies in advance of permit application. They also vary in the way they do their business and live up to expectations. In the Deep Basis, development results were different from the commitments made by individual operators in a number of cases.

Deep Basin Research Program

With the above limitations in mind, the Deep Basis Research Program has been established to consider the overall and cumulative effects of rapid oil and gas development, in order that a proactive management approach can be taken. This approach addresses the two main problems facing resource managers: (1) A large area of land where detailed biophysical information and information about the sensitivity of the area to disturbance is not available; and (2) Components and timing of exploration and development critical to determination of an end use landscape require careful definition.

Available biophysical data for the study area is being collected in order to determine deficiencies and establish priority areas where new information needs gathering. This is being accomplished using an integrated ecological land classification (ELC) and derivative interpretations as a data base. ELC is an approach which allows the resource manager to con= sider the landscape as ecological units and to organize complex interrelationships into identified geographical areas with similar properties. ELC units, because of their assessed inherent biological potential, allow for extrapolation of known information and management practices to units of similar conditions. Key parameters utilized in ecological classification include physical characteristics (climate, soil, landform, surficial deposits) as well as biological (vegetation) factors. Units will be classified according to their potential to withstand surface disturbance, and the extrapolative capability of this sensitivity rating will then be tested. The units will be assessed also for existing and potential resource capability for timber, recreation, wildlife, etc. By categorizing the landscape according to sensitivity and resource value, the resource manager will be able to prioritize his level of effort and direct his attention to the sensitive areas.

Initial mapping of the area is being done at 1:100,000 (land section) scale. Where sensitive areas or areas where extensive activity occur, the ELC will be refined to the 1:15,000 (land type) scale. This terrain and resource sensitivity analysis will then form the basis for day-to-day review and approval of continuing development proposals. Further, it will provide a basis from which to consider how inidividual access roads, pipelines, etc. and long-term pattern development can be assessed.

Mapping and time sequencing of linear developments is forming a monitoring program to assess decision points and issues during oil and gas activity that control long-term overall land use. All linear facilities are being continuously assessed for pattern development, and will be superimposed on the ecological data base as available.

The second phase of the approach is to tackle the planning aspects of the petroleum development. As mentioned, the exploratory phase was well underway before the area was identified as a major play. The Deep Basis program will bring the companies together with the renewable resource managers to review and assess the development history of the area to the present. The main goal of this group will be to plan for the reduction of future surface disturbance by carefully assessing facility needs, locations and designs for further development. The group will consider road, pipeline, and powerline planning requirements specifically from an end land use perspective. Potential and achievable maximization of multiple purpose rights-of-way will be identified, as well as strategic nodal features controlling pattern development. Critical development elements already in place will be assessed for locational significance.

AN APPROACH TO ASSESSING VISUAL COMPATIBILITY OF TRANSMISSION LINES AND THE LANDSCAPE

W. M. Bakowski[1], J. K. Nickerson[1], and D. F. Perry[1]

ABSTRACT.--As a part of the United States Department of Energy project to optimize the design of UHV conductor support systems, an in-depth study of methods and theories which could be applied to visual assessment and improve transmission line/landscape compatibility has been completed. This paper describes the process that has been used to identify and evaluate principal factors equating to transmission line/landscape compatibility and to conceive how public opinions should be considered and incorporated into an overall visual assessment.

INTRODUCTION

Although much progress has been made toward reducing the overall environmental impact of transmission lines, two persistent and frustrating problems remain: assessing and minimizing visual impact, and accounting for the attitude and role of the public in the assessment process. As a part of the United States Department of Energy (D.O.E.) project to optimize the design of UHV conductor support systems (transmission structures), D.O.E. requested that aesthetics and potential visual impact be considered. With respect to visual impact assessment, methodologies developed to date deal adequately with landscape quality, viewers and visibility, but the relationship of transmission lines to the landscape in terms of compatibility has not been clearly defined. The second problem and most dynamic aspect of visual impact assessment, public opinions and perceptions, is just as important as compatibility in determining visual impact. However, it also has not been adequately addressed to date. Both of these problems are important to the development of an effective and responsive visual assessment process and are the subject of this paper.

The firms of Charles T. Main, Inc., designers of the new structures, and Kane and Carruth, Landscape Architects, had the responsibility for the technical aspects of the visual impact study. The Institute on Man and Science conducted the key Researcher and Local Citizen's Workshops.

The approach to our analysis of these two problems combined technical analysis with a participatory process. Engineers, planners, and citizens were involved in the review, evaluation, and modification of the decision-making process as it pertains to transmission lines and visual impact

1 C. T. Main, Inc., Boston, Massachusetts.

assessment. Three primary efforts were involved with this approach: compatibility analysis, an experts workshop, and a citizens workshop. The compatibility analysis was intended to provide a simple, but workable technique to systematically evaluate the relationship between landscape and transmission line characteristics. The experts' workshop was principally intended to evaluate and modify the compatibility analysis technique and other assessment concepts. The citizens workshop was a means of involving citizens unfamiliar with visual assessment in defining how they perceive their role as those being visually impacted.

COMPATIBILITY ANALYSIS

Development of a compatibility analysis technique is important as part of the larger project:

1. Although many techniques have been developed for visual impact assessment, few have specifically defined landscapes and transmission lines relative to one another.

2. There is a clear need for an approach to visual impact assessment simple enough to be understood and applied by the public.

3. Defining the relationship between the landscape and transmission lines will provide a basis for making structure, right-of-way and conductor decisions that integrate aesthetics and visual concerns with structural and environmental concerns.

The compatibility analysis began with the specific objective of determining the visual compatibliity of alternative structure types in landscapes representative of various parts of the United States (representative landscapes). Optimized structure designs were used as examples to identify those factors which contribute to their increased or decreased visibility and compatibility. These structures were simulated in photographs of actual landscapes.

This objective was modified after the experts' workshop. It was recognized that rights-of-way and conductors had to be included in the compatibility analysis. Secondly, locally recognizable landscapes (characteristic landscapes), not representative landscapes, were found to be the only valid basis for analysis. It was modified again after the citizens workshop. In order to improve the clarity of the assessment framework, professional jargon had to be simplified.

Compatibility is defined as having the capability of existing together in harmony. The concept, as it has been developed in this study, is that the components of transmission lines and landscapes can be similar or dissimilar. Analysis of their components, in terms of similarity, provides a basis for determining compatibility and identifies where changes in transmission lines can improve compatibility. The application of this concept hinges on the visual components of line, form, color and texture, and these being common to both the landscape and transmission lines.

To be effective in the decision-making process, the compatibility analysis requires that a local study area be identified and local citizens' perceptions of their environment be taken into account. For each of these components a list of descriptors, such as bold, vertical, or simple, would be developed based on local landscape characteristics. At the experts' workshop, descriptors such as simple, thin, and not massive were used in a positive way to describe structures, while heavy and complex exemplify negative descriptors. Where the line, form, color and texture of the structure, conductors, and right-of-way are similar to that of the landscape, there would be a minimal contrast resulting in less visibility and greater compatibility. To assist in the implementation of such an analysis, a compatibility matrix was developed to match transmission line descriptors to landscape descriptors in categories of high, medium, and low compatibility.

The following discussion defines line, form, color, and texture and the way these visual components relate to the assessment of compatiblity between landscapes and transmission lines.

Line is defined as the path that the eye follows when perceiving abrupt differences between patterns in the landscape (Bureau of Land Management 1980). Lines in the landscape include ridgelines, roads, and woodlines. These may be described in many ways, such as bold or weak, straight or curving, vertical or horizontal. In a similar fashion, a structure may fit into one or more of these categories. For instance, a single shaft steel pole structure may be perceived as a strong, vertical element, and would be less compatible than a low profile H-frame structure in a horizontal landscape, such as the plains. Also, the right-of-way can exhibit a strong horizontal or vertical line as defined by the limit of the cleared area (Figure 1).

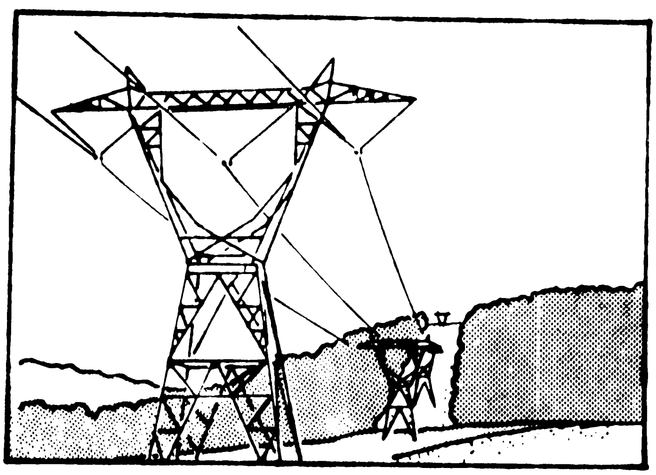


Figure 1. LINE: Landscape slightly rounded; Structure straight and vertical.

Form is the mass or shape of an object or a combination of objects which appear unified, often defined by edge, outline, and surrounding space (Bureau of Land Management 1980).

Whereas form implies three dimensions, many times structures appear to have only two. Two dimensions of an object are referred to as its shape.. Form in landscape is created by topography and vegetative pattern, and can be flat or rugged, simple or complex, bold or distinct. Structures and their related conductors and right-of-way also create a form that can be described in similar terms. Compatibility is achieved when the shape of a structure is similar to the form of a landscape and when structure or right-of-way size does not dominate its surroundings (Figure 2).

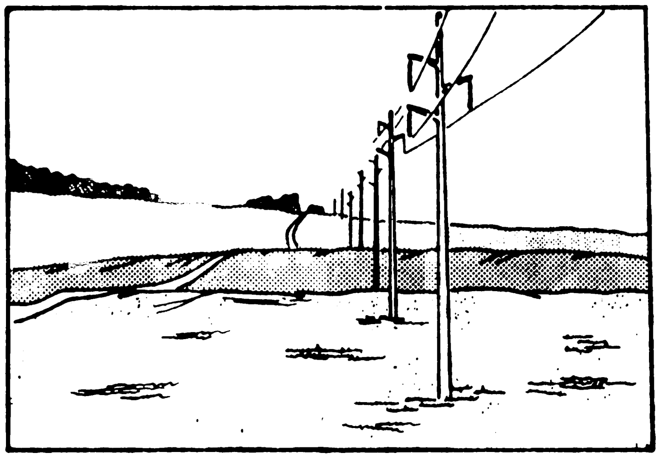


Figure 2. FORM: Landscape flat to rolling; Structure thin and vertical.

Typically, landscape colors in the foreground (within one-half mile of the viewer) are distinct, while colors in the middleground and background become muted. Structure colors are associated with the material used; i.e., wood poles are brown, lattice structures are gray (galvanized) or brown (weathering steel). Rights-of-way also create colors in the landscape depending on clearing techniques, access road development, restoration, and maintenance procedures. Thus, one should determine the general color and right-of-way treatment resulting in minimal contrast.

Texture in the landscape is created by the combination of vegetation, soil, rock, water, topography, and man-made modification. The texture of a structure is created by the material used and the configuration it is given, as well as the appearance of the right-of-way (Figure 3).

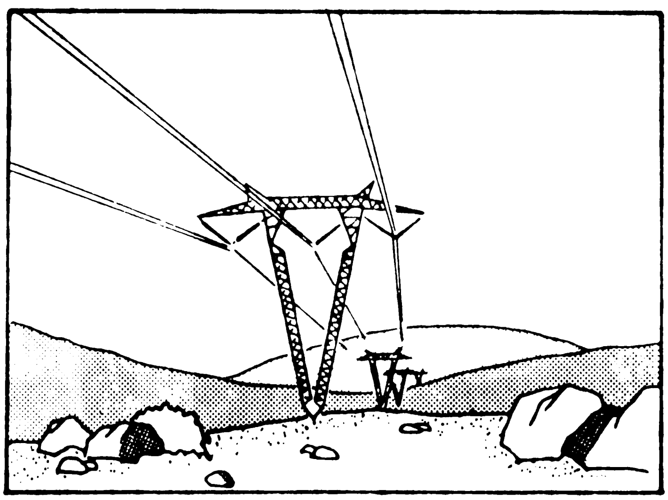


Figure 3. TEXTURE: Landscape smooth; Structure fine.

Coarse, medium, and fine are three typical descriptors used to define the texture of either a landscape or a structure. Lattice structures, with their many members, have more texture than tubular steel poles. A selectively cleared right-of-way has more texture than a clear-cut right-of-way. A higher potential for minimizing contrast exists in landscape of more texture.

An interesting aspect of visual assessment is the effect of distance. For compatibility analysis, structures in the foreground often create the greatest contrast with the landscape; however, even with a small increase in distance, the conductors and right-of-way often become the more contrasting factors. Overall, as distance from the viewer increases, the intensity of color and discernible texture diminishes and the potential for compatibility increases.

WORKSHOPS

At the outset of the project, it was recognized that an invaluable, available resource was the body of experts in the fields of aesthetics and visual impact. It was also clear that aesthetic preferences, as they relate to visual impact assessment, involve individual perceptions of the environment. In the opinion of the project team, an experts' workshop followed by a citizens' workshop was the best means to gather and integrate both expert and public opinions into the study.

The first workshop for the experts was designed around several objectives, including the following: (1) to evaluate key concepts such as compatibility analysis and representative landscapes; (2) to consider the feasibility of visual preferences for particular structures based on representative landscapes; (3) to assess the workability, validity, and reliability of an existing visual impact assessment methodology pertaining specifically to transmission lines as a basis for improving the assessment process; and (4) to evaluate methods of accurately representing structures in landscapes used to enhance the assessment process and to provide a better means of public communication.

Two criteria were utilized in the selection of experts: that they be nationally recognized in the area of aesthetics (and/or visual impact); and that their work was a reference used in the existing methodology to be used in the workshop. Disciplines represented by the experts included landscape architecture, psychology, geography, and environmental planning. During the two-day workshop, questions by the authors, as well as many more posed by the experts, were discussed at length. Some of the ideas were well received, while others were rejected. The questions and answers raised provided valuable insight and input into establishing a basis for a more detailed analysis of the concept of compatibility. It also provided additional direction for the citizens workshop. More significant results included the following: (1) compatibility analysis must take into account not only structures, but also the conductors and right-of-way appearance; (2) depending on the location of the viewer, structures may be less important than the conductors and right-of-way appearance; (3) landscapes used in the analysis must be project specific, not representative; (4) structure preference based on aesthetic values is only meaningful when locally recognizable landscapes are used; (5) the elements of line, form, color, and texture may be an appropriate basis for compatibility analysis; (6) the structure selection process should be a part of the overall siting process, not separate from it; (7) a flexible framework for visual analysis is more useful than a step-by-step approach; and (8) simulations are a key to comprehensive visual analysis and essential to conveying potential visual impacts to the public (Figure 4).

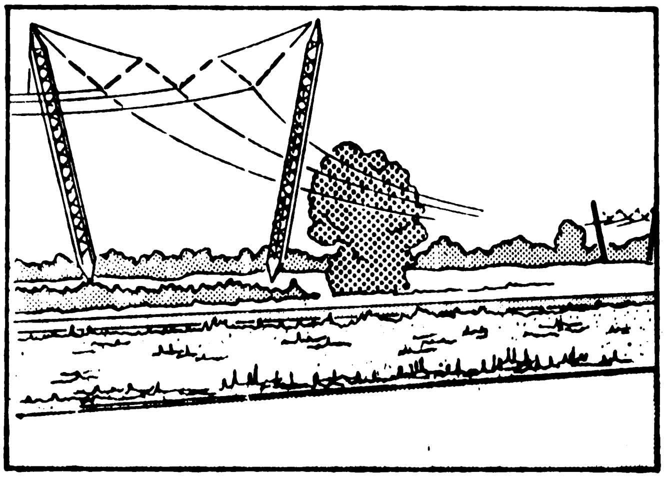


Figure 4. SIMULATION: Sketch of structures superimposed on landscape.

As was previously stated, current individual assessment techniques effectively evaluate three of the four major components of visual impact: (1) landscape quality, (2) viewers, and (3) visibility. The study has established a fourth major component: transmission line/landscape compatibility.

An essential aspect of compatibility is the individual's perception of the viewed environment. Yet, this dynamic aspect of the individual's and public's role is not adequately provided for in most visual impact assessment processes. Too often, the siting of transmission lines is a "closed system" involving engineers and planners. In most instances, public input takes the form of agency review or testimony after the design is complete. Seldom are opportunities provided for comprehensive input from the public during the design and assessment process.

This study has assumed that the visual assessment process can be improved by evaluating public viewpoints. The citizens workshop helped in the investigation of this assumption. Specifically, the objectives of the citizens workshop were as follows: (1) to consider the concept that visual assessment must be based upon local landscapes; (2) to assess and comment on the assumption that local citizens' perceptions may differ from those of the professional; (3) to evaluate the role and extent of citizen participation in the visual assessment process; (4) to determine the clarity of the framework; and (5) to comment on various methods of graphic representation used in visual assessment.

Citizens at the workshop represented university, contractor, agricultural, consumer, environmental, regulatory, and political viewpoints. To carry out the objectives of the workshop, a transmission visual assessment framework document was prepared. The document described a visual assessment approach in relation to the overall siting process with particular emphasis on key concepts and assumptions involving local citizen involvement. This document was evaluated by the citizens on the basis of its workability, clarity, and usefulness. Results of the workshop included the following: (1) Workability - specific steps for assessing visual impact such as compatibility analysis presented in the visual assessment framework, were logical, reasonable, and workable; however, the participants did feel that the citizens and professional viewpoints did differ, and that their perceptions should be integrated into the process; (2) Clarity - the greatest drawback of the framework was in the clarity of the language used to describe the process. Terminology commonly used by federal agencies in documents pertaining to visual assessments, as well as jargon used by the landscape architect and planner, were considered superfluous; (3) Usefulness - the usefulness of a visual assessment process was considered high, both as a means of minimizing visual impact and improving the siting process; (4) Citizens felt that graphic representations such as slide simulations were very useful in communicating potential compatiblity and visual impact (Figures 5 and 6).

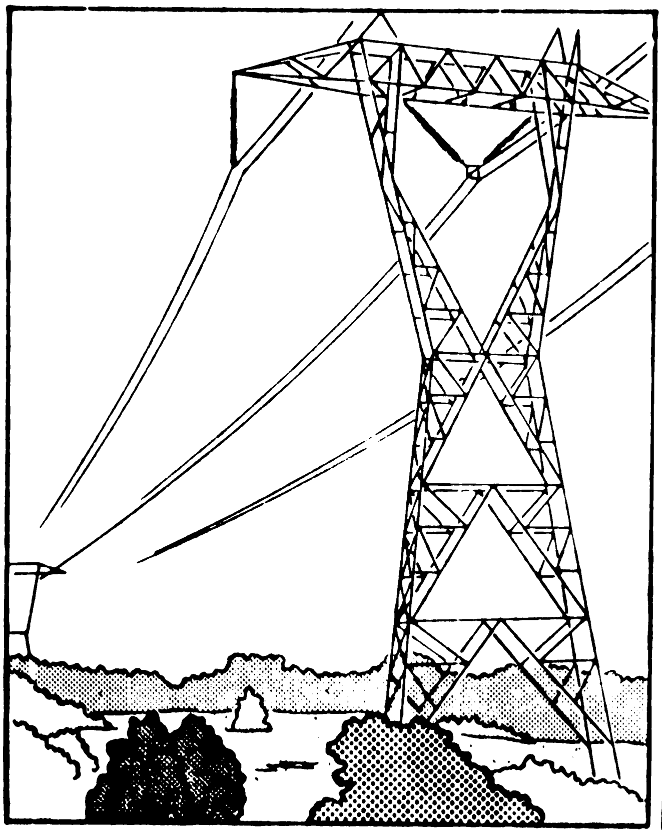


Figure 5. Low compatibility.

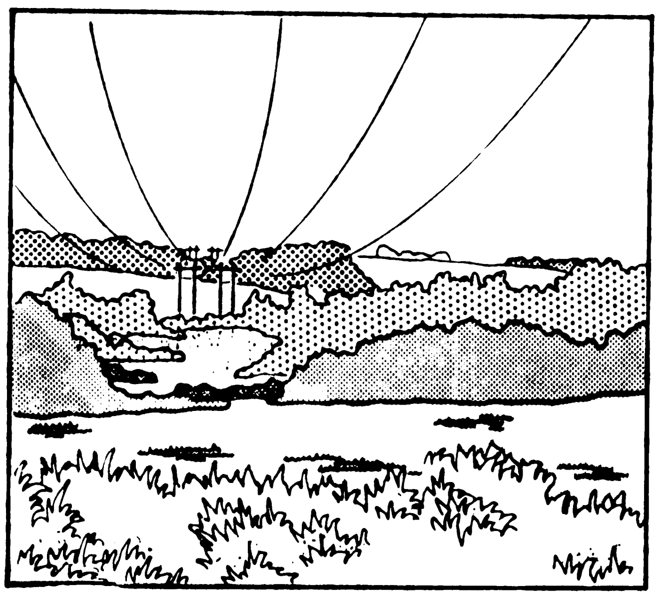


Figure 6. High compatibility.

The approach developed to define the relationship of transmission lines to the landscape in terms of compatiblity, and the findings as a result of the experts and citizens workshops, will contribute to solving the persistent problem of visual impact assessment and the role of the public in the process. The findings of this study will help the engineer and planner responsible for designing and routing transmission lines, as well as governmental agencies and local citizens.

For those designing, routing, and assessing the impact of a transmission line, several significant findings have evolved from this study: (1) There is a definable relationship in terms of line, form, color, and texture that exists between landscapes and transmission lines. Analysis of these four components can provide a more defensible position for structure design, structure selection, and evaluation of right-of-way management techniques; (2) Minimizing structure height and width while maintaining proper proportions will result in a less visually impacting design; (3) Physical appearance of the structure is important, but potential structures must be considered in terms of right-of-way appearance, conductors, and hardware; (4) When dealing with aesthetics and visual impact assessment, there are no universal solutions. Each project study area, as well as its resident citizens (public), must be considered on its own characteristics, to develop the most responsive and least impacting solution; and (5) Graphic representation is very important to visual assessment when dealing with the public and more aids of this type should be used in the process.

With respect to the public, it must be understood that they may perceive visual impact differently than the expert or consultant. Citizens' perceptions can be influenced by non-analytical and perhaps unquantifiable cultural and emotional factors. Also, in dealing with the public, it is essential that terms used be simple enough or defined so as to be understood by the citizen. Visual aids, such as simulations, can provide extremely useful information to the planner, and are most useful in enhancing the understanding of the public.

A system of routing and visual impact assessment that incorporates these findings will permit the designer and planner to make better decisions, will make the design more defensible and licensable from a regulatory agency's standpoint and more understandable to the public, and will help bridge the credibility gap between the citizen and the utility.

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QUANTITATIVE COMPARISON OF THE AESTHETIC IMPACT OF ALTERNATIVE TRANSMISSION LINE CORRIDORS: A CASE STUDY

Alan Sicherman[1], Thomas O. Baily[2], and Walter R. Odening[3]

ABSTRACT.--A study of the aesthetic impact of alternative transmission line routes was done by Woodward-Clyde Consultants for the Bureau of Reclamation for a proposed line in the 250-mile by 50-mile (400 km x 80 km) area connecting Las Vegas, NV, with Phoenix, AZ. Aesthetic impact was one of four issues of primary concern in the comparison of routes. Many different situations existed with respect to aesthetic impact along each of the alternatives. A procedure was needed to aggregate the different aesthetic impacts and to express the result in specific terms. A methodology called decision analysis provided the necessary aggregation techniques to systematically address such aspects as the varying distances of the potential viewer from the proposed line, the effects of "doubling up" existing lines versus a new line, new lines not near major highways, and the effects of background which may camouflage a line and lessen its impact. Decision analysis was used to compare the aesthetic impact of the routes and to rank order the alternatives.

INTRODUCTION

In 1976 Woodward-Clyde Consultants (WCC) was retained by the Bureau of Reclamation to analyze and rank alternative corridors (Figure 1) for a proposed transmission line (WCC, 1976). Alternative corridors were selected on the basis of distance, location of existing utility corridors, engineering constraints (rivers, mountains, lakes), and land use constraints (recreation areas, parks, wildlife refuges, urban areas, and Indian reservations). Three corridor options (V-1, V-2, V-3) varying in length from 48 to 63 miles were considered in connecting Potosi Mountain and Mead Substation. Six corridor options (I, II, III, III-Bridge, IV, and IV-Bridge) varying from 248 to 275 miles (400-500 km) were considered in connecting Mead and Liberty Substations.

The corridors were ranked using decision analysis. Four significant objectives were identified in evaluating the alternatives. These objectives were to minimize construction costs and the impact of the proposed

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project on bighorn sheep populations, aesthetics, and current land use plans of Clark County, Nevada. Other factors were considered to be much less significant or were approximately equal in magnitude for all the alternatives and hence not useful for differentiating among them. This paper focuses on how the aesthetic impacts of corridors were analyzed and compared.

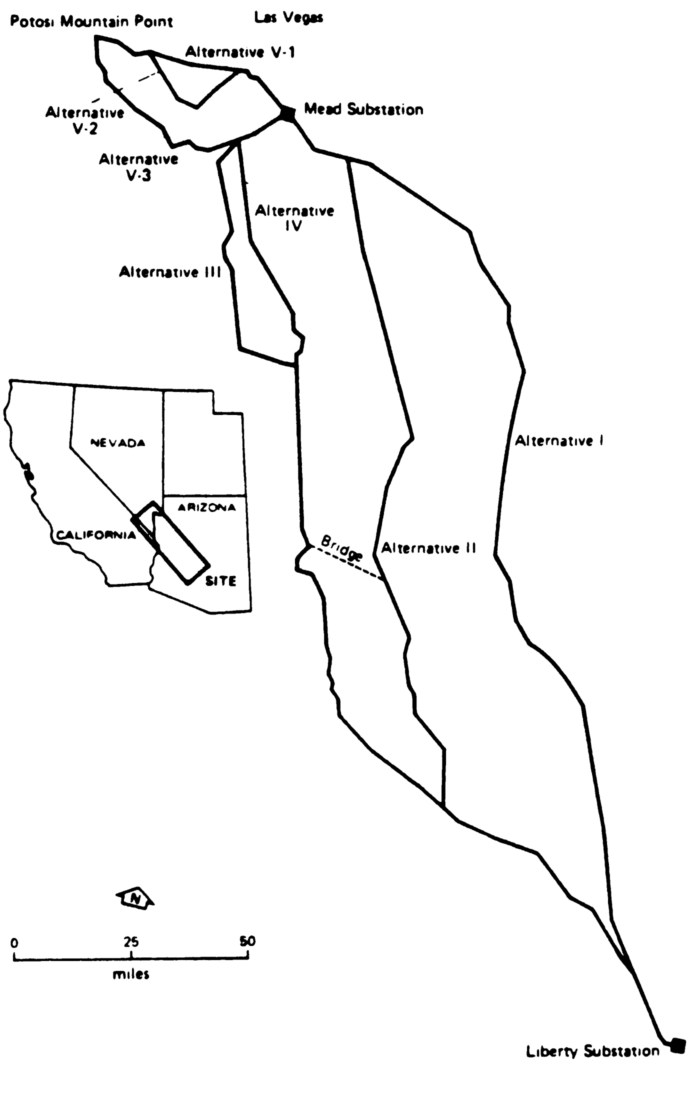

Figure 1. Alternative corridors.

AESTHETIC IMPACT CONSIDERATIONS

The different important aesthetic impact considerations are described below.

Distance From Viewer

Almost all of the people viewing the alternative corridors do so from major highways and roads (Interstates 15 and 40; U.S. Highways 95, 93, 466, 66, and 60; the state road to Alamo Dam in Arizona; the state roads in Lake Havasu City). Visibility of a power transmission line depends on the distance of the line from the viewer. WCC observations along several existing transmission line corridors show that transmission lines are not readily visible under most lighting conditions when they are at least four miles from the viewer. The human eye has difficulty discerning objects that subtend an angle less than approximately one degree which is about the angle a transmission line tower subtends when four miles from a viewer. A line has the greatest impact when it is 1/4 mile from a road, which is the closest distance that existing lines are to highways in the study area except when they cross the road.

Doubling an Existing Line

Most of the alternative corridors examined follow existing power transmission lines. Federal criteria for siting transmission lines suggest that new lines be placed in existing transmission corridors (USDA and USDI, 1971). Placement of a new transmission line next to an existing one increases the visibility of the lines. The degree to which visibility is increased depends on the distance of the "double" line from the viewer. At four miles, visibility is still negligible. At 1/4 mile, two lines tend to disrupt the view of the landscape.

Camouflage

The texture and color of background mountains can decrease contrasts between transmission lines and the natural landscape making them harder to see. Based on WCC field observations in the vicinity of the corridors, the degree of camouflaging depends on (1) the distance between the viewer and the transmission line and (2) the distance between the line and background mountains. If the viewer is one mile or less from the transmission line, the line cannot be camouflaged, no matter where the background mountains are located. As distance increases beyond one mile, the potential for camouflaging increases. If the background mountains are more than three miles from the transmission line, they do not decrease the visibility of the line. As the distance of background mountains decreases from three miles the potential for camouflaging increases.

Scenic Areas

Most landscapes along the corridors have essentially the same visual character (e.g., similar patterns of vegetation and land forms). However, the Sandstone Bluffs landscape located about 15 miles (24 km) west of Las Vegas, Nevada, has a high enough visual quality (e.g., variety of forms, strong color constrasts, no existing transmission lines) to be given separate consideration.

DECISION ANALYSIS CONCEPTS FOR COMPARING ALTERNATIVES

Because of the different situations along each of the transmission line routes with respect to the considerations just discussed, a procedure was needed to aggregate the different aesthetic impacts in order to compare the routes. Decision analysis is a formalized procedure that incorporates the judgements of the decision maker (or consultants in this case) in comparing options. The approach assesses preferences for situations that are easier to compare than the alternatives and then determines the rank order for the actual alternatives that is consistent with the preferences expressed for the simpler situations. It accomplishes this by using the decision maker's responses to calibrate a mathematical model called a multiattribute utility function. (The mathematical model and procedures used are derived formally on a theoretically sound basis.) This model aggregates the consequences of each alternative into a single number (utility) that can be used to rank order them. Decision analysis is described in detail in Keeney and Raiffa (1976). The utility function incorporates (1) the preferences of the decision maker for different levels of a particular impact, and (2) the tradeoffs between different types of impact.

To illustrate these concepts, consider a single new transmission line a certain distance from a major highway. The aesthetic impact is related to the distance from the highway as discussed earlier. Decision analysis provides techniques for quantifying a decision maker's preferences for this impact. One such technique is called the 50-50 chance lottery method. In this method a decision maker is asked which of two hypothetical impacts is worse. Choice 1 is the impact of a line placed 3/8 mile from the highway. Choice 2 is an uncertain impact with a 50% chance of an impact equivalent to a line 4 miles away and a 50% chance of an impact equivalent to a line 1/4 mile away. The decision maker is asked if he would prefer the 3/3 mile impact for sure or the uncertain choice 2. In this instance, most people would prefer the gamble. However, if choice 1 were changed to be 3 miles away, most people would not take the gamble. Somewhere between 3 miles and 3/8 miles there is a distance where the decision maker will find it equally preferable to take either choice 1 or 2. This "indifference" point can be used to model a decision maker's preferences for impact as a function of distance. There is no a priori reason why this indifference point should be half-way between 1/4 and 4 miles. The decision maker may feel that the impact drops off rather quickly with distance. Using techniques such as this one, decision analysis models preferences for particular impacts.

A second preference issue involves tradeoffs. For example, suppose (hypothetically) one had to choose (solely on the basis of aesthetic impact) between doubling up an existing line 1/4 mile away from a highway or putting a same length new line 1/4 mile from another highway. Doubling an existing line is perceived by many people to have less incremental aesthetic impact than a new line the same distance from a highway. Suppose the new line were 4 miles away, however. In this case, the new line would be preferred. Somewhere between 1/4 and 4 miles, a decision maker will again be indifferent between the line at that distance and a doubled-up line 1/4 mile away. The indifference represents a tradeoff between single line impact versus the impact of doubling up an existing line. The decision analysis approach used these concepts to compare the aesthetic impact of corridors.

IMPLEMENTATION OF DECISION ANALYSIS APPROACH

The decision analysis approach was to consider separately each of the aesthetic impact considerations discussed earlier and then combine them to determine an overall aesthetic impact. First, it was determined that when the background was assumed to be a regional landscape, the worst impact consisted of a new corridor (where none existed before) being put in at a distance of 1/4 mile away from a major highway. Since this impact was reasonably well defined and could be readily imagined by the project team, this impact was chosen as a reference with which to compare other impacts.

Next, varying distance of a corridor from a major highway was considered. Utility functions were calibrated to assess preferences (of the WCC project team) over this distance using the 50-50 chance lottery technique. An example is shown in Figure 2. Two functions were assessed, one for a single corridor and one for a "doubled" line. One can see from Figure 2 that the preferences are not proportional to the distance. The relative impact falls off rapidly with increasing distance for a new line.

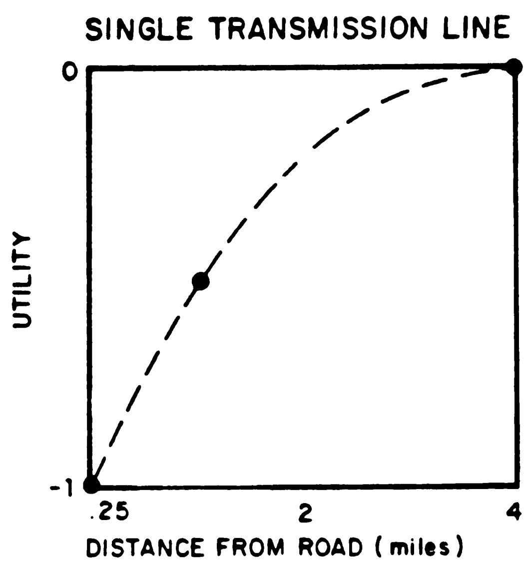

Figure 2. Preference assessment for distance.

Next, the problem of aggregating the varying impacts along the many miles of corridor was considered. It was determined that (1) preferences (utility) for the number of miles of corridor any fixed distance from a highway (a "stretch" of corridor) were linear (proportional to the number of miles); (2) preferences for distance from a highway were not affected by the number of miles of corridor involved; and (3) preferences over a stretch of corridor and preference comparisons between stretches of alternate corridors were not affected by impacts on the corridors outside those stretches.

These determinations justify the use of a simple function to aggregate miles of varying impact:

$$u\text{ (corridor)} = \Sigma_i m_i u_i$$

where

u = utility of the corridor
m_i = number of miles of impact level i corresponding to a certain distance i of the corridor from the highway
u_i = utility of distance i scaled from -1 to 0 (see Figure 2)

This function made aggregation simple. For example, 100 miles of the worst impact (u_i = -1) has an overall utility of -100. In fact, n miles of the worst impact always has utility of -n. Suppose 80 miles of impact level u_i = -.5 and another 20 miles of impact level u_i = -.25 are considered. Using the function, the overall utility of this corridor is -45. This, however, has the same utility as a corridor with 45 miles at the worst impact and 55 miles of no impact. The preference function indicates that these are equally preferred. Thus the 80-20 corridor impact can be converted to a "standardized" scale of equivalent number of miles of worst impact. (It is equivalent to 45 miles of the worst impact).

Tradeoffs between a mile of a new corridor line versus other types of impacts provided the final bits of information needed to convert aesthetic impacts to the "standardized" scale. The results of these tradeoffs were as follows:

(1) A "doubled" line one-quarter mile away was indifferent to a brand new corridor two miles away from a major highway. This is consistent with the policy of locating new lines along existing corridors. It indicates aesthetic impact from doubling up an existing line is less than that of a new line at the same distance from a highway.

(2) A new corridor in an area not parallel to a major highway but not totally pristine (e.g., containing ranch roads, etc.) was indifferent to a doubled line three-quarters of a mile away from a major highway.

(3) A new line through the Sandstone Bluffs scenic area was indifferent to an additional 35 miles of a new corridor one-quarter mile away from a major highway in aesthetic impact.

(4) Camouflage has the effect of making some lines as visible as if they were further away. A member of the WCC project team estimated this equivalent distance for different situations.

Using these results, an analysis was done (with maps providing distance estimates from highways) to produce figures for equivalent numbers of miles of maximum line impact on viewers from a major highway for each of the alternatives (Table 1). Table 1 shows that several corridors have about 15 miles (24 km) of this impact. This is directly due to the fact that the candidate corridors parallel existing lines as much as possible. Only Corridor II would have significant stretches of new line not paralleling existing lines. Corridor V-Options 1 and 2 have this same condition in addition to passing through the Sandstone Bluffs.

Table 1. Equivalent length of aesthetic impact.

Corridor	Aesthetics	Actual Corridor Length
I	15.2	248 mi/400 km
II	51.25	256 mi/412 mi
III	13.85	275 mi/443 km
III B	18.27	273 mi/400 km
IV	12.81	261 mi/420 km
IV B	16.20	264 mi/452 km
V-1	69.79	48 mi/ 77 km
V-2	75.27	58 mi/ 93 km
V-3	1.00	63 mi/100 km

The combination of Corridors V-3 and I was recommended considering all of the factors in addition to aesthetics.

CONCLUSION

The results of this study were not very sensitive to the preferences described here, since all the corridors have almost the same length and parallel existing lines for the most part. The advantage of the decision analysis approach was that the preferences underlying the comparison were clearly described and the aesthetic considerations involved were directly addressed. Interested parties with different preferences could use the same framework to see if the comparison would change given their preference input.

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HISTORICAL/ARCHITECTURAL EVALUATION OF VEPCO 230 kV TRANSMISSION LINE

Gregory Wroniewicz[1] and John R. Kern[2]

ABSTRACT.--In January, 1978, Virginia Electric and Power Company (Vepco) applied to the Virginia State Corporation Commission (SCC) for a certificate to construct a double circuit 230 kV transmission line between substations at Charlottesville and Remington. Vepco's application stated that the proposed line would replace an existing 115 kV line along the same alignment. Vepco's application was denied by the SCC in November, 1980. The SCC based its dismissal in large part on testimony from local residents who stated the new line would adversely impact the historic integrity of some 20 homes in the area which were built in the 1700s and 1800s. In early 1981 Vepco contracted Commonwealth Associates, Inc. (CAI) to prepare a historical and architectural evaluation of the transmission line. This evaluation is an important study because it presents criteria for assessment of cultural significance and for determining transmission line impact upon significant cultural resources. The outcome of the case is not yet determined.

INTRODUCTION

Virginia Electric and Power Company (Vepco) applied to the Virginia State Corporation Commission (SCC) in January, 1978, for a certificate of public convenience and necessity under Section 56-46.1 of the Code of Virginia to rebuild an existing single circuit 115 kV transmission line between Charlottesville Substation and Remington Substation for double circuit 230 kV operations.

The proposed construction is along a utility corridor which had its beginning in 1926. Right-of-way acquisition was started in 1926 for the construction of a 69 kV single circuit H Frame line between Charlottesville and Remington. Some rights-of-way were for a specified width of 70 feet; however, the majority were for an unspecified width. The 69 kV line was completed in the late 1920s. Load growth made it necessary to convert the 69 kV line to 115 kV operation in the mid-1940s.

Load growth continued to the point that the original 4/0 ACSR conductor was inadequate. The line was rebuilt and a larger conductor installed

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between the fall of 1959 and the summer of 1960. Many of the structures were replaced to accommodate the increased loading. A few of the unspecified width right-of-way parcels were renegotiated for a 100 foot specified width.

Load has continued to grow over the years on the eleven substations served by this line. The application to the SCC was for a certificate of convenience and necessity to rebuild the existing line to meet the increasing load and provide a reliable source for the Charlottesville and Remington areas.

Pursuant to the order of the SCC dated April 11, 1980, public hearings on the request to rebuild the line were held before a hearing examiner on May 27, May 28, and July 21, 1980. On October 2, 1980, the hearing examiner filed a report with the SCC recommending that the SCC enter an order denying Vepco's application as filed because "Although Company's proposal would make use of existing rights-of-way, it has not been shown that it would reasonbly minimize adverse impact on the scenic, environmental, and historic asset of the area affected." On November 28, 1980, the SCC denied Vepco's application. In early 1981 the SCC ruling was appealed by Vepco to the Virginia Supreme Court.

In February, 1981, Commonwealth Associates, Inc. was retained to review the historical aspects of the area and prepare a historical and architectural evaluation of the Charlottesville to Remington line. The first section of the Charlottesville to Remington transmission line to be studied was from Charlottesville to Gordonsville.

METHODOLOGY

The approach for the historic and architectural evaluation and impact assessment of the Charlottesville to Gordonsville transmission line was divided into three general areas: historical background research; existing sites record search; and architectural field reconnaissance. Local historical background was researched to gain an understanding of the role of the project area within the general county and state history. The project area for the Charlottesville to Gordonsville line covered the counties of Albemarle, Louisa, and Orange. Existing sites record search sought to assess the information already known about previously recognized significant structures within one mile of the existing corridor and substations. Architectural field reconnaissance completed the record by locating other potentially significant structures within the project area.

Historic Background Research

Research for the Historic Overview was conducted in Charlottesville, Virginia, during an eight-day period in February, 1981. Printed sources at the University of Virginia's Alderman Library were consulted for a comprehensive review of the study area history and state history. These sources included items in the Rare Book Collection, the Theses and Dissertations Collection, and the circulating historic collection (magazines and books).

Interviews were conducted with William Runge, curator of rare books for the University, and Bernard Chamberlain, a local amateur historian. The library of the Albemarle County Historical Society also was checked.

The Historic Overview incorporates information obtained during the study of material relative to the project area and the state. The quality of readily available data for each county varied widely; of the counties studied, a comprehensive county history was available only for Albemarle County.

Other information incorporated in the Historic Overview was gleaned from the review of published Federal Census records compiled between 1790 and 1940. These sources include not only data relative to population studies but also present basic statistical evidence relative to agricultural land use and industrial development. In some instances, such as in the 1840, 1850, and 1900 enumerations, basic statistical evidence relating to housing costs and the expansion of structural development in the three county study area also was obtained.

Existing Sites Record Search

An existing sites record search was conducted during the beginning of the fieldwork in February, 1981. Supplementary work was carried out through March and April. Four main sources of known sites were used: the National Register of Historic Places (NRHP), the Virginia Historic Landmarks Commission-State Register Sites (VHLC-SRS), State Inventory Sites (VHLC-SIS), and the Historic American Buildings Survey Catalog (HABS). The majority of the work was done at the Virginia Historic Landmarks Commission offices in Richmond, Virginia. An environmentalist of the Landmarks Commission staff and a regional representative for the Historic Landmarks Commission in Albemarle County were contacted.

The National Register of Historic Places and the Virginia Historic Landmarks Commission-State Register Sites are officially recognized lists (by the federal and state governments, respectively) of historic, architectural, and archeological sites of cultural significance. A considerable amount of detailed information is required for these sites to support significant claims. Relatively few significant sites in Virginia are listed because of the manpower efforts necessary to properly research them. Both lists of sites were investigated at the Landmarks Commission. The names and numbers of sites within each county were noted and locations of listed sites within the general project area were mapped. A two-mile-wide corridor, centered along the line route, was determined to delineate the general project area. Within this area mitigative measures might be called for as a result of potential impact from proposed modifications to the line.

The Virginia Historic Landmarks Commission-State Inventory sites are recorded on a set of maps and by data files on potentially significant sites throughout the state. While no complete list exists, approximate numbers of sites per county were determined. Those sites located within the general project area were mapped and site forms were copied.

The Historic American Buildings Survey (HABS) Catalog is a published book which enumerates levels of available information and detail about various sites in Virginia; this information is located in this federal agency's collection in the Library of Congress. This book is organized in two parts, the catalog and the inventory, and sites listed in the catalog are not repeated in the inventory. Listing is done alphabetically, first by location or vicinity, then county, then site name. Only specific locational data of each site are available, and no complete mapping of HABS sites is known to exist. All entires were checked for location in the three county overall project area, and a list of sites by county was then compiled. Sites were plotted by written description if near the general project area (as described by the HABS listing location or vicinity). In some cases, when the site listing by the VHLC-SIS and HABS conflicted, the VHLC-SIS mapped location was presumed correct.

Together, these four sources provide a reasonably complete picture of previously known sites within the general project area. The existing sites record search was accomplished prior to the file reconnaissance, allowing the visitation of all noted sites within the corridor for an on-site evaluation. As well as investigating previously recorded sites within the general project area, other planning studies also were inspected. The Piedmont Environmental Council produced a visual easement study of the Keswick to Cismont are in 1976 and newsletters.

Architectural Field Reconnaissance

The architectural field reconnaissance portion of the project was divided into three sections: data collection, evaluation, and assessment. Data collection consisted of a selective architectural survey where all structures within the specific project area were viewed, but only potentially significant structures were recorded with photographs and field forms. Evaluation by a multidisciplinary team of professionals involved a detailed analysis and critique of the sites located by the data collection, and site-specific research to confirm their potential significance. Assessment included field recording and analysis of the relationship of the project to the sites.

Data Collection

A selective architectural survey of the specific project area occurred between February 6 and 9, 1981. All structures were viewed by a team of professionals, but only those sites of potential significance that might be affected by the transmission line project were recorded.

The key element of a successful survey is the quality of in-the-field evaluations. Commonwealth used a team of professionals to insure quality evaluations. The in-the-field evaluation of each site was based on general criteria of design quality, representative historic style, and site integrity. Any site with any of the above criteria which might be affected by the project was recorded. Impact to significant structures was judged according to distance to the transmission line and whether the line would be visible from the site. Impacts to the site by other projects, such as existing highways also were considered. At the data collection stage of the fieldwork, all potentially significant sites, except those obviously not affected by the project, were recorded. The evaluation team attempted to consider all possibly affected sites at this stage, because future critiques of both significance and impact were built into the project methodology, virtually eliminating the omission of a possibly significant site.

The reason for doing a selective survey is to maximize efficiency. Past experience with architectural surveys has shown that only about 10% of the structures in any area are potentially significant. Field time and printing efforts come by using this method, but not so drastically. Each site must still be viewed, and most of the field time is needed for travel from site to site rather than data collection at the site.

Once a site was determined to be potentially significant and impacted, it was recorded. Recording consisted of confirming the site location on a map, photographing the structure, and completing a field form.

Accurate location of the site is critical, especially for projects where impacts need to be assessed. United States Geological Survey (USGS) 7.5' quad maps were used throughout the project to help locate the site in question. In addition, project information provied by Vepco was on maps based on USGS quads. The Virginia Historic Landmarks Commission has their inventory sites marked on quads for the entire state, and National Register sites are required to be located using UTM coordinates marked on USGS quads.

35 mm black-and-white photos of all surveyed structures were taken of the main structure (the house), taken from a vantage point that showed the architectural design and mass to best advantage.

A field form was specifically developed for the project and included location data, structure description, and site significance information on the front, and photograph and sketch grid on the back.

Evaluation

Architectural evaluations are subjective decisions about the relative merits of a site in comparison to the architecture of the area in general. A contextual understanding of the history and architecture of the area is necessary to eavluate site significance. A staged approach was used to make the critique as objective as possible. The evaluations were made by a multidisciplinary team of professionals with expertise in history, architectural history, architecture, and planning.

Architectural evaluations of historic structures were based on design quality, historic style, and site integrity. Design quality included visual proportion and construction execution. Historic style was judged according to whether the structure's design conformed to specific characteristics of scale, shape, material, and details. Site integrity concerned the relationship of the structure to the land and other buildings or features around it. Each site was considered according to design criteria and the relative merits of the site to others around it.

The evaluation process was staged to limit errors. The initial evaluation was done in the field followed by two evaluation sessions in the office. The in-the-field evaluation occurred at the same time as the selective survey, eliminating only the sites that obviously were not significant. The site selection criteria were refined to become more critical during each successive session.

Prior to the first office evaluation session, the evaluation team was briefed on the project scope and general findings. Slides were shown of some of the structures in the area, and a review of the historic research was provided. With an understanding of the context of the project, each structure was viewed by the team. The relative merits of each site were discussed, and a group concensus resulted. By using an evaluation team representing several disciplines, a broad viewpoint was gained.

The first evaluation session focused on the design merit of all the structures surveyed and produced a list of potentially significant structures. The second evaluation session considered project impact. Structures not impacted were reported but not analyzed further. The second session produced the final list of potentially significant structures.

The final aspect of the evaluation process was site-specific research, done on all potentially significant sites to confirm any presumptions about age. Once confirmed, the research was used to reinforce the evaluation and document the structure more completely.

Tax records, oral tradition, and especially the stylistic trends exhibited by the structure itself all offered certain guides in site-specific research. Although the original patent deeds were granted by the British Crown or provincial governors during the pre-Revolutionary War period, an intensive title search back to the original patents was not warranted in most cases. Almost any structure in itself provides the architectural historian with information on specific historical stylistic or design trends, and such evidence can be correlated with the site-specific documentation to provide an efficient method for interpreting the written sources.

Structures cannot be classified entirely within specific stylistic groupings. Indeed, modification and growth through the construction of room additions or changes of exterior embellishments may potentially obscure the original design elements of a structure or create a multistylistic form, the separate design attributes of which cannot be readily distinguished.

Supplemental site-specific historical research was conducted on those structures identified during the field investigation as being of architectural significance and potentially impacted by the line construction. Similarly, a number of sites identified during previous surveys and listed in the historic sites inventory file at the Virginia Historic Landmarks Commission also were investigated. This latter group consisted of sites which also would be potentially impacted, but for which only scant historical information was available. In at least one instance, further site research was conducted because the available information appeared spurious when compared to the stylistic composition observed during field investigations (i.e., Dunlora:68-128).

In attempting to establish a meaningful historical context, information contained in deed conveyances has proven to be extremely useful. The types of data offered through this medium ranged from direct allusions to locational descriptions of dwelling house or home place to an actual map placement on a property plat. More commonly, however, less specific data relating to property subdivisions through sales or inheritance provided important clues for building construction periods. As smaller parcels were subdivided from the original patent tracts during the nineteenth century, a steady progression of development took place which is reflected through house construction design variables. For the most part a direct connection was established between these stylistic changes and literature sources itemizing the subdivision of land tracts through time.

Assessment

Visual impact evaluations and assessments are subjective decisions of "how well (the line) relates to its surroundings" (EDAW Inc., 1975). Since this study addressed the visual impacts on historic sites, only the surroundings of those sites identified as culturally significant were assessed.

Preliminary evaluations of impact were made during the selective architectural survey. Proximity of the site to the line was the major criterion, but sites reasonably close to the line were eliminated, if vegetation or topography obviously blocked the view of the line, or if another existing intrusion of greater impact was between the site and the line.

All sites of potential significance inventoried by the survey were visited by a field team of professionals with expertise in architecture and landscape design to reevaluate the impact and collect basic data. This second evaluation again emphasized distance and visibility of the line from the historic site, but some sites were eliminated because the line was too far away, or too little of it was visible to cause an impact.

Those sites felt to be impacted to some degree were photographed from vantage points near the historic structure, and sketch maps of the property were made.

Additional data for each site were collected after the first field trip including aerial photographs of each site. Quad maps for each site were reproduced and together with photographs and notes, form a "site file" to be used for the final evaluation.

The final evaluation refined its criterion of visual impact into three general areas: amount of visibility, complexity of landscape, and background complexity. The amount of visibility referred to the view of the line from the structure. Complexity of landscape concerned the number of elements, natural and manmade, in the immediate area long the length of the line. Background complexity regarded the ability of the background to shield the line from view (Ontario Hydro 1974; CAI 1975).

Landscape image is often used in these studies, but this fourth criterion was eliminated from consideration (with one exception) for one reason: landscape image refers to public perceptions of the environment. All of the sites examined in this project have an historic element and are perceived similarly; the point becomes moot.

Each site was evaluated by these criteria and a final assessment was made regarding the degree of impact of the proposed project.

PROTECTION OF THE ENVIRONMENT DURING PLANNING AND CONSTRUCTION OF TRANSMISSION LINE PROJECTS

William S. Scott[1]

ABSTRACT.--Once a route for a new transmission line has been selected, a number of plans and procedures are implemented to minimize adverse environmental effects of the construction of the line. Environmental constraints for tower location and access roads are identified and mapped. Reports are prepared for any designated sensitive areas along the route so that special attention can be paid to these areas. These reports document the nature of the sensitive area, evaluate its sensitivity, and make recommendations for construction procedures to minimize impacts. Recommendations for access road crossings of streams are also prepared on an individual basis. Input during the construction of the line includes effects on future operation and maintenace activities. To this end, restoration is carried out near the end of the construction stage in order to repair any environmental damage that may have occurred, and to ensure that future problems will not occur. Once the line has been built, an inspection is undertaken to evaluate the effectiveness of the environmental procedures and recommendations.

INTRODUCTION

In Ontario, the planning and construction of transmission lines is subject to the Environmental Assessment Act. Ontario Hydro meets the requirements of this legislation by using a two-stage process. In the first stage, environmental assessment of various alternatives is undertaken in order to select a route for a transmission line. This involves studies and investigation on a macroscale. In the second stage, responsibility for the project is transferred to another group, and environmental concerns are addressed on a specific basis.

The purpose of this paper is to present the procedures followed in the second stage of the overall process. By way of introduction, however, the first stage of the process involves the identification of the end points of a proposed transmission line, the identification and value weighting of constraint or sensitive areas, and selection of alternative routes to avoid as many high value constraint areas as possible. The routes are evaluated, and one is selected. Once a center-line for the line has been determined, the project is transferred to the second stage of the process.

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CONSTRAINT MAPPING

Up to this point in the process, information has only been collected on a macroscale basis, and although the route selection process attempts to avoid as many constraint areas as possible, not all can be avoided. The first procedure used in the second stage of the overall process is the preparation of detailed constraint maps. The purpose is to identify and describe all areas of environmental concern that may be affected by the transmission line.

Types of concern would include agricultural land, soils susceptible to compaction and/or rutting, stream crossings, wetland communities, significant wildlife areas, significant aquatic communities, erodible slopes, potential drainage problems, recreation areas, and aesthetics. Air photo interpretation, International Biological Program (IBP) Reports, existing literature, and field inspections are used to identify these constraint areas. In addition, contact is made with local Ministry of Natural Resources and Conservation Authority officials.

Once all of the information has been gathered, the locations of the areas of concern are recorded by marking all of the information on a roll plan, or by preparing a report which refers to spans and tower number, or by a combination of both methods. The technique used depends primarily on the project and type of terrain. Very general recommendations are made at this stage and usually take the form of a defined objective to be achieved and several suggested alternatives for achieving that objective. For example, on heavy textured agricultural soils there is a high potential for soil compaction and rutting. In order to minimize soil compaction, rutting and general disturbance to the agricultural land, it is recommended that construction be carried out in winter or late summer when the ground is either frozen or dry and firm. The information contained in the constraint map is used in finalizing tower locations and for access road layout.

SENSITIVE AREA REPORTS

In some cases, proposed transmission lines are located across designated environmentally sensitive areas. These are areas that have been designated by IBP reports, government ministries, or local conservation authorities. Whenever a transmission line is planned to traverse one of these areas, a separate Sensitive Area Report is prepared.

The report provides a detailed description of the area and the reasons the area has a unique character. The sensitivity of the areas is examined in relation to the construction and maintenance activities associated with the transmission line. An assessment is made and recommendations are prepared in an attempt to minimize or mitigate the potential impacts of the line.

The process of data collection for Sensitive Area Reports is similar to that used for constraint mapping, except the level of detail is greater.

ACCESS ROAD LAYOUT

The procedure for access road layout is a joint effort between representatives from the environmental group and from the construction force. The information contained in the Constraint Map and Sensitive Area Reports is used in conjunction with field inspection in order to determine the most suitable location for access roads. Whenever possible, constraint areas are avoided by terminating access roads on either side of an area, or by locating the access road off the right-of-way. In this latter case, off right-of-way access would have to be negotiated with the property owner.

In all cases, the owner/tenant is contacted for input on the location of the road regardless of whether it is to be a temporary or permanent road. In many cases, a constraint area cannot be avoided as when a tower is located between two constraint areas and adjacent property owners are not agreeable to off-corridor access. In cases such as this, the least disruptive route is selected.

Once the route is selected, consideration is given to the type of access to be used and to the timing of its use. If the road is to be used only during dry conditions or in the winter, then no additional precautions are taken. In wet areas or during wet seasons, a variety of access road construction is used. Depending on the situation, roads can be made with gravel overlying a filter fabric material to prevent mixing with the underlying soil, with gravel placed on subsoil after the topsoil had been removed, with corduroy or timber logs, with timber mats, or with compacted snow and ice. These latter three alternatives are not used very frequently, but have been used when the situation warranted.

Whenever an access road has to cross a river, stream or drainage ditch, a specific recommendation is prepared for the crossing. The most suitable location is selected and the morphology of the stream banks and valley are investigated to determine the suitability of using culverts or fording the water course. If culverts are installed, the required end area of the culvert is calculated in order to determine the appropriate size to be used.

CONSTRUCTION MONITORING

During the actual construction of the line, forestry contractors or Ontario Hydro forestry crews selectively clear the vegetation along the right-of-way. Line profiles are used to determine the maximum height allowable under the line at all locations along the line. All compatible species are left, and in sensitive areas, some noncompatible species are pruned instead of being removed. Special treatment areas where normally noncompatible species might be left would include visually sensitive road crossings, highly erodible slopes, sensitive river valleys, or sensitive wetlands.

All construction crews receive an envrionmental briefing prior to starting a project, so that they can be made aware of the areas of concern and why the concern exists. In addition, passive reminders, such as signs, to warn crews to use only one access route or that they are in an environmentally sensitive area, and physical barriers such as temporary fencing remind crew members not to take short cuts across a stream or steep slope.

Occasionally, unexpected situations arise during the course of a project. Examples could include complaints of water wells drying up, drainage interruptions, or more commonly, the initiation of gully erosion. These situations are attended to immediately with the intent not only to solve the immediate problem, but to prevent or minimize the likelihood of a continuing maintenance problem.

RESTORATION

As the project nears completion, recommendations for restroation are being prepared. In agricultural land, stone is removed wherever it was used. In areas where a permanent access is required, the stone is left. In agricultural areas where the access road was across the bare soil, the access route is cultivated, or if extensive soil compaction is present, chisel plowing or rototilling is utilized to restore productivity.

All disturbed areas in nonagricultural areas are graded if necessary to remove ruts and seeded to produce a grass cover. This helps to control soil erosion, controls the growth of noxious weeds, and helps to reduce the regrowth of noncompatible woody species.

Additional care is taken on disturbed slopes that are susceptible to erosion. This could include sodding or seeding with the application of an erosion control blanket. Also, at visually sensitive areas, tree screens are sometimes planted.

MANAGEMENT PLAN PREPARATION

Concern for the environment does not stop once the transmission line is built and placed into service. The information gathered prior to and during construction is re-evaluated with respect to maintenance activities that will be carried out during the operation of the line. The information is updated and a Management Plan is prepared for the line.

The Management Plan divides the line into relatively homogenous areas, and specifications for maintenance activities are prepared for each area. Typical examples include restricting access in biologically sensitive locations, using a shorter maintenance cycle to reduce required tree to conductor clearances, pruning instead of removal of incompatible trees at screens, use of dormant spraying instead of foliar application of herbicides and restricting the use of herbicides adjacent to streams. The management plan can also stipulate the types of secondary land uses that are allowed on the right-of-way in each of the management areas.

SUMMARY

By the use of this second-stage process and adhering to the Management Plan, Ontario Hydro's operations and maintenance personnel are following through on a long-term commitment to environmental protection that started in the early planning stages, continued through the construction process and is manifested in its management, thereby minimizing any adverse impacts of transmission lines.

USE OF COMPUTER MODELS IN CONSTRUCTION OF ELECTRICAL TRANSMISSION LINES IN VIRGINIA

Leonard J. Simutis[1] and Benjamin C. Johnson[2]

ABSTRACT.--This paper describes the analysis procedures and results of studies to aid Appalachian Power Company in the evaluation and selection of alternative transmission line corridors for 765 kV lines planned for construction in southwestern Virginia.

INTRODUCTION

The major objective of the research was to provide technical assistance to Appalachian Power Company in the selection, display, and analysis of appropriate criteria to assess the geophysical, ecological, social, economic, and aesthetic consequences of the proposed electrical transmission facilities for 765 kV lines planned for construction in southwestern Virginia.

STUDY AREA

The principal area of research and technical assistance provided by Virginia Tech project staff was the delineation of alternative one-half kilometer corridors for the 765 kV transmission lines to (1) connect the proposed Brumley Gap hydro-electric facility with the Baker-Broadford line to the north; (2) connect the proposed Brumley Gap hydro-electric facility with the transmission facility at Stanley Valley to the southeast; and (3) provide a direct link between the Stanley Valley generating facility and the existing Baker-Broadford line.

The overall study area for the corridor studies was defined jointly by the VPI&SU study team and Appalachian Power Company personnel. Initially, two study areas were developed, the first to examine the Brumley Gap/Baker-Broadford line connection, and the second to study the other two alternatives. These two data banks were later merged into one large study area.

METHODS

The research team prepared six computer-aided models as follows: (1) overall constraints; (2) potential social disruption; (3) potential

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economic cost; (4) potential ecological disruption; (5) potential geophysical disruption; and (6) potential aesthetic disruption.

The computer-generated models are mathematical manipulations of the combinations of the data coded in the variables for the study area. Each cell is processed to generate a score which is a measure of the relative suitability of that cell in terms of the criteria applied in a particular model. The scores generated are very useful in making comparisons among alternative corridors.

The score for each cell is converted to a printed map symbol, or level of gray tone. The legend for each map displays the variables used in the model, the resequencing of the variable to conform to the hierarchy of 1 = very high suitability to 9 = very low suitability, and the weight applied to each variable. The display of the map itself is a range of gray tones representing the relative degree of constraints encountered in a particular corridor location. The darker shades represent areas with the most constraints; lighter areas are those with fewest constraints. In no case are the values represented on the maps absolute; rather they indicate relative areas of high to low degree of suitability.

The analysis of the models allowed generation of alternative corridors one cell wide; or one-half kilometer in width for each of the three study sites. Further field studies and aerial photographic interpretation will need to be undertaken of the alternative corridors for final tower location and alignment.

The main source of data was USGS 1:24,000 quadrangle maps. Additional information was obtained from local agencies, previous planning studies, state agencies, historical societies, and similar organizations.

Data were coded in 1/2 km grid cells using the UTM coordinate system. The data were coded on op-scan sheets, which were converted to punched cards. The accuracy of coding was verified using paired comparisons of cells drawn from a random sample of the data.

Overall Constraints

The Overall Constraints model indicates which areas within the study area will present constraints to the development of a 765 kV transmission line, if the guidelines of the Virginia State Corporation Commission (SCC) are followed. Major consideration in this model was given to identifying (1) existing population areas; (2) major transportation facilities; (3) historic and archeological sites; (4) areas with recreational facilities; and (5) areas of unstable geological conditions, such as the presence of sinkholes.

The Overall Constraints model served as a comparative tool, and as the major benchmark in comparing the potential strengths and weaknesses of the various corridor alternatives.

Potential Social Disruption

The Potential Social Disruption model is an attempt to discover which possible transmission corridors would have the least disruptive influence on the existing social environment of the study area. Existing communities, cultural features, historic landmarks, and similar concerns were strongly emphasized in assessing the potential impacts of the location of the transmission line corridor.

Potential Economic Cost

This model describes the potential economic cost for the construction of a transmission line in each cell. The general assumption of this model is that costs will increase as a function of complex land use, complex terrain and topography, poor vehicular access, and heavy forestation.

Potential Ecological Disruption

The Potential Ecological Disruption Model has been prepared as one of two basic environmental models within the study. Potential Ecological Disruption addresses the problems that can be associated with the transmission line's impact on forest and wildlife productivity. Potential Geophysical Disruption deals with the potential impacts of a powerline corridor on the soils and earth's surface.

The Potential Ecological Disruption model consists of six sub-models: (1) cold water habitats, (2) warm water habitats, (3) productive coves, (4) cliff habitats, (5) wetlands, and (6) forest productivity.

Potential Geophysical Disruption

This model is concerned with the potential impact that a transmission line corridor could have on the surface of the land. The Commonwealth of Virginia passed in 1974 a law prohibiting soil erosion and sedimentation on any construction project. This model responds in a general way to this legislation, estimating the areas to avoid with the corridor. Whenever possible, transmission line corridors should avoid areas of existing soil erosion and potentially erodable lands, sinkholes, and other surficial hazards.

Potential Aesthetic Disruption

The major purpose of this model is to develop an assessment of the potential visibility of the transmission lines, and to mitigate, by location of the corridor, the potential visual disruption the line might cause, particularly in areas of high population concentration.

The model took into consideration visibility from building concentrations, visibility from transportation routes, visibility from historic landmarks, and visibility from towns. The model also included as constraints the location of historic landmarks and public lands and buildings.

Particular efforts in the final line location studies can beneficially limit visibility of the line by use of screening vegetation, and by taking advantage of localized terrain characteristics to shield the line and towers from view. However, these aspects of potential visual disruption could not be a part of the computer simulation, since the data scale was not appropriate for such site-level analysis.

The basic approach to generating and comparing alternative corridors depends on the ability of the computer programs to access, statistically analyze, and compare the potential consequences of alternative corridor locations. For each of the three studies, alternative corridors were generated by running a minimum path search program against the results of the Overall Constraints model to generate the minimum distance-minimum impact corridor from a specified origin to a specified destination.

RESULTS

There were 44 potential corridors identified between Brumley Gap and the Baker-Broadford line, since 4 potential station sites and 11 potential interconnect sites were identified by Appalachian Power Company. Similarly, there were 4 potential routes between Stanley Valley and the 4 potential station sites at Brumley Gap. Finally, there were 11 potential corridors between Stanley Valley and the 11 potential interconnect points along the Baker-Broadford line identified by Appalachian Power Company. Further comparative analysis was conducted to narrow alternatives to one corridor for each of the three studies using the Overall Constrains model. This model summed the occurrence of identified constraints in all alternative corridors between a specified origin and destination. For each corridor, total length, and the sum of the constraints (or impact scores) were computed.

For each of the alternative sites and interconnect points, alternative corridors were generated. The most favorable corridors are those which minimize both length and impact scores. Table 1 summarized representattive corridor alternatives, lengths, and impact scores for some of the station sites and interconnect points in the Brumley Gap to Baker-Broadford Study. The best alternatives between station site 1 and the Baker-Broadford line are those which interconnect at locations 3 and 4, (the length and scores are the lowest) and station site 2, 3, and 4 interconnect points 3 and 4 are most preferable. Station site 3 has a slight overall advantage in both length and impact score.

The data in Table 2 indicate that the example corridors between Stanley Valley and Brumley Gap are nearly identical in length, although there is some variation in impact scores, with station sites 1 and 2 having lower impact scores than station sites 3 and 4.

Table 3 indicates that the most favorable corridor alternatives for a direct link between Stanley Valley and the Baker-Broadford line call for interconnect at sites 3 and 4.

Interconnect points 3 and 4 are the most desirable for interconnects with Brumley Gap, and they are equally acceptable for interconnects with Stanley Valley. All other alternatives are less attractive, either

Table 1. Summary of representative corridors between Brumley Gap and the Baker-Broadford line using the Overall Constraints model.

Station Site	Interconnect Site	Length (mi)	Impact Score
1	1	41	53
	2	31	47
	3	30	43
	4	31	43
	5	36	60
	6	35	56
	7	34	51
	8	39	70
	9	38	65
	10	68	100
	11	69	101
2	1	40	51
	2	40	50
	3	32	43
	4	33	44
	5	39	61
	6	38	59
	7	37	55
	8	42	73
	9	41	68
	10	72	104
	11	73	105
3	1	39	54
	2	39	53
	3	33	48
	4	34	49
	5	40	66
	6	39	64
	7	38	59
	8	43	78
	9	42	73
	10	73	109
	11	74	110
4	1	43	59
	2	43	58
	3	35	51
	4	36	52
	5	42	69
	6	41	67
	7	40	62
	8	45	81
	9	44	76
	10	68	106
	11	69	107

because of comparatively longer line length, higher impact scores, or a combination of both factors.

Table 2. Summary of representative corridors between Brumley Gap and Stanley Valley using the Overall Constraints model.

Station Site	Length (mi)	Impact Score
1	122	147
2	124	151
3	125	156
4	115	140

Table 3. Summary of representative corridors between Stanley Valley and the Baker-Broadford line using the Overall Constraints model.

Interconnect Site	Length (mi)	Impact Score
1	162	199
2	151	191
3	150	188
4	151	188
5	155	205
6	154	201
7	153	196
8	158	215
9	157	207
10	145	222
11	145	222

EVALUATION PROCESS FOR SELECTION OF RECOMMENDED ALTERNATIVES

The determination of corridors appropriate for detailed analysis was carried out primarily by use of the SEARCHR program and the Overall Constraints model. Detailed comparisons of the corridors, however, were also undertaken by comparing the potential consequences of employing the corridor for line location in terms of the other five computer models: potential social disruption, potential economic cost, potential ecological disruption, potential geophysical disruption, and potential aesthetic disruption.

Given the very large number of data points (cells) in the models, statistical transformation of the data was accomplished assuming that the data would conform to a normal distribution. For each model, the data were transformed so that the mean for all cells in the study area was 5, with a standard deviation of 1. Scores greater than 7 should then occur less than 2.28% of the time, while scores below 3 should also occur less than 2.28% of the time. These are the two "tails" of the normal distribution. From a statistical standpoint, a model should have most of the scores in the 4-6 range, with a greater than expected number of cells with a greater than expected number of cells with scores of 3 and below--significantly lower in potential impact--and with few or no scores of 7 and above--those with potentially significant impact scores--providing most suitable corridors.

Tables 4-6 summarize for selected corridors the total number of cells which are low and high in potential impact. For the Brumley Gap to Baker-Broadford segment, the alternatives are quite similar except for the station site 1 to interconnect 4 segment. Each interconnect to site 4 has a larger number of highly suitable cells than does interconnect site 3. Table 5 indicates that the simulated impacts of the alternative corridors are virtually identical, which should occur since the station sites are in close proximity. A similar situation holds for the Stanley Valley to Baker-Broadford segment summarized in Table 6, although interconnect site 4 has a slight edge in the number of potential low impact cells.

Table 4. Comparison of models for representative corridors between Brumley Gap and the Baker-Broadford line.

Station Site	Interconnect Site	Total Potential Low-Impact Cells	Total Potential High-Impact Cells
1	3	26	0
	4	34	3
2	3	22	0
	4	28	0
3	3	23	0
	4	29	0
4	3	23	0
	4	29	0

Table 5. Comparison of models for representative corridors between Brumley Gap and the Stanley Valley.

Station Site	Total Potential Low Impact Cells	Total Potential High Impact Cells
1	41	29
2	40	29
3	40	29
4	36	29

Table 6. Comparison of models for representative alternative corridors between Stanley Valley and the Baker-Broadford line.

Interconnect Site	Total Potential Low Impact Cells	Total Potential High Impact Cells
2	76	22
3	75	22
4	78	22

SUMMARY

The use of computer models is a valuable tool in assisting in the analysis of large volumes of data and in selection of preferred alternative corridors.

LEGAL STANDARDS AND PROCEDURES APPLICABLE TO ELECTRIC TRANSMISSION LINE SITING IN PENNSYLVANIA: A DECADE OF CHANGE

Louise A. Knight[1] and Allison K. Turner[1]

ABSTRACT.--The methods and standards of electric transmission line regulation in Pennsylvania have changed substantially during the last ten years. In 1970 a state Constitutional amendment imposed on the Pennsylvania Public Utility Commission additional duties to oversee the environmental impacts of any action it approved. The Commission responded by promulgating new comprehensive regulations on siting of transmission lines and by judging cases before it much more scrupulously than before. A case history provides insight into these changing attitudes. Evaluation and modification of the present system of regulation continues in an ongoing effort to balance the interests of the public and the utilities.

INTRODUCTION

The Pennsylvania Public Utility Commission (Commission) historically reviewed the need for and siting of electric transmission lines under authority set forth not in the Public Utility Code but in the Pennsylvania Business Corporation Law.[2] Pursuant to its terms, the utility constructing the transmission line was and is required to seek a certificate of public convenience from the Commission if it were unable to purchase needed right-of-way and were forced to resort to a condemnation to procure the right-of-way. The intent of the Business Corporation Law is essentially to provide protection to owners of private property against arbitrary exercise of condemnation by a utility by giving the property owner an opportunity to inquire into the need and reasonableness of the transmission line before authorizing the taking of that property.

The result of this method of regulation was that the Commission was usually called upon to review the siting of the transmission line in a very limited context. (Although all forms of Commission review require a determiniation as to the engineering need for the proposed facilities, this paper has largely been confined in scope to the elements of siting review.) In the first place, the Commission reviewed the line only as it

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2 15 P.S. §§1322 and 3272. "P.S." and "Pa.C.S." as used herein are legal notation for Purdon's Statutes and Pennsylvania Consolidated Statutes, respectively.

would affect individual parcels of land; it did not review the entire line, nor did it review any other impacts. Furthermore, the Commission could only grant or deny the utility's request to use eminent domain power; it had no flexibility to modify the route of the line. Since the standard of approval was whether the utility had been wanton, arbitrary, and capricious in its route selection, almost no individually protested eminent domain applications were denied. In fact, the only instance of such a denial occurred where the line would have created significant safety hazards because the operation of a forced water irrigation system under the proposed line created the potential of contact.

The decade of the 1970's witnessed a change to a much more sophisticated approach to siting overview by the Pennsylvania Commission. The thrust of this change was to move the focus of the investigation from a review based on inquiry into the impact of individual pieces of private property to a review of the entire line as it affected both public and private interests. This transformation occurred as the result of changes on several different levels: Constitutional and, within the Commission itself, both legislative and adjudicatory.

THE CONSTITUTIONAL AMENDMENT

The first change occurred in 1970 when Article I, Section 27 (Section 27) of the Pennsylvania Constitution was adopted. It provided the following:

> The people have the right to clean air, pure water, and to the preservation of the natural, scenic, historic, and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people.

In subsequent litigation interpreting Section 27, the Pennsylvania Supreme Court affirmed lower court decisions which held Section 27 to be self-executing (Commonwealth v. National Gettysburg Battlefield Tower, Inc., 8 Pa. Commonwealth Ct. 231, 302 A.2d 886 (1973), aff'd 454 Pa. 193, 311 A.2d 588 (1973); Payne v. Kassab, 11 Pa. Commonwealth Ct. 14, 312 A.2d 85 (1973), aff'd 468 Pa. 226, 361 A.2d 263 (1976)). Self-executing means that no implementing legislation or regulations were needed to carry out the mandate of Section 27. A three-pronged test for implementing Section 27 was enunciated in the Payne case:

(1) Was there compliance with all applicable statutes and regulations relevant to the protection of the Commonwealth's public natural resources?

(2) Does the record demonstrate a reasonable effort to reduce the environmental incursion to a minimum?

(3) Does the environmental harm which will result from the challenged decision or action so clearly outweight the benefits to be derived therefrom that to proceed further would be an abuse of discretion?

The extent to which each state and local agency functions as a trustee also has been investigated by the courts, which concluded that Section 27 cannot legally operate to expand the powers of a statutory agency (Community College of Delaware County v. Fox, 20 Pa. Commonwealth Ct. 335 A.2d 860 (1975)). Environmental review of transmission line siting by the Commission pursuant to Section 27 has, however, never been challenged in the courts on the grounds that such review illegally exceeds the Commission's delegated statutory authority. Finally, in a decision arising directly out of a Commission transmission line proceeding, a further effect of Section 27 was found to be that the burden or proving that the test set forth in the Payne case was satisfied, is intensified once the adverse impact of a certificate of public convenience is raised as an issue by a protestant or intervenor to the application proceeding (Pennsylvania Department of Environmental Resources v. Pennsylvania Public Utility Commission, 18 Pa. Commonwealth Ct. 558, 335 A.2d 860 (1975)). Thus, the passage and subsequent judicial interpretations of Article I, Section 27 of the Pennsylvania Constitution constituted the first elements leading to the evolution of a more active Commission policy on transmission line siting during the 1970's.

COMPREHENSIVE SITING REGULATIONS

In 1976, the Commission opened proposed rule-making docket 76 PRMD 8, which set forth comprehensive regulations on transmission line siting promulgated under authority of the Public Utility Code. Factors which contributed to the perceived need for the regulations, in addition to Section 27, were (1) a vigorously protested and well-publicized case under the Business Corporation Law which visibly underscored limitations and deficiencies of Commission regulation of siting under that particular law and (2) a generally heightened public awareness of the impact of electric transmission lines, especially high voltage lines which were perceived to have potentially significant health and safety effects. The so-called Blooming Glen case entailed 7 years of litigation. The line traversed an area of northern Bucks County, Pennsylvania, much of which is pastoral and scenic. The most vocal property owner objected to the route across his property and also contended that the line either was unnecessary or an unreasonable solution to whatever engineering problem existed. The case became the focus of media attention which projected the local confrontation as a fight between one man protecting his home against the power of a giant utility. As a sidelight, the publicity suggested that the Commission was unwilling or at best unable to protect this landowner and the public generally from the actions of the utility. The Commission ultimately found that the line was necessary and the siting proper, but the publicity and proceeding itself did point out how limited the scope of Commission oversight was under the Business Corporation Law, 50 PA. P.U.C. 480 (1977).

The proposed regulations were the subject of an extensive hearing and comment period. The final product was published in the Pennsylvania Bulletin on May 20, 1978, and is now codified at 52 Pa. Code §§57.71 et seq. In summary, the regulations require the filing of an application for Commission certification of the selected line right-of-way. This certification is not a certificate of public convenience, since this transmission line review is a product of agency regulation not legislation; certificates of public convenience are authorized only under statute. The application by the utility for certification is to be served not only upon the Commission but also upon the state Department of Environmental Resources and the State Historical Commission for review by those agencies. (The Department of Environmental Resources has never opposed an application for certification of a specific route; the Historic Commission did, as a result of its review, become an active party in one case involving a preferred route which imposed upon a site listed in the National Register). A hearing process allows participation of any interested party, which generally includes the Commission's Trial Staff, after which an administrative law judge (ALJ) issues an initial decision; that initial decision automatically becomes final unless one of the parties appeals it to the Commission. A grant of certification is not a grant of authority to condemn property; rather, because the regulations only supplement Commission review of transmission lines in that regard, the applying utility is also required to obtain a certificate of public convenience in a separate proceeding if right-of-way must be condemned because of a landowner's opposition. This two-step procedure has been viewed as unsatisfactory for several reasons which will be discussed below.

The utility's application is to include the following siting information (52 Pa. Code §57.73: "Pa. Code" is the legal notation for the Pennsylvania Code, the codification of administrative regulations): (1) a general description of the route; (2) a description of all studies made as to identify the projected environmental impact of the line on archeologic, geologic, historic, scenic, or wilderness areas of significance; (3) a list of efforts made to minimize that environmental impact; and (4) all reasonable alternate routes. Appropriate maps and aerial photographs are also required. During the comment period, many interested parties urged that utilities be required to file the equivalent of a federal environmental impact statement; the Commission rejected those suggestions, favoring the flexibility to require more or less, depending on the individual line. The decision approving or rejecting the application is to be based on the following siting criteria: (1) compliance with all applicable statutes and regulations providing for the preservation of the Commonwealth's natural resources, and (2) proof that the line will have minimum adverse environmental impact, considering the electric needs of the public, the state of available technology and the available alternatives. The Commission also has the power to condition or modify the route as it deems appropriate; thus, its decision is no longer limited to either approving or rejecting the utility's proposed route.

The Commission's regulations governing the certification of transmission lines defy strict categorization as to whether corridor planning or centerline methodology is being endorsed. While the regulation describing the contents of the application bluntly requires "a description of the corridor planning methodology" for alternate routes, the obligation of the applicant to locate "archaeologic, geologic, historic, scenic or wilderness areas of significance" extends to an area "within two miles of the proposed right-of-way" (52 Pa. Code §§57.73(8),(10)). This latter requirement obviously implies confinement of the proposed high voltage structure to an area beyond which, up to two miles, a variety of sensitive areas must be located, with the reasonableness of the anticipated encroachment of these areas a matter of argument. To not measure these two miles from the centerline of the proposed right-of-way, a reference point that does not exist in corridor planning, improperly confers an unlimited impact zone consisting of the full breadth of the right-of-way. To date, the Pennsylvania Commission, firmly steering a middle course, requires electric utilities to construct their corridor for planning purposes but to confine their projections to a definite pathway in its midst. Trial Staff has, in at least one case, filed a motion to require the utility to define a centerline.

HARRISON-PREXY-YUKON 500kV TRANSMISSION LINE

Perhaps the most compelling example of the Commission's attitude on transmission line siting resulting from an actual case. In 1977, the West Penn Power Company (West Penn) filed over sixty appliations for certificates of public convenience granting authority to condemn right-of-way for its Harrison-Prexy-Yukon 500 kV electric transmission line. The line was to extend from the Harrison generating station in West Virginia to a major substation at Yukon, southeast of Pittsburgh, extending a total of 60 miles within Pennsylvania. This case was thus based on the provisions of the Business Corporation Law and not on the siting regulations, although the siting regulations became effective early in the proceedings. An application filed under the siting regulations was rejected during the proceeding on the grounds of insufficiency.

The parties to the proceeding included West Penn (company), Commission Trial Staff, and numerous landowners who faithfully attended the 20 days of hearings in Pittsburgh. The protesting landowners were motivated by many diverse reasons, but a common theme was their resentment of the alternately indifferent and cavalier attitude exhibited by the company during negotiations with landowners and throughout the presentation of its case. (The quality of evidence presented by West Penn reflected little concern for its probative value. It self-described the testimony of its environmental witness as "window dressing" and demonstrated its insensitivity to the landowners by refusing to accompany the Administrative Law Judge on a tour of the line's proposed route.)

The disputed issues in the case were whether the H-P-Y line was needed, whether the route selection process and the route itself were reasonable and whether West Penn has satisfied the <u>Payne</u> test with regard to Section 27. The Commission's decision with regard to each clearly shows its willingness and confidence to apply rigorous standards of siting oversight.

The case was finally decided by order adopted May 29, 1980. The Commission rejected West Penn's contention that the line was neceessary. This was the first time the Commission ever denied a certificate of public convenience for a transmission line on such grounds. The basis of the decision was that, in fact, West Penn had failed to meet its burden or proof. The evidence submitted by West Penn with regard to engineering necessity was found to be "so incomplete, inadequate or inaccurate that it did not meet the 'reliable, probative and substantial' [evidence] standard" set forth in Section 332(b) (66 Pa. C.S. §332(b)) of the Public Utility Code; thus, it lost all probative effect (Order of May 29, 1980,

A. 100200 et al., page 10). This determination was made despite the fact that no engineering witness testified contrary to West Penn's witness. The Commission found that, "being the trier of fact and the agency possessing expertise in the matter of utility regulation, [it is] not required to accept even uncontradicted testimony as true." While this is a landmark decision, it is not easy of application. Staff's argument of this position in a subsequent case was rejected by ALJ Judge and the Commission, where opposing expert engineering testimony on engineering need was introduced. Neither does it solve the question of what burden of proof opponents must carry if they do submit opposing testimony.

West Penn's route selection was ultimately rejected by the Commission because it failed to present persuasive testimony and evidence as to the reasonableness of the siting process and the route itself. The ALJ was greatly assisted in evaluating the company's case by acceding to a landowner's request to take a view of the line. While such views are not unusual in the context of damage proceedings in Common Pleas Courts, it was unprecedented in the context of a Commission proceeding. Owing to the length of the line, the view took place during two days in October, 1978. The ALJ was accompanied by a stenographer who recorded his observations, questions put to landowners, all of whom were duly notified of the visit, and the answers to those questions. The Trial Staff and several landowners also took part in the entire view although, as noted above, the company refused to send a representative.

The ALJ found that, for the most part, West Penn's witnesses merely presented conclusions that adequate planning was done. Although the company testified that many factors such as present and future land use, geography, scenic areas, etc., were evaluated, there was little testimony presented tending to show how the company actually used the data and information it allegedly gathered to plan an acceptable route. Virtually each time a specific example was examined, the company was contradicted by other witnesses or by what the ALJ himself had observed. For example, with regard to present and future land use in Greene County, one of the counties traversed by the line, West Penn's environmental analyst stated that the line would cross remote areas where little population growth was projected. The County Planner for Greene County later directly contradicted that testimony, stating the Greene County's population was expected to double by the year 2000 and that the line would bisect the part of the county most suitable for development. In another instance, the environmental analyst testified as to the placement of a major river crossing. She stated that the proposed route was necessitated because of the steepness of the southwest bank of the river. The ALJ found, based on his view, that the southwest bank was actually gradual and that the proposed route traversed an area that was steeper than the surrounding areas. Thus, the ALJ and the Commission concluded that West Penn had not produced a credible case to prove the reasonableless of its route selection.

Finally, the Commission found that West Penn had also failed to satisfy the Payne task. Although the company had complied with applicable statutes and regulations, it did not even attempt to show any effort to minimize environmental impact. Rather, the environmental analyst answered upon cross-examination simply that the transmission line would have no environmental impact. Trial Staff obtained copies of guidelines with respect to planning, construction, and maintenance of transmission lines and submitted them into the record. In each case, cross-examination showed that the guidelines were, in fact, generally disregarded. The ALJ aptly summarized West Penn's environmental assessment as "a total charade."

Thus, for the first time, the Commission did not grant any of the requested certificates of public convenience to a utility, thus barring the construction of an electric transmission line. That decision was based on three separate grounds, each of which standing alone, would have warranted disapproval: engineering need, siting, and compliance with Section 27. While the issues and conclusions in this case were litigated under the old standards, they reflected clearly the spirit of the comprehensive regulations. The decision underscored the conviction of the Commission to assume greater responsibility in regulating transmission line siting.

West Penn chose not to appeal this decision but did seek reconsideration which was denied. West Penn is free to file new applications for this line under the siting regulations or eminent domain provisions but has never done so.

CURRENT ISSUES AND FUTURE CONCERNS

Several cases have been litigated under the Commission's siting regulations, although most were still planned originally prior to the adoption of the siting regulations. In those cases the eminent domain and siting applications were consolidated to avoid a two-step proceeding. In general, the utilities have adopted their planning techniques to accommodate the concerns reflected in those regulations. Of course, for some utilities, the change has been more dramatic than for others. Approximately half of the eight major electric companies in Pennsylvania have retained consultants to assist in their routing process; the others have built or augmented their in-house programs. Pennsylvania Power and Light Company, for example, used a consultant to assist in developing its in-house program and also to do generic studies, such as one on pole design and color. West Penn has chosen to reinforce and train its in-house staff and almost all of its subsequent transmission line applications have been granted.

Obviously, then, additional siting review imposes additional costs. A survey of companies with active construction program reveals that estimated incremental costs vary from $4,000-$8,000 per mile (out of a total engineering cost of about $25,000 per mile) to an absolute difference of $10,000-$20,000 per line. The additional costs are imposed not only by consultants or more in-house environmental analysts or similar personnel, but also by the need for attorneys, exhibits and prepared testimony, and more clerical help. The benefits, which are more difficult to quantify, are better siting and right-of-way management and more public confidence in both the Commission and the utilities resulting from a more thorough planning and review process. The Commission on the other hand has not greatly increased its expenditures on its review. Staff has had only limited access to outside experts, and no additions to Staff have been made specifically for transmission line review.

Despite somewhat diminished expectations of growth, major electric utilities in Pennsylvania continue to present cases supporting requests for certification of high voltage lines. Certification is currently being sought for transmission line projects ranging from taps measuring less than two miles in length to high voltage lines that will traverse 20 to 30 miles of land. Limitations on the Staff resources that can be devoted to certification proceedings have, of necessity, shaped the manner in which the Commission's Staff participates in these cases. Very short lines or taps that are noncontroversial to surrounding landowners and which pose no significant addition to the environmental impact of existing man-made structures may require no more staff involvement than a verification of compliance with Commission filing requirements. Comprehensive interrogatories refined to an almost standardized format through experience can often elicit sufficient information so that Staff can determine whether a line of significant length requires further investigation.

Discovery skills, improved over the course of a series of certification proceedings, has permitted the Staff to limit its participation in cases to those issues in which Staff testimony is critical to a proper Commission evaluation of the merits of the request. This is in contrast to the lengthy discovery and hearing process applied to early certification cases that established what were the procedures and methodologies employed by major electrics in determining need for new transmission facilities and their likely impact on the environment. This has allowed Trial Staff to focus its continued participation on lines where unusual issues arise.

Three recent applications are exemplary of such issues. In one such application, which involves a tap to South Union, the alternate selected by the company utilizes a major highway right-of-way. The highway is a by-pass of a large population center but nonetheless passes through several smaller centers. Significant opposition developed during the hearings from landowners whose property would not be traversed by the right-of-way, but who would nonetheless be located less than 200 feet from large unguyed single steel poles. This type of participation is probably not permissible in an eminent domain proceeding. Staff testified for alternate siting and the ALJ ordered consideration of a new route. The company continues to seek its original selection. The other two applications were filed separately but were for two links of a three-line project. The total mileage covered is over 36 miles. Although the utility wished to pursue them separately, they have been consolidated. Although some routing issues have been raised, the engineering need for the project is being seriously questioned.

The siting regulations have undergone constant revisions since their adoption in 1978 as awkward procedures are smoothed out and minor substantive changes made. The single most important development has been a desire by both the Commission and the utilities to avoid the necessity for dual proceedings when right-of-way must be condemned. Currently, the utilities do not intend to survey center lines and identify landowners for future lines; since the regulations do not require that landowners be notified or centerline identified, this approach is clearly permissible. Only after the proposed corridor or route is certified by the Commission under the siting regulations will the utilities undertake to obtain the right-of-way; hence, only after the siting proceedings do the landowners have an opportunity to protest the line. For the time being, Trial Staff has sought to provide landowners notice of the certification proceedings by having newspaper publication of the proposed affected area or holding meetings with local citizens. In addition, ALJ's have required landowner notification since many lines undergoing siting review even now were planned prior to the regulations, when landowners were routinely identified during the planning process. Unfortunately, dual proceedings perforce will occur because utilities will refrain from approaching landowners until certification is completed unless a consolidated proceeding can be devised. Currently, a committee of utility and Commission Staff is investigating an acceptable format.

CONCLUSION

Clearly, although a decade of change has transpired, in Pennsylvania's transmission siting procedures, more change is on the way. The Siting Regulations must be regarded as being at an intermediate point in an evolutionary process. Particular consideration will have to be given to landowner notice and participation. Will individual notices become a requirement? If so, how will those to receive notice be identified since several alternate routes will almost always be involved? Will the Commission become more involved in modifying the routes for which utilities apply? What kind of record will be required upon which the Commission may base such modifications? Developing sound solutions to these problems will require the best joint efforts of both the Commission and the utilities.

THE ENDANGERED SPECIES ACT AND RIGHTS-OF-WAY MANAGEMENT: REQUIREMENTS, RESULTS, AND IMPLICATIONS OF THE SECTION 7 CONSULTATION PROCESS

Thomas G. Shoemaker[1]

ABSTRACT.--Section 7 of the Endangered Species Act requires all federal agencies to consider the conservation needs of threatened and endangered (T&E) species in planning and implementing their actions. Section 7 requirements are particularly far-reaching because they apply to nearly all development projects. A review of U.S. Fish and Wildlife Service (FWS) files for Region 6 was completed to better define the specific effects and implications of the Section 7 Consultation Process on rights-of-way planning. Although rights-of-way projects have a high potential for encountering T&E species or their habitats, serious conflicts are infrequent. The rights-of-way planning process is relatively flexible and a variety of comparatively simple techniques have been employed to avoid or reduce the severity of impacts to T&E species. Although Section 7 consultation appears to function effectively within FWS's Region 6, there is room for improvement, particularly through development of management guidelines which can facilitate early consideration of T&E species in project planning.

INTRODUCTION

Section 7 of the Endangered Species Act of 1973 (Act), as amended, specifically prohibits federal agencies from taking actions which would jeopardize the continued existence of a threatened or endangered (T&E) species or adversely modify designated critical habitat. This protective requirement is far-reaching because it applies to all actions which an agency may fund, authorize, or actually carry out. There have been past instances in which Section 7 requirements have seriously conflicted with planned development projects. Subsequent controversy has resulted in the widely held view that the Endangered Species Act, and Section 7 in particular, is a major impediment to new development.

Clearly, the protective restrictions of Section 7 affect most development projects, at least during the planning process. However, the degree to which they impede development is not clear cut. The real effects of the Section 7 requirements depend on the nature of the development and its

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location, on the vulnerability or sensitivity of the T&E species encountered, and on the extent to which the development planning process can accommodate the needs of the T&E species.

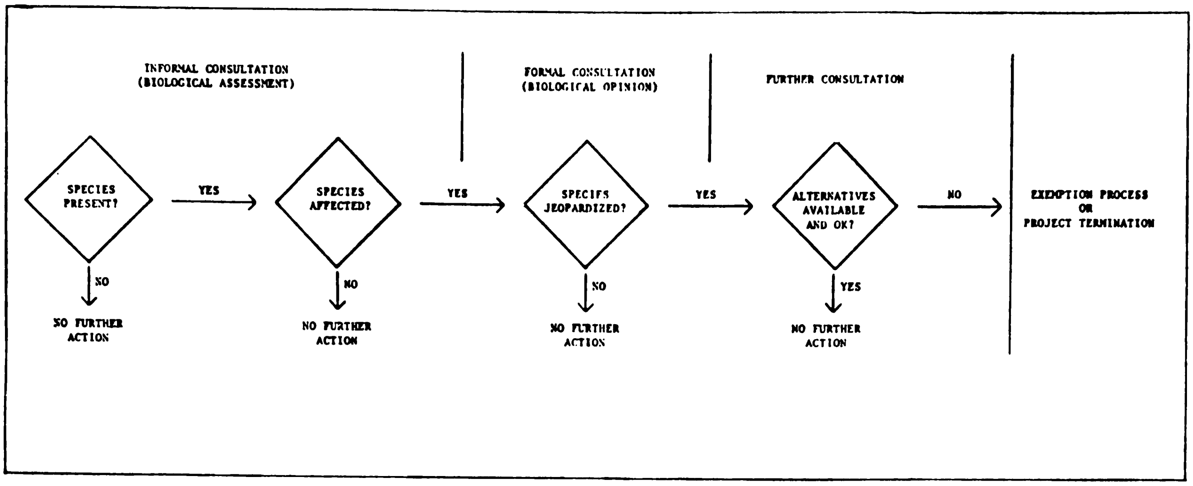
In this paper an attempt is made to provide some clarification of the effects of Section 7 of the Act on ROW projects in the U.S. Fish and Wildlife Service's (FWS) Region 6: Montana, Wyoming, Utah, Colorado, Kansas, Nebraska, South Dakota, and North Dakota. Basic statistics are presented regarding the number of ROW projects affected by Section 7 requirements during the period November 1978 to September 1981 and the number of ROW projects in which serious conflicts were encountered. Information presented was obtained by reviewing Section 7 file information in the Denver Regional Office of FWS's Office of Endangered Species (OES).

This is followed by a review of the specific nature of T&E/ROW concerns and the measures which have been taken to reduce or eliminate potentially adverse effects. Finally, suggestions for improvement of the Section 7 process are included.

SECTION 7 CONSULTATION PROCESS

In addition to the protective requirements discussed above, Section 7 of the Act also includes procedural requirements. These have been generally separated into two processes, the Section 7 Consultation Process, and the Exemption process, which govern the manner in which a federal agency is to identify, resolve, and document potential conflicts between its actions and the conservation needs of T&E species. The Consultation Process is essentially a Congressional requirement that federal agencies consider the needs of T&E species early in the planning of a proposed action and attempt to prevent significant adverse effects. The Exemption Process was added to the Act in the 1978 amendments and provides a means of exempting agency actions from the protective requirements of Section 7. The Exemption Process may be initiated only following the Consultation Process and only in circumstances in which an irresolvable conflict exists on a project of regional or national significance. In fact, the Exemption Process has not frequently been used and has not been initiated on any ROW project in the nation, to date (September 1981).

The review of ROW project/T&E species interactions was thus completed within the context of the Section 7 Consultation Process. The Process includes several decision points which reveal the nature of, and relative potential for, conflicts in interactions between T&E species and ROW developments. Unfortunately, the Section 7 Consultation Process implemented by the FWS is not well defined in the Act, in FWS regulation, or in any publication which is widely available. The skeletal diagram in Figure 1 and the following paragraphs outline the major steps in the process which are referred to in this paper.



Informal consultation, which may include preparation of a formal Biological Assessment, is used primarily to determine if any T&E species are present, and if they may be affected by the proposed action. Informal consultation may also be used to (1) establish working relationships, (2) enhance information exchange to expedite formal consultation, (3) promote early development of options and project modifications, (4) identify potential problem areas, and (5) obtain FWS technical assistance in planning (Reyes-French and Shoemaker 1982).

Formal consultation is specifically required by the Act if an agency action may affect (in any way) a T&E species or designated critical habitat. During the 90-day consultation period, the FWS reviews the proposed action and its potential effect on T&E species, determines the significance of the effects, and discusses with the federal agency any project modifications which may be needed to limit adverse effects. During consultation, the agency (or applicant) may not close out any project alternatives or modifications by irreversibly or irretrievably committing resources to the proposed action. At the close of consultation, FWS issues a Biological Opinion regarding the potential effects on T&E species. The opinion reaches one of three conclusions: (1) the action will promote the conservation of the species, (2) the action is not likely to jeopardize the continued existence of the species, or (3) the action is likely to jeopardize the continued existence of the species (or adversely modify critical habitat). The latter opinion effectively precludes the agency action unless an exemption is obtained or the action is modified. When a "jeopardy" opinion is issued by FWS, it must include a discussion of "reasonable and prudent" alternatives which would meet the protective requirements of Section 7 and fulfill the intended purpose of the action.

The third phase of consultation, "further consultation," can be used for discussion of these alternatives, development of additional alternatives, or other negotiations designed to eliminate the conflict between the T&E species and the proposed development.

ROW PROJECTS IN REGION 6

The eight state area of FWS Region 6 is ecologically diverse, including ecoregions ranging from alpine tundra to short grass prairie. Twenty-five T&E species are listed for the region, including 10 plants, 1 mussel, 6 fishes, 1 reptile, 3 birds, and 4 mammals. Six critical habitat areas have been designated. Region 6 is also rich in energy, mineral, and timber resources and is the scene of rapid development and increasing human population. Rights-of-way projects, including pipelines, highways, railroads, and electric transmission lines are a common component of the expanding development.

There were 86 ROW projects which had been discussed (by letter, phone, or personal meeting) with OES personnel between November 1978 and September 1981 (Table 1). In 26 instances, informal consultation had begun with a request for information or other technical assistance, but no further information was present in the files. Presumably, these projects were either abandoned or a determination had not yet been made regarding the need for formal consultation. In 30 cases it was determined during informal consultation that the project would not affect T&E species and formal consultation was not required.

Table 1. Results of section 7 process for ROW projects in Region 6. (1978-1981).

	Informal Consultation		Formal Consultation		Further Consultation	
	Info. Request	"No Effect"	Non-Jeopardy	Jeopardy	Resolved	Unresolved
Pipelines	4	3	11	-	-	-
Highways	8	17	5	1	-	1
T-lines	13	10	10	2	2	-
Railroads	1	-	1	-	-	-
TOTAL	26	30	27	3	2	1

In the remaining 30 cases, potential effects on T&E species were identified and formal consultation was initiated. Because ROW projects often extended over large geographic areas, many individual projects involved potential effects on more than one species or effects on one species in more than one location. A total of 67 ROW/T&E species interactions were reviewed in formal consultations (Table 2).

On 27 of the 30 projects which required formal consultations, potential T&E concerns were either minor (adverse impacts were insufficient to jeopardize the species) or were resolved thorugh project modifications agreed on during consultation. Biological opinions in these cases concluded that the ROW was not likely to jeopardize the continued existence of the T&E species. Three ROW projects involved T&E species conflicts which were not resolved in formal consultation and resulted in "jeopardy" rulings. Two of these cases were later resolved during further consultation. The remaining case is currently unresolved, pending development of additional alternatives. This case is unusual because the ROW itself does not jeopardize the species. The issues are related to increased development following improvement of a highway.

Table 2. Summary of species of concern in formal consultations on ROW projects in Region 6.

Species	CO	KS	MT	ND	NE	SD	UT	WY	Total
Bald eagle (*Haliaeetus leucocephalus*)	5		4	2	3	1	4	1	20
Black-footed ferret (*Mustela nigripes*)				1	1	1	3	7	13
Peregrine falcon (*Falco peregrinus anatum*)	4		2	2		1	2	1	12
Whooping crane (*Grus americana*)		1		1	2		1	1	6
Grizzly bear (*Ursus arctos horribilis*)			4						4
Gray wolf (*Canis lupus*)			2						2
Utah prairie dog (*Cynomys parvidens*)							2		2
Humpback chub (*Gila cypha*)	2								2
Colorado squawfish (*Ptychocheilus lucius*)	2						1		3
Bonytail chub (*Gila elegans*)	1								1
Clay phaceleis (*Phacelia argillacea*)							1		1
Uinta basin hookless cacus (*Sclerocactus glaucus*)							1		1
TOTAL	14	1	12	6	6	3	15	10	67

Table 3. Impact concerns and conservation measures recommended by FWS for ROW projects in Region 6.

Species/Impact Concern	Project Type[a]	Conservation Measures
Bald Eagle		
1. Physical removal of winter roost sites[b]	H,P,T	1a. Avoid roost areas. b. Limit extent of disturbance. c. Acquire and protect alternative habitat areas.
2. Disturbance of individual birds	H,P,T	2a. Time construction to avoid peak use periods. b. Maintain buffer zone between disturbance and use areas.
3. Electrocution hazard	T	3a. Design for raptor protection.
4. Collision hazard[b]	T	4a. Design towers to minimize hazard.
5. Increased exposure to shooting/ harassment	T	5a. Locate center line away from major human use areas including existing roads.
6. Damage to food supply due to oil spill.	P	6a. Develop plan for detection and clean-up.
Black-footed ferret		
1. Physical disturbance of ferrets	P,T,H,R	1a. Minimize disturbance of prairie dog colonies. b. Survey prairie dog colonies for presence of ferrets. c. Minimize construction in ferret habitat during periods when animals are immobile.
Peregrine falcon		
1. Disturbance of nesting birds[b]	P,T	1a. Maintain buffer zone between eyries and disturbance sites. b. Minimize disturbance during key nesting period.
2. Loss of hunting habitat	P	2a. Reduce extent of permanent disturbance.
3. Electrocution hazard[b]	T	3a. Design for raptor protection.
4. Collision hazard[b]	T	4a. Separate facilities from key hunting habitats.
5. Increased exposure to shooting/ harassment	T	5a. Locate t-line away from existing roads or other human use areas.
Whooping crane		
1. Collision hazard at river crossing[b]	T	1a. Avoid areas with high potential for use. b. Locate in areas avoided by cranes such as existing bridge crossing. c. Use corridor concept. d. Enhance conductor visibility.
2. Oil spill damage to habitat	P	3a. Monitor whooping crane use. Temporary work halt if adverse effect is possible.

Table 3. Continued.

Species/Impact Concern	Project Type[a]	Conservation Measures
Grizzly bear		
1. Habitat loss	H,T	1a. Limit extent through use of existing corridors.
2. Disturbance due to ROW access	H,T	2a. Limit access to ROW (gates, few access points).
		b. Total closure of ROW (logging road) during key periods.
3. Cumulative effect of secondary development following ROW construction	H	3a. Unresolved. Develop new alternatives.
Gray wolf		
1. Habitat loss	H,T	1a. Limit extent through use of existing corridors.
2. Disturbance due to ROW access		2a. Limit access (gates, few access points).
3. Cumulative effect of secondary development following ROW construction	H	3a. Unresolved. Develop new alternative.
Utah prairie dog		
1. Physical disturbance	T	1a. Limit disturbance in habit areas.
		b. Live trap and relocate animals in construction path.
T&E fishes		
1. Sediment increases during construction of river crossing	H,P	1a. Time construction to avoid spawning season.
2. Habit degradation due to erosion	P	2a. Revegetate disturbed area.
T&E plants		
1. Physical disturbance	T	1a. Survey potential habitat and avoid if species present.

[a]H - Road or Highway
P - Pipeline
T - Transmission Line
R - Railroad

[b]Concern was a factor in a jeopardy ruling.

The potential concerns expressed in the 30 Biological Opinions on ROW projects are summarized in Table 3. As was expected, the potential concern varied with the type of project, and the species in question. However, patterns emerged for several species which very likely represent the major areas of concern apt to arise in a ROW development.

For example, it is difficult for many long ROW projects to entirely avoid prairie dog towns in Region 6. Because black-footed ferrets are associated with prairie dog towns, there is a possibility that ferrets could be affected. Surface disturbance is comparatively small in most ROW projects, so the major concern is not habitat loss, but the actual disturbance of ferrets. In the majority of these cases, FWS requested that a search for ferrets or their sign be conducted to minimize the possibility of their disturbance.

As another example, bald eagles are relatively common winter residents in some portions of Region 6, especially where water courses or rivers remain open and adjacent stands of cottonwoods provide roost and perch sites. Potential concerns generally center on the physical loss of perch or roost sites and/or disturbance of eagles during construction, although electrocution and collision hazards may be issues with transmission lines. Serious conflicts in these areas can generally be avoided by providing an undisturbed buffer zone between habitat areas and the ROW, by adjusting the local construction period to avoid high use seasons, and by appropriate design of transmission tower structures.

Table 3 also summarizes the measures which were actually recommended by FWS to eliminate or reduce potentially adverse effects associated with ROW developments. The measures generally involved techniques which can be categorized as follows (Reyes-French and Shoemaker 1982): (1) Use of existing corridors where possible; (2) avoidance of key habitat features in route selection; (3) creation of undisturbed buffer zones around key habitat features; (4) adherence to timing constraints during key seasonal periods; (5) limits on ROW access after construction; and (6) design of special "control technologies" to mitigate specific impacts. None of these techniques for limiting impacts to T&E species differs substantively from those commonly employed in modern ROW planning and development.

CONCLUSIONS AND RECOMMENDATIONS

Certain facts and impression emerge from the review. Section 7 affects ROW projects by requiring consideration of T&E species issues in all phases of development, from planning through operation, but does not pose an impenetrable roadblock to new highways, pipelines, or transmission lines; 30 ROW projects were planned such that they would not affect T&E species in any way. ROW projects appear to have a high potential for encountering T&E species. However, ROW planning appears to be sufficiently flexible to avoid serious conflicts by incorporating relatively simple and minor modifications into project plans and specifications. Thirty ROW projects encountered T&E species concerns and required formal consultation. Only one remains unresolved.

Thus, if one looks only at outcome, the Section 7 process appears to function effectively with ROW projects in Region 6. Consultation, in its three major phases, is producing ROW development plans which do not jeopardize the continued existence of T&E species or adversely modify their critical habitats. This is the intent of Section 7.

However, it is useful to look beyond outcome to process. The Section 7 Consultation Process may not be functioning as efficiently as it could in resolving potential conflicts. The fact that 30 ROW projects required formal consultation indicates that many of the recommendations for limiting impact may have been developed relatively late in project planning. Yet many of the recommendations were straightforward and were applied in several instances. They could have been incorporated into proposed project plans at an early stage to assure that T&E species would not be adversely affected. Such an approach would offer twin benefits. It would reduce the number of formal consultations required. Also, development of T&E species management measures earlier in planning would provide greater flexibility for evaluating alternatives and more lead time for incorporating the measures into project design and schedule.

For example, formal consultation was completed 13 times for ROW projects crossing black-footed ferret habitat (prairie dog towns). Each time, a search for ferret sign was required as a means of limiting potential disturbances to ferrets. Prior commitment to such surveys could have eliminated the need for formal consultation. Publication of approved ferret survey procedures and requirements would offer project planners the opportunity to compare the costs of the survey to costs, for example, of an alternative alignment to avoid prairie dog towns.

Such an approach would require cooperation between FWS, federal agencies, and private ROW developers. In particular, it would require ROW project proponents to voluntarily commit to measures to prevent or reduce impact on T&E species. Similarly, it would require FWS and other federal agencies to develop and publish planning and/or management guidelines to facilitate early planning. The Section 7 Consultation Process needs to proceed toward two goals, protection of T&E species and facilitation of project planning. The increased emphasis on early planning suggested would enhance both goals (also see Reyes-French and Shoemaker 1982). In addition, it would help erase the notion that the protection of T&E species is incompatible with development projects.

ACKNOWLEDGMENTS

Wayne J. Wathen of the Office of Endangered Species, U.S. Fish and Wildlife Service, Denver, Colorado, provided access to the Section 7 files and office space during their review. Scott L. Ellis, Andrew C. Ludwig, and Lanny W. Reed of ERT also provided review comments on the draft.

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HIGHWAY ALIGNMENTS AND AN ENDANGERED SPECIES, AN ACTIVE PROCESS

John Rieger[1]

ABSTRACT.--In October, 1978, the vernal pool plant San Diego mesa mint (*Pogogyne abramsii*) was formally designated as an endangered species on the federal list of Endangered and Threatened Species. Two Interstate 15 highway projects planned by the California Department of Transportation in San Diego, California, were affected by this action.

Mitigations used to reduce impacts on the mesa mint included detailed biological resource mapping in the area of the proposed alignments, redesign of the alignments, modification of slopes, and minor changes in freeway construction procedures. Consultation review by U.S. Fish and Wildlife Service under the Endangered Species Act resulted in a *no jeopardy* decision with acquisition of replacement populations to mitigate those populations impacted by the highways.

Significant impact reductions were realized by close coordination between project engineer and biologist. This relationship prevented unnecessary project delays.

INTRODUCTION

The California Department of Transportation (CALTRANS), acting as the agent for the Federal Highway Administration (FHWA), is presently working toward the completion of the Interstate Highway System in the San Diego region. Interstate 15 (I-15) represents the inland corridor for north-south highway travel in western San Diego County. Within the City of San Diego, Interstate 15 crosses a series of broad mesas upon which vernal pools exist. Vernal pools are small, seasonal ponds found in association with mounded topography. These pools serve as habitat for a number of rare and endangered species. The pools vary in shape and size from 3 ft (1 m) to 66 ft (20 meters) in diameter. The mounds formed in association with the pools usually do not exceed 3 ft (1 m) in height.

Rapid residential and industrial development, continuing agricultural practices, off-road vehicle activity, and highway construction in the City of San Diego were reasons cited for listing one of the rare vernal pool plants, the San Diego Mesa Mint (*Pogogyne abramsii*), as endangered (under

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the Endangered Species Act of 1973) on September 28, 1978. This action by the U.S. Fish and Wildlife Service (USFWS) provided protection for the vernal pool habitat, since the Endangered Species Act itself provides ". . . means whereby ecosystems upon which endangered and . . . threatened species depend many be conserved."

In addition to the normal environmental clearances needed for the two I-15 projects, the listing of mesa mint required the FHWA to initiate a formal consultation with the USFWS as directed in Section 7 of the Endangered Species Act. Section 7 is that portion of the act which requires federal agencies to promote the goals of the act by coordinating with the USFWS on actions that will affect endangered species.

The consultations involved both projects on Interstate 15. The first project planned for construction was the I-15 Bypass. The second project, I-15 Extension, connects with the Bypass on the south and is planned for construction after the completion of the Bypass (Figure 1). Both projects occur entirely on Miramar Naval Air Station. This paper recounts the design, planning and actions undertaken by CALTRANS (acting as agents for the FHWA) to resolve the endangered species issue.

PROJECT ALIGNMENTS

I-15 Bypass

Methods. A biological survey of the proposed alignment indicated the presence of vernal pools. Since avoidance of impact is the first concern in the endangered species process, the Bypass alignment was surveyed to the east and west for vernal pools to determine if the proposed alignment was the least damaging route. Examination of potential alternatives indicated no reduction in vernal pool impact would occur by moving the original alignment. The capability to move eastward was limited by the northern terminus and the resulting curve radius limitations for highways. The alternative of improving the existing highway, which serves the same travel function, was not available because a Navy regulation required moving the alignment a given distance from the end of a Navy aircraft runway.

A biological assessment of the impacts to San Diego mesa mint and vernal pools that would result from construction of the proposed highway alignment was submitted to USFWS.

Results. The USFWS reviewed this biological assessment and handed down a no jeopardy decision provided that CALTRANS acquire "equivalent or greater value vernal pools," currently in private ownership, to be set aside as a public preserve.

This condition required an extensive survey of the privately owned vernal pools. Several acquisition proposals which would satisfy the 1.3 acre (.53 ha) pool area, needed to mitigate the project area, were examined. During this survey and evaluation process, FHWA and USFWS were continually consulted to ensure a prompt response to a final proposal for acquisition. On January 31, 1980, USFWS accepted a mitigation proposal for the project. Caltrans is currently proceeding with the acquisition of 26 acres (10.5

ha) of vernal pool habitat (consisting of 1.3 acres (.53 ha) of pool area and adjacent upland) to be managed by the California Department of Fish and Game as a preserve.

I-15 Extension

Methods. An initial biological survey determined the presence of several vernal pools occurring within the proposed right-of-way. Once again, the possibility of avoidance through redesign of the project was examined. Redesign efforts were aided by the topography present and by the availability of undeveloped land to the east and west of the original alignment. The vernal pools in the area of the Extension project are considered to be the highest quality vernal pool habitat in San Diego. This situation made it especially important to be innovative in the design of the highway in order to eliminate or reduce vernal pool impacts. The original alignment was essentially a straight route between two projects. The redesign changed this route into a drawn out "s" shaped alignment (Figure 1). This redesign significantly reduced vernal pool impacts by moving the road off of the mesas and into the canyons. This change avoided impacting the most pristine vernal pool habitat in the region.

Because this new alignment needed to gain elevation to connect with the previously approved Bypass project and to climb out of Murphy Canyon, several cuts of the canyon rim were necessary. This change in design necessitated detailed information in order to assess the impacts of the new cuts on vernal pools and San Diego mesa mint.

An engineering survey crew was sent out, along with staff biologists, to accurately map the locations of the pools occurring along the edge of the mesas. With this information, it was then possible to determine the exact nature of the vernal pool impacts and to examine in close coordination with the design engineer several specific design modifications that would eliminate or minimize vernal pool impacts. The most significant of these modifications was to increase the cut slope angle at the roadside from 2:1 to 1.5:1. This change was possible because the soil in this location is stable enough to maintain the steeper slope. Soils data obtained from a study of vernal pool hydrology indicated that this measure would not negatively affect the hydrologic characteristics of pools near the cuts. Three vernal pools were identified which would not be impacted if certain modifications to the design were made. It was possible to increase the slope near the top of the road cut at each specific pool location. This action would create small points of land which would be slightly steeper than the proposed 1.5:1 slope of the cut canyon wall. An additional vernal pool was too large to make such a design change feasible. The solution in this instance was to accept a partial impact to the pool and to create a dirt berm near the cut slope, thus preserving 90% of original area of this partially impacted pool. Previously collected data indicated that this would be a viable mitigation.

Results. The redesign and minor changes of the project did not eliminate all of the vernal pool impacts. However, impacts were reduced to less than one-tenth of the vernal pool area that would have been impacted by the first alignment and design. In the biological assessment of the Endangered Species Consultation with USFWS, CALTRANS (and FHWA) proposed to mitigate these remaining vernal pool impacts by acquiring a nearly equivalent area of privately owned vernal pools near the project site. The USFWS reviewed this assessment and, once again, (on October 19, 1981) issued a no jeopardy decision, contingent upon acquisition of the privately owned vernal pools.

Additional Design Mitigations

To prevent accidental destruction of vernal pools during the construction period of each of the two projects, a condition is included in the plans and specifications to have right-of-way fences constructed as the first order of work. By doing this it is possible to more effectively prevent accidental disturbance to pools in off-site areas by construction vehicles and activities.

Drainage systems from the highway are directed to major drainages in the region and not involved with the vernal pool drainage systems. This feature prevents potential off-site impacts to pools from highway runoff.

CONCLUSIONS

The projects discussed in this paper demonstrate some of the planning tools and mitigation options that are available within highway rights-of-way for the protection of isolated sensitive resources, such as vernal pools. Unlike utility rights-of-way, highways occupy a large portion of the purchased right-of-way. This severely restricts the use of on-site mitigation options for highway projects. Another undeniable fact of highway rights-of-way is that operation and safety considerations prevent use of much of the available undeveloped land within the right-of-way. Because of these facts, off-site mitigation of endangered biological resources is a very important option in highway design and construction.

Additionally, as these case studies indicate, there are frequently opportunities to reduce significant biological impacts through redesign and alteration of proposed highway alignments. The degree of impact reduction that ultimately results from such redesign and realignment efforts is contingent upon a variety of factors including (1) the innovativeness of the design engineer, (2) perception of the "worth" of certain biological resources and the engineer's acceptance of the validity of resource protection as a reason for redesign, and (3) the completeness of technical data supplied by the biologist.

In summary, the ultimate highway design and avoidance (or reduction) of biological impacts will depend upon close coordination between the design engineer and the biologist, and the commitment of each to the project. It is the primary responsibility of the biologist to provide the necessary technical information at an early stage in the planning process, so that the design of a project may proceed on schedule. Similarly, it is the project engineer's responsibility to provide sufficient time for the biologist to conduct necessary studies.

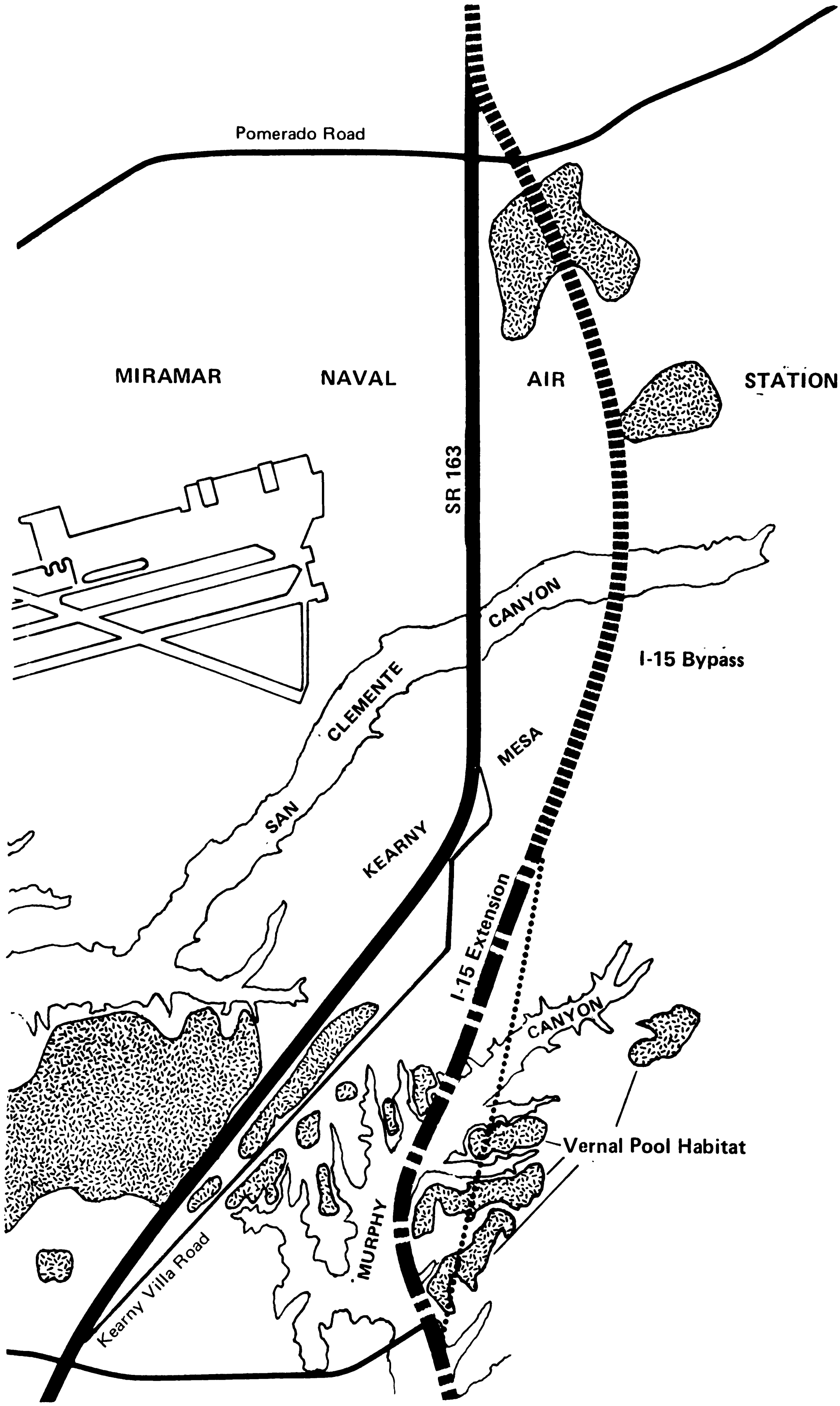

Figure 1. Interstate 15 project location map showing vernal pool habitat locations and the original I-15 Extension alignment (dotted line).

VEGETATION MANAGEMENT

Doug Smith, Session Chairman

REVEGETATION GUIDELINE DEVELOPMENT FOR PIPELINE RIGHTS-OF-WAY

Stephen G. Long[1] and Scott L. Ellis[1]

ABSTRACT.--This paper outlines the procedures that can be used to develop a revegetation guidelines manual from which revegetation techniques and seed mixtures can be selected for specific on-site conditions. A step-wise method of incorporating a literature review, ecological data, environmental and political constraints, and post-reclamation land use objectives into the revegetation planning process is presented. The importance of various types of environmental data and their relationships is shown. An example, drawn from the Northern Tier Pipeline guidelines, is presented showing how specific techniques can be selected from a set of guidelines given defined on-site conditions.

INTRODUCTION

A large crude oil pipeline constructed across several states affects a variety of landowners and environments in its path. One of the critical issues influencing pipeline construction approval by government agencies is a demonstration of how the pipeline right-of-way will be revegetated. The purpose of this paper is to describe how revegetation manuals were developed to provide guides to good revegetation practices along the proposed Northern Tier Pipeline (NTPC) that crosses the states of Washington, Idaho, Montana, North Dakota, and Minnesota (Figure 1).

A revegetation guideline manual serves several purposes during the permitting and implementation phases of a pipeline project. During the permitting stage, the manual provides a basis for discussion between regulatory agencies and the pipeline company concerning revegetation performance standards. During negotiations for right-of-way easements, the manual can again be used to define performance standards. During the construction phase, the manual is used to set specifications for revegetation contractors, and to guide on-site revegetation supervisors in their work. Finally, a revegetation guidelines manual defines monitoring procedures to determine whether successful right-of-way vegetation has been achieved.

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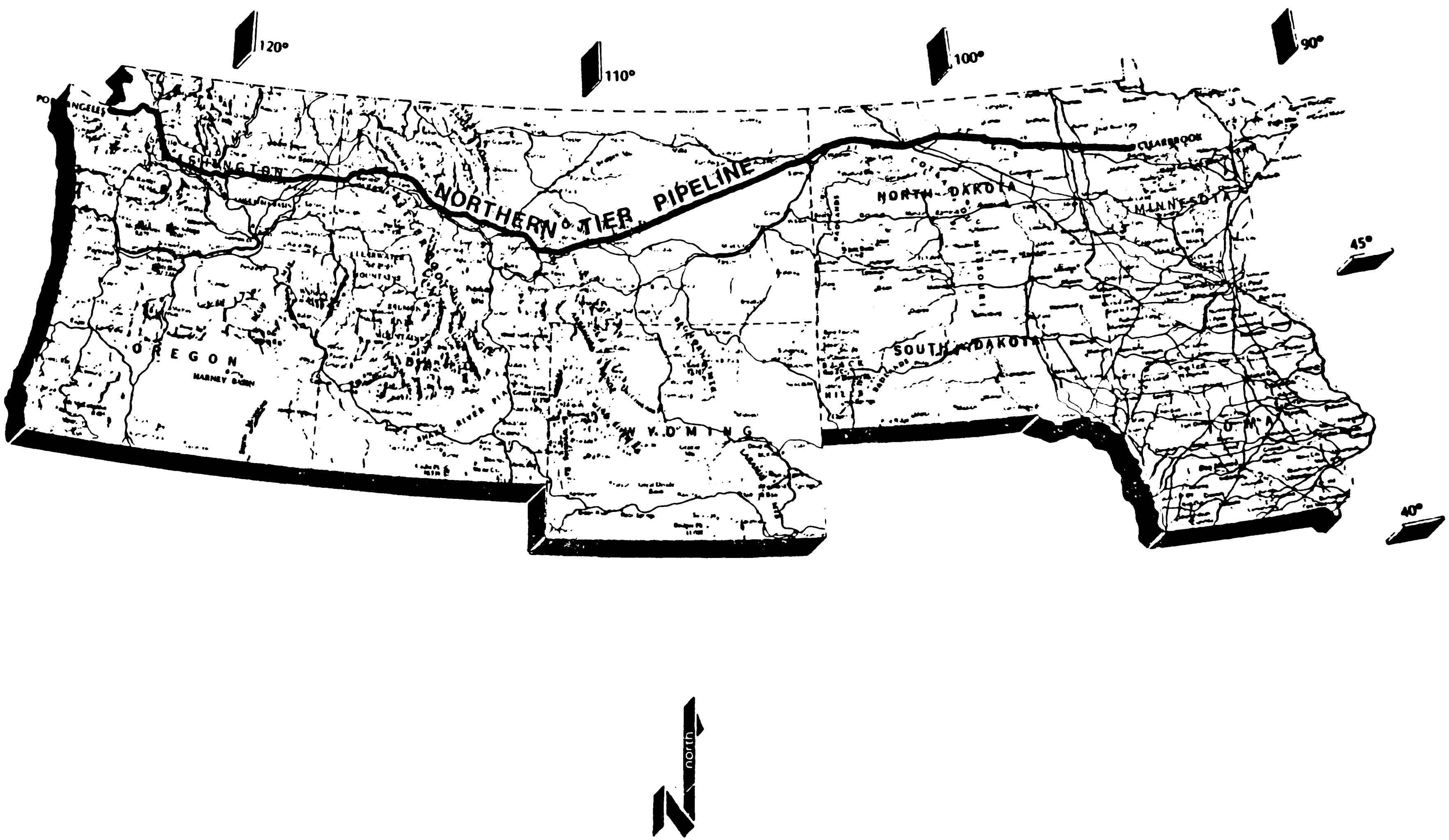

Figure 1. Map of the Entire Northern Tier Pipeline Route.

Considering the multiple uses expected of a revegetation manual, several major criteria define the content of the manual:

1. Credible. Local authorities and site-specific literature on appropriate revegetation practices must be consulted.

2. Comprehensive. Analysis of soil and climate factors must be sufficient to define a full range of site conditions that may be expected over a given segment of the pipeline. This analysis is derived from baseline data collected from the project studies.

3. Understandable. Environmental components (climate, soil, terrain topography) must be segmented into easily described units that can be recognized and analyzed by on-site revegetation specialists and interested landowners.

4. User oriented. The potential end use of revegetated areas must be considered at all locations on the pipeline.

Other factors that influence manual content are the level of specificity of techniques required and timing of manual preparation in relation to centerline survey and construction schedule.

Background

Since individual states differ in their pipeline revegetation requirements, regulatory concerns dictated that a revegetation manual be developed for each state. In addition, the ecological diversity within each state required a high degree of individual manual specificity to allow development of solutions to site-specific problems along the proposed route.

Analysis of construction techniques, revegetation goals and objectives, and possible future route alignment changes established the concept and form of the NPTC revegetation guidelines. Since the project was in the planning and permit acquisition stage, a revegetation manual could not be prepared which would cite specific techniques covering specific portions of the right-of-way. Too many factors, including final route alignment, were unknown. It was therefore determined that a "guideline" approach could be used to develop a revegetation manual which could be used in a flexible way to develop site-specific revegetation technique prescriptions. Such a manual could assimilate appropriate existing data, outline techniques for completing additional data requirements, point out potential revegetation problems on a county-wide basis, and present a body of applicable revegetation methods from which to choose. The NTPC representative in charge of right-of-way revegetation would then have a reference document suitable for selecting specific techniques backed by an identified body of literature if unanticipated conditions should arise.

METHODS

Data and Literature Acquisition

The first step in developing the guideline manual was to review existing data concerning pipeline construction techniques and requirements, environmental conditions along the proposed route, and suggested revegetation methods. An extensive amount of environmental data including soil type, erosion potential, and vegetation mappping information was collected for the State and Federal Environmental Impact Statements supporting this project. Analysis of these data identified possible constraints or opportunities for revegetation.

Following a general regional literature review, a more detailed literature review was conducted at the county or regional level. Emphasis on "in-state" literature provided an accurate picture of site-specific revegetation goals and methods. Topics evaluated during the literature review included soil material handling, seedbed preparation, seeding and transplanting concerns, and erosion, sedimentation, and pollution control. Post-reclamation management and monitoring methods were also analyzed.

County Office Field Visits

After the existing data were reviewed, we interviewed the District Conservationist (Soil Conservation Service) to obtain first-hand knowledge of revegetation constraints and opportunities. Soil chemical and physical characteristics were discussed in detail as were erosion potential and flooding. Other concerns such as slopes, high water tables, soil texture, and weed and insect problems were evaluated. Where possible, problem areas were sketched on a map of the propsed right-of-way provided for this purpose. The District Conservationist and his agency colleagues were also able to discuss the concerns of private landowners within their district relative to land use, vegetative species selection, revegetation goals, and weed control. Similar visits to Forest Service offices were conducted to compile this same informaton for federally-administered land along the proposed right-of-way.

Phase 2 resulted in a practical, field-oriented chapter for the Manual describing revegetation constraints in each county. Forewarned with this knowledge, the NTPC revegetation specialist can begin to plan the rudiments of a revegetation program far in advance of pipeline construction for each country through which the right-of-way passes.

Manual Preparation

A manual was then prepared which could be used to develop revegetation specifics for any point on the right-of-way, given site-specific soil data, construction specifics, and any pertinent land use information or constraints. With this information, the manual user could select methods for seedbed preparation, seeding, fertilization, mulching, chemical soil stabilization and weed control. The user could also select an appdrpriate cover crop or permanent seed mixture adapted to known site conditions. Should critical areas (sodic soils, steep slopes, stream crossings, etc.) be encountered, the manual user was provided with specifications for techniques to address each of these special situations. Specifications for establishing supplemental plantings for wildlife or aesthetic purposes were also included, as were vegegation monitoring and maintenance methodologies. Figure 2 depcits the process in which the manual was designed to be used to direct and implement a site-specific revegetation program.

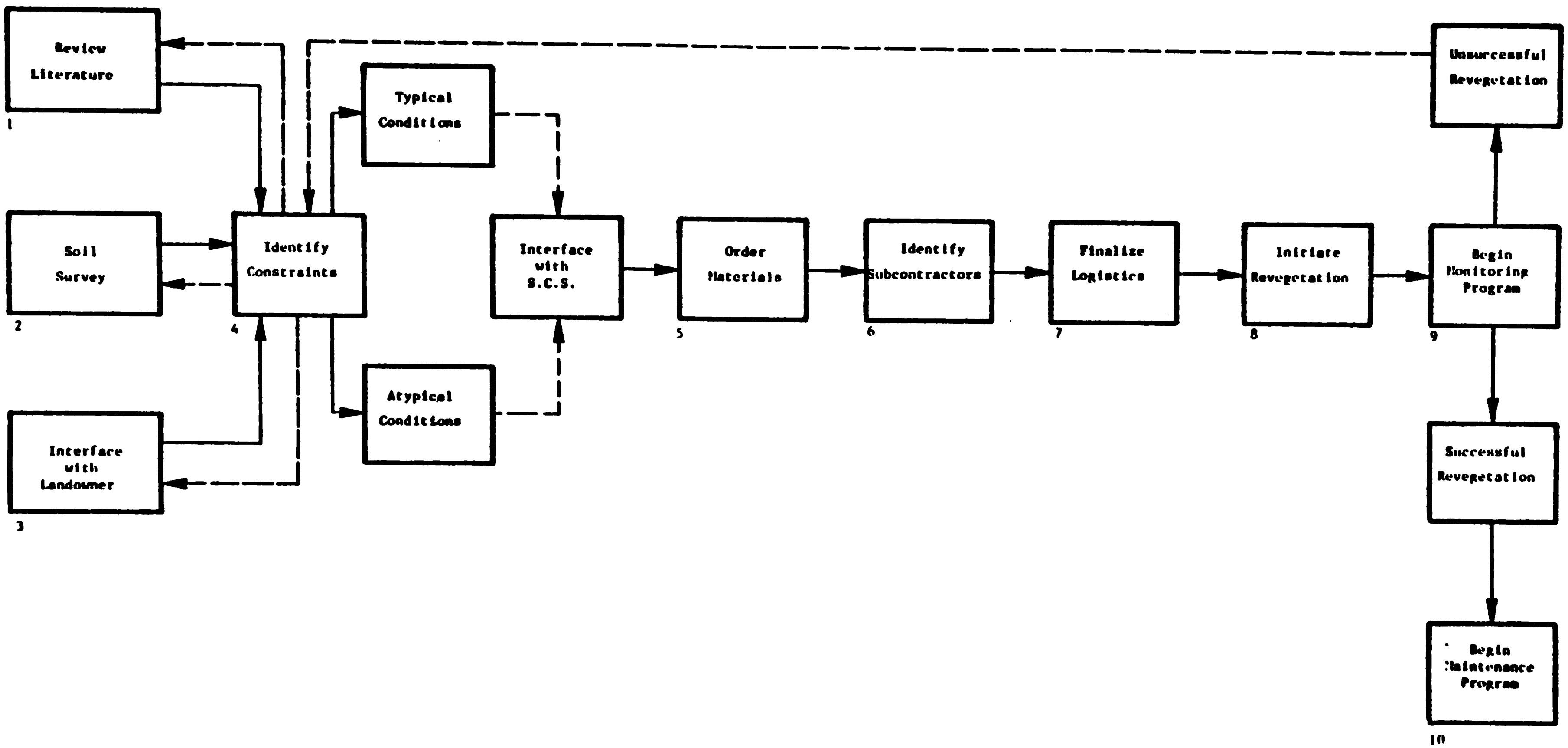

Figure 2. Flow Chart Illustrating Step by Step Procedures for Revegetation of the Northern Tier Pipeline System Right-of-Way in Washington.

RESULTS

The manual is organized according to the chronology of the revegetation process: (1) description of revegetation constraints by pipeline segment, (2) procedures for selecting appropriate revegetation techniques, (3) specifications for identified techniques, (4) revegetation monitoring, and (5) right-of-way management and maintenance.

Pipeline Right-of-Way Description

This section includes descriptive information on pipeline routing, natural communities, and land ownership for different segments of the pipeline. Much of this material is presented in map or table form, or can consist of references to specific baseline information developed elsewhere. This information may also be contained in appendices organized by pipeline segment in order to provide an easy reference for the revegetation specialist.

Revegetation Constraints

During the development of site-specific revegetation plans, this chapter identifies physical, chemical, and management constraints along the proposed route for each county through which the pipeline will pass to determine the potential need for special revegetation techniques. Typically, highlighted problems include soil texture extremes, excessively shallow soils, high coarse fragment content in soils, high soil salt or sodium levels or other problems related to soil chemistry, soil compacting, drainage limitations, flooding potential, high erosion potential (steep slopes, physical instability), noxious weeds, limitations and specifications imposed by landowners.

Soil Survey and Soil Analysis Guidelines

Although general soil mapping is often available for the pipeline right-of-way, a site-specific soil survey may be needed to define soil segregation specifications for certain segments of the line and to identify special soil problems at a more detailed level of resolution. This chapter defines the field procedures to be used in soil mapping and sampling based on those developed by the National Cooperative Soil Survey. The chapter also defines the soil parameters to be assessed during any required survey. Parameters directly affecting revegetation potential were stressed rather than those of a descriptive nature. Chapter contents include discussions concerning survey objectives, available soil information, field procedures and analysis, personnel qualifications, soil description guidelines, sampling overview, specific soil analysis and characterization methods, survey timing, and soil suitability guidelines (for revegetation). This chapter is supplemented with several appendices detailing the location and content of available soil information, classification of soils along the route, and detailed procedures for soil sampling, field description, and laboratory analysis.

Revegetation Procedures--Typical Conditions

Typical conditions are defined as those conditions where normal range seeding or agronomic activities can be practiced by virtue of amenable soil, topographic, and climatic factors.

Specific issues addressed for the various construction sites (right-of-way, temporary access roads and storage areas, waste disposal site) include short-term erosion control with cover crops, specifications for various methods of soil preparation and seeding, fertilization and mulching methods and requirements, and general specifications for weed control.

Revegetation Procedures--Sensitive or Atypical Conditions

This chapter defines specific revegetation techniques to be applied to problem areas, in addition to or in place of, the techniques described in Chapter 6. Each problem type is discussed separately in terms of the special techniques required to overcome site conditions. Special techniques may include variations in soil handling, seedbed preparation, fertilization, seed or planting mixtures and rates, mulching, etc. Technique specifications are detailed to permit an understanding of the time, effort, special materials, and machinery which could be required.

A sample of representative problem situations includes rocky soils; shallow soils; steep slopes; muck, arid, and muck-acid soils; saline, alkaline, and saline/alkaline soils; sand areas; and stream crossings.

Special seed mixtures for each of these conditions, if required, are included in Chapter 6 for each general soil type and precipitation zone.

Species Selection and Planting Dates

Species selection for different pipeline segments is determined by soil and climatic factors as well as the end use goals of revegetated areas. Information derived from the literature and field surveys is synthesized into seed mixtures that will meet the adaptability criteria for various site conditions encountered. Different mixtures are developed on the basis of soil texture (sandy, loamy, clayey) and/or land use and for atypical conditions as described in Chapter 5 for each precipitation zone along the proposed route. Lists of applicable species for wildlife enhancement, esthetics, and screening purposes (Chapter 7) are also listed by precipitation zone. A map showing the precipitation zones the pipeline will cross is included in this chapter (Figure 3) to compliment this information and to aid in species and mixture selection. The mixtures are designed to be used as cited or may be modified as conditions warrant based upon site conditions, land use objectives, and/or seed availability. Species varieties, where appropriate, are also noted.

A discussion of the characteristics of soils and atypical conditions along the proposed route is provided to aid in determining the appropriate seed mixture or species which would be adapted to site conditions. Information concerning seeding rate modifications, plant material origins, appropriate temporary cover crops, and time of seeding (by county) is also given to complete the seeding discussion.

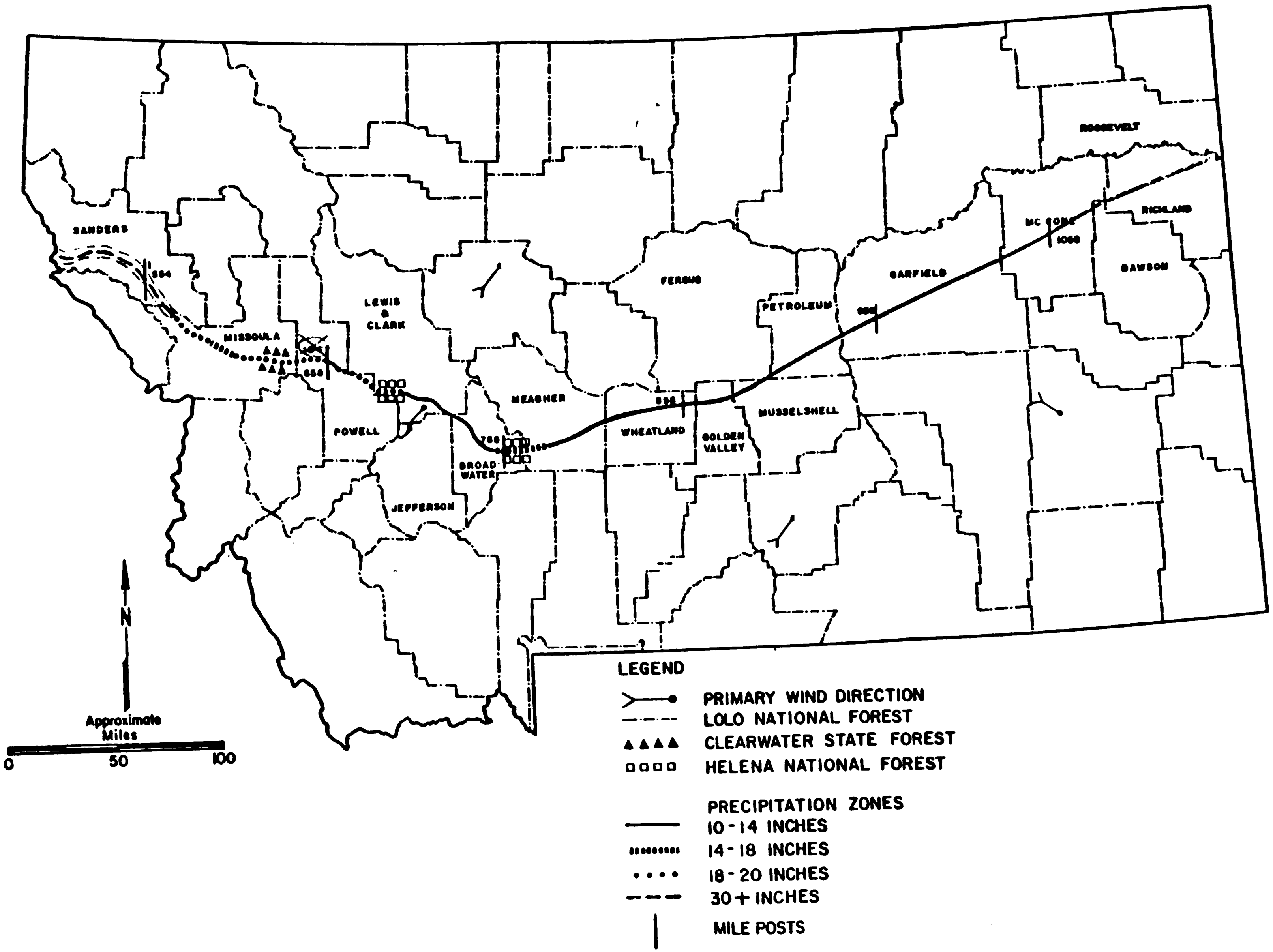

Figure 3. Major Precipitation Zones Along the Pipeline Route.

Supplemental Legume, Shrub, and Tree Planting

Specifications for plantings related to wildlife enhancement, aesthetics, and screening objectives are applicable only on specific portions of the right-of-way. The chapter provides specifications for supplementatl legume, shrub, and tree seeding, shrub and tree seedling planting, and transplanting wild or nursery grown tree stock. Detailed specifications for plant materials handling and seedling protection are also given.

Monitoring Revegetation Success

Methods used to measure revegetation success over the length of the pipeline include periodic aerial surveys to gain an overall perspective on revegetation success and ground surveys to quantitatively measure ground cover and to evaluate site-specific problems (e.g., erosion, weed invasions).

Right-of-Way Management and Maintenance

Maintenance in this context means the removal of undesirable plant species from the pipeline right-of-way. Undesirable species include those that interfere with routine inspection and maintenance of the pipeline, conflict with desired land uses for the right-of-way, and compete with desirable species.

Various control methods are described, including mechanical treatments, and application of herbicides. Herbicide formulations and recommended seasons of application are provided in this chapter. Selection of control methods depends on the types of vegetation to be controlled (woody or herbaceous), and local restrictions.

EXAMPLE OF MANUAL USE

To illustrate the capability of this type of manual, the NTPC Montana revegetation guideline is cited here to solve the following theoretical revegetation problem.

Assume the final pipeline route has been surveyed and construction will begin shortly. The revegetation specialist is in the process of developing revegetation prescriptions for western Meagher County, Montana. The problem at hand is the revegetation of a stream crossing area. The specialist is specifically concerned with the floodplain bordering the water course. Referring to Chapter 2 (Revegetation Constraints), the specialist finds that flooding can be a problem along the water course as well as moderate soil salinity and sodium levels. High rodent populations and noxious weed invasions are possible on the site. The specialist has also noted that the disturbed site should be planted with shrub seedlings due to screening and wildlife concerns.

Soil data collected and interpreted (in accordance with Chapter 3 specifications) by the soil scientist during final route alignment indicates that soils are of a medium texture (sandy loam-loam-silt loam), contain limited coarse fragments, are deep (60 inches), have a 7.5-8.0 pH, and have EC and SAR values of 6.0 and 10, respectively. The slopes are nearly level.

The precipitation zone map included in the manual shows the site to be in the 14 to 18 inch precipitation zone. With this information, the specialist prepares the revegetation prescription for these sites.

Reviewing the manual "Table of Contents," the specialist finds that revegetation techniques for stream-crossing sites are included in Chapter 5 (Revegetation Procedures-Sensitive or Atypical Conditions) thereby overriding the revegetation techniques described for non-critical areas in Chapter 4 (revegetation Procedures-Typical Conditions). The specialist therefore selects seedbed preparation, planting, fertilization and mulching techniques specifically recommended for non-riparian stream-crossing zones for field implementation. Since shrub seedlings will also be planted to fulfill screening and wildlife objectives, the specialist adopts the appropriate shrub planting procedures from Chapter 7 (Supplemental Legume, Shrub and Tree Plantings).

The specialist, having selected the appropriate plant establishment techniques, then turns to the revegetation species selection process. The specialist compares species selection criteria outlined in Chapter 6 (Species Selection and Planting Dates) with soil data from the future construction site. It is found that the site-specific soils falls into the category of "Non-Saline/Alkaline and Moderately Saline/Alkaline Soils." Considering this fact and the precipitation zone of the construction site, the specialist turns to the table "Species Lists and Seed Mixture for the 14-18 Inch Precipitation Zone" (Table 1) in Chapter 6. From this table, the mixture adapted to "non-saline/alkaline and moderately saline/alkaline soils-loamy textures" is selected. The mixture is accepted as is or is modified at the discretion of the specialist depending upon land use goals, seed availability, etc., with identified alternate species. The appropriate shrub species, given the stated site objectives, are chosen from another portion of this table for adaptability analysis and eventual selection. Following seed mixture selection, the preferred species varieties are selected from a separate table provided in Chapter 6.

To complete the revegetation prescription for these sites, the specialist identifies the appropriate Meagher County planting time based on the construction schedule. Vegetation monitoring (Chapter 8) and maintenance (Chapter 9) notations and suggestions are recorded for this site. The body of revegetation technique and seed mixture information is then put into prescription format and given to those responsible for field implementation.

RECOMMENDATIONS

A manual that describes revegetation procedures for a multi-state pipeline project provides a useful tool for the revegetation specialists during the permitting, construction, and maintenance phases.

The revegetation specialist must be able to develop revegetation specifications for a particular pipeline location based on clearly defined and comprehensive criteria. The NTPC manual relates field conditions to a broad array of revegetation recommendations. A specific set of appropriate revegetation techniques are then prescribed for the combination of site characteristics encountered.

Table 1. Non-riparian stream-crossing mixtures.

Drilling 11 pounds of pure live seed/acre is a standard practice for vegetating grassed waterways in Montana. This rate will be used for non-riparian crossing sites where grassed waterway techniques will be practiced. Species on site will aid in determining the components of the seed mixture. Yearly moisture availability will determine alternate species for seeding. The "Grassed Waterway or Outlet" guide listed in the references will be used for this purpose.

Non-Saline/Alkaline and Moderately Saline/Alkaline Soils		
Sandy	Loamy	Clayey
On-site evaluation will determine the proper seed mixture.	Western wheatgrass 3.60 (33%) Streambank wheatgrass 3.70 (33%) Smooth brome* 3.70 (34%) Total 11.00 Alternates: Pubescent wheatgrass (not for moderately saline/alkaline soils), beardless wildrye, creeping foxtail, intermediate wheatgrass	Same as for "Loamy"

Strongly Saline/Alkaline Soils

On-site determination of existing vegetation will determine seed mixtures in this case. The literature indicates that few species are well adapted to this type of planting. Possible species for use are given below in terms of a pure planting rate and will be adapted to mixtures (on a percentage basis) as site conditions indicate.

Beardless wildrye	4.00-6.00
Creeping foxtail	3.00
Inland saltgrass	3.00-4.00
Streambank wheatgrass	5.00-7.00
Tall wheatgrass	10.00-13.00
Western wheatgrass	6.00-8.00

*Smooth brome has a fair tolerance to moderately saline/alkaline soils. The amount of this species may need to be decreased in favor of other species under these conditions.

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VEGETATION RECOVERY OF A PIPELINE RIGHT-OF-WAY ON A TEXAS COASTAL BARRIER ISLAND

Gregory J. Odegard[1], James F. George[1], John A. Sproul, Jr.[1], and Ted M. Sawyer[1]

ABSTRACT.--A study was conducted during 1980 and 1981 to investigate the recovery of vegetation cleared in 1979 from a natural gas pipeline right-of-way (ROW) across Padre Island National Seashore on the Gulf Coast of Texas. Field data were collected to determine the overall effects and duration of pipeline construction-related impacts on dune and interior barrier island vegetation. Experimental study plots were used to sample vegetational cover on the right-of-way and adjacent undisturbed areas. In less than two growing seasons, the disturbed ROW has undergone rapid recovery in terms of vegetative cover, diversity, and species composition.

INTRODUCTION

With the increasing need for adequate sources of domestic natural gas and oil, increasing exploration and development activity is occurring offshore in the Gulf of Mexico. Currently, production of natural gas off the Texas and Louisiana shores totals more than 24% of the nation's gas production (4.8 trillion cubic feet in 1978). Interior Secretary James Watt has called for leasing one billion acres of offshore land for oil and natural gas exploration over the next five years. By contrast, only about 40 million offshore acres were made available for exploration by the Interior Department between 1953 and 1981. The proposed program calls for 14 lease sales in the Gulf of Mexico. With this activity comes concern regarding environmental impacts resulting from the construction of facilities to transport the new production to the mainland. Of particular concern to states like Texas will be the effects this construction will have on the coastal zone.

Research Studies

There have been few studies dealing with the environmental impacts of natural gas pipeline construction reported in the literature, and even fewer describing recovery of plant communities after construction. Vegetative recovery of pipeline ROWs has been evaluated in the Mojave Desert

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(Vasek et al. 1975, Lathrop and Archibald 1980). Pipeline and utility ROWs of various ages in several locations in the western United States have been examined (Odening et al. 1979). These studies concluded that recovery of vegetation in semi-arid regions is a lengthy process. However, this finding does not relate to more mesic environments. Odegard (1978) reported a study which evaluated the rates of recovery of species composition and biomass along a 36-inch-diameter pipeline buried in a salt water marsh and a fresh water wetland in southern Maryland. Aerial photography and sampling data indicated that vegetation was returning to the backfilled areas within one year following wetlands excavation. Odegard (1979) compared varying responses and recovery rates for pipeline ROWs in forest, agricultural, and estuarine ecosystems. While impacts on agricultural lands were found to be small and short in duration, impacts on forested areas were larger and of longer duration because the ROW was clearcut and cleared of large trees and shrubs for the life of the pipeline. Wetland impacts were intermediate, with several growing seasons required for complete revegetation. Farnworth (1979) investigated vegetative recovery in freshwater tidal marsh areas disturbed by the construction of two 30-inch diameter natural gas pipelines in the Savannah National Wildlife Refuge of Georgia. He found recovery of vegetative cover over the ROW almost complete at the end of one full growing season. Relative to the surrounding undisturbed marsh, the disturbed marsh had fewer plant species and lower diversity but a greater aboveground standing crop biomass. However, none of these studies directly relate to the vegetation types occurring along the Texas Gulf Coast.

Willingham et al. (1975) studied vegetation recovery on sand dunes crossed by a buried pipeline on Matagorda Island north of Corpus Christi, Texas. They found no significant difference in vegetation biomass, diversity, or species composition between the ROW and control areas after three to four years following construction. They also visually inspected other coastal dune areas crossed by pipelines, and found a general trend toward return of plant communities present on nearby controls. However, they cautioned that large primary dunes require more time to recover than do smaller dunes. Pipeline construction impacts on interior barrier island vegetation were not examined. Dahl et al. (1975) cautioned that active blowout dunes could occur on formerly stable dunes if the vegetative cover is weakened or destroyed.

It is obvious that more research is needed to determine vegetation recovery rates of pipeline ROWs crossing barrier island and onshore ecosystems to prepare for the impacts associated with increased development of offshore oil and gas reserves.

Study Area

Padre Island is a long, narrow barrier island located in the Gulf of Mexico along the southern coast of Texas, extending from Corpus Christi Bay on the north to near the mouth of the Rio Grande. The northern two-thirds of the 110-mile-long island, known as North Padre Island, is separated from South Padre Island by the Port Mansfield Channel. Much of Padre Island was acquired by the National Park Service in 1963, as Padre Island National Seashore. The study area is located on North Padre Island, within the National Seashore, approximately three miles south of the Malaquite Beach Recreation Area.

Table 4. Dominant species by plot and sample date.[a,b]

Plot	Sample Date: April 1980	Sample Date: May 1981
900 feet		
Control	Cyes, Leco, Pase	Leco, Pase, Cafa
ROW	Paam	Paam, Cyes, Crpu
1500 feet		
Control	Elmo, Bamo, Angl	Elmo, Scam, Cafa
ROW	Scam, Bamo, Oedr	Elmo, Bamo, Scam
3050 feet		
Control	Elmo, Anvi, Jusc	Anvi, Elmo, Papo
ROW	Oedr, Elmo, Scam	Elmo, Oedr, Bale
5000 feet		
Control	Pamo, Scam, Elmo	Scam, Pamo, Elmo
ROW	Scam, Pamo, Plvi	Elmo, Scam, Coba

[a]Species listed in decreasing magnitude of importance values.

[b]Key to species symbols presented below.

Key to Species Symbols

*Angl *Andropogon glomeratus*
*Anvi *A. virginicus*
*Bale *Baptisia leucophaea*
*Bamo *Bacopa monnieri* (L.) Wettst.
*Cafa *Cassia fasciculata*
*Coba *Coreopsis basilis* (Otto. & Dietr.) Blake
*Crpu *Croton punctatus* Jacq.
*Cyes *Cyperus esculentus* L.
*Elmo *Eleocharis montevidensis*
*Jusc *Juncus scirpoides* Lam.
*Leco *Leptoloma cognatum* (Schult.) Chase
*Oedr *Oenothera drummondii*
*Paam *Panicum amarum*
*Papo *P. portoricense* Desv. *ex* Hamilt.
*Pamo *Paspalum monostachyum*
*Pase *P. setaceum* Michx.
*Plvi *Plantago virginica* L.
*Scam *Scirpus americanus*

CONCLUSIONS

Data derived from this study indicate that vegetative cover, species composition, and diversity of the ROW disturbed during pipeline construction are trending toward equilibrium with the associated undisturbed control area adjacent to the ROW. Species similarity data indicate disturbed areas are becoming reestablished with the distinct vegetative composition that existed prior to construction. A salient feature of the vegetative recovery has been the rapid response shown by the vegetation over a period of less than two growing seasons. Visual evaluation confirmed that the impacts of Hurricane Allen on the vegetation and topography of the study area were equally borne by the ROW and adjacent undistrubed areas.

The climate of Padre Island is subtropical and semi-arid with mild winters and hot, humid summers. The climate is intermediate between the humid, subtropical coastal area to the northeast, and the semi-arid area to the west and southwest. Annual precipitation averages approximately 28 inches at nearby Corpus Christi, with peaks in April through June and August through October (U.S. Dept. of Commerce 1970). Soils of Padre Island developed on recent marine and eolian sands, and consist of mostly fine to very fine sands. Coastal dunes consist of fine sands washed from the Gulf and shifted by the wind. Leeward of the coastal dunes are Mustang and Galveston soils which are found at elevations of less than five feet above mean sea level and higher, respectively. Galveston soil has a loose sand surface layer underlaid by light grey find sand; lower levels remain most of the time. The Mustang soil series consists of nearly level, deep, sandy soils that are wet and frequently salty. They occupy low areas, are occasionally flooded at high tide, and may be marshy. The surface layer ranges from light brownish gray to white (Franki et al. 1965).

Judd et al. (1977) reported that the vegetation of Padre Island occurs in distinct zones which correspond closely with topographic features; vegetation is dominated by herbaceous species in contrast to barrier islands on the east coast of the United States. Six major terrestrial topographic zones for Padre Island between the Gulf and Laguna Madre to the west were denoted by Dahl et al. (1975). These were vegetated backbeach, foredune complex, old deflation plain, young deflation plain, active dune field, and wind-tide flats. The two deflation plain zones are often combined into a single grouping known as mid-island flats. The topographic features and associated vegetative communities of concern to this study are the foredune complex and mid-island flats.

Characteristic native vegetation of the foredune complex consists of the grasses: sea oats (Uniola paniculata), saltmeadow cordgrass (Spartina patens), and gulfdune paspalum (Paspalum monostachyum); and the forbs, goatfoot morning glory or railroad vine (Ipomoea pes-caprae), and beach eveningprimrose (Oenothera drummondii); bitter panicum (Panicum amarum) may be present (Dahl and Goen 1977). Common native vegetation expected to be found on the mid-island flats, while varying with topography, includes bushy bluestem (Andropogon glomeratus), seashore dropseed (Sporobolus virginicus), gulfdune paspalum, saltmeadow cordgrass, broomsedge bluestem (Andropogon virginicus), and several species of sedges such as Scirpus americanus and various species of Cyperus. Common forbs are beach eveningprimrose, whitestem wild indigo (Baptisia leucophaea), and prairie senna (Cassia fasciculata) (Dahl et al. 1975).

The study site consisted of a 100-foot-wide ROW extending from the edge of the Gulf of Mexico to existing facilities located approximately 6300 feet inland. Construction along the ROW occurred from August-September 1979. The grading, trenching, and leveling activities effectively removed existing vegetation the full length and width of the ROW. A minimum of three feet of natural soil cover was replaced over the pipeline. The foredunes were breached for pipeline construction and rebuilt. Revegetation of the reconstructed foredunes, conducted in March 1980, consisted of applying a fiberglass matting; fertilizing with 120 pounds nitrogen, 60 pounds phosphorus and 180 pounds potassium per acre; and sprigging bitter panicum culms at 2-foot intervals. Due to a severe drought occurring in the area at that time, irrigation water was trucked in and applied as a spray. A fence was erected to control vehicular and pedestrian traffic. The National Park Service supervised all reclamation work. The remainder of the ROW inland from the foredunes was left to revegetate naturally.

METHODS

To test the hypothesis that ROW vegetation would approximate preconstruction conditions as exemplified by adjacent, undisturbed control areas, study plots were positioned in the ROW following construction and in adjacent, undisturbed vegetation. Four study plots were established along the length of the ROW, each randomly placed in a distinct topographic-vegetative area exhibiting a specific vegetative type. Locations were (1) leeward foredune, 900 feet (274 m) inland from water's edge on the Gulf at mean sea level; (2) bushy bluestem flat, 1500 feet (457 m); (3) broomsedge bluestem flat, 3050 feet (930 m); and (4) sedge flat, 5000 feet (1524 m).

At each of the four study plots along the ROW, a permanent 164 feet (50 m) transect was established within the ROW (ROW transect), and an associated transect was located in undisturbed vegetation on the ROW's on the north side (Control transect). Control transects began 16.4 ft (5 m) north of the northern edge of the disturbed ROW and extended 164 ft (50 m) due north. The ROW transect on the foredune complex began 16.4 ft (5 m) south of the northern edge of the ROW and extended due south across the ROW for 164 ft (50 m). Due to presence of an access road within the ROW on the mid-island flats, the remaining ROW transects each had to be divided into two 82 ft (25 m) sub-transects. On sample dates, 10 random points were selected along each 164 ft (50 m) transect; a 8 in X 20 in (20 X 50 cm) Daubenmire quadrat was placed at each random point. The percentage of aerial cover and number of plants of each species encountered were recorded.

Sample dates were April, July, and October 1980, and May 1981. However, for purposes of comparison between ROW and Control plots, data are presented for the first and last sample dates only.

Statistical analyses and tests conducted with the data included analysis of variance for unbalanced data using multiple regression techniques, Duncan's multiple range test for testing groups of means, and the t-test for comparing Control and ROW transect means. Species nomenclature is that of Gould (1969) and Jones (1977).

RESULT AND DISCUSSION

The similarity in vegetative cover between paired Control and ROW transects increased between April 1980 and May 1981 (Table 1). Vegetative cover for ROW transects generally increased over time, with cover on Control transects either fluctuating or remaining constant. The effects of Hurricane Allen, which occurred in August 1980, are reflected in data collected on the Control transect for the 1500-foot plot in May 1981.

Table 1. Percent vegetative cover for paired ROW and Control transects on two sample dates.

Plot	Date: April 1980	May 1981
900 feet		
Control	16.8	39.7
ROW	4.2	16.8
1500 feet		
Control	91.0	17.8*
ROW	13.2	9.0*
3050 feet		
Control	60.5	62.4
ROW	11.9	36.8
5000 feet		
Control	47.2	21.8
ROW	0.8	14.2

*Inundated by Hurricane Allen in August 1980.

In April 1980, vegetative cover differed significantly ($P<0.05$) between Control and ROW transects for all sample plots; in May 1981, only two of the four plots displayed significant differences (Table 2). For all plots, probabilities of a real difference between Control and ROW transects decreased (P levels sharply increased) between April 1980 and May 1981, indicating a trend toward increased similarity of cover.

Table 2. Results of t-tests for vegetative cover between Control and ROW transects at two sample dates.

Plot	Probability of larger t — Date: April 1980	May 1981
900 feet	0.0009	0.0096
1500 feet	0.0001	0.0049
3050 feet	0.0001	0.0823
5000 feet	0.0002	0.2335

While the cover data indicate a trend toward recovery of the disturbed ROW, another goal for vegetative recovery of such disturbed areas is reestablishment of the composition that existed prior to disturbance. To ascertain the recovery rate of the disturbed ROW species composition toward the goal of equivalency with associated undisturbed Control areas, Jaccard's similarity index (Greig-Smith 1964) was calculated for both transects comprising each plot for each sample date. The results show that the percent similarity of vegetation, interpreted as the number of species in common between Control and ROW transects, increased noticeably between April 1980 and May 1981 (Table 3).

Table 3. Jaccard's percent vegetative similarity index between ROW and Control transects.*.

Plot	Date	
	April 1980	May 1981
900 feet	9.1	23.1
1500 feet	17.6	20.8
3050 feet	35.3	42.9
5000 feet	15.4	42.9

*Number of species in common, expressed as a percentage of total number of species, ranging from 0 (totally dissimilar) to 100 (identical).

Increased diversity of vegetative communities is often associated with community stability and successional progression (Whittaker 1975). The Shannon-Wiener index of diversity was calculated using importance values, computed by summing relative frequency, relative density, and relative dominance (Whittaker 1975). Averaged over all Control transects, this index of diversity was 1.93 in April 1980 and 1.79 in May 1981; for all ROW transects it was 1.16 in April 1980, and 1.68 in May 1981. The number of species found on ROW transects increased from 16 species in April 1980 to 26 species in May 1981, while the total number of species encountered remained relatively constant (34 species in April 1980 and 37 species in May 1981).

Table 4 summarizes the dominant species present at each plot on both sample dates. These data support the diversity and similarity data which indicate that the disturbed ROW is reestablishing the species composition that existed prior to disturbance.

On August 9, 1980, Hurricane Allen, the second strongest tropical storm of this century, swept the Texas Gulf Coast, and struck Padre Island in the immediate vicinity of the study area. The hurricane completely removed the windward portion of the foredune, including a study plot established earlier. Windward foredunes along much of Padre Island were impacted to various degrees. Impacts to the dunes on the ROW were indistinguishable from impacts to adjacent dunes. The hurricane differentially impacted vegetation in the study area. Vegetation on leeward foredunes and on the 5000-foot plot (farthest from the Gulf) was not adversely impacted by the hurricane. However, the 1500-foot plot immediately inland on the foredunes was drastically impacted, probably due to infusion of salt water from storm surges. The storm changed the percent cover and species composition of the 1500-foot plot by removing the codominant bushy bluestem from the species complement. Although bushy bluestem was not evident on the May 1981 sample date, codominants such as Eleocharis montevidensis and Scirpus americanus both reasserted their dominance by the May 1981 sample date.

The comparison of Control and ROW data between the April 1980 and May 1981 sample dates (Tables 1 through 4) indicates a clear trend toward vegeta tive recovery during approximately one and one-half growing seasons since disturbance, and demonstrates the ability of this ecosystem to recover rapidly from disturbance resulting from pipeline construction.

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REVEGETATION ALONG PIPELINE RIGHTS-OF-WAY IN ALASKA

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ABSTRACT.--The Trans-Alaska Pipeline System for transporting crude oil from Prudhoe Bay to Valdez has recently been completed. The Alaskan Natural Gas Transportation System for transporting gas from Prudhoe Bay to the "Lower 48" is under construction. The rights-of-way of both these major pipelines traverse the arctic and subarctic climatic zones, where severe environmental conditions require specialized measures for revegetating disturbed terrain. On the oil pipeline right-of-way an aggressive grass seeding and fertilizing program was used for revegetation, while on the natural gas pipeline natural reinvasion will be encouraged. These different approaches reflect different management goals and changing technologies as revegetation research progresses in the far north. This paper presents some of the implications of these methods for long-term restoration of disturbed terrestrial areas.

INTRODUCTION

Until the 1970s there was very little artificial revegetation activity in Alaska. Terrestrial disturbances caused by man were small and localized, since development was quite limited. Roadsides accounted for most of the disturbed areas that were revegetated, and the techniques used generally mimicked those in use in the temperate U.S. However, the authorization of the Trans-Alaska Pipeline System (TAPS) and its completion in the summer of 1976 rapidly changed this situation. The size of this project (800 mi or 1280 km long) and the political climate of heightened environmental awareness and stringent regulations made revegetation in the Arctic and the Subarctic a subject of active research and a focus of concern for regulatory agencies. Later, the issuance of the permit for the right-of-way for the proposed Alaskan Natural Gas Transportation System (ANGTS) in December 1980 ensured a continuing emphasis upon the development of northern revegetation techniques. This paper summarizes the methods used along TAPS and compares them with the methods being proposed for the Alaskan segment of ANGTS.

The TAPS and ANGTS projects encounter a wide range of environmental conditions, many of which are not encountered elsewhere in the United States

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(Johnson and Van Cleve 1976). Therefore, the revegetation strategies developed for them must be suitable for both arctic and subarctic conditions.

Low temperature is undoubtedly the single environmental factor most frequently cited as limiting for plant growth in these regions. Low temperatures are most likely to limit plant growth in the northernmost portions of Alaska. Native plant species have both physiological and morphological adaptations which at least partially compensate for low soil and aboveground temperatures (Chapin et al., 1979), while introduced species are frequently adversely affected (McCown 1973). The distribution of permafrost or permanently frozen ground (Fig. 1) limits the depth of the rooting zone and hence the volume of soil from which roots can absorb nutrients. Low soil temperatures also retard decomposition so that nutrient cycling is impeded, thereby further limiting plant nutrient uptake, especially in permafrost areas.

The shortness of the arctic and subarctic growing seasons is partially offset by the long summer photoperiod in the high latitudes. However, in these extreme photoperiods most introduced plant species find it difficult to adapt to new environmental cues in order to initiate such activities as flowering and winter hardiness at the appropriate times. The photoperiod differences, coupled with extreme winter conditions and sporadic midsummer freezes, decrease the chances of finding introduced plant species which will readily adapt to the Arctic, and to a lesser extent the Subarctic.

Arctic and subarctic plants have adapted to these environmental conditions by such features as high root-to-shoot ratios to facilitate nutrient uptake, extreme winter hardiness, prostrate growth forms to avoid snow abrasion in alpine and arctic areas, and reduced reliance upon sexual reproduction (Saville, 1972; Bliss, 1979). Such features maximize changes for long-term survival, but they also have important repercussions for revegetation. For example, low growth forms are easily overtopped by faster growing introduced species, while low seed production may impede the commercial development of some native species for revegetation.

Finally, several facets of the cultural situation in Alaska affect revegetation. Much of Alaska is entirely undeveloped, and there are numerous areas of high scenic value. The highway completed in order to construct TAPS (Fig. 1) was almost entirely within wilderness territory and was the first through road to reach the Arctic Ocean in North America (Brown and Berg, 1980). Consequently, the large areal extent of wilderness and scenic areas necessitates much more of an emphasis upon maintaining aesthetic wilderness values than elsewhere in the United States.

TRANS-ALASKA (OIL) PIPELINE SYSTEM

The Trans-Alaska Pipeline Sytem (TAPS) disturbed more than 193,000 ac (78,000 ha) of land (Pamplin 1979). Most of this area was actively revegetated by the pipeline contractor in order to comply with environmental regulations. The primary goal of revegetation was erosion control (Lucas 1975). After extensive testing of commercially available grass species, seed mixes were developed for use along the right-of-way. These

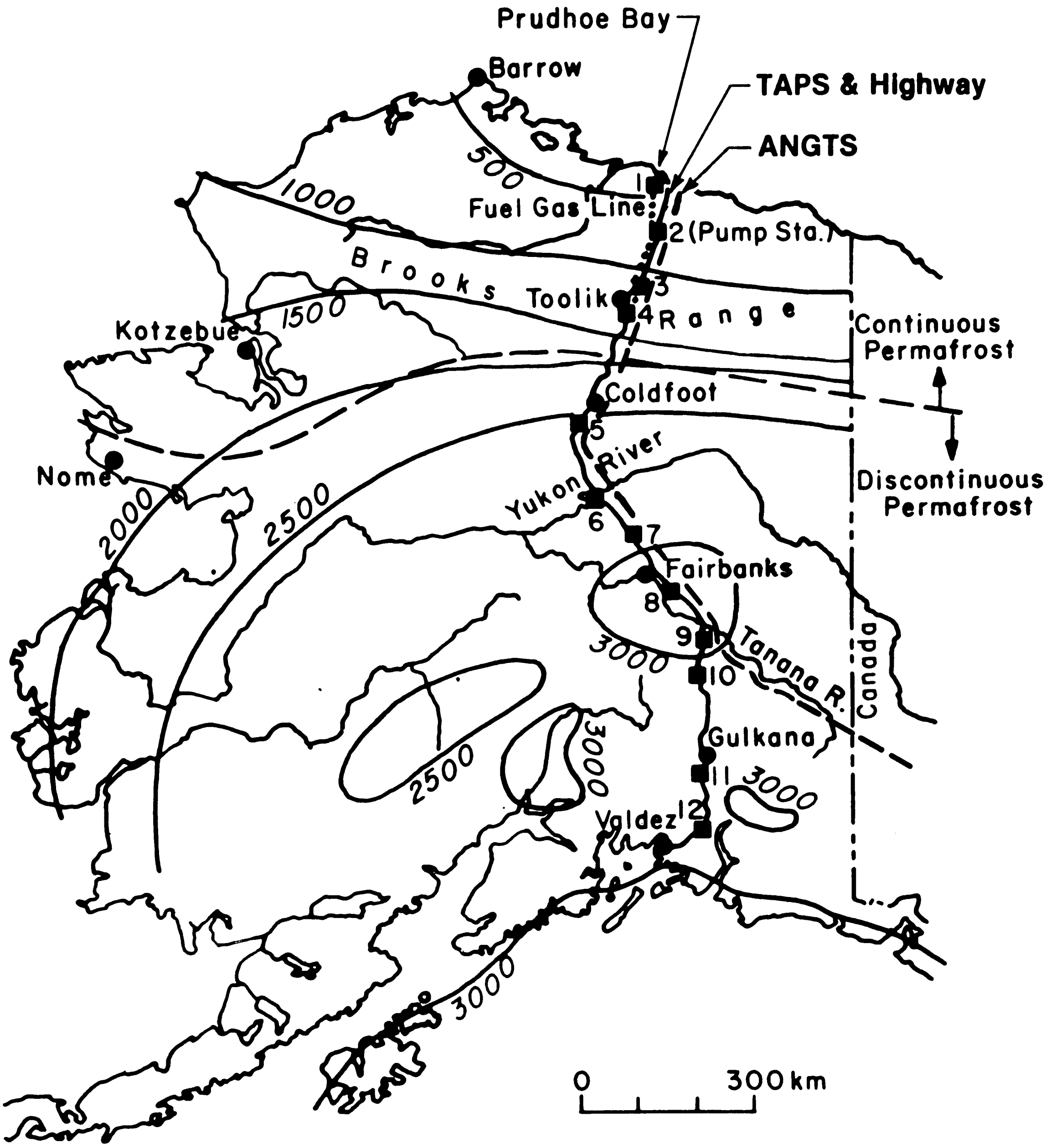

Figure 1. Map of Alaska showing TAPS and ANGTS routes, including pump stations, the boundary between the continuous and discontinuous permafrost zones, and isotherms of degree-days above freezing (degree-days from Hartman and Johnson 1978).

Table 1. Revised 1977 seed mixes (kg/ha) used along TAPS (Lucas 1975, Hubbard 1980). Numbers in parentheses are the amounts used in the original 1975 mix.

	Seed mix 1 North Slope: Sect. 6 (Toolik to Prudhoe Bay)	Seed mix 2 Brooks Range: Sect. 5 (Coldfoot to Toolik)	Seed mix 3 Int.: Sect. 1,3,4 (Coldfoot to Valdez except Alpine)	Seed mix 4 Alpine: Sect. 2 (Gulkana to Tanana R.)
Arctared fescue (*Festuca rubra*)	12.3 (16.5)	4.5 (16.5)		4.5 (11.1)
Nugget bluegrass (*Poa pratensis*)	12.3 (11.1)	10.1 (11.1)	5.6 (0)	
Redtop (*Agrostis alba*)	1.5 (5.5)	3.4 (5.5)		
Boreal red fescue (*Festuca rubra*)	10.1 (5.5)	10.1 (5.5)	101.6 (4.4)	5.6 (4.4)
Durar hard sheep fescue (*Festuca ovina var. duriuscala L.*)		10.1 (0)	(4.4)	
Climax timothy (*Phleum pratense*)		4.5 (5.5)	2.2 (0)	
Meadow foxtail (*Alopecurus pratensis*)		11.2 (5.5)	6.7 (13.2)	12.3 (11.1)
Sydsport bluegrass (*Poa pratensis*)			(3.3)	14.6 (5.5)
Manchar brome (*Bromus inermis*)			10.1 (5.5)	2.2 (0)
Annual rye (*Lolium multiflorum*)	14.6 (16.5)	13.4 (16.5)	7.8 (11.1)	7.8 (11.1)
Tall arcticgrass (*Arctagrostis latifolia*)	1.1 (0)			
Total	51.5 (55.1)	67.3 (66.1)	43.6 (41.9)	47.0 (42.2)
Seeds/m^2	5600 (7500)	7700 (8600)	3100 (2600)	5200 (3400)

seed mixes relied upon a limited number of commercial grass species which had demonstrated during the screening process that they were well adapted to the severe arctic and subarctic conditions. The four mixes were to be used in the following main geographic zones: (1) North Slope, (2) Brooks Range (Fig. 2), (3) Interior (Fig. 3), and (4) Alpine (Table 1). Also, fertilizer mixes were developed (Table 2) on the basis of extensive soil testing and some field evaluation. The relatively high seeding rates (2600-8600 seeds per m) and the moderate to high fertilizer levels were developed with erosion control in mind. The higher fertilizer and seeding rates were used on the Arctic Coastal Plain or North Slope between Prudhoe Bay and the Brooks Range and in the alpine tundra through the Brooks Range (Fig. 1).

Table 2. Fertilizer composition and application rates along the trans-Alaska pipeline (Lucas 1975).

Nutrient Elements	Mixture		
(%)	III[a]	IV[a]	V[a]
N	14.1	13.1	10.9
P_2O_5	7.1	14.6	15.1
K_2O	21.3	17.5	14.5
S	5.0	1.3	5.2
Mg	4.2	4.4	3.6
Cu	0.49	0.36	0.36
Zn	0.57	0.58	0.48
B	0.14	0.14	0.12
Mo	0.0255	0.0262	0.0218
Application rate (kg/ha)	660	660	715

[a]Employed on areas corresponding to the following alignment sheets: III - Coastal and interior; IV - Alpine interior; V - Brooks Range and North Slope.

The seed mixes used along TAPS in 1975 and 1976 utilized commercially available, introduced grass species exclusively. After 1976 a small amount of a native grass, tall arcticgrass (Arctagrostis latifolia), was added to the northernmost mix. But difficulties in producing seed and the long lead times required precluded the more extensive use of other native plant seeds in the mixes. The rapidly growing annual ryegrass (Lolium multiflorum) in the seed mix provided a very rapid temporary vegetative cover for at least one year and sometimes for two or more years (Johnson 1981). Finally, areas were reseeded and/or refertilized as needed to achieve acceptable levels of vegetative cover.

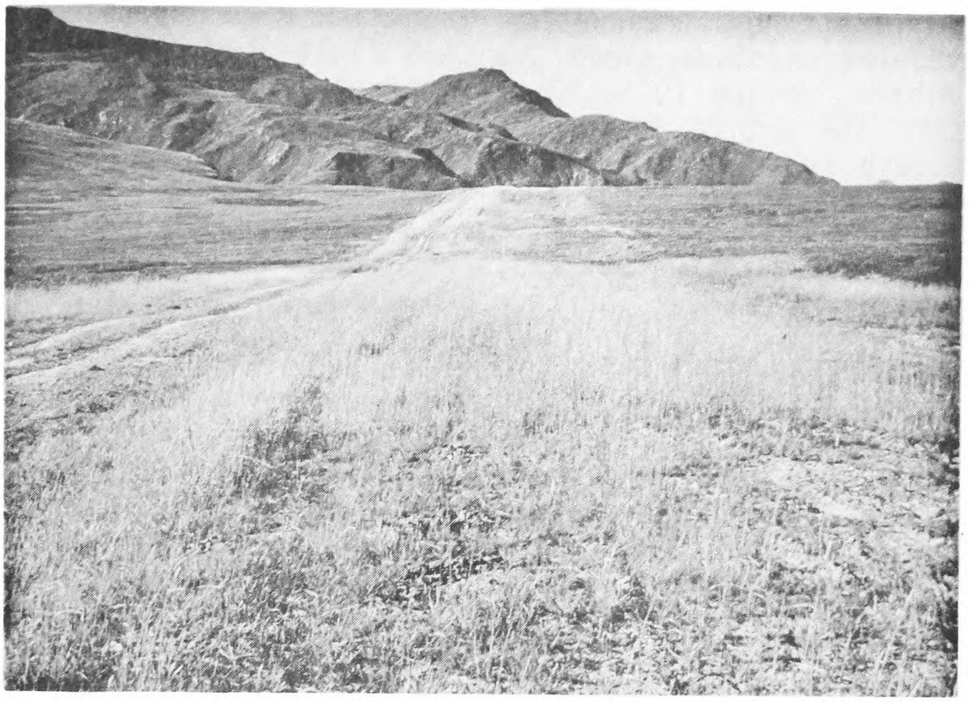

Figure 2. Buried oil pipeline right-of-way through Brooks Range.

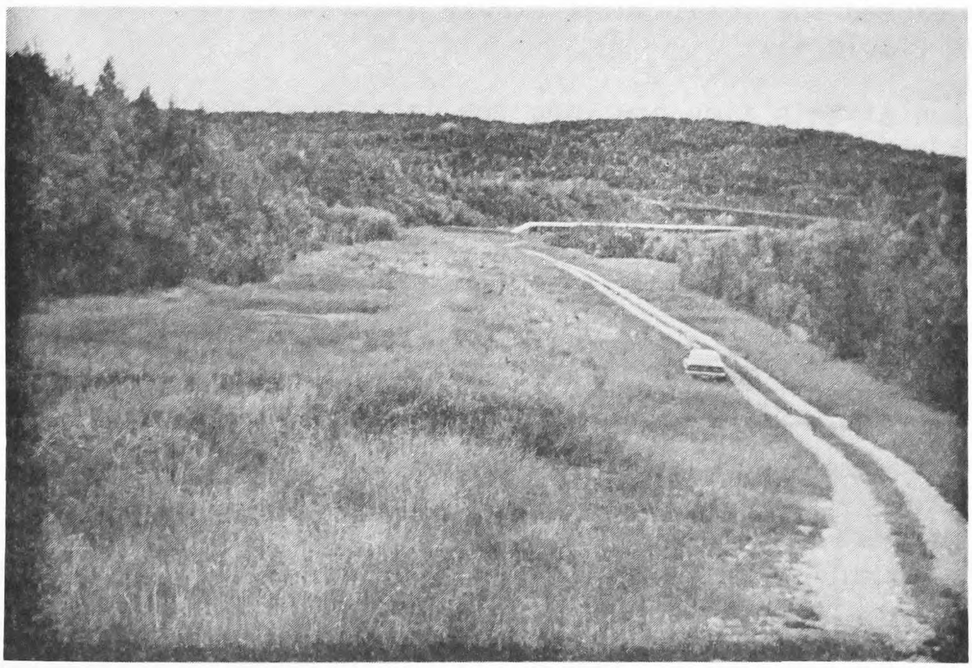

Figure 3. TAPS right-of-way just north of Fairbanks; aboveground pipeline in background.

In order to observe the short-term success of these vegetation methods and the long-term effect upon reinvasion by native plant species CRREl conducted a revegetation study along the TAPS right-of-way from Prudhoe Bay to Valdez, Alaska, during 1975-1981. Approximately 60 sites were established to span the entire route and to represent the various types of disturbances such as road cuts, gravel pits or material sites, workpads, and fill or disposal sites. During active construction and revegetation (1975-1978) visual estimates of the approximate percent vegetative cover were recorded. In 1979 permanent plots were established, and from 1979 to 1981 percent vegetative cover was recorded annually.

In most instances there have been few serious erosion problems after areas were successfully revegetated. Total live vascular plant cover along the entire right-of-way averaged close to 50% for the six years, 1976-1981 (Table 3). The overwhelming majority of this cover is produced by the commercial grasses in the revegetation seed mix. For the more detailed 1979-1981 portion of the study, the TAPS right-of-way was separated into five main physiographic zones from the southern coastal zone near Valdez, Alaska, northwards to the alpine interior, interior, alpine or Brooks Range, and finally to the North Slope or Arctic Coastal Plain. The data from each of these five areas show that in most instances the total vascular plant cover is generally remaining fairly constant (Table 4). The most significant change along the route is that the percent moss cover increased from 24 to 37% between 1979 and 1981 (Table 3). Usually, the moss cover has increased underneath a cover produced by the seeded grasses and is not readily noticeable. The volunteer native vascular species cover has remained low throughout the study. On only 15% of the study sites did it exceed 10% total cover (Table 3), but it is slowly increasing in some areas (Table 4).

It is not known at this time how long the introduced grasses will continue to provide significant levels of vegetative cover. Once environmental guidelines have been met the practice of refertilization will decrease and significant changes in plant cover and species composition will undoubtedly occur along portions of the route. Native plant reinvasion has been disappointingly slow, but it is impossible to determine the relative significance of such factors as low seed production by natives, physical or chemical inhibition of germination by litter or established plants, or competition by seeded grasses.

ALASKAN NATURAL GAS TRANSPORTATION SYSTEM

The Alaskan Natural Gas Transportation System (ANGTS) route in Alaska will extend some 740 miles (1184 km) from Prudhoe Bay to the Alaska-Canada border (Fig. 1). It parallels TAPS from most of the route (550 miles or 880 km) and then veers east along the Alaska Highway to the border. Therefore, many of the revegetation problems it encounters duplicate those of TAPS.

Unlike TAPS, the primary revegetation goal of the ANGTS is to reestablish native plant communities on disturbed areas. Except for highly erodable sites, erosion control is considered to be one of several secondary goals. In order to meet these goals several different strategies will be employed. First, there will be a major emphasis upon providing an optimum

Table 3. Average percent vegetative cover (mean, std error) for 50 sites along TAPS.

Year	Litter	Total Vascular[b]	Moss	Native Vascular
1976	NA[a]	53	NA[a]	NA[a]
1977	NA[a]	56	NA[a]	NA[a]
1978	NA[a]	48	NA[a]	NA[a]
1979	49 (6)	44 (4)	24 (7)	3 (2)
1980	46 (4)	50 (3)	30 (4)	5 (2)
1981	56 (3)	53 (2)	37 (3)	7 (2)

[a]NA = data not available.
[b]Total cover by both introduced and native higher plants.

Table 4. Yearly changes in percent vegetation cover along TAPS.

Section	Years	Litter	Total Vascular	Moss	Native Vascular
Coastal	1979-80	NA[a]	NA[a]	NA[a]	NA[a]
	1980-81	+17%	-3%	+24%	- 1%
Alpine (Interior)	1979-80	NA[a]	NA[a]	NA[a]	NA[a]
	1980-81	- 7%	+3%	+27%	0
Interior	1979-80	- 3%	+4%	+12%	+ 7%
	1980-81	+ 5%	+4%	+ 1%	+ 5%
Alpine (Brooks)	1979-80	- 9%	+8%	+14%	0
	1980-81	+15%	+6%	+ 6%	+10%
North Slope	1979-80	+ 5%	0	+11%	+14%
	1980-81	+10%	+4%	+10%	+ 3%

[a]NA = data not available.

seedbed for natural reinvasion. Whenever possible the upper organic layers will be stripped off and stockpiled nearby during site clearing. This material will then be respread over the area and tilled into the subsoil once construction is completed. Research is also being conducted to determine the amount of buried seed in these organic layers and the likelihood that they will remain viable until the material can be redistributed over the site. Buried seed may reduce or even eliminate the need to seed some areas.

Since there is increasing evidence of the adverse effects of high seed and fertilizer applications upon native plant reinvasion; both the areal extent and the active seeding rates will be reduced. Non-erodable areas will probably receive low levels of fertilizer but will not be seeded unless the likelihood of natural reinvasion or site recovery potential is judged to be low. In order to evaluate site recovery potential, research is currently underway to determine the succession rate on previously disturbed sites of varying ages and substrates in each of the major zones: (1) North Slope, (2) Brooks Range, (3) Yukon River to Brooks Range, and (4) Yukon River to Alaska border. The site recovery potential will be evaluated based upon both the growth potential of the substrate; i.e., its ability to provide adequate nutrients and moisture, and the reinvasion potential of the surrounding vegetation; i.e., its ability to produce and disperse viable seed into the site combined with the likelihood of germination from viable buried seeds in stockpiled substrate (Table 5).

Table 5. Site recovery potential.

Reinvasion potential	Growth potential: High	Growth potential: Medium	Growth potential: Low
High	High	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Low

Active seeding will be restricted to areas classed either as erodable or sites with low recovery potential. Seeding rates will be based upon ongoing research, but they will probably be much lower than TAPS. Seed mix rates presently being evaluated vary from 1000 to 3200 seeds/m (6-32 kg/ha) or about 38% of those rates using along TAPS. Several different mixes and rates are being tested in order to formulate distinct seed mixes for various geographic zones and for sites of different erodability. Annual ryegrass is only being considered for highly erodable areas. It is hoped that the seed mixes will rely almost exclusively upon native grasses.

Since completion of TAPS, research has continued on developing native arctic and subarctic grasses for revegetation, several of which have been registered and released for seed production (Mitchell 1979). Therefore, the ANGTS proposes to primarily use in its seed mixes three of these species: (1) tundra glaucous bluegrass (Poa glauca), (2) Alyeska polargrass (Arctagrostis latifolia) and (3) sourdough bluejoint reedgrass (Calamagrostis canadensis). An adapted legume, alsike clover (Trifolium hybridum), may also be used in the mixes for areas south of the Yukon River along the ANGTS. The highest seeding and fertilizer rates will be used on erodable sites with low succession potential. Of course, this proposed revegetation scheme is contingent upon acceptable responses of these native grasses in the ongoing test program and adequate production of seed by commercial growers in Alaska. Some seed production of these native grass varieties is already in progress.

The proposed revegetation methods of the Alaska segment of ANGTS rely heavily upon the unique adaptations of native arctic and subarctic plants to ensure successful vegetation recovery. They seek to facilitate natural reinvasion onto disturbed sites by a combination of organic reuse, minimal seeding and fertilization, and extensive reliance upon the limited but expanding number of commercially available native grasses. Some of these approaches were previously used along TAPS, but to a much more limited extent.

If successful, these new methods will help to minimize the visible long-term impact of large construction projects in Alaska while simultaneously lessening the potential for ecological problems with introduced revegetation species which might persist or even become weeds. The rapid reestablishment of native species will also help to decrease the impact upon wildlife populations from lost habitat.

SUMMARY

Large pipeline rights-of-way in Alaska encounter a variety of severe environmental conditions, many of which are associated with low temperatures. The Trans-Alaska (oil) Pipeline System completed in 1976 relied upon moderate to high seeding rates, primarily of introduced grasses, to control erosion of disturbed sites. Preliminary observations of these seeded areas reveal little erosion but also very low reinvasion by species of native vascular plants.

In order to accelerate the process of native plant reestablishment the proposed Alaska segment of the Alaskan Natural Gas Transportation System will minimize active seeding programs and will utilize seed from native grasses whenever possible. For the most part, introduced grasses utilized along the oil pipeline right-of-way will only be used in cases of severe erosion. It is hoped that this approach will minimize ecological problems while accelerating the reestablishment of native vegetation.

ACKNOWLEDGMENTS

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This report was technically reviewed by Antonio Palazzo and Leslie Viereck.

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STRAW MULCH FOR EROSION CONTROL AND PLANT ESTABLISHMENT ON HIGHWAY RIGHTS-OF-WAY IN SAN DIEGO COUNTY

Burgess L. Kay[1], Walter L. Graves[2], and Robert L. Koenigs[3]

ABSTRACT.--Straw is used throughout the world as a mulch to protect disturbed soil surfaces, and to encourage establishment of plant cover. In southern California, the practice has been largely replaced by the currently popular hydroseeding technique--hydraulic applications of seed, fertilizer, mulch fibers, and chemicals in a water slurry.

Field tests consistently demonstrate that cereal straw, broadcast on the soil surface at 2000-3000 lb/acre and held with a tackifier, fiber, or net, or applied at 8000 lb/acre and incorporated with a crimper or roller, is vastly superior to hydraulic mulching for reducing soil loss. The decomposed granite soil is protected to a much greater degree before plant growth begins, infiltration is increased, and the resulting plant establishment is greatly improved. The increased soil protection adds flexibility to the time of erosion control practices following construction. Straw practices are discussed.

INTRODUCTION

Cereal grain straw, and sometimes hay, have long been used to protect the surface of exposed soils, and to aid in the establishment and growth of plants. The use of hydroseeding (hydraulic applications of seed, fertilizer, mulch fibers, and chemicals in a water slurry) has become so common in southern California in recent years that the practices of straw use have largely disappeared. Hydraulic application of mulches is accomplished in the seeding-fertilizing operation, which may result in lower manpower requirements and thus, less cost. However, the fiber products may not offer the same mulching properties (surface protection and modification of temperature and moisture conditions) as straw or hay.

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METHODS

Both field plots on highway slopes in San Diego County and experimental slopes under artificial rainfall conditions at Davis were used to compare the effectiveness of hydraulic mulches and straw. In field plots, the decomposed granite subsoils were covered with 2000 lb/acre barley straw. The straw was held in place by hydraulically applying wood fiber (Conwed Hydromulch[R]) over the top at 800 lb/acre. This treatment was compared to wood fiber mulch alone at 2500 lb/acre. The 2000 lb rate of straw would be minimal, while 2500 lb of fiber excessive compared to common practices (Kay 1978A). All plots were fertilized and seeded with clover-grass mix before mulching.

In the controlled experiment, mulch treatments were applied to decomposed granite surfaces 2 ft x 4 ft and the surfaces inclined to either 5:1 or 2:1 (horizontal to vertical measurement). These were subjected to artificial rainfall of 3mm drops at the rate of 6 inches/hour, and the water and soil leaving the surface was measured. Barley straw mulch treatments at 3000 lb/acre applied to the surface and held in place with asphalt emulsion (SS-1 at 200 gpa), and hydraulically applied wood fiber (Silvafiber) at 1500 lb/acre (the highest practical commercial rate) and 3000 lb/acre were compared to bare soil.

RESULTS

The field treatments were applied February 2, 1979, much too late for best plant growth, but some plant material was established. Growth of both the seeded species and barley, which volunteered from the straw, made the straw treatments stand out six weeks after seeding. Greater numbers of seeded plants also appeared on the straw treatments. Soil loss was minimal from the straw treatment and much less than from the hydraulic treatments.

Davis experiments show minimal soil loss from the straw treatment at six hours (36 in. of rain) at either 2:1 or 5:1 slopes (Fig. 1). Soil losses were greater at 2:1 than 5:1 slopes from all treatments. Losses from unprotected surfaces were 34 tons and 12 tons/acre compared to 2.5 tons and 64 lb/acre with straw. Wood fiber at the 1500 lb rate (F-1500) offered almost no protection at 2:1 slopes and moderate protection at 5:1 slopes. The excessive rate of 3000 lb (F-3000) only offered moderate protection on either slope gradient.

Water yield (runoff) was reduced by straw because of increased infiltration. The percent of water recovered as runoff from the 5:1 slope was 2, 33, 37, and 44% respectively for the straw, bare 1500, and 3000 lb of fiber treatments. Differences on the 2:1 slope were not as great (41, 44, 49, and 47%). Drops striking the straw were broken up and held long enough to infiltrate. Not all of the unrecovered water was due to infiltration, since some of it is lost in drops bouncing from the slope or leaking down the sides of the containers. The fiber was constantly dislodged by the impact of the raindrops and much of it was washed from the slope. The ability of straw to absorb the impact of raindrops is important; kinetic energy, which would otherwise dislodge soil particles, is dissipated. Free-falling drops also puddle the surface and destroy soil aggregates which are important to percolation. This protection is effective at any time of the year and can add greatly to the flexibility of erosion control programs. The completion date may not be compatible with the start of the growing season, so the interim protection offered by straw, but not by hydraulic mulches, is important.

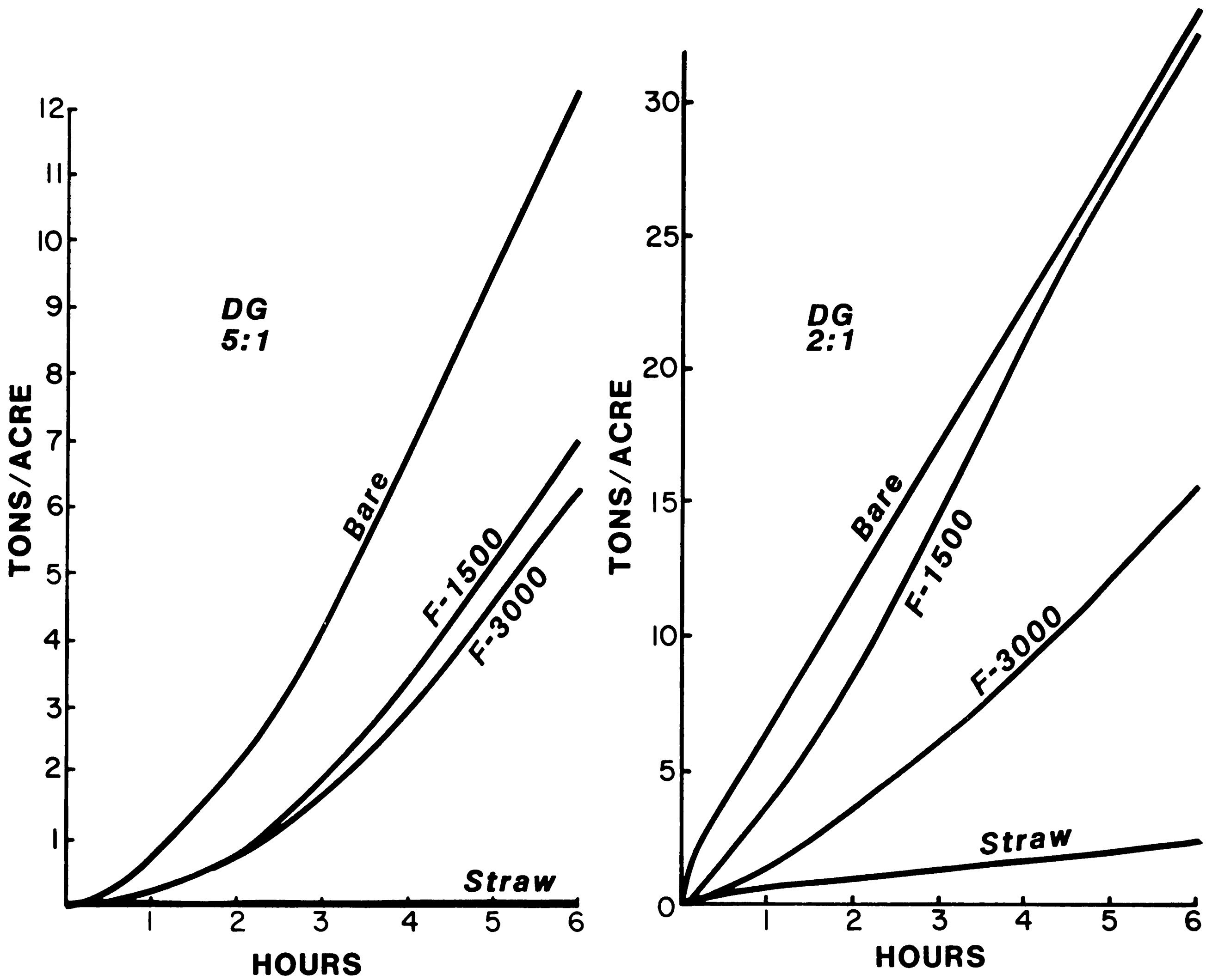

Figure 1. Soil loss from artificial slopes inclined 5:1 (left) and 2:1 (right) when protected by straw or wood fiber (F-1500 and F-3000).

DISCUSSION OF STRAW PRACTICES

Clean grain straw, free of noxious weeds, is preferred. The straw can be expected to contain 0.5 to 5.0% cereal seed by weight, which may result in considerable plant cover in the first year. This cover provides additional erosion protection, but may also be prohibitively competitive with the planted erosion control or beautification mixture. Rice straw is sometimes used because neither the rice nor the associated weeds can be expected to grow on most nonirrigated disturbed lands. In areas where cereal crops are uncommon, hay is sometimes used although it is normally more expensive than straw. Wild-grass hay may be a valuable source of native plant material if cut when the seeds are ripe but not shattered.

The mulch effect of straw can be expected to increase plant establishment. Meyer et al. (1971) obtained fescue-bluegrass establishment of 3, 28, and 42% with respective surface straw mulch treatments of 0, 1, and 2 tons/acre. Straw has been shown to increase plant establishment in decomposed granite (Kay 1974). Seeding the annual grass Blando Brome (Bromus mollis) resulted in 7, 6, 26, 35, and 131 seedings/ft^2 respectively on the untreated fiber mulch at 1000, 2000, and 3000, and straw at 2000 lb/acre on a 2:1 slope. On 1.5:1 slopes, the number of plants were 1, 13, 29, 35, and 131, and at 1:1 0, 10, 27, 20, and 155. Fertilizer must be applied to compensate for the nitorgen tied up in decomposing the straw.

The amount of straw used depends on the erodibility of the site (soil type, rainfall, and length and steepness of slope), kind of straw (Grib 1967), and whether plant growth will be encouraged. Increasing rates of straw give increasing protection. Meyer et al. (1970) show that as little as 1000 lb/acre reduced soil losses by two-thirds, while 4 tons/acre reduced losses by 95%. Straw to be crimped is commonly used at 2 tons/acre, while straw punched into fill slopes in California is at 4 US tons/acre in a split application and rolling operation (2 tons/acre each). Straw held down with a net should be limited to 1.5-2 tons/acre, and straw held with a tackifier should be limited to 1-1.5 tons/acre if plant growth is important. Too much straw may smother seedlings by intercepting all light or forming a physical barrier. Also, some grass straw (notably annual ryegrass, Lolium multi-florum) may contain inhibitors that have a toxic effect if used in excess. A good rule of thumb is that some soil should be visible if plant growth is desired. Higher rates of straw may still satisfy these requirements if the straws are vertically oriented, e.g., by crimping or punching. Excessive straw on the surface may be a fire hazard.

Straw can be applied with specially designed straw blowers or spread by hand. Commercial mulch spreaders or straw blowers advertise a capability of up to 15 US tons/hour and distances to 85 ft. The length of the applied straw can be controlled in most blowers by adjusting or removing the flail chains. Straw to be crimped or punched should be relatively long to be incorporated into the soil effectively and still leave tufts or whisker dams. Rice straw is wiry, does not shatter readily, and consequently, does not blow as well as straw of wheat, barley, or oats; it may come out of the blower in "bird nests." Blown straw, other than rice, lies down in closer contact with the soil than hand-spread straw and is anchored more successfully with a tackifier (substance sprayed on straw to hold it in place. Wind is a serious limiting factor in applying straw, though it can be an asset in making applications downwind. Dust, a problem in urban areas, can be overcome by injecting water into the airstream used to blow the straw.

Straw or hay usually needs to be held in place until plant growth starts. Water puddles the soil around the straw and helps hold it in place. Also, wet straw "mats down" and is not easily moved. Common methods of holding straw in place are crimping, disking, or rolling into the soil; covering with a net or wire; or spraying with a chemical tackifier. Swanson et al. (1967) found similar protection from prairie hay applied as a loose mulch or anchored with a disk packer (crimper). Commercial machines with blunt notched disks forced into the soil by a weighted tractor-drawn carriage accomplish crimping, but they will not penetrate hard soils and cannot be pulled on steep slopes.

Rolling or "punching" is done with a specially designed roller. A sheepsfoot roller, commonly used in soil compaction, is unsatisfactory for incorporating straw. Specifications of the California Department of Transportation contain the following provisions (State of Calif. 1975): "Roller shall be equipped with straight studs, made of approximately 7/8 inch steel plate, placed approximately 8 inches apart, and staggered. The studs shall not be less than 6 inches long nor more than 6 inches wide and shall be rounded to prevent withdrawing the straw from the soil. The roller shall be of such weight as to incorporate the straw sufficiently into the soil so that the straw will not support combustion, and will have a uniform surface."

The roller may be tractor-drawn on flat areas or gentle slopes. On steeper slopes with top-of-slope access, the roller may be lowered by gravity and raised by a winch in yo-yo fashion, commonly from a flatbed truck. Requirements are soil soft enough for roller teeth penetration and access to the top of the slope. This treatment, common in highway fill slopes in California, can be used on much steeper slopes than a crimper can. Punched straw may not be as effective as contour crimped straw because of the staggered arrangement of tucked straw instead of the "whisker dams" made by crimping (Barnett et al. 1967).

A variety of nets have been used to hold straw in place: twisted-woven kraft paper, plastic fabric, poultry netting, concrete reinforcing wire, and even jute. The price and the length of service required should determine the product used. Nets should be anchored at enough points to prevent them from whipping in the wind, which rearranges the straw.

The most common method of holding straw, particularly in the eastern U.S., is use of a tackifier. This method may be used on relatively steep slopes which have limited access and soil too hard for crimping or punching. Asphalt emulsion, the tackifier used most commonly, is applied at 200-500 gal/acre either over the top of the straw or simultaneously with the straw-blowing operation. Recent tests (Kay 1978B) have shown that 600 gal is superior to 400 gal, and that 200 gal/acre is unsatisfactory. Wood fiber or new products used in combination with wood fiber, has been equally effective, similar in cost, and environmentally more acceptable (Table 1). Terratack I[R] is a gum derived from guar, Terratack II[2] is a semi-refined seaweed extract, and Ecology Controls M Binder[R] is a gum from plantain, (*Plantago insularis*). The remaining products are emulsions used in making adhesives, paints, and other products. Though wood fiber alone is effective as a short-term tackifier, glue must be added to give protection beyond a few weeks. Increasing the rate/acre of any materials increases their effectiveness.

Table 1. Effect of tackifier products on wind stability of barley straw broadcast at 2000 lb/acre.

Product	Chemical	Fiber (lb)	Water (gal)	Wind speed (mph) at which 50% of straw was blown away
None				9
SS-1 asphalt	200 gal			40
SS-1 asphalt	400 gal			80
SS-1 asphalt	600 gal			84++
Fiber only		484		47
Fiber only		736		84
Fiber only		986		84++
Terratack I	45 lb	150	750	68
Terratack II	90 lb	300	1500	84++
Ecology Control M-Binder	100 lb	150	700	84+
Styrene butadiene copolymer emulsion	60 gal	75	400	84
Polyvinyl acetate	100 gal	250	1000	54
Copolymer of methacrylates and acrylates	100 gal	250	1000	76

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PLANT MATERIALS AND TECHNIQUES FOR REVEGETATION OF CALIFORNIA ROADSIDES

Raimond F. Clary, Jr.[1]

ABSTRACT.--In 1978, the California Department of Transportation (CALTRANS) in cooperation with the Federal Highway Administration (FHWA) contracted with the U.S. Department of Agriculture Soil Conservation Service (SCS) to test plant materials and planting techniques for revegetation along California highways. This 5-year study concentrates much of its efforts in the Mojave Desert and surrounding areas. The study focuses on three major problems: (1) the establishment of herbaceous and shrub species in the Mojave Desert; (2) a determination of the rate of invasion of woody plants onto highway cut and fill slopes; and (3) the revegetation of problem soils (serpentine soils, high and low pH soils, and high boron content soils). In addition, the study monitors plantings established during a similar study that took place between 1970-76. The prior study dealt with revegetation problems in four specific geographic areas. These were: (1) the north-central coastal foothills; (2) the Sierra-Nevada foothills; (3) the Tahoe Basin; and (4) the Alturas vicinity (northern California). This past study resulted in a publication 'Plant Materials Study'. The findings from the current study will be summarized in a report in 1983.

INTRODUCTION

Attempts to find methods and plant materials for revegetating California roadsides are now being made as a result of a five-year agreement between the California Department of Transportation (CALTRANS), in cooperation with the Federal Highway Administration (FHWA), and the U.S. Department of AGriculture, Soil Conservation Service (SCS). The study began in 1978 and will conclude in June 1983. All expenses incurred by SCS while making this investigation are being reimbursed by CALTRANS.

The study is divided into four phases. Three are related to specific problems. These are (1) the establishment of herbaceous and shrub species in the Mojave Desert; (2) a determination of the rate of invasion of woody plants onto highway cut and fill slopes; and (3) the revegetation of problem soils (serpentine soils, high and low pH soils, and high boron

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content soils). The fourth phase monitors and evaluates plantings made during a similar CALTRANS-SCS study which took place between 1970 and 1976.

METHODS AND PROCEDURES

The Establishment of Herbaceous and Shrub Species in the Mojave Desert

Approximately one-third of the time spent on this project involves the desert environment. The objective is to test as many grasses and shrubs as possible using different establishment techniques. In Febraury of 1978 through 1982, herbaceous and shrub species were direct seeded in single plots and in combination with one another. Containerized shrubs were planted in the fall of 1978 and the winter of 1979; however, due to high winter mortality, plantings in subsequent years were made only in the late spring. Containers included both book binders (1-1/4" x 1-1/4" x 8") and standard gallon cans. Mag Amp slow-release fertilizer was applied at the time of planting.

Some plants of each accession were watered in July and August of 1979. Fifty percent of all container plants are now being irrigated monthly from March through October. First year plantings are located on Highway 14 near Lancaster and on Highway 35 near Ridgecrest, California.

During the second planting season, direct seedings and containerized shrub plantings were made at Edwards AFB; along Highway 395 near Ridgecrest, Little Lake and Bishop; and along Interstate 40 about 40 miles east of Barstow. In the third and fourth year, plantings were made at these same sites with the exception of Edwards AFB. Over 2200 shrubs have been planted to date in the Mojave Desert and adjacent areas.

When attempting to revegetate wildlands, there always exists the problem of seed and plant procurement. The SCS has a coordinated plant materials program which utilizes the cooperative efforts of 22 Plant Materials Centers (PMCs) throughout the U.S. These PMCs often furnish small amounts of seed for testing purposes. During the first year of the study, seed and plant materials were obtained from PMCs and commercial sources. During the second, third, and fourth years, native collections were the primary source. Shrub propagation begins in July at the Lockeford PMC. After seedling emergence, plants are transported to the Antelope Valley Resource Conservation Districy (AVRCD) Nursery in Lancaster where they are grown to adequate size for outplanting in February or March.

The Determinants of the Rate of Natural Invasion of Woody Plants

Certain highway slopes following construction may not require intensive revegetation if conditions that encourage the natural growth of woody plants on cut and fill slopes exist.

In this study approximately 600 circular inventory plots 13 feet (4 m) in diameter were set out on slopes of known age. Soil series, parent material, elevation, seed source (species and distance), percent slope, and average annual precipitation were recorded for each site.

Attempts were made to set out at least 10 circular plots at each location. Shrubs within these plots are identified, measured and then located by measuring radially from a center stake. Radial distance associated with a 12-hour clock angle give exact locations of each shrub. Review of plots will show any change in plant number or size.

Problem Soils in Plant Establishment

A problem soil, as it relates to this study, is a soil that is difficult to vegetate due to its structure or some toxic substance or element. Actually, only a small percentage of the ground disturbed during construction is considered a problem soil. When encountered, however, these soils require intensive revegetation treatments. Plantings have been made on four different problem soils. These are (1) a volcanic tuff near Bishop, (2) a decomposed granite site south of Little Lake on Highway 395, (3) serpentine soils near Ione and San Andreas, and (4) a high boron content soil near Boron, California. Direct seedings and containerized shrub plantings have been made on each of these soils.

Monitoring of Plantings Made During the 1970-76 Study

Over 2500 plantings were made between 1970 and 1975 as part of a previous CALTRANS-SCS cooperative study. All plantings made during this prior study were reviewed in the first and second year of the present project. The plantings will again be reviewed in the fourth year of this study. Plant species are being evaluated for such items as longevity, stand density, cover, and adequacy for use in revegetation.

RESULTS AND DISCUSSION

The Establishment of Herbaceous and Shrub Species in the Mojave Desert

Negative results have been obtained from direct seedings of the commonly available perennial grasses. Several annual grasses, however, show definite revegetation possibilities. 'Wimmera-62' ryegrass (*Lolium rigidum*) and Red brome (*Bromus rubens*) produced good stands at all sites except during years of well-below annual precipitation. Several perennial grasses, planted as container stock, have survived for one year. Those showing potential are 'Critana' thickspike wheatgrass (*Agropyron dasystachyum*), 'Largo' tall wheatgrass (*Agropyron elongatum*), and 'Paloma' Indian ricegrass (*Oryzopsis hymenoides*).

The most encouraging results are from woody plants both in direct seedings and container plantings. Success has depended more on whether a native shrub was used than on the type of treatment (container size, irrigation, mulch, etc.). 'Marana' fourwing saltbush (*Atriplex canescens*) and desert saltbush (*Atriplex polycarpa*) did well in the direct seedings and container plantings. 'Dorado' bladderpod (*Isomeris arborea*) did well from seed whereas rubber rabbit brush (*Chrysothamnus nauseosus*) responded best in the container plantings.

Only a small percentage (5%) of the shrubs planted in the first year of the study survived. Most of the mortality was caused by rodents. Less rodent damage occurred near busy freeway interchanges and areas where natural shrub cover was sparse. These areas were less conducive to large rodent populations.

To adequately test the container plants it was necessary to use a device that would protect the plants long enough to allow them to obtain growth and survival data. A commerically available rodent protector made of perforated plastic has effectively protected plants for over two years. These protectors break down after four or five years of exposure to sun light.

Natural Invasion of Woody Plants

Approximately 600 circular plots have been established at selected sites in the Sierra-Nevada foothills, Sierra-Nevada mountains and Mojave Desert to study the natural invasion of woody plants. Certain key factors seem to determine the rate and success of invasion. Generally, the rougher the slope, the steeper it can be and still furnish the conditions necessary for plant establishment. Success, however, depends on the stability of the parent material and the erodibilty of the soil. On the more erodible soils and parent material, plants are found on the gentler slopes. Plant numbers decrease as the slope angle increases. Road fills usually do not present the natural revegetation problems that cut slopes do. Fills provide a better growing media for woody plants.

Problem Soils

Very little information could be found regarding the revegetation of serpentine soils in California. Most of the work has been done where summer rains are common. Literature is available on the revegetation of decomposed granites but little that directly applies to drier conditions.

Direct seedings of perennial grasses on serpentine soils were failures. Several annual grasses including 'Blando' brome (*Bromus mollis*); 'Zorro' annual fescue (*Vulpia myuros*); Red brome and 'Wimmera-62' ryegrass did produce good stands the first year after seeding. Slopes were also fertilized with a good response from resident seed. During the second year after treatment, growth was severely reduced.

Container plants of 'Luna' pubescent wheatgrass (*Agropyron intermedium trichophorum*), 'Berber' orchardgrass (*Dactylis glomerata*), (*Melica harfordii*), and 'Largo' tall wheatgrass have survived for one year on these serpentine soils.

California buckwheat (*Eriogonum fasciculatum*) is the only woody plant to show any potential for direct seedings on serpentine soils. Two year old seedings have produced vigorous dense stands. Container plants of Digger pine (*Pinus sabiniana*), Coulter pine (*Pinus coulteri*), Ponderosa pine (*Pinus ponderosa*), and Jeffrey pine (*Pinus jeffreyi*) show about 50% survival after two years. Container plants of California buckwheat also look vigorous. No irrigation was applied to these plantings.

Big sagebrush (*Artemisia tridentata*), 'Marana' fourwing saltbush, rubber rabbit brush, and pinyon pine (*Pinus monophylla*) look very good on the volcanic tuff north of Bishop. Crested wheatgrass (Agropyron cristatum) is the only grass showing any success from direct seedings.

'Marana' fourwing saltbush, rubber rabbit bush, desert saltbush and creosote bush (Larrea tridentata) are promising shrub species on the granitic soil near Little Lake on Highway 395. Desert saltbush and Red brome responded fairly well in direct seedings.

Wolfberry (Lycium andersonii) and 'Marana' fourwing saltbush have been affected little by the boron in the soils near Boron, California. Spinescale (Atriplex spinifera) also looks to be well adapted to these types of soils.

Monitoring of Plantings Made During the 1970-76 Study

It is generally concluded that perennial grasses do poorly in erosion control seedings in the Mediterranean climate of California. Numerous trials during the 1970-76 CALTRANS-SCS study show this to be the case. One exception may be 'Luna' pubescent wheatgrass. 'Luna' has produced good stands on north exposures where deep soils of good moisture-holding capacity are present. Annual grasses such as 'Blando' brome or 'Wimmera-62' ryegrass adequately produce the type of cover wanted on newly exposed roadbanks.

In the Tahoe Basin and northeastern California, perennial grasses have performed well. 'Luna' pubescent wheatgrass, 'Tegmar' intermediate wheatgrass (Agropyron intermedium), 'Sherman' big bluegrass (Poa ampla), and 'Durar' hard fescue (Festuca longifolia) all produced good erosion control covers and have persisted in some plantings for over ten years.

CONCLUSION

This study is now in its fourth year. The last plantings that will bear any significant information as far as this project is concerned were made in October 1981. A large number of desert species have and will be planted during this planting season. Much of the last year of the study will be spent evaluating plantings and summarizing data for incorporation into a final CALTRANS report scheduled for publication in 1983.

MANAGEMENT OF FOREST STANDS ON HIGHWAY RIGHTS-OF-WAY

Harold E. Young[1]

ABSTRACT.--Highways traverse forested areas in many sections of the United States. Foresters can and should play a vital role (1) in the location of rights-of-way, (2) in the initial decisions as to the management of forest stands on new rights-of-way, and (3) in the maintenace practices on rights-of-way. Forests can be managed to produce fiber and revenue, while meeting all highway safety requirements.

INTRODUCTION

Ecologically sound forest management needs to be incorporated into highway design, construction, and maintenance to reduce pollution, to provide an additional source of raw material to lessen the mounting pressure on our forests, and to reduce the cost of highway maintenance by the continuous sale of forest products from forest stands on the highway rights-of-way.

Highway Design

Four lane divided highways are planned and designed so that motorists can drive at high speed with a minimum or risk. Federal standards of vertical and horizontal highway curvature result in 300 foot (91 m) rights-of-way and large land fills and hill reductions.

Many factors are considered in locating major highways including the impact on local communities, traffic flow, relationship to other highways, and construction costs.

When a major highway passes through a forested area, separate roadways are cleared of all vegetation, exposing four edges of the established forest. There are dramatic changes in the wind, light, moisture, and soil temperature relationships on these edges that result in the death of trees.

The land fill areas and those segments of the highway that are designed to have the roadway several feet higher than the local terrain act as dikes to alter the long-established drainage patterns and thereby change the

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soil moisture regime. The magnitude of this dike effect is more pronounced in areas where the land is relatively flat. When both roadways are raised, the median strip will hold water for part of the year unless adequate provisions are made to properly drain the median, a procedure which would add to the overall cost. Under such poor drainage conditions trees may drown over a period of several years, depending on the species and tree vigor. The accumulation of salt in water-logged areas most likely hastens death.

Landscaping

The landscape architect brought his highly developed parks and estates perspective to the highway rights-of-way. The highways' lawns are graced with trees and shrubs, sometimes exotic to the region. The landscape architects have even extended this to forest stands on the rights-of-way by removing trees to bring about a park-like effect within what had been a natural stand. Such a further reduction in trees beyond the roadway building requirements causes even more drastic environmental and community effects by increasing exposure. More wind, more light and the drying effect on the soil that often occur as an aftermath of such thinning result in top breakage, blowdown or tree death.

Salt

Salt has been effectively used in large quantities since World War II to reduce driving hazards caused by snow and ice. There is also ample evidence that salt has killed many trees and shrubs.

Forest Ecology

Ecology is the science of the interrelationships of organisms in and to their complete environment. Forest ecology is concerned with the forest as a biological community.

A proper and detailed study of forest ecology would include environmental factors such as light, temperature, moisture, wind, climate, soil, nutrients, etc. and community factors such as competition, succession, disturbance, spatial relationships, biotic factors, etc. In addition, it would involve the action and interaction of all of these factors on each other.

Some general forest ecology concepts, subject to local variations due to species, environmental and community factors are as follows:

1. Sudden and permanent disturbances that change environmental and community factors can weaken tree and shrub vigor, often resulting in death. Death will seldom occur immediately as deterioration in tree vigor will depend on the nature of the distrubance.

2. Death may occur to trees ranging from seedlings to mature specimens, depending on the extent of local changes.

3. ROW construction through forest exposes formerly interior portions. The exposed portions of the forest will experience changes in light, wind, temperature, and moisture content of the soil which affect tree vigor.

4. Weakened conditions of trees and shrubs due to ROW construction, plus damage caused by heavy equipment, can increase the incidence of insect and disease damage.

5. ROW construction often changes local drainage patterns, thereby either increasing or decreasing moisture for established trees and affecting the vigor of the trees.

6. Salt accumulation can result in tree death.

Forest Management of Highway Rights-of-Way

Forest stands on highway rights-of-way should be managed as follows:

1. The forester should be involved in the general location of a new highway as well as specific local design to bring the ecological considerations into proper focus.

2. Upon delineation of the roadway to be cleared of vegetation as well as other segments of the rights-of-way that should be clear-felled due to environmental changes imposed by the new highway, the forester will then arrange for the harvest of all trees being removed.

3. In order to minimize changes in environmental and community factors, none of the trees in the remaining forest stand following completion of (2) would be removed. It will be anticipated that some trees and shrubs will die in the future due to environmental changes created by clearing the roadway. By periodic examination of the highway forests, trees will be marked for removal every few years to eliminate high cost of annual removal of some trees. This salvage operation should be conducted as a small timber sale.

4. Natural regeneration in the highway forest or that occurring in areas that were cleared of vegetation should not be disturbed except for safety clearances on roadway edges.

5. Native species will be added in the form of seed or as planted seedlings, depending on local conditions, to increase the stocking of existing stands and as cover for areas that were cleared in the construction process.

6. Instead of planting grass along the roadside, either wood chips will be spread to retain banks or a thin layer of wood chips with seed will be used to provide a puckerbrush cover which will be periodically harvested under the supervision of the forester.

The management of highway rights-of-way by foresters should be much less costly than management by landscape architects. In addition, there will be an appreciable difference in aesthetic appearance. The difference to most motorists should be negligible. Certainly the effort to maintain the forest stands remaining on the rights-of-way as nearly natural as possible should provide better food and cover for animals and birds--particularly in light of the periodic harvesting that will insure that the vegetation is low and thus available.

STABILIZING HIGHWAY RIGHTS-OF-WAY WITH ROSE CLOVER IN SOUTHERN CALIFORNIA

Walter L. Graves[1], Burgess L. Kay[2], Tom Ham[3], and Robert L. Koenigs[4]

ABSTRACT.--Hykon rose clover, an early maturing variety of *Trifolium hirtum*, has proven more reliable than the annual grasses *Lolium multiflorum* or *Bromus mollis* for first-year cover on disturbed soils. If properly inoculated with the correct *Rhizobium* bacteria, clover does not require nitrogen. Because of its high seed production and a large percentage of hard seed, it returns following even the driest seasons; it is also less competitive with wildflowers. Another variety that showed promise was Kondinin. Sirint and Troodos varieties were less satisfactory, while Olympus and Wilton were not satisfactory. In the fourth growing season, Hykon remained the most persistent. Nitrogen fixation has resulted in increased amounts of grass and total ground cover.

INTRODUCTION

Early maturing varieties of rose clover (*Trifolium hirtum*) have been found useful in revegetating southern California roadside embankments and other critical areas to control erosion and improve soil (Graves et al. 1980). This annual legume, said to grow in soils where few other plants survive, is adapted to areas of San Diego County below 3600 ft (1100 m) that receive low and highly variable rainfall and have frequent dry winters and poor soils (Fig. 1). In its original habitat--the Mediterranean region of North Africa, Asia Minor, and southern Europe--it grows in dry, sterile fields, on slopes and sandy steppes, and along roadsides.

This clover, being a legume, is known to fix significant amounts of nitrogen and has been measured to fix up to 66 kg/ha under California conditions (Holland et al. 1969).

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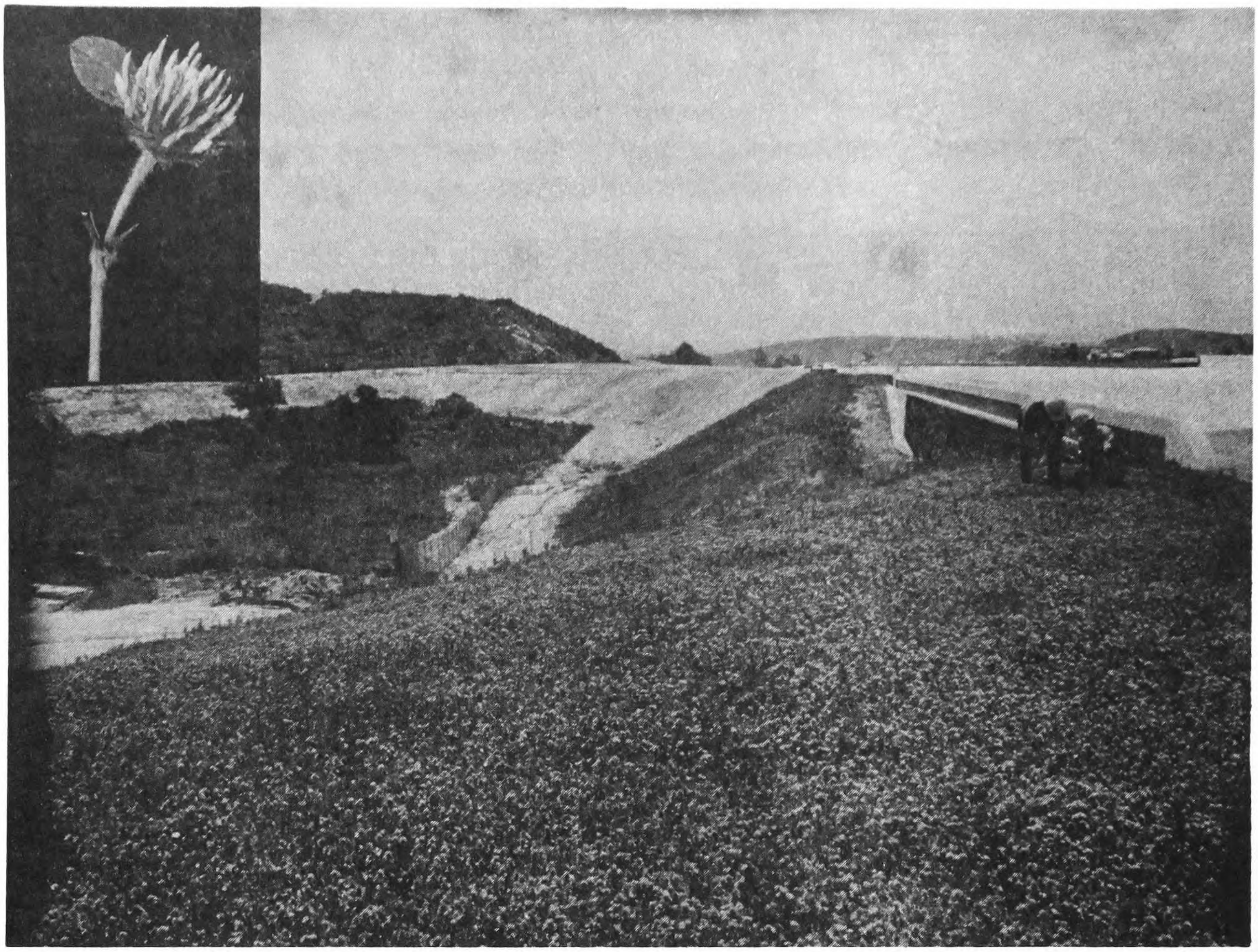

Fig. 1. Second-year Hykon rose clover along Highway I-15 North of Escondido, April 1978. New construction in background has recently been punched with straw to control erosion until rose clover is established. Upper left corner is flower of rose clover in full bloom.

Rose clover was introduced by R. M. Love to California in 1944. Hundreds of range trials have been conducted throughout the state to evaluate its adaptation, persistence, and ability to improve range forage production (Love and Sumner 1952, Williams et al. 1957). It is now commonly recommended for range seedings in California as a good forerunner to other clovers on low-fertility soils (Murphy et al. 1973).

In the 1950's, San Diego County rose clover range trials were encouraging, and in 1962, a range field planting of a late-maturing variety, Wilton, was established successfully at a site having 30 in (750 mm) of average annual rainfall (McKell et al. 1970). Late maturity of this variety was a disadvantage because of the variable rainfall and the usual lack of spring rain. Still, rose clover seemed a prime candidate for San Diego County, because its large amount of hard seed would allow it to lie dormant during the low-rainfall years (Bailey 1966).

It was not until the 1970's that rose clover began to gain some attention in California for uses other than range reseeding for forage production. New uses included roadsides (Kay 1972), fuelbreaks (Adams and Kay 1973), landscaping (Kay et al. 1978), and cover crops (Graves and Breece 1979).

In California past seedings of roadsides and other nonirrigated critical areas have depended primarily on annual ryegrass (Lolium multiflorum) and more recently Blando brome (Bromus mollis) plus massive applications of nitrogen fertilizers to establish ground cover in the shortest time at the lowest cost. Unfortunately, this has several disadvantages. Grasses have given highly variable first-year establishment results and compete excessively with wildflowers and other native plants included in seed mixtures. High rates of fertilizer in combination with grass result in a large amount of plant material--much in excess of what is necessary for erosion control--and excess fertilizer may be released into runoff water. The heavy mat of dry grass is a fire hazard in the summer, and it will restrict the reestablishment of itself and other desirable showy plants such as poppies, lupines, and shrubs (Kay 1972).

ROSE CLOVER VARIETY TRIALS

In 1974, equipped with several early-to-late maturing rose clover cultivars (all, except Wilton, developed by Australian researchers) plus improved strains of inoculating bacteria and inoculation techniques, a roadside-revegetation trial was initiated under unirrigated conditions to evaluate the varieties for their ability to establish and persist and to compare them with grasses for soil building in critical areas in southern California. From 1974 to 1978, rose clover varieties were seeded on 18 roadside sites and embankments in San Diego County to evaluate their ability to stabilize highway rights-of-way.

All seed was coated with Pelinoc^{R}, a commercial bacterial inoculum. Plots were broadcast-fertilized with triple superhphosphate at 110 kg/ha and mulched with barley straw at 2200 kg/ha after seeding. The mulch was anchored with wood fiber at 880 kg/ha.

During the first year (1977-78), Hykon, an early maturing cultivar, significantly outyielded all other varieties and also produced more winter growth. Hykon's winter growth could be a factor in its high productivity, allowing it to take full advantage of the short period of ideal growing temperature with available moisture during March and April.

Kondinin, the second-highest yielder, was similar to Hykon in adaptability to San Diego County but yielded less total dry matter. Both Troodos and Sirint, cultivars similar to Hykon or maturing slightly earlier, were less productive.

Some mildew on Wilton influenced total production. The variety seems less adapted for use because of its later maturity. Olympus, the variety maturing earliest, gave the poorest yield, apparently because it is unable to take advantage of the entire growing season (Table 1).

Table 1. First-year production of rose clover varieties planted at north Escondido I-15 embankment site.[a]

Variety	Dry-matter yield[b] (kg/ha)
Hykon	5200 a
Kondinin	2940 b
Troodos	2860 bc
Sirint	1980 cd
Wilton	1840 d
Olympus	1600 d

[a]Each plot sampled by four squares (30 x 30 cm) in June 1978.

[b]Means followed by the same letter are not significantly different at the 5% level by Duncan's multiple range test.

By the end of the fourth year (1980-81), during which the seasonal rainfall was below average, the Hykon variety maintained its superiority over the other varieties in the trial (Table 2). Troodos replaced Kondinin as the second best variety. Of equal importance is the fact that in that poor-rainfall year, all plots produced a better than average ground cover. We attribute this to the invasion of naturalized grasses and forbs from outside the rose-clover-seeded plots. These plants grew in response to the nitrogen fixation that had occurred during the preceding three years of rose clover growth.

Table 2. Fourth-year ground cover production of the plots of rose clover varieties planted at north Escondido I-15 embankment site.[a]

Variety	Dry-matter yield (kg/ha)[b]		
	Rose clover	Naturalized grasses and forbs	Total
Hykon	177	2547	2724
Kondinin	32	2053	2085
Sirint	18	2211	2229
Troodos	106	2269	2375
Wilton	1	2505	2508
Olympus	0	2575	2575

[a]Each plot sampled by four squares (30 x 30 cm) on April 16, 1981.

[b]Yields are average of two reps.

The 1980-81 plant production, plus residue build-up from previous years, was quite adequate to provide highway right-of-way erosion protection for the initial rains of the fifth season while plant growth reestablished itself.

COMPARISON WITH GRASSES

Rose clover was also compared with annual ryegrass and Blando brome, for erosion control and persistence. In the first growing season, both annual ryegrass and Hykon were visually estimated to be slow in covering the soil during the cool, early part of the growing season (December-February). No real difference between them showed up until March, when moisture stress began to occur. During March and April, Hykon grew more, attaining 90% plant cover by the flowering period. Annual ryegrass has a longer maturation season than Hykon. Growth tapered off in early April as soil moisture was depleted, attaining only 40% cover by the end of the first growing season. Rainfall apparently was not adequate for annual ryegrass to mature, and no seed was produced. Thus, by the third year, the clover plots had abundant seed and nitrogen, whereas the ryegrass plot had neither.

In the first growing season, Hykon and ryegrass had similar dry matter yield, but by the third season the Hykon yield was almost six times that of the ryegrass. By then the ryegrass samples were a mixture of volunteer red brome (Bromus rubens) and forbs, as well as barley from the straw and some ryegrass, whereas the Hykon sample was predominantly Hykon. Therefore, the ryegrass planting was deteriorating while the Hykon stand was improving (Table 3).

Table 3. First- and third-year production of Hykon rose clover and annual ryegrass on south Escondidio I-15 off-ramp.

Variety	Dry-matter yield[a]	
	1st year	3rd year
Hykon rose clover	2000	6020
Annual ryegrass	1420	1060

[a]Average of two 30-cm-square samples from each plot in first year (late May 1977) and two 1-meter-square samples from each plot in third year (June 1979).

In the Blando brome trial, the Hykon rose clover outyielded this grass during the above average rainfall year of 1977-78 (5200 kg/ha compared with 4710 kg/ha).

DISCUSSION

Grasses on San Diego County roadsides must be fertilized with nitrogen to maintain an adequate ground cover. However, Rose clover, if properly inoculated, supplies nitrogen to the soil and thus maintains good ground cover without fertilization. During the establishment year of 1977-78, the 5200-kg/ha yield of Hykon had 13.8% protein. Assuming that 90% of the nitrogen produced was in the tops, 127 kg/ha nitrogen was left on the site to be cycled back to subsequent plant growth. This is equivalent to 635 kg/ha of ammonium sulfate.

These results should encourage engineers and landscape architects to place early maturing rose clovers in specifications for erosion control on many of the construction sites at lower elevations (below 3600 ft (1100 m)). Present estimates are that some 618 ac (250 ha) of State Highway rights-of-way have been seeded with this species since the program was started in 1975. In San Diego County, this clover has become a standard in erosion control mixes for State Highway construction.

ACKNOWLEDGMENTS

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RIGHT-OF-WAY REHABILITATION MONITORING USING OBLIQUE AERIAL PHOTOGRAPHY

R. J. Stedwill[1] and R. E. Cooper[1]

ABSTRACT.--Following the construction of the Squaw Rapids to The Pas 230 kV transmission line in east-central Saskatchewan in Spring 1980, an oblique air photo monitoring program was undertaken to determine the extent of revegetation, soil disruption and problem areas. Air photos were taken in June and October 1980, and September 1981, with a preliminary ground truth study undertaken during the summer of 1981 specifically investigating revegetation composition and creation of ruts.

This is a relatively inexpensive method of monitoring revegetation and other changes in the right-of-way and is a useful long-term tool for right-of-way management.

INTRODUCTION

Saskatchewan Power Corporation (SPC), the prime electrical and gas utility of Saskatchewan, initiated negotiations with Manitoba Hydro of Manitoba during the early part of 1977 to determine the possibility of a third interconnection between the two utilities. Two existing interconnections were located at Kennedy and Yorkton (Fig. 1). A northerly point was preferred between SPC's Squaw Rapids Switching Station and Manitoba Hydro's Rahls Island Switching Station near The Pas, Manitoba.

Environmental Concerns

Saskatchewan's Environmental Review Process. A proposal suggesting five route alternatives was examined in early 1978 by the Environmental Assessment Secretariat of Saskatchewan Environment, and an "overview" Environmental Impact Statement (EIS) submitted in June of 1978. After examination by a board of inquiry, a 72.5 mi (116.6 km) route was approved in February 1979 (Fig. 2).

Approval included a number of conditions, one of which required monitoring clearing of the right-of-way and construction of the line. Clearing and construction began in February 1979 and were inspected by Corporation personnel to ensure that all environmental requirements and safeguards were being adhered to. Biweekly reports were filed with the approval issuing agency, usually accompanied by photographs of the line and

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1 Saskatchewan Power Corporation, Regina, Saskatchewan, Canada.

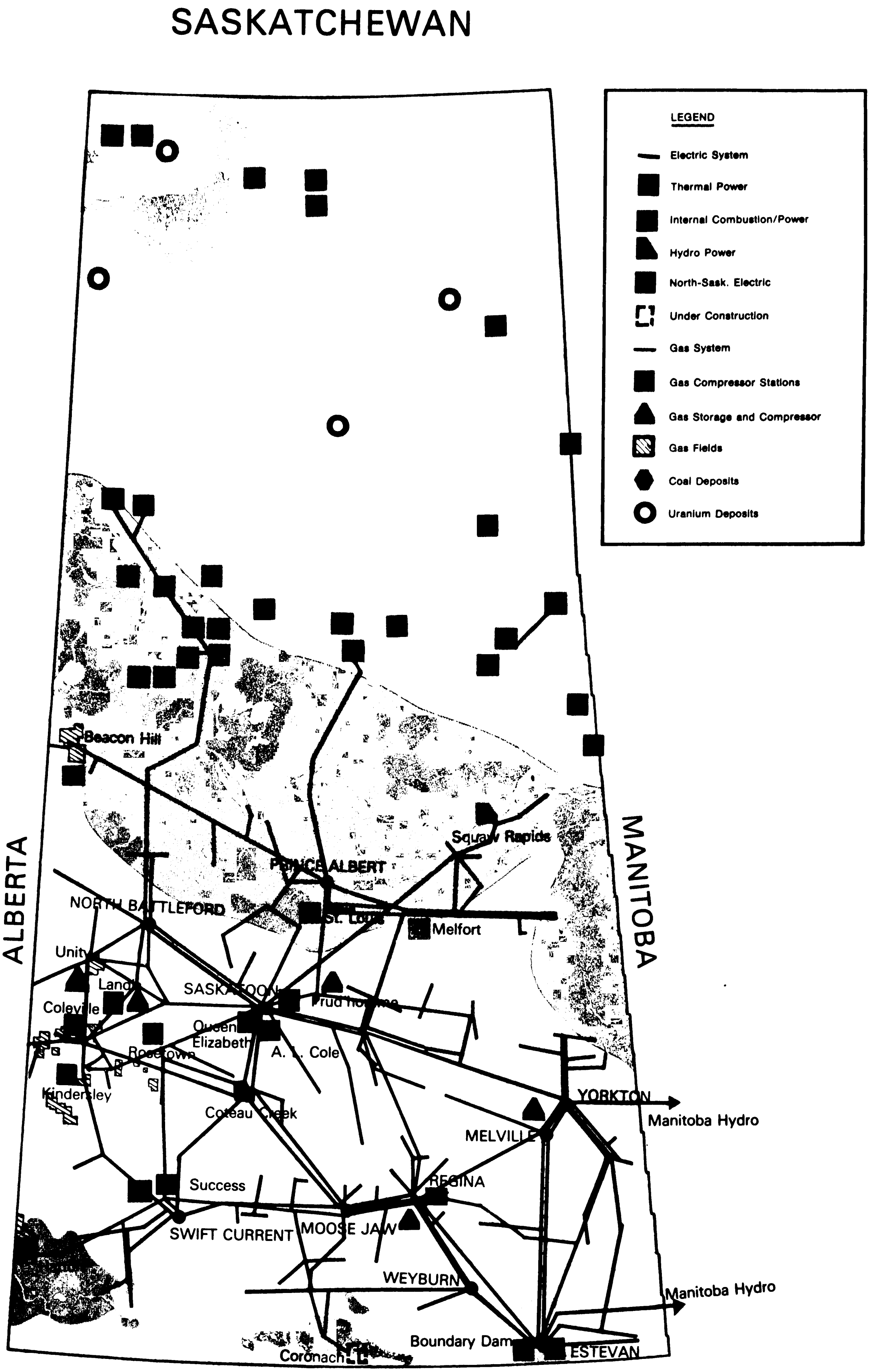

Figure 1. Existing interconnections between Manitoba and Saskatchewan electrical grids.

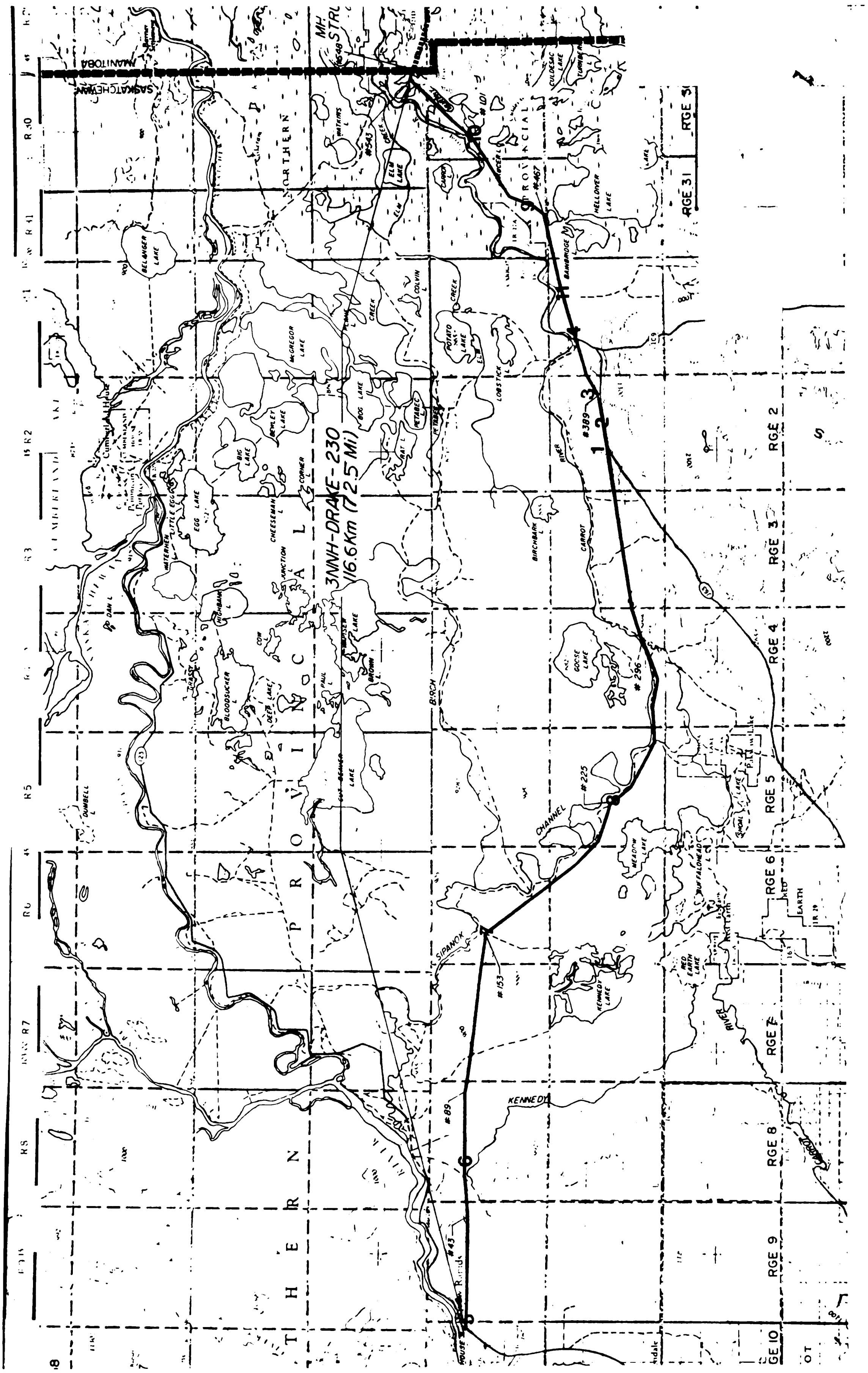

Figure 2. 230 kV route plan Squaw Rapids-The Pas.

right-of-way. These reports were submitted until construction and clean up were complete.

METHODS

Oblique Aerial Photography Monitoring

Oblique aerial photographs using 35 mm film were taken beginning in mid-1980 to permanently record the line as built, to identify and record areas where problems had been encountered such as muskeg and water crossings, and to document areas along the right-of-way which had suffered some environmental damage, primarily rutting.

The first flight of the line occurred June 17, 1980, at an altitude of approximately 394 ft (120 m). The second flight occurred approximately four months later, with the third flight being flown about a year after the second. All flights were from west to east.

A ground truthing study was conducted during the summer of 1981. Eleven sites (Fig. 2) were surveyed, with species lists made and voucher specimens taken.

RESULTS

Aerial Photography

The original monitoring during construction of the line and the first flight disclosed severe soil disturbance and rutting along the right-of-way. The right-of-way was cleared during the winter on the muskeg; however, construction in the winter and dry part of the summer, as preferred, was not possible due to a combination of a late spring and a wet summer and fall during construction of the line in 1979, resulting in severe disturbance in some locations.

Frames from photographs taken at different times can be isolated for before and after comparisons and give the viewer the impression of actually being in the aircraft. For example, the two subsequent flights revealed that vegetation growth during the summers of 1980 and 1981 was considerable. Detailed analyses are difficult, however, because of different angles of obliqueness, varying altitudes between frames, uncoordinated frame overlap, and some difficulties with shutter speed and/or focusing.

The photographs also form a relatively inexpensive and excellent record of what was actually built. They have been used in discussions regarding creek crossing construction and structure location relative to road access.

Ground Truthing

Eleven sites were visited to conduct a study of the vascular plants located on and adjacent to the right-of-way. The vegetation survey identified 208 taxa in 52 different families. A second survey is planned for 1982 to compare the distribution or relative abundance of different species. A 1982 aerial photography survey is also planned. Ground surveys did not detect the extensive evidence of rutting seen on aerial photographs. Only two examples of rutting were found on the ground.

Although lacking data on species abundance or distribution, it is clear that vegetation has established itself well in the period since construction.

The ground study identified five of Saskatchewan's rare plants: Potamogeton epihydrus, Elymus glaucus, Polygnum scandens, Diervilla lonicera, and Sambucus raremosa.

DISCUSSION

Oblique aerial photography offers a perspective which makes identification of soil disturbance possible, where not picked up on the ground studies. Photography also confirms the extent of revegetation, and compliments the detail of ground studies.

RECOMMENDATIONS

Future flights should be taken in the fall prior to leaf drop so that a full summer's growth may be evaluated. Some control must be maintained on altitude and angle of photography to ensure more equal analysis of films. This may be accomplished by proper sequencing of check points on the ground.

Oblique aerial photography is a good tool for the purposes of communication between expert and layman and when either one or both cannot view the line personally and for situations other than vegetation monitoring.

Although not as definitive as the ground truth study, the use of oblique aerial photography offers a broad perspective of the overall line, identifies problem areas immediately, and identifies some characteristics of the right-of-way not readily seen from the ground; all at reasonable cost.

ACKNOWLEDGMENTS

Photography was flown by Western Aerial Transmission Surveys.

USE OF LOW-LEVEL PHOTOGRAPHY TO MANAGE TRANSMISSION LINE RIGHTS-OF-WAY

Joe A. Johnson[1]

ABSTRACT.--Since 1974, Bonneville Power Administration (BPA) has been using low-level color photography of its rights-of-way to help identify areas requiring brush control, line relocations, site conditions for future line taps, design types of construction and their relocations. While the low-level photography system was originally started in the Lower Columbia area for use as an aid in contract brush preparation, all four areas in the BPA system have now adopted it to facilitate line maintenance. Using the low-level system has resulted in decreased trips to the field, better site-specific management, and substantial monetary savings.

INTRODUCTION

In 1973, BPA began to experiment with the use of aerial photography to identify maintenance problems on powerline rights-of-way (ROWs). At that time, the commercially available aerial product was low-level color strip transparencies taken from a camera mounted horizontally in a fixed-wing aircraft. The resulting photography recorded what was behind the aircraft, rather than what was ahead and was accompanied by a tape narrating ROW conditions.

Due to performance and contracting problems, BPA decided to develop a more reliable system. Early efforts consisted of taking photographs of the ROW from a helicopter with a hand-held camera and taping the rolls of exposed film together to form strip photography. Beginning with the purchase of a motorized camera in 1974, BPA has since developed a system which serves a variety of purposes resulting in significant dollar and manpower savings. The present system produces continuous color strip photography of every powerline in the BPA system. The color transparency strips can be mounted on reels and conveniently viewed in any office on a Dukane Model 27A25 viewer. The low-level photography displays ROW vegetation, buildings, gardens, and bodies of water.

DISCUSSION

Originally, the low-level photography system was designed to identify areas beneath powerlines where brush control was needed. Typically,

1 Department of Energy, Bonneville Power Administration.

photography is used during the winter season to review the ROW and select areas for contract brush control in the spring. The low-level photography produces detailed instruction for the contractor and is used with a Plan and Profile (P&P)--an illustration of topographic features, land use patterns, ownership, and major features of the existing electrical system--and high altitude photography, which can be used to locate major features, such as powerlines and access roads. In this example, high level photography functions as a photographic map. (If necessary, the instructions produced with these aids can specify accurate locations and detailed prescriptions for very small tracts.)

Although originally developed for use in the brush control program, low-level photography has become an integral part of many BPA planning processes and activities. In addition to its use in developing a site-specific vegetation management prescription, it is used for work planning (e.g., scheduling brush crews); to identify access routes, appropriate equipment, and potential danger trees; to check the condition of access roads, including necessary erosion control measures, or to forecast or modify road improvement contracts; to locate noxious weeds; and to verify office records for brush control or other ROW activities.

Low-level photography has also demonstrated its utility in locating new lines or access roads, line revisions, or line taps. Preliminary review of the low-level photography is helpful prior to field activities, such as timber cruising or land surveying. It can also be used to verify the type of structure presently on a ROW or the need for airway marker balls, airway lighting, or other installation details associated with various structures. In emergencies, such as unanticipated outages, low-level photography is helpful for planning the appropriate corrective actions. For those unfamiliar with an area, such as new foremen or contractors, low-level photography provides essential background information. Low-level photography has also been used to verify public or landowner complaints and to check out problem situations, which has enabled BPA to respond more promptly. All of the uses described above have resulted in a savings of dollars, manpower, or travel expenses, and, in some case, have improved BPA's ability to respond to public or landowner concerns.

Low-level photography is used with a computer-based data storage and retrieval system (ROWDATA). Together, low-level photography and the computer-based data system form the basis for site-specific vegetation management prescriptions and a historical record.

The present BPA photography system uses a Nikon F2AS camera with the following accessories: 85mm F-2.0 lens, 250 exposure back, MD-2 motor drive, 52mm polarizing filter, control attachment DS-1, EE aperture servo, and pistol grip with electrical connecting cable. Additional accessories used with this system include 250 exposure film cassettes, bulk film cassette loader, Bungi cords for hanging camera in helicopter, battery chargers for rechargeable batteries, and 35mm film splicer.

The camera is mounted on a Bell 206 Jet Ranger, and the only alteration to the aircraft is the installation of two small hooks placed on the passenger side where the fuselage connects to the windshield. Flights are made 25 to 50 ft above the conductor (approximately 100 ft above the ground, depending upon the height of the conductor). The ideal flying speed is 90 mph, but speeds may range from 90 to 100 mph, depending upon the amount of light available. Because the polarizing filter reduces light by approximately two and one-half times, light must be bright enough to shoot at a minimum of 1/250 second. On a bright day, 1/500 second is recommended. Photography is taken while flying down the center conductor, photographing ahead on line. Each line is photographed individually, even where there are multiple lines on a right-of-way. Each mile marker (located on top of the first tower in each mile) is photographed separately, making additional numbering of the photographs unnecessary. Generally, one exposure is required for each tower and also for the area between spans.

Photography should be scheduled for a season when the leaves are still on the hardwoods. Time of day may also be important to reduce shadows. For north-south lines, photographing at noontime avoids the long shadows cast by trees on the ROW side in the morning. Also, for north-south lines, overcast skies are desirable to avoid flying directly into the sun. When photography is complete, the film is developed, edited, spliced, and mounted on 100-foot plastic spools. Film can be viewed on a Dukane Model No. 27A25 viewer. Approximately 75 to 90 miles of right-of-way photography is contained on a 100-foot roll of film (mileage is slightly higher for steel structure lines than for wood pole lines). An average of 250 to 300 miles of photography can be taken in a single day, using the system described above. This system requires only two people, the pilot and a photographer.

SUMMARY

Although originally developed as an aid in brush control work, the low-level photography system is now used for a variety of planning purposes and activities. Its use has been expanded from a single area to all four of BPA's areas. The low-level photography system has demonstrated its cost effectiveness. Its use has significantly contributed to the design and maintenance of a reliable powerline grid system.

COMPUTER-AIDED RIGHT-OF-WAY MANAGEMENT

Winston S. Acton[1]

ABSTRACT.--The Bonneville Power Administration has developed a computer-based data storage and retrieval system (called ROW-DATA) for managing its 120,000 acres (48,600 ha) of power line rights-of-way. The system enables the manager to select the size of each of the management units based on the various environmental and site specific considerations. The capabilities of this system empower the manager to maintain massive quantities of data records with only a tiny fraction of the time and effort of the manual recordkeeping system. One of the most significant benefits of this system is the ability to produce numerous reports or summaries based on the various criteria selected by the manager. Thus, a very time consuming manual task is reduced to mere minutes using the computer. These capabilities make this system a powerful tool for the right-of-way manager.

INTRODUCTION

Bonneville's transmission system traverses the four Pacific Northwest states of Washington, Oregon, Montana, and Idaho. The significant differences in climatic, geological and geographic conditions existing between the states cause a multitude of variations in the growth patterns of the vegetation species. This, in turn, results in the need for a variety of methods and materials for controlling the growth of the vegetation. The ROWDATA system permits the right-of-way manager to keep a close surveillance on the vast number of units which comprise the rights-of-way. The ability of the manager to maintain such a close surveillance is totally dependent on the reliability of the data base. The data base, therefore, is a vital key to the effectiveness of using the computer as an aid to proper management of rights-of-way.

DISCUSSION

Right-of-way data is compiled on a standard eighty-column punch card, preprinted to identify data base items for the user (Fig. 1). Coding is as follows:

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1 Bonneville Power Administration, Vancouver, WA 98663.

RIGHT-OF-WAY DATA

Program: ROWDATA　　Coded By:　　Date:　　Job Code:　　Page　of

IDEN	ADNO	1 2 3 4
	MIL	5 6 7
	SR	8 9
	S	10
FROM	±	11
	DIST	12 13 14 15
DIMENSIONS	LNGTH	16 17 18 19 20
	A-WDH	21 22 23 24
	O-WDH	25 26 27 28
	O-ACR	29 30 31 32
LAND	S&C	33 34 35
	OWN	36 37 38
	C	39
	W	40
TREATMENT	MO	41 42
	YR	43 44
	MD	45 46
	A	47
	RTE/AMT	48 49 50 51
	MIXTUR	52 53 54 55 56 57
FUTURE		58 59 60 61 62 63
USER1		64 65 66 67 68
USER2		69 70 71 72 73
USER3		74 75 76 77 78
CN		79 80

For RS ⟶ | ± ADNO | ± MIL | ± SR | S |

End COMMENTS ⟶

⟵ STOP IDEN ⟶

TEST FORM BPA 1415 3-9-81

Test Form BPA 1415 3-9-81

Figure 1

I. DATA RECORD

Item	Cols.	Description and Coding
ADNO	1-4	Four-digit ADNO number for ROW. Must be numerical. A compressed abbreviation for AREA, DISTRICT, and Transmission line NUMBER. AREA (A) - A one-digit code identifying each of the four geographical quadrants of the power system as shown in Appendix IV. DISTRICT (D) - A one-digit code identifying each of the subdivisions of the maintenance AREA. NUMBER (NO) - A two-digit code identifying each transmission line located within the boundaries of the DISTRICT. Historically, Bonneville's Transmission lines are identified by a name which is composed of the two terminal substation names. Since names are too cumbersome for computer programs, each line name was assigned this two-digit number.
MIL	5-7	One to three-digit mile number of reference structure, right justified. Leading blanks are automatically replaced by zeros. Resulting field must be numerical. A three-digit code is required because many of Bonneville's power lines exceed 99 miles in length.
SR	8-9	One or two-digit structure number of reference structure, right justified. Leading blank is automatically replaced by zero. Resulting field must be numerical. A structure may be a steel tower, a wood pole structure, or any other structure that supports the conductor. A two-digit code is required since the number of structures per mile often exceeds 9.
S	10	One-letter suffix identifying a management unit within a span. Blank if the management unit includes the whole span ahead of the reference structure. Must be alphabetic. A single code letter is used rather than a number because this provides the manager with greater versatility in describing the management unit. In this program each management unit is currently represented by an equivalent rectangular area. Some of the factors causing this minor disparity are bodies of water (streams, rivers, lakes, and ponds), canyons, and boundary lines (state, county, and ownership).
+DIST	11-15	A plus sign (+) in column 11 followed by a one to four-digit number, right-justified, indicating the distance ahead of the reference structure that the management unit begins.

Item	Cols.	Description and Coding
LNGTH	16-20	A one to five-digit number, right justified, indicating the length of the management unit in feet. Leading blanks are automatically replaced by zeros. If the resulting field is not numerical, it is automatically set to zero.
A-WDH	21-24	Acquired width. A one to four-digit number including one decimal place, right justified, indicating the acquired ROW width in feet. Leading blanks are automatically replaced by zeros. If the resulting field is not numerical, it is automatically set to zero.
O-WDH	25-28	Occupied width. A one to four-digit number including one decimal place, right justified, indicating the occupied (maintained) ROW width in feet. Leading blanks are automatically replaced by zeros. If the resulting field is not numerical, it is automatically set to zero.
O-ACR	29-32	Area. A one to four-digit number including one decimal place, right justified, indicating the management unit acreage. If the input field is all blank, the value is automatically calculated as length times occupied width divided by 43560, then if the calculated value is greater than 999.9, it is set to 999.9. If the input field is not all blank, leading blanks are automatically replaced by zeros, then if the resulting field is numerical, it becomes the value, but if the resulting field is not numerical, it is automatically set to zero.
S&C	33-35	A three-letter code indicating the state and county the management unit is in.
OWN	36-38	A three-letter code indicating the fee owner of the management unit.
C	39	A one-letter code indicating the management classification of the management unit.
W	40	A one-letter code indicating whether weed control is required (1) at structure sites, (2) on the ROW, (3) both within the management unit, or (4) neither.
MO	41-42	A two-digit number indicating the month the management unit was treated. (The leading zero is coded for months 01 through 09.)

Item	Cols.	Description and Coding
YR	43-44	A two-digit number indicating the year the management unit was treated.
MD	45-46	A letter code indicating the treatment method used on the management unit.
RTE	47-51	A one to three-digit number, right justified in a five-character field, indicating the rate (gallons or pounds per acre) herbicidal mixture was applied to the management unit. If the input field has an "A" in column 47 followed by a one to four-digit number, right justified, indicating the total amount of material applied to the management unit, then rate is automatically calculated as amount divided by occupied acres. In either case, leading blanks are automatically replaced by zeros. If the resulting field is not numerical, or if there is calculating error, rate is automatically set to zero.
MIXTUR	52-57	A six-character code indicating the herbicidal mixture used on the management unit.
FUTURE	58-63	A six-character code indicating the approach (contract or force account), method, fiscal year, the fiscal quarter of planned future treatment on the management unit.
USER	64-78	A fifteen-character field left over at the end of the data record text. On input, any coding in this field will be stored in the data record but it will not be printed in the output books.
CC	79-80	On data records, column 79 is always blank and column 80 contains the numeral 0. On input transactions, columns 79-80 contain control coding.

Data Processing

The driving program is written in COBOL and processes the data to produce a readable, double-spaced printout. When bound into a book, the printout is very useful in checking a particular unit, a group of units, or even an entire line. Summaries can also be produced for selected criteria. For example, the manager may need a listing of all the units treated in 1979 using a certain mixture on a particular large owner's land. By entering the criteria, a listing of only a few hundred units can be selected from the many thousands contained in the data base. The units requiring treatment in future years can be forecast.

SUMMARY

ROWDATA, which is Bonneville's most recently revised ADP management system, has been operational for nearly one year. It has proved to be successful for Bonneville's purposes. This management system has been tailored to meet this organization's goals. The information presented herein should be sufficient to enable any other organization to modify and adapt this system to meet its requirements.

PRELIMINARY EVALUATION OF GARLON HERBICIDE AS A TOOL FOR NATURAL GAS PIPELINE RIGHT-OF-WAY MANAGEMENT AT SOUTHERN WEST VIRGINIA

Richard J. Hendler[1], Phillip E. Reynolds[2], Walter D. Betsch[3], William Ollice[4], and John Williamson[5]

ABSTRACT.--Dow Chemical Company, U.S.A. and The Columbia Gas Transmission Corporation are currently working together to develop an effective chemical vegetation management program for tree overgrown natural gas pipeline rights-of-way located in West Virginia. Such rights-of-way are presently obscured from aerial view making rapid helicopter inspection of the lines for possible gas leaks impossible. If a chemical spray program can be developed for reclaiming tree overgrown pipelines, helicopter inspection will be possible allowing cost effective and less labor intensive operational maintenance of the lines. As part of our joint effort to develop such a program, Dow and Columbia tested the efficacy of an EPA recently labeled herbicide, Garlon* (triclopyr), on a tree overgrown natural gas pipeline right-of-way located near Williamson, West Virginia.

Aerial spraying was accomplished during July 1981 with the intent of quantifying the efficacy of Garlon on large trees. Although the efficacy of Garlon on small trees is well established, its efficacy on larger trees (6 inches or more) has not been well documented. Preliminary efficacy data obtained from the test are reported here. Percent leaf brownout and defoliation data are presented for 21 tree species of varying diameter (1-20 inches) based upon a field inventory of numerous plant

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4 Columbia Gas Transmission Corporation, 1700 MacCorkle Avenue, S.E., Charleston, WV 25314.

5 Columbia Gas Transmission Corporation, P. O. Box 382, Inez, KY 41224.

*Registered trademark of The Dow Chemical Company, Midland, MI.

specimens 27 and 55 days following spraying. In the present report, preliminary efficacy data resulting from treatment with Garlon 3A alone versus treatment with a mixture of Garlon 3A and Tordon* 101 (picloram + 2,4-D) is discussed.

INTRODUCTION

As mandated by federal law, natural gas transmission companies must have a periodic pipeline patrol program to inspect their pipelines for leaks and other factors which may affect their safety and operation. Leakage inspection is most easily accomplished by inspecting the vegetative ground cover for brownout caused by gas leaks. In terrain with slight or moderate relief, inspection may be accomplished by walking the rights-of-way. In steep mountainous terrain such as is common in West Virginia and the Appalachian Region, inspection of rights-of-way by walking is time-consuming and poses potential safety hazards to employees. In all terrains, optimal inspection of rights-of-way is accomplished by helicopter patrol. In order for a helicopter patrol to be successful in spotting vegetative ground cover brownouts, woody vegetation on the rights-of-way must be controlled. The control of woody vegetation is also necessary should ground inspection and repair of a suspected leak prove necessary.

A number of methods for controlling woody vegetation growth on natural gas pipeline rights-of-way exist, including aerial herbicide application, ground herbicide application, mowing and manual removal. The method chosen is a function of time, cost and terrain. In steep, mountainous terrain, similar to that in West Virginia, the most practical method for vegetation control is helicopter spraying of rights-of-way (Spangler, 1979). Many natural gas pipeline rights-of-way in West Virginia are overgrown with large trees (typical sizes include 60 ft (19 m) tall, 15 in (6 cm) diameter and 50 years old) that obscure the location of the right-of-way when viewed from the air. This problem is specific to natural gas pipeline rights-of-way, and infrequently occurs in instances involving electric transmission rights-of-way since these must be kept clear of brush in order to prevent power outages. Prior to the recent EPA suspension of 2,4,5-T use on rights-of-ay, this herbicide, in combination with other herbicides, was considered to be particularly effective in rendering tree-covered rights-of-way clear for helicopter inspection.

As a result of the void created by the suspension of 2,4,5-T, an environmentally-desirable herbicide that controls a broad spectrum of undesirable brush species is being sought. The EPA approved and labeled herbicide, Garlon*, is believed to be such a herbicide. Garlon efficacy has been documented for smaller trees than those typically found growing on tree overgrown West Virginia natural gas pipeline rights-of-way (Byrd et al., 1974; Byrd et al., 1975a; Byrd et al., 1975b; Ryder, 1976; Voeller et al., 1976; Byrd et al., 1977a; Byrd et al., 1977b; Stoin, 1977; Byrd and Colby, 1978; Fears and Dickens, 1978; Lichy, 1978). The extensive diversity of the tree cover as well as the size and the degree of tree replication employed in this study provides the most severe test of Garlon efficacy to date for right-of-way vegetation management. Should Garlon prove to be effective in killing large trees, it is likely it will provide a new and powerful tool for managing these rights-of-way.

METHODS

Site Description

A forest-covered, natural gas pipeline right-of-way located in Mingo County, West Virginia, was selected as the test site (Fig. 1). The right-of-way chosen is Columbia Gas Line B-18, and occurs on land owned solely by Cotiga Land Development Corporation. The right-of-way passes through the Miller's Creek Watershed, located between Kermit and Williamson, West Virginia, adjacent to the Kentucky border. The watershed ranges from approximately 500 to 1700 ft (152-518 m) in elevation. The right-of-way chosen for the study parallels the Parker Fork of the watershed and is approximately 1200 ft (366 m) at its highest elevation and 800 ft (244 m) at its lowest elevation. Forest cover at the site is mixed mesophytic and consists of at least 35 tree species (Braun, 1950). Land uses include coal, oil, timber and natural gas production.

Helicopter Spraying

During the summer of 1980, four test plots (Fig. 1) were established along Line B-18 at the Miller's Creek Watershed, each approximately 2 acres (0.8 ha) in size. On July 29, 1981, two of the test plots (areas 3 and 4) were sprayed aerially using a helicopter equipped with MICROFOIL BOOM** having .060 in (0.15 cm) nozzles. Herbicides were applied by Mr. James Murphy of Minit-Men Helicopters based out of Columbus, Ohio. Area 3 was treated with a Garlon 3A mixture consisting of 3 gallons of Garlon 3A concentrate plus 22 gallons of water equalling a total volume delivery of 25 gallons spray per acre. Area 4 was treated with Garlon 3A plus Tordon* 101 (picloram 2,4-D) mixture consisting of 1.5 gallons of Garlon 3A and 2 gallons of Tordon 101 with 21.5 gallons of water equalling a total volume delivery of 25 gallons per acre. The right-of-way was treated to a width of 40 ft. Helium-filled weather balloons were used to mark the test plots.

Efficacy Inventory

On August 25, 1981 (27 days) and on September 22, 1981 (55 days), an inventory of sprayed trees was made. For purposes of this report, only trees directly sprayed, as opposed to those side-trimmed or crowned, are discussed. On both dates, these trees were subjectively evaluated for percent brownout. On September 22, the trees were additionally evaluated, prior to the onset of autumn coloration, for their extent of defoliation. Defoliation was evaluated subjectively using an index ranging numerically from 0 to 5: 0 being no defoliation and 5 reflecting complete defoliation. Trees evaluated on the two dates were numerically tagged so that a follow-up evaluation for percent kill can be determined. Evaluation for percent control is planned for May 1982.

**Registered trademark of Union Carbide Agricultural Products Company, Inc.

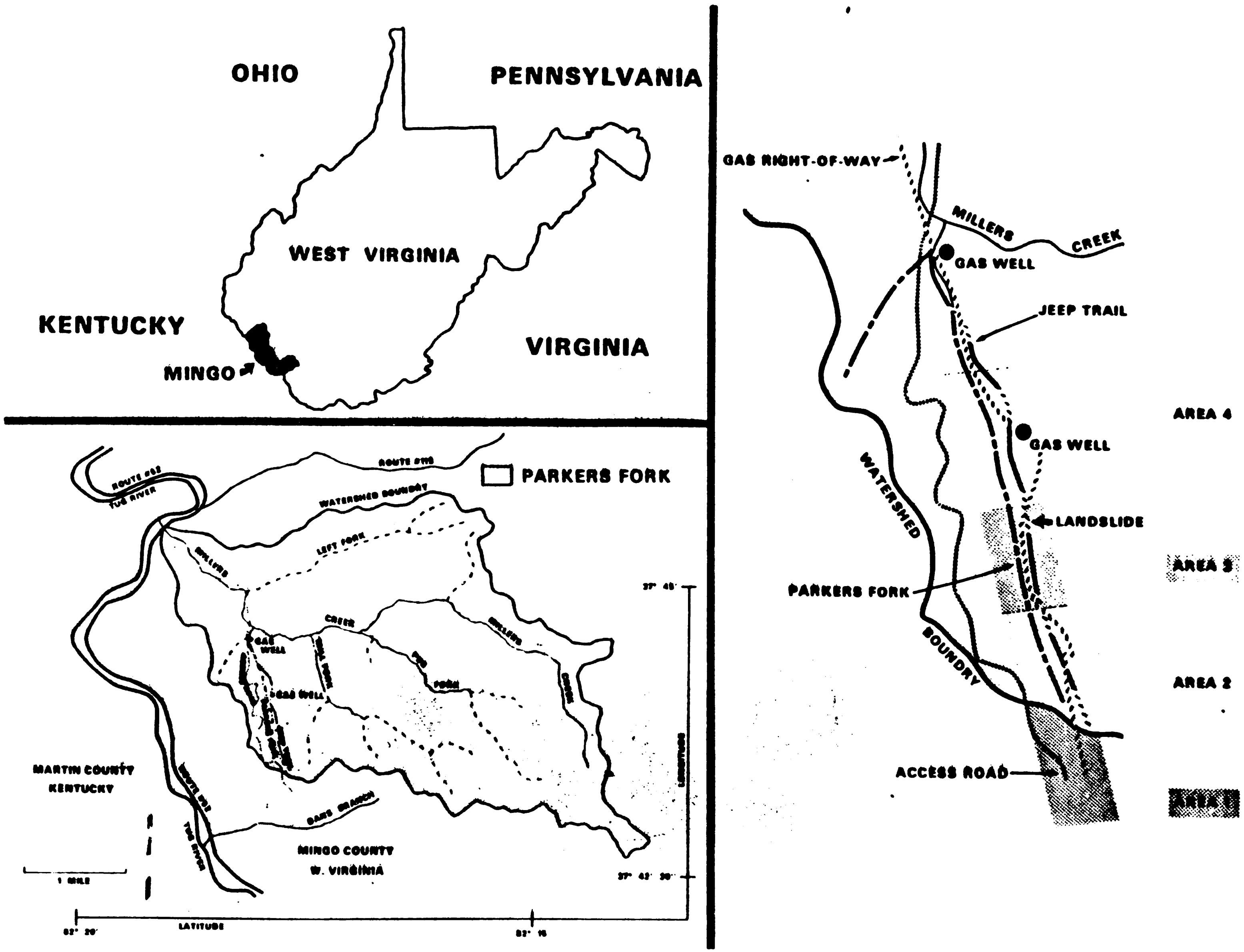

Figure 1. Map showing the location of the Miller's Creek Watershed.

RESULTS

Effects of Herbicide Treatment, Tree Species and Time of Brownout

Table 1 reveals that a mixture of Garlon 3A and Tordon 101 generally produced higher percent leaf brownout for nearly all tree species when compared with Garlon 3A alone. Additionally, higher percent brownout values were generally observed 55 days after spraying. Higher percent brownout values for redbud (*Cercis canadensis* L.) and sugar maple (*Acer saccharum* Marsh.) are especially noticeable 55 days after spraying. Variation in percent brownout for various tree species is evident. Relatively higher percent brownout values were observed for tulip poplar (*Liriodendron tulipfera* L.), black birch (*Betula lenta* L.), dogwood (*Cornus florida* L.), and white oak (*Quercus alba* L.) whereas lower percent brownout values were noted for shagbark hickory (*Carya ovata* (Miller) K. Koch), white ash (*Fraxinus americana* L.), magnolia (*Magnolia virginiana* L.) and cucumber (*Magnolia acuminata* L.). Variation in percent brownout for species in the oak family appears to exist. Percent brownout is greatest for white oak, least for northern red oak (*Quercus rubra* L.), and intermediate for American beech (*Fagus grandifolia* Ehrhart) and black oak (*Quercus velutina* Lamark) 55 days after treatment with Garlon 3A alone.

Effects of Tree Species Diameter on Brownout

Lower percent brownout values were observed for trees of increasing diameter treated with Garlon 3A alone (Table 2A). A similar trend seems to hold for trees sprayed with a mixture of Garlon 3A and Tordon 101 (Table 2B). Examples include white oak 27 or 55 days after spraying (Table 2A), shagbark hickory 55 days after spraying (Table 2A), and tulip poplar 27 days after spraying (Table 2B). Although a decrease in brownout appears to result with trees of increasing diameter, it also appears that larger diameter trees treated with a combination of Garlon 3A and Tordon 101 exhibit slightly higher percent brownout values than those treated with Garlon 3A alone. Examples of this may be observed for white oak, shagbark hickory and beech. Tables 2A and 2B confirm that higher percent brownout values occurred 55 days following spraying for all tree size classes.

Nearly all understory trees are in the 1 to 6 inch diameter class. Higher percent brownout values were observed for trees in this 1 to 6 inch class (Tables 2A and 2B), which demonstrated that herbicide penetration of the canopy occurred.

Defoliation Response of Trees to Herbicide Treatment

Leaf loss data 55 days after spraying is presented in Table 3. For some tree species in the 1 to 6 inch diameter class, slightly higher mean defoliation index values were observed following combined traetment with Garlon 3A and Tordon 101. Species exhibiting this response are shagbark hickory, dogwood, sugar maple, tulip poplar, cucumber, and red elm (*Ulmus fulva*). Additionally, 1 to 6 inch (2.54-15 cm) white ash and magnolia trees show higher index values when treated with both herbicides as contrasted with treatment with Garlon 3A alone. Still other tree species (1-6 inch diameter class) showed slightly lower mean index values following treatment with the Garlon 3A and Tordon 101 combination. Examples

Table 1

Percent brownout for various tree species following herbicide treatment

Species	Garlon 3A only				Garlon 3A + Tordon 101			
	27 days		55 days		27 days		55 days	
	%	n*	%	n	%	n	%	n
White oak (Quercus alba)	70	82	96	81	79	16	91	26
Shagbark hickory (Carya ovata)	31	15	64	26	46	11	75	27
Black birch (Betula lenta)	78	47	84	7	57	6	90	22
Flowering dogwood (Cornus florida)	82	11	86	5	95	18	68	27
Redbud (Cercis canadensis)	65	2	100	2	98	5	100	4
American beech (Fagus grandifolia)	44	10	66	17	64	5	81	14
Black oak (Quercus velutina)	--	0	89	5	--	0	68	4
Sugar maple (Acer saccharum)	42	7	87	7	65	11	92	26
White ash (Fraxinus americana)	27	4	43	3	75	8	100	4
Sweetbay magnolia (Magnolia virginiana)	14	4	10	1	36	4	55	2
Tulip poplar (Liriodendron tulipfera)	84	58	100	22	93	8	98	14
Sassafras (Sassafras albidum)	--	0	--	0	--	0	90	1
Hophornbeam (Ostrya virginiana)	--	0	--	0	100	1	100	2
Tupelo (Nyssa sylvatica)	94	4	70	5	92	4	100	7
Cucumber (Magnolia acuminata)	10	1	18	3	30	1	65	1
Red elm (Ulmus fulva)	87	26	100	6	98	2	100	2
Red oak (Quercus rubra)	59	10	59	14	72	2	20	1
Chestnut oak (Quercus prinus)	--	0	50	1	--	0	0	--
Sycamore (Platanus occidentalis)	100	2	100	3	--	0	0	--
Black locust (Robinia pseudoacaeia)	100	1	--	0	--	0	--	0
Staghorn sumac (Rhus glabra)	100	1	100	2	--	0	--	0
Buckeye (Aesculus glabra)	--	0	90	3	--	0	--	0

* n = number of trees observed

Table 2A

Percent brownout according to tree size following
Garlon 3A treatment

	Garlon 3A only											
	27 days						55 days					
	1-6" dbh		7-12" dbh		≥ 13" dbh		1-6" dbh		7-12" dbh		≥ 13" dbh	
	%	n*	%	n	%	n	%	n	%	n	%	n
White oak (Quercus alba)	76	49	64	29	52	4	97	51	98	26	80	4
Shagbark hickory (Carya ovata)	30	11	58	2	10	2	69	15	64	9	30	2
Black birch (Betula lenta)	78	46	70	1	--	0	95	5	55	2	--	0
Flowering dogwood (Cornus florida)	82	11	--	0	--	0	86	5	--	0	--	0
Redbud (Cercis canadensis)	65	2	--	0	--	0	100	2	--	0	--	0
American beech (Fagus grandifolia)	42	6	28	2	68	2	78	10	50	6	50	1
Black oak (Quercus velutina)	--	0	--	0	--	0	85	2	88	2	100	1
Sugar maple (Acer saccharum)	42	7	--	0	--	0	85	6	--	0	100	1
White ash (Fraxinus americana)	28	3	25	1	--	0	15	2	100	1	--	0
Sweetbay magnolia (Magnolia virginiana)	17	3	5	1	--	0	10	1	--	0	--	0
Tulip poplar (Liriodendron tulipfera)	85	54	--	0	76	4	99	18	100	1	100	3
Tupelo (Nyssa sylvatica)	92	3	--	0	100	1	70	5	--	0	--	0
Cucumber (Magnolia acuminata)	10	1	--	0	--	0	12	2	30	1	--	0
Red elm (Ulmus fulva)	87	26	--	0	--	0	100	6	--	0	--	0
Red oak (Quercus rubra)	44	6	82	4	--	0	54	6	51	5	82	3
Chestnut oak (Quercus prinus)	--	0	--	0	--	0	--	0	50	1	--	0
Sycamore (Platanus occidentalis)	100	2	--	0	--	0	100	3	--	0	--	0
Black locust (Robinia pseudoacaeia)	100	1	--	0	--	0	--	0	--	0	--	0
Staghorn sumac (Rhus glabra)	100	1	--	0	--	0	100	1	--	0	--	0
Buckeye (Aesculus glabra)	--	0	--	0	--	0	90	1	--	0	--	0

* n = number of trees observed

Table 2B

Percent brownout according to tree size following combined treatment with Garlon 3A and Tordon 101

	Garlon 3A + Tordon 101											
	27 days						55 days					
	1-6" dbh		7-12" dbh		≥ 13" dbh		1-6" dbh		7-12" dbh		≥ 13" dbh	
	%	n*	%	n	%	n	%	n	%	n	%	n
White oak (Quercus alba)	82	6	71	7	92	3	88	18	100	5	98	3
Shagbark hickory (Carya ovata)	50	10	--	0	10	1	76	24	92	2	30	1
Black birch (Betula lenta)	57	6	--	0	--	0	90	22	--	0	--	0
Flowering dogwood (Cornus florida)	95	18	--	0	--	0	68	27	--	0	--	0
Redbud (Cercis canadensis)	98	4	100	1	--	0	100	3	100	1	--	0
American beech (Fagus grandifolia)	55	4	--	0	100	1	80	13	--	0	100	1
Black oak (Quercus velutina)	--	0	--	0	--	0	68	4	--	0	--	0
Sugar maple (Acer saccharum)	65	10	--	0	65	1	93	25	--	0	80	1
White ash (Fraxinus americana)	75	8	--	0	--	0	100	4	--	0	--	0
Sweetbay magnolia (Magnolia virginiana)	36	4	--	0	--	0	55	2	--	0	--	0
Tulip poplar (Liriodendron tulipfera)	99	6	85	1	65	1	98	6	98	5	98	3
Sassafras (Sassafras albidum)	--	0	--	0	--	0	90	3	--	0	--	0
Hophornbeam (Ostrya virginiana)	.100	1	--	0	--	0	100	2	--	0	--	0
Tupelo (Nyssa sylvatica)	90	3	100	1	--	0	100	6	100	1	--	0
Cucumber (Magnolia acuminata)	30	1	--	0	--	0	65	1	--	0	--	0
Red elm (Ulmus fulva)	98	2	--	0	--	0	100	2	--	0	--	0
Red oak (Quercus rubra)	72	2	--	0	--	0	--	0	20	1	--	0

* n = number of trees observed

Table 3

Mean defoliation index values for various tree species following herbicide treatment

	55 days											
	Garlon 3A only						Garlon 3A + Tordon 101					
	1-6" dbh		7-12" dbh		≥ 13" dbh		1-6" dbh		7-12" dbh		≥ 13" dbh	
	$\bar{x}$	n*	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
White oak (Quercus alba)	1.5[a]	51	1.9	26	2.8	4	1.2	18	1.6	5	2.0	3
Shagbark hickory (Carya ovata)	1.3	15	1.1	9	1.0	2	1.4	24	1.0	2	1.0	1
Black birch (Betula lenta)	4.0	5	2.0	2	--	0	2.7	22	--	0	--	0
Flowering dogwood (Cornus florida)	1.4	5	--	0	--	0	1.5	27	--	0	--	0
Redbud (Cercis canadensis)	1.5	2	--	0	--	0	1.0	3	3.0	1	--	0
American beech (Fagus grandifolia)	1.9	10	0.6	6	0.0	1	1.5	13	--	0	2.0	1
Black oak (Quercus velutina)	2.5	2	3.0	1	2.5	2	1.2	4	--	0	--	0
Sugar maple (Acer saccharum)	1.3	6	--	0	3.0	1	1.5	25	--	0	1.0	1
White ash (Fraxinus americana)	1.0	2	3.0	1	--	0	4.0	4	--	0	--	0
Sweetbay magnolia (Magnolia virginiana)	2.0	1	--	0	--	0	3.5	2	--	0	--	0
Tulip poplar (Liriodendron tulipfera)	3.2	18	3.0	1	4.0	3	3.5	6	2.2	5	2.3	3
Sassafras (Sassafras albidum)	--	0	--	0	--	0	3.0	1	--	0	--	0
Hophornbeam (Ostrya virginiana)	--	0	--	0	--	0	3.5	2	--	0	--	0
Tupelo (Nyssa sylvatica)	2.2	5	--	0	--	0	2.0	6	1.0	1	--	0
Cucumber (Magnolia acuminata)	0.0	2	1.0	1	--	0	1.0	1	--	0	--	0
Red elm (Ulmus fulva)	3.3	6	--	0	--	0	3.5	2	--	0	--	0
Red oak (Quercus rubra)	1.2	6	1.2	5	2.7	3	--	0	0.0	1	--	0
Chestnut oak (Quercus prinus)	--	0	0.0	1	--	0	--	0	--	0	--	0
Sycamore (Platanus occidentalis)	2.3	3	--	0	--	0	--	0	--	0	--	0
Staghorn sumac (Rhus glabra)	2.0	1	--	0	--	0	--	0	--	0	--	0
Buckeye (Aesculus glabra)	3.0	1	--	0	--	0	--	0	--	0	--	0

[a]Defoliation index values range from 0.0 to 5.0. A value of 0.0 reflects no defoliation. A value of 5.0 reflects complete defoliation.

* n = number of trees observed

include white oak, black birch, beech, and tupelo. For certain tree species, an increase in mean index values was observed with increasing tree diameter, whereas other tree species exhibited an opposite trend. Examples of tree species showing an increase are white oak, red oak, black oak, sugar maple and white ash. Two species showing a decrease include hickory and beech.

DISCUSSION

Preliminary data presented in this paper suggest that Garlon 3A is an effective herbicide for controlling large trees on natural gas pipeline rights-of-way. Garlon 3A in combination with Tordon 101 appears to be a more effective chemical combination for controlling unwanted large tree growth. Percent tree kill data to be obtained in May 1982 will be compared with percent brownout and defoliation data presented in this paper.

Dow Chemical and Columbia Gas plan to apply Garlon 4 on Line B-18 during the summer of 1982. Such testing will allow for a complete evaluation of which herbicide formulation or which herbicide combination is more effective in controlling large tree growth.

During July 1981, sections of tree overgrown rights-of-way were marked for aerial spraying using helium-filled weather balloons. Although this method was effective, it will not be practical on a large scale basis. In preparation for anticipated aerial spraying of tree covered rights-of-way, Dow and Columbia are planning to test a dormant season chemical spray method for marking such lines. Testing of the method is planned for March 1982 on a natural gas pipline right-of-way near the Miller's Creek Watershed. If the dormant season marking method is successful, follow-up spraying of the marked pipeline right-of-way is planned for summer 1982.

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COMPUTER VEGETATION MANAGEMENT

Franklin J. Chan[1]

ABSTRACT.--The Pacific Gas and Electric Company is developing an automated record-keeping system to aid in the establishment and management of vegetation in extensive landscaped areas. Restoration of vegetation on disturbed sites due to the construction of power plants, transmission lines, gas lines, and utility roads is essential and required by regulatory agencies. The system, Computer Vegetation Management (CVM), is being developed to document pertinent data on species, environmental conditions, special problems, horticultural treatments, and follow-up work. Cost data for projects are also included. CVM has the capability to provide a wide range of reports including extensive historical records of projects or species to smaller, more specific reports on special subjects or problems and recommendations. The broad data base allows communicating information which can be applied to various management and research uses.

INTRODUCTION

In developing energy resources for the generation of electricity, utility companies are actively involved in restoring natural landscaped areas because much of the construction of power plants, transmission lines, pipelines, roads, and related facilities occurs in these areas. In addition, recreation and wildlife areas are developed in response to mitigation measures as conditions for use permits. The Pacific Gas and Electric Company is responsible for the revegetation of extensive areas at numerous projects throughout northern and central California. A wide range of environmental conditions are found in this region including the Sierra Nevada Mountains, the foothills, the central valley, the coastal areas, riparian and marshland areas, and the desert.

Although other computerized systems have been developed for tree inventories (Sacksteder and Gerhold 1979), few systems have been developed for revegetation purposes. A data base system is being utilized to record locations of rare plants and animals in California (Nature Conservancy 1981). The need to develop an in-house automated record-keeping system is essential with respect to the numerous projects, the wide range of

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environmental conditions, and the nature of revegetation projects. Computer Vegetation Management (CVM) is being developed to aid in establishing and managing vegetation. The goals of CVM include (1) assuring more successful plantings, (2) providing more effective management, (3) reducing maintenance and conserving energy and water resources, and (4) providing economical costs.

DISCUSSION

The Nature of Revegetation Projects

Understanding the nature of revegetation projects is important in establishing the value of a computerized record-keeping system. Revegetation or the establishment of vegetation in extensive landscape areas is an applied biological process involving many professional disciplines including horticulture, botany, landscape architecture, engineering, wildlife management, soil science, plant pathology, and others. It also involves a number of supportive industries: erosion control contracting, landscape contracting, forestry contracting, landscape maintenance, laboratory services, plant nursery, seed suppliers, and materials and equipment suppliers.

The establishment of vegetation in extensive landscaped areas presents some of the most difficult horticultural problems that could possibly be encountered (Chan 1979). Reasons for this level of difficulty may include the nature of the construction sites, remote areas, the lack of irrigation, difficult soil conditions, and other environmental extremes including high and low temperatures, drought, high winds, and flooding conditions. Other common problems include weed competition, insect and animal depredation, and erosion. To add to these problems, the lack of trained skilled labor, proper timing, and available adapted plant materials and supplies are often limiting.

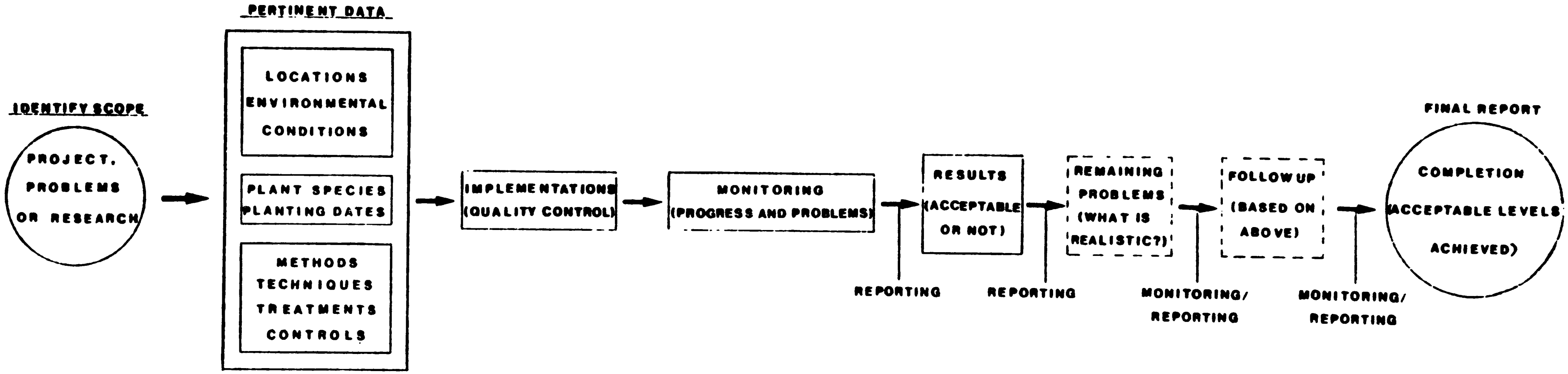
Because revegetation projects tend to be difficult, they also tend to be costly. Revegetation projects should be planned as multiple year projects. The initial planting and follow-up work to establish plants should be considered capitalized costs. The technological development utilizing computer techniques is important not only in improving the state-of-the-art but in reducing costs.

Applications of CVM

CVM is useful for horticultural management and research purposes. The extent of how it will be used depends upon the user, the need for documentation, and the operational use of the stored data. Major examples are given which outline some specific applications.

Management. Management uses include planning, scheduling and coordination, quality control, analysis and problem solving, monitoring, communications, reporting, and cost analysis. A flow chart, Figure 1, depicts the process used in revegetation in which various steps must be fulfilled in order to bring projects to a conclusion. Ideally, projects are concluded successfully, but the nature of revegetation problems are such that limited results may occur because of special problems in which longer

CVM – COMPUTER VEGETATION MANAGEMENT



OTHER FEATURES:

HISTORY OF PROJECT - DATES AND EVENTS
AUTHORITY OR RESPONSIBILITY - DATA CONTRIBUTOR, OBSERVER, AUTHOR, DESIGNER
COSTS - TREATMENT COSTS, MAN-HOURS, PROJECT COSTS
REFERENCES - DRAWINGS NO., SOIL REPORT NO., ENVIRONMENTAL IMPACT REPORT NO.

Figure 1. Flow Chart.

periods of time and resources are needed to solve the problem. Proper documentation of these problems, and documenting reasonable efforts made may result in favorable review by the regulatory agencies and the general public even if there are limited results.

In conjunction with controlling the revegetation process, CVM is also a way to readily communicate information on projects between departments allowing the review of the status or progress of the projects and to provide information to company managers and officials who need to respond to questions about environmental issues and revegetation.

CVM can also be used as a design criterion. The information stored in CVM not only identifies adapted species for ecological situations but is also coupled with data on plant size, form, texture, color, and landscape uses. It allows the manager to produce landscape plantings which are not only adapted well and require low maintenance, but are functional and aesthetically pleasing.

Research. The process of accomplishing projects as depicted in Figure 1 is in itself a form of applied research achieved by CVM because of the nature of revegetation problems and the uniqueness of each site. The difference between operational plantings and test planting is the degree of difficulty or the significance of the planting and the distinction is often slight. At times, test plantings are mandated by the regulatory agencies. Examples include determining the most effective and feasible means of reestablishing a colony of a rare plant species which may be threatened by construction activities, or solving a special problem affecting vegetation because of the emission of a cooling tower. These are examples of plantings which would be considered experimental because results are not predictable. Test plantings are often conducted prior to operational plantings to assure results.

Revegetation research is important because limited information is presently available which can be applied directly to new projects. CVM is an integrated approach which would provide sufficient data to predict which plant species and planting methods are best suited for new projects. This capability is enhanced as the pertinent data stored is increased.

Data Base Design

CVM has a broad data base which provides pertinent information on the horticultural and ecological requirements of establishing plants. The data base content includes 56 input fields pertinent to any plant or plant group and 26 input fields relative to any site. Forty-two tables of entry codes are provided to communicate information in addition to numerical values that are required by the input fields. In spite of this vast amount of data entries, the system is simplified so that users are able to establish what data is pertinent and then deal with only those fields and values with which they need to work.

The major grouping of data in the master file is described as a "logical record." A logical record consists of any of seven different physical records in any combination: site environment, site maintenance, site comments, species environment, species landscape usage, species planting methods, and species problems. Each logical record consists of parent and child segments. Parent segments consist of site records, whereas child segments consist of plant-species present at the site.

Each logical record is uniquely identified by a reference number (key). The reference number is composed of division code, project location code, and species code (child segment only). Each physical record shall also contain an update data, viewer class, viewer date, and viewer code. By employing "viewer date" (observation date) as a key, an historical trail may be maintained.

Record formats, field descriptions, and system tables have been developed but are not a topic of discussion in this paper.

DATA BASE MAINTENANCE

Processing Overview

The update program will be written in the 60 character set of PL/1 for use on the company's computer system. The data base will be stored on magnetic tape and will contain an inventory of landscaped-site and associated plant species. The update program will enable the user to make additions to, deletions from, and modificatons of the data base.

When an update of the data base is to be performed, the user will collect update information from the field and set up requisite job steps for a data base maintenance run.

The update program will validate and post transactions against the data base producing: an updated data base, a file of rejected transactions, and file activity maintenance reports. The file activity reports will contain listing of rejected transactions and appropriate error messages, listings of deleted records, and file activity statistics. The file of rejected transactions, together with the file error messages report, will enable the user to easily rectify indicated errors.

Update Transactions

For each transaction, there shall be an accompanying transaction code where: D = Deletion; I = Insertion, M = Modification of records.

The deletion (action code = D) of a logical record may be accomplished by specifying appropriate key information. A "child" segment may be deleted without affecting associated segments unless it is a "base" segment.

The addition/creation (action code = I) of a logical record begins with site record establishment, after which child segments may be added as needed. A child segment cannot be added to a landscaped site which has not been established. For descriptions of plant-species related problems, a problem description record must be established before problem, treatment, tolerance, or results can be described.

To modify (action code = M) a field, one simply places the new information in the appropriate position of the coding form. The modification of non-keyed fields (replacements) does not normally impact other fields. The modification of keyed fields necessitates a two-step procedure, deletion of the old and insertion of a new updated record. To "blank out" a field (nonkeyed), an asterisk is placed in the appropriate field on the coding form. To replace an element within a multiple occurring field, the entire field must be replaced.

Coding forms will consist of seven different types in as many colors. An observer in the field will typically inventory all seven in a folder. Some types of coding forms will consist of two parts. Color coding will facilitate ease of identification. Each form will contain two sections, keyed and nonkeyed information. All keyed information is mandatory.

File Maintenance Activity Reports

A set of file maintenance activity reports will be created for each pass of the update program. Three reports shall be produced: error messages, listing of deleted records, and file maintenance activity statistics.

An error message will be produced for each invalid field of the rejected transaction. Each message will consist of the invalid transaction, a diagnostic message, and an underscore of the erroneous data. The error messages report is to be used in conjunction with the rejected transaction file for easier correction.

The file maintenance activity report will contain statistics on number of data base records: read, written, modified, passed, added, deleted, transactions read, and rejected.

Rejected Transactions File

A file of rejected transactions will be created if invalid transactions are encountered. The arrangement of the rejected records will be in the same order as the error messages. If the file is directed to a disk dataset, the facilities of the TSO editor may be employed for rectification of errors. After resolution of errors, the rejected transactions may be resubmitted for processing against the master file.

Data Base Content

A general outline of the data base content is presented in Table 1.

Reporting

CVM reports are categorized into three levels of reporting. The levels correspond to the relative length of the report and to the specificity of information. The first level consists of the master file report of (a) each site and (b) each plant or plant groups. These reports are the most extensive in size and are general in nature. Reading these reports is time consuming, and relationships of horticultural and ecological relationships are not as easily analyzed. However, they are useful to managers who need an overview of projects and are planning and estimating costs. The second level of reports is intermediate in size and pertains to more specific subject matters which allows for easier analysis of horticultural and ecological relationships. They are more useful for field project managers and environmental horticulturists. Being more specific, they save time in reading and analyzing. The third level of reports is even more short and specific. These reports are either (a) listings of plants that are successful or tolerant under specific environment conditions, special problems or special treatment, and (b) listing of sites by plant or plant group, special problem, or specific environmental conditions. The third level could be viewed as plant recommendations for specific conditions or a listing of sites with specific environmental conditions, or special problems. Table 2 lists and categorizes the various CVM reports in addition to several maintenance file reports.

Table 1

A listing of informational categories of sites and plant species for Computer Vegetation Management. Pacific Gas and Electric Company

- -Plant Species--coding of scientific name and specific suffix number
- -Location and Description--including PGandE and nonPGandE locations
- -Environmental Conditions--including climate, soil, slope conditions, vegetation type, and climatic zones.
- -Aesthetic Quality of Site--a rating for evaluation
- -Land Use and Visibility to Public--a priority indicator
- -Landscape Costs and Maintenance-including maintenance tasks and manhours
- -Plant Speciation of Landscape Site-plant performance
- -Irrigation Management-nonirrigation is a goal
- -Fertilization Management--a supplemental aid for establishment
- -Soil Amendment Program--a supplemental aid for establishment
- -Planting Methods--compared to determine the most effective and economic means
- -Species Statistics--including quantity, size, health, percent germination, percent survival, growth rate
- -Special Problems--including site specific problems
- -Pests, Diseases, and Weeds--identified for treatment
- -Landscape Usage--including various design criteria
- -Experimental Records--a long-term research tool
- -Contributor of Data--a reference or authority guide

Reporting Parameter Requirements

The user will be able to specify the production of any or all 15 reports. As a step in the preparation of the jobstream, the user will be required to code a parameter card indicating desired reports. The requestor's use identifier and password should be entered to provide access to confidential information such as experimental data. For reports with ad-hoc capability, auxiliary information must be passed on a one time per card basis within the jobstream, or the indicated report will not be processed. Although "cards" are mentioned as the job initiation vehicle, this is not necessarily the only method to submit a request. Alternatively a command list may be used to prompt the requestor to give relevant information.

Table 2

A listing of reports available from Computer Vegetation Management.

Level I

1. "Site Master Record" (RPT01): A listing of fields for each landscaped-site record by key sequence.
2. "Species Master Record" (RPT02): A listing of fields for each plant-species performance by species.

Level II

3. "Species Performance Record Report" (RPT03): A listing of historical plant-species performance by species.
4. "Project Report" (RPT04): A synopsis environmental condition, plantings, and site evaluations of landscaped project sites by location.
5. "Planting and Change Report" (RPT05): A listing of historical planting performance by landscaped-site.
6. "Nonirrigated Planting Report" (RPT06): A planting and performance evaluation report by nonirrigated sites.
7. "Contributor File Summary Report" (RPT07): A report of contributor research and experimentation, and recommendations by data contributor.
8. "Cultural Treatment Report" (RPT08): A cross-reference listing among any cultural/treatment practice and recipient plant-species by treatment. For a particular treatment, listings of species, location, data contributor, planting information, methods of treatment and results, are presented (ad-hoc capability).
9. "Experimental Summary Report" (RPT09): A listing of experimental methods of plant treatment(s) by problem type (ad-hoc capability).
10. "Site Specific Problem Report" (RPT10): A listing of landscaped-sites by problem type (ad-hoc capability).
11. "Specific Design Usage Report" (RPT11): A listing of plant-species by outstanding features or special design usage (ad-hoc capability).
12. "Species Information--Environmental Conditions" (RPT12): A listing of environmental conditions by species.
13. "Environment Conditions and Species Adaptation Report" (RPT13): A listing of environmental conditions, adapted species, and naturally regenerated species by landscaped-sites.

Level III

14. "Successful Establishment Report" (RPT14): A listing of species by combinations of environmental variables; e.g., slope aspect and soil type (ad-hoc capability).
15. "Species Tolerance Report" (RPT15): Listings of species by tolerance factors; e.g., sunlight availability and presence of pests.

Miscellaneous File Maintenance Reports

16. "File Maintenance Activity Report" (RPT0A): A listing of rejected transactions and associated error messages.
17. "File Maintenance Activity Report" (RPT0B): A listing of deleted records.
18. "File Maintenance Activity Report" (RPT0C): File maintenance activity statistics.

Controls

For successful reporting the following conditions must be met: the data base must be available; a parameter card must be present; the contents of the parameter card must be valid; ad-hoc request parameters specified (if indicated). If compliance with these requirements is not achieved, appropriate error messages will be issued, and processing terminated. The user at this point should make the required correction(s) and resubmit for processing.

The user identifier combined with the password (if valid) controls access to privileged information, its ommission would be equivalent to an invalid code combination. When access codes are omitted or invalid, privileged information will not appear on report(s). The user identifier and password are defined and distributed by the database administrator.

SUMMARY

The expectations of CVM include providing the following: (1) Accurate horticultural information on adapted species and techniques for the establishment of vegetation in a wide range of environmental conditions; (2) Current and reliable information and methodology for the management of vegetated areas covering large geographic areas; (3) A system of applied research allowing for long-term evaluation and rapid retrieval of current and past evaluations; and (4) Cost benefits.

CVM is to be utilized by the Pacific Gas and Electric Company. Future value may lie in the system being generally available to outside users and the general public. It is designed to provide horticultural and ecological information to establish landscaped areas which would require less maintenance because of the use of adapted plants. Costs can be reduced by identifying economical and effective plant establishment procedures which allow plants to grow in balance with the existing natural environmental conditions. Significant energy and water would be conserved.

ACKNOWLEDGMENTS

Much appreciation is given to Mr. Fred Perfetto, Ms. Laurie Scheemann, Ms. Marianne Giovannetti, and Ms. Devon Hoffman of the Engineering Computer Applications Department and Mr. Ittsei Nakagawa, Mr. Tak Kojima, and Mr. Rockford Thompson of the Civil Engineering Department of PGandE for their contributions to the development of the CVM program. Thanks is also given to Mr. Juan Richardson and Mr. Lester Chin of Contract Programmire, Informatics.

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COST COMPARISON OF RIGHT-OF-WAY TREATMENT METHODS

Paul A. Johnston[1]

ABSTRACT.--The progress to date of a 3-year impact study of cost comparison of right-of-way (ROW) treatment methods being conducted by Asplundh Environmental Services (AES) for the Empire State Electric Energy Research Corporation (ESEERCO) is reported. Objectives attained thus far include: (1) site selection and pretreatment baseline data collection for 126 treatment units located on 18 ROWs in New York State, and (2) applications of seven standard ROW treatment methods (five herbicidal and two mechanical), with three replications of each. Pretreatment data cover density/height of vegetation (analysis of variance); composition of capable (tall-growing) species (by species-area curve); abundance and sociability of non-target desirable species; mesic habitat; soils evaluation (compaction, dry bulk density, humus type, and erosion); visual effects (computer analyzed); ROW edge study (identifying ecotones); wildlife habitat evaluation of selected species; and statistical relationships of various factors at the 95% significance level. Cost data of applying treatments were tabulated and treatment quality evaluated. The final report (c. 1983) will give complete cost comparison of ROW treatment methods, their environmental impacts, and initial treatment effectiveness.

INTRODUCTION

The best solutions to right-of-way (ROW) management problems vary from one region of the nation to another because of differences in climate, topography, soils, vegetation, wildlife, land uses, and social values. Empire State Electric Energy Research Corporation (ESEERCO) began a research program to evaluate different ROW management techniques in New York State to increase the safety, economy, and environmental compatability of electric energy in New York. The first project (1973) established the state-of-the-art in ROW management techniques through a literature search and consultations with nationally recognized experts in the field. The second project examined the "record in the field" in New York and was conducted by Asplundh Environmental Services (AES) on 22 representative ROWs. ESEERCO's third project conducted by AES is an intensive cost comparison of ROW management techniques and associated environmental

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effects. The study meets the three requirements of a complete study of environmental impact (Green 1979), including a baseline study, an impact study, and biological monitoring. Controls are included to detect any changes not related to the impact.

METHODS

In the first 2 years of the AES 3-year cost comparison study, the following has been accomplished: site selection, pretreatment baseline data collection and analysis, and application of seven standard ROW treatment methods (five herbicidal and two mechanical) on six density/height classes of tall-growing (capable) species combinations, replications of each, for a total of 12 treatment units, each consisting of a 1760-foot (537 m) length of an entire ROW segment. Another portion of the study evaluates four additional special treatment methods performed on areas of one acre each, replicated three times.

Pretreatment

Pretreatment baseline data collection includes existing conditions on study ROWs and their treatment units, density/height classes found, similarity of capable species found throughout New York, desirable non-target plant communities found, boundaries of pretreatment edge, soil compaction conditions, visual conditions, wildlife habitat evaluation for selected species, conditions on study ROWs to be treated with girdling and herbicide injection treatment methods, statistical relationships of various factors at the 95% significance level, and cost data and treatment quality for all treatment methods applied.

Site Selection

The cost of applying a treatment method is directly related to accessibility to the ROW and the density and height of tall-growing (capable) species. Eighteen of the 50 candidate ROWs submitted by ESEERCO qualified as study ROWs. A study ROW contained at least three of New York State's five prevalent capable species: white ash, red maple, red oak, black cherry, and quaking aspen. Height and density were divided into six classes. Study ROWs had at least 2.3 miles (3.7 km) of mesic habitat (moist but well-drained sites) and traversed a Northern Hardwoods forest type or one of its variants found in New York. Each ROW had a documented treatment history and was reasonably accessible. Study ROWs were divided into seven treatment units (1760 feet long (537 m)) aggregating 126 treatment units on 18 ROWs.

Capable Species

Trees capable of growing to over 20 feet (6 m) endanger safe and reliable energy transmission and are responsible for most maintenance problems in New York State. A prime goal of the study is comparing the costs of treatment of capable species. A species-area curve determined the optimum plot size for vegetation sampling in each density class. The density and height of capable species were evaluated by the analysis of variance. Forty-six capable species were found on study ROWs throughout the state. Sorensen's Quotient of Similarity was used to calculate the similarity of species composition.

Desirable Non-Target Species

Over 550 plant species were identified on study ROWs. Desirable non-target species were evaluated by abundance and sociability data. Herbaceous cover generally increased with decreasing tree and shrub cover. Total herbaceous cover was high on ROWs and low in adjoining woods (due in part to forest competition reducing light infiltration).

ROW Edge

ROW edges were studied to identify the boundaries of the ecotone (transition area between two or more biotic communities). Data were collected by the line transect technique. Data indicated a definite edge effect. The influence of the forest edge extends into the ROW area and affects vegetation composition. Also apparent is the influence of ROW clearing on composition and density of understory vegetation in immediately adjoining woods.

Soils

Surface soil properties were evaluated on ROWs and off-ROW sites for bulk density, penetrometer resistance, and thickness of surface organic layers at the A1 horizon.

Visual

Analysis of the visual impacts data related them to the magnitudes of each of the six basic visual components: form, line, color, value, intensity, and texture. Results included measuring change in variable values correlated to the change in magnitude of each visual component and provided a value indicating the significance of that change.

Wildlife

Effects of vegetation treatment methods on ROW wildlife habitat were assessed by a habitat evaluation procedure that concentrates on a species' food and cover requirements, and provides a general rating useful in comparing ROW habitats. Species selected for study included rufous-sided towhee, gray catbird, ruffed grouse, meadow vole, and white-tailed deer. The habitat for each of these species was assessed on all treatment units in medium density (1500 to 2900 stems per acre (3700-7160 stems/ha)) and high height (over 6 feet (2 m) high) ROWs, and will be compared to habitat ratings derived from 1982 field data (post treatment) to assess the effects of seven different treatment methods on wildlife habitat.

Treatments

Treatment methods were applied in the following sequence:

Dormant Basal	-	March-Late April 1981
Cut and Stump	-	Late April-Early June 1981
Hand Cutting	-	Early May-Mid June 1981
Mowing	-	June 1981
Aerial Foliage	-	Late June-Early July 1981

Summer Basal	-	Mid June-Late July 1981
Selective Ground Foliar	-	Mid July-August*

* One site was unavoidably delayed until early September.

Treatment-cost coordinators collected data relating to the cost effectiveness of each treatment method. These data will be used to develop (1) Cost comparison of treatments in relation to density and height of target vegetation, adjusted for terrain conditions that affect accessibility; (2) Effects on cost due to terrain conditions that limit or restrict accessiblity or treatability; and (3) Recommended ROW maintenance in relation to density and height of capable vegetation and terrain conditions.

SUMMARY

The entire study will be completed in June 1983. The analysis of data will provide a comparison of costs and environmental effects of treating capable species at various density/height classes on ROW conditions found in New York State.

Specific results will include a report of changes in density and height of capable species, abundance and sociability of desirable non-target species, soil compaction due to treatments, and changes in wildlife habitat.

IMPLICATIONS OF LANDOWNER MAINTENANCE OF POWERLINE RIGHTS-OF-WAY

Robert E. Tillman[1], Brad L. Hahn[2], and Richard O. Kimmel[3]

ABSTRACT.--As a result of landowner complaints, the West Virginia Department of Agriculture imposed new regulations governing aerial applications of herbicides to rights-of-way (ROWs) in 1981. The regulations require electric utility companies to offer landowner maintenance agreements whereby the utility would compensate landowners for maintaining vegetation on ROWs crossing their property. Rate of compensation was equivalent to per acre cost of aerial treatment. This paper describes the results of a DOE study on costs per acre incurred by landowner maintenance using experienced and inexperienced clearing crews. Per acre maintenance costs ranged between \$87 and \$406 with an average of \$114.

INTRODUCTION

In 1981, the West Virginia Department of Agriculture imposed new regulations governing the aerial application of herbicides to powerline ROWs. One section of the regulations (29-A-a-d) requires electric utilities to offer a Landowner Maintenance Agreement (LMA) whereby landowners could elect to maintain vegetation under powerlines crossing their property. The regulations did not define specific guidelines for the LMA program, which has resulted in variations in the type of agreements offered by the different utilities operating in West Virginia.

The regulations were instituted as a result of landowner complaints regarding aerial spraying of herbicides. Off-ROW damage to gardens, crops or other desirable vegetation, and a lack of prior notice for spray programs were common complaints. The public also criticized the unsightly initial brown-out of vegetation which followed growing season aerial applications of herbicides. Fueled by the Agent Orange controversy, some people expressed serious concern with the toxicity and carcinogenicity of the herbicides. At the time, local newspapers carried reports of

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individuals developing rashes after being sprayed by aerial applicators. Regardless of the scientific evidence available on the health effects of herbicide use, the general public in West Virginia, as elsewhere in the country, took a strong stand against involuntary exposures to herbicides.

In contrast, the utilities stress that when herbicides are properly used, they are environmentally safe, a position supported by documented research and a safety record maintained over 30 years of herbicide applications. The utilities point out that aerial applications of herbicides are the most economical methods to control the growth of woody vegetation on ROWs and that the application methods and rates are environmentally sound, thereby posing no threat to human or animal populations.

The central issue of the new regulations was not which view was right or wrong, but whether a landowner should be forced to accept an involuntary exposure to herbicides resulting from utilities' aerial spray programs. The Department of Agriculture solved the dilemma by requiring the utilities to offer an option to landowners allowing them personally to maintain the vegetation on segments of ROW crossing their property rather than accepting the utility vegetation management program.

In general, a LMA requires the landowner to prevent ROW woody growth from exceeding a height of 10 to 12 ft. Stump height of felled trees must not be greater than 3 in from ground level and no slash can be permitted to remain within 10 ft of tower sites. After a utility inspector has examined the site, landowners are compensated for work accomplished, based on the current per acre cost of aerial treatment--roughly $175/acre in 1981. Time intervals for compensation are determined by the time intervals between aerial applications on adjacent or similar ROWs elsewhere. Historically, this interval is between 6 to 10 years, depending on vegetation, terrain, and company maintenance policy. If landowners fail to meet company standards, the utility is free to resume normal ROW maintenance procedures, including aerial applications.

Landowner Implications

Acceptance of a LMA places a considerable amount of responsibility and liability on the landowner. With the exception of one West Virginia utility, the companies require each landowner to conduct the difficult and dangerous operation of side-trimming. The steep vertical edges of powerline ROWs maintained by aerial sprays require periodic trimming or felling to prevent the growth of edge trees into electric lines. Without bucket trucks or climbing gear, the side-trimming presents distinct risks of electrocution or damage to the powerline, especially when performed by untrained personnel.

Financial factors must also be considered for a landowner accepting a LMA. Using current costs, a West Virginia owner would receive $175 per acre every treatment cycle. Depending on the amount and type of vegetation present on the ROW, the owner may have to perform more than one maintenance operation during that period to meet LMA conditions. Production rates for hand-cutting are available from a West Virginia study utilizing both experienced and inexperienced labor.

The study in West Virginia was supported by an Appropriate Technology Small Grant from the U.S. Department of Energy (Kimmel, Tillman and Wooley 1981). It included eight hand-cutting projects on six different ROWs, totalling 41.1 acres. Three transmision-line ROWs (Carbondale, Darrah-Winfield, and Campbell) and three distribution-line ROWs (Rondy, West and White) were selected for the study. The Darrah-Winfield and Campbell lines were cleared using both inexperienced and experienced crews (shown as I and II respectively in Figure 1).

Hand-cutting rates average 11.5 worker-hours/acre (W-h/a) with a range between 8.8 and 40.6 W-h/a. A distinct difference was exhibited between the inexperienced crews (16.8 W-h/a) and experienced crews (9.2 W-h/a). The cost per acre in Figure 1 is calculated on the arbitrary basis of $10 per worker-hour. This is a reasonable hand-labor work rate in the study region.

The Empire State Electric Energy Research Corporation in New York State has also conducted studies on the costs of hand clearing, but those data were not available for this symposium. The comparison between the two studies would have been interesting.

The results of the West Virginia study can provide only a rough method of estimating landowner production rates, since the type of terrain, form and density of vegetation, experience level, and nature of the equipment are significant variables to consider. High stem density of quick growing species, dense understory, or steep slopes will present severe obstacles to an inexperienced and poorly equipped landowner.

FINANCIAL CONSIDERATIONS

A landowner may wish to calculate an estimated hourly reimbursement rate for manual clearing for ROW maintenance. Under the current agreements, a landowner would receive a per-acre payment based on the cost of aerial application each time the utility plans to treat adjacent and similar vegetation. As noted previously, this treatment cycle can vary between 3-7 years, depending on site variables. Using the 1981 per-acre aerial treatment cost of $175 and a treatment cycle of 7 years, the landowner could earn $15.22 per hour if the 11.5 W-h/a average of the West Virginia study could be matched, and if only one treatment were required. However, if two manual treatments are required and the worker-hour rate remains the same, hourly compensation is halved to $7.61 and would decrease to $5.07 if a third treatment were necessary. In addition, the owner must consider equipment investment, maintenance, and depreciation, plus operating costs for fuel, lubricants, and safety equipment (hard hat, gloves, eye protection, ear plugs, and protective boots are strongly recommended).

The figures for compensation rates must be considered crude guides since a number of variables influence the estimated hourly rate. The number of manual clearing operations required in the maintenance cycle will depend on species composition of the vegetation, site productivity and climate. Clearing rates are influenced by stem density, terrain, type of equipment used, and worker experience. Other potential benefits may be added. For instance, fuelwood may be taken by clearing; it has an economic value. Clearing would be designed to enhance wildlife, another economic plus.

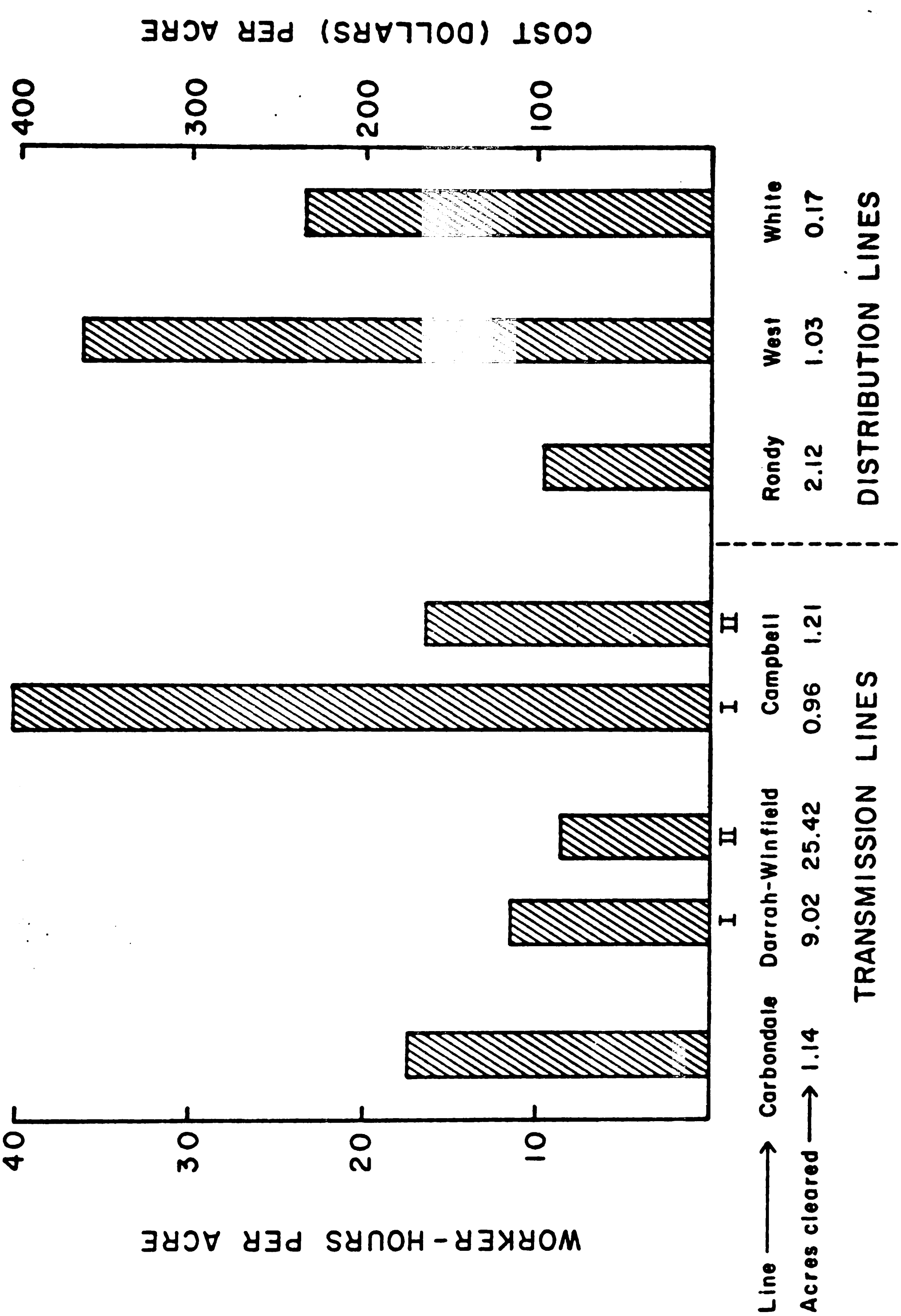
COST (DOLLARS) PER ACRE
400
300
200
100
WORKER-HOURS PER ACRE
40
30
20
10
Line ⟶
Acres cleared ⟶
Carbondale
1.14
I
II
Darrah-Winfield
9.02
25.42
I
II
Campbell
0.96
1.21
TRANSMISSION LINES
Rondy
2.12
West
1.03
White
0.17
DISTRIBUTION LINES

Figure 1.

Many landowners may consider the physical labor as recreational or therapeutic if their regular work does not involve outdoor labor. The satisfaction of working one's land is an important intangible benefit worth considering. In West Virginia, it appears that the most important factor in landowner willingness to enter a LMA is the fact that they no longer must submit to an involuntary exposure to herbicides on their own property.

POWER COMPANY IMPLICATIONS

Telephone contacts with West Virginia utilities officials were made to determine the attitudes within the company toward the LMA. Opinions expressed were variable, as expected, especially since the agreements had just been implemented. All the officials recognized potential positive and negative aspects of the program.

Increased costs for implementation and supervision were stated as a major concern. The program will require additional man hours to perform the following duties: initial inspection to determine eligibility, measure acreage, explain responsibilities, line inspection, payment, and extra visits if problems are encountered. At average current personnel rates of $19 per hour, these additional duties can escalate ROW management costs. However, if landowners are sincere in their commitment, these administrative costs can be minimal and perhaps result in net savings to the company.

Currently, the agreements have had minor effects due to a limited landowner response. For instance, Mongehela Power (Mon Power) has 23 LMAs signed and 5 completed (Nancy Crow, personal communication, 7 Febraury 1982), while Appalachian Power Company (APCO) has less than 10, although more letters of intent have been filed (H. Caldwell, personal communication, 7 February 1982). The limited landowner response can be due to two factors: (1) The LMA agreements are new (1980) and have not been widely publicized; and (2) ROW treatment has not been programmed for those areas with the greatest opposition to aerial spray programs. The utilities are anxious to gauge the landowner response as the program matures.

The officials also expressed concern with liability factors. Although the contracts clearly state that property owners accept full responsibility for damage or injuries while maintaining ROW vegetation, the power companies could still face litigation brought by an injured landowner. Courts may well decide that the utilities are negligent by allowing untrained owners to work near dangerous high voltage electric lines. One company chose to minimize this risk by providing all side-trimming, the most dangerous work, in the LMA.

However, economic benefits were acknowledged by the power company officials. On sections of ROW where aerial sprays were not feasible or allowable, companies would have to employ more expensive ground treatment methods to maintain secure vegetation. Under an LMA, this could be accomplished at the same cost of aerial treatment since this price is the legal upper limit of the maintenance agreement. This cost difference would be considerable in areas of limited access and/or high stem densities. The most important aspect of an LMA is the opportunity to improve public relations. Conflicts over the use of aerial sprays will be reduced, a major benefit to the company. In addition, the company will be adding to the local economy, rather than paying out-of-state applicators. The LMA demands a cooperative exchange between owner and utility, which is more desirable than conflict, in or out of court. However, the value of this improved relationship is difficult to quantify and the power companies will have to assess these benefits qualitatively.

SUMMARY

Landowner maintenance agreements are a new and unique innovation in ROW management policy. To be sure, the program will have problems and, perhaps, increased costs. However, if social benefits are increased to the local area, which must carry the burden of transmission lines, but rarely the benefits, then the program should be judged successful. Most importantly, the regulations do achieve the primary objective in providing landowners with an alternative to involuntary exposure to aerially applied herbicides. If the LMA grows under a spirit of true cooperation between utility and landowners, it may provide a model worthy of consideration by other areas facing similar problems.

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EVALUATION OF WOODY VEGETATION ON NEW TRANSMISSION LINE RIGHTS-OF-WAY

Donald W. Allsbrooks[1], Dale K. Fowler[1], and Linda J. Fowler[1]

ABSTRACT.--This study was conducted during the summers of 1978, 1979, and 1980 to compare density and growth of tree seedlings and resprouts on seeded and unseeded portions of a 4.9 mi (7.9-km) section of a new right-of-way in eastern Tennessee. The study right-of-way was initially cleared in the spring of 1978 and was maintained by rotary mowing in early spring of 1981. Initial ground cover restoration on the seeded portion conformed to current Tennessee Valley Authority practices of disking, fertilizing, and establishing a seedbed of Kentucky-31 fescue grass (*Festuca arundinacea*), while the unseeded portion was allowed to revert to native vegetation. Mean stump resprout and seedling densities for the combined 3-year period were highest on the unseeded portion, with 1119 and 13,501 stems per ac (2764 and 33,347 per ha), respectively. The seeded portion supported a mean resprout density of 729 stems per ac (1800 per ha) and a seedling density of 2712 stems per ac (6699 per ha). Mean height and growth for seedlings and resprouts were greatest on the unseeded portion of the right-of-way. Mean height for stump resprouts was approximately double that for seedlings at the conclusion of the study. The economics and the future maintenance implications of both approaches to ground cover restoration along new rights-of-way are discussed.

INTRODUCTION

In constructing new rights-of-way (ROW) through wooded areas, the Tennessee Valley Authority (TVA), currently shear clears all woody vegetation to within 3 in of the ground level. Next, footings or grillages are placed at structure locations and areas for wire setup are established. The transmission towers are assembled, erected and conductors attached to the towers. Cleanup and restoration is dependent upon the season, but ultimately a seedbed is prepared and fertilizer and Kentucky-31 fescue grass (*Festuca arundinacea*) are applied along the rights-of-way.

Ground cover restoration operations on new rights-of-way have been effective in stabilizing the soil, controlling erosion, and improving the appearance of the rights-of-way but are costly (currently \$200/ac (\$500/ha)). TVA initiated a research program in 1975 to determine if an

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economic advantage could be gained by incorporating volunteer vegetation into the restoration phase of right-of-way development. This study compares the growth parameters and reclearing economics of woody plant communities along seeded and unseeded prortions of a new TVA right-of-way in east Tennessee. Specific study objectives were to (1) compare erosion potential by estimating the annual standing crop biomass of ground cover on seeded and unseeded rights-of-way; (2) document and compare the species composition, density, and growth rates of volunteer woody seedlings and stump resprouts; (3) compare the density and species composition of tree species posing a potential threat to electrical transmission during the first rights-of-way reclearing operation; and (4) compare the economics of reclearing seeded and unseeded portions of new transmission line rights-of-way.

METHODS

A 4.9 mi (7.9 km) section of the Watts Bar-Roane 500-kV transmission line in Roane County, approximately 7.4 mi (12 km) southwest of Oak Ridge, Tennessee, was selected for study. The study site, which is located within the "eastern deciduous forest province" (Bailey 1978), is underlain by limestone, cherty dolomite, and acid-sandstone-shale rock strata. These parent material types were considered in the study design, and the treatments and transects described below were distributed equally on portions of the right-of-way underlain by each substrate type.

The 174 ft wide (53 m) transmission line right-of-way was cleared of woody vegetation in March 1977. Line construction began in June 1977 and was completed by September 1977. In October 1977 part of the right-of-way was disked and seeded with Kentucky-31 fescue at the rate of 70 lbs/ac (78 kg/ha), while the remaining portion was allowed to revert to volunteer vegetation.

A total of 24 transects 6.6 X 98 ft (2 X 30 m) was established on both seeded and unseeded treatments of the study line. Six plots, 6.6 X 16.4 ft (2 X 5 m), were subsequently located along each of these 48 transects (288 plots total). All woody vegetation within these plots was then identified as to species and classified as either seedlings or stump resprouts. The following measurements were taken within each plot in September 1978, 1979, and 1980: (1) the height of tree seedlings, (2) the annual growth of tree seedlings, (3) the height of the tallest resprout stem, (4) the annual growth of the four tallest stems of each resprout (which were averaged to obtain a mean annual growth of each resprout), and (5) the total number of stems emerging from each stump resprout.

In addition to these measurements, all ground cover, except tall woody vegetation, was clipped to ground level within six 1.6 ft^2 (0.5-m^2) plots that were located 3.3 ft (1 m) outside of each transect. Plant biomass was separated into wooody, herbaceous, and grass components, ovendried at 212°F (100°C) for 24 hours, and weighed to the nearest gram. Standing crop biomass estimates were derived in lbs/ac (kg/ha) for each experimental treatment (seeded and unseeded).

All statistical tests were selected from the Statistical Analysis System Users Guide (Helwig and Council 1979) and performed at $P < 0.05$ level of significance unless otherwise indicated.

RESULTS AND DISCUSSION

Plant Biomass Estimates

In 1977 a volunteer vegetation biomass estimate of 2632 lbs/ac (2948 kg/ha) was calculated by Fowler et al. (1981) for a portion of the Watts Bar-Roane study site. This 1977 estimate represented the first growing season of volunteer vegetation (prior to seedbed preparation on seeded right-of-way), while 1978, 1979, and 1980 estimates in this study represent second, third, and fourth growing seasons, respectively. It is noteworthy that standing crop biomass estimates of ground cover were not significantly different between seeded and unseeded right-of-way during the 1978, 1979, and 1980 growing seasons (Fig. 1). These data agree with Fowler et al. (1981) findings that ground cover comprised of volunteer vegetation can potentially be as effective as seeded fescue in controlling right-of-way erosion.

Both 1978 and 1979 biomass estimates on seeded and unseeded right-of-way represent an approximate twofold increase over the initial estimate reported by Fowler et al. (1981). However, 1980 estimates were approximately 50% lower than the 1978 and 1979 estimates. This decrease may be explained by the shading effect produced by the rapid growth of the taller woody vegetation. These results indicate that seeding an entire transmission line right-of-way simply to restore ground cover and control erosion is often not cost effective. However, there are other factors to consider, and these will be discussed later in this paper.

General differences also existed between seeded and unseeded right-of-way with respect to the herbaceous, grass, and woody components of the biomass estimates. As expected, grass biomass estimates were significantly higher on right-of-way initially seeded with Kentucky-31 fescue. However, there was no significant difference in herbaceous biomass estimates between seeded and unseeded areas in 1978 and 1979 ($P < 0.05$). It was not until 1980 that herbaceous biomass estimates became significantly higher on the unseeded right-of-way ($P < 0.05$). Woody biomass estimates for unseeded right-of-way were also significantly greater ($P < 0.05$) than similar estimates for seeded right-of-way during the three consecutive years of the study. This difference was expected since total stem density was much higher on unseeded right-of-way (Fig. 2).

Woody Stem Density

An average of 50 seedling and 34 resprout species occurred on the unseeded right-of-way over the combined 3-year study period, while the seeded right-of-way supported 35 seedling and 28 resprout species. However, as evidenced by the increasing number of seedling species found on seeded right-of-way during the 1980 survey, species differences between seeded and unseeded right-of-way would probably not be a significant factor by the second maintenance cycle.

During the first growing season (1977) seedlings and resprouts were allowed to develop on all portions of the study right-of-way. However, these stem densities were greatly reduced on the seeded portions of the rights-of-way because of the intensive tractor disking that occurred

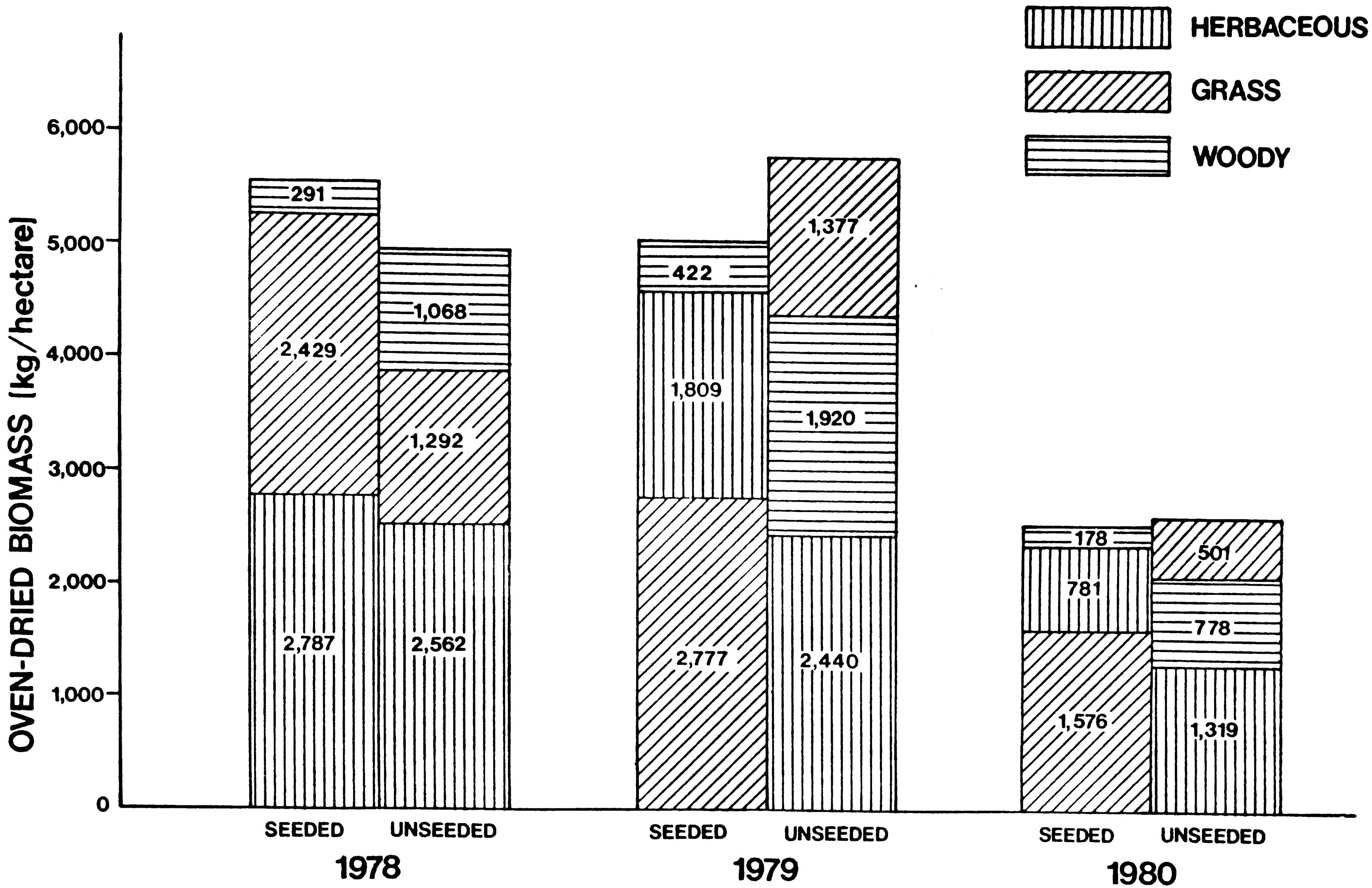

Figure 1. Oven-dried biomass estimates on seeded and unseeded right-of-way.

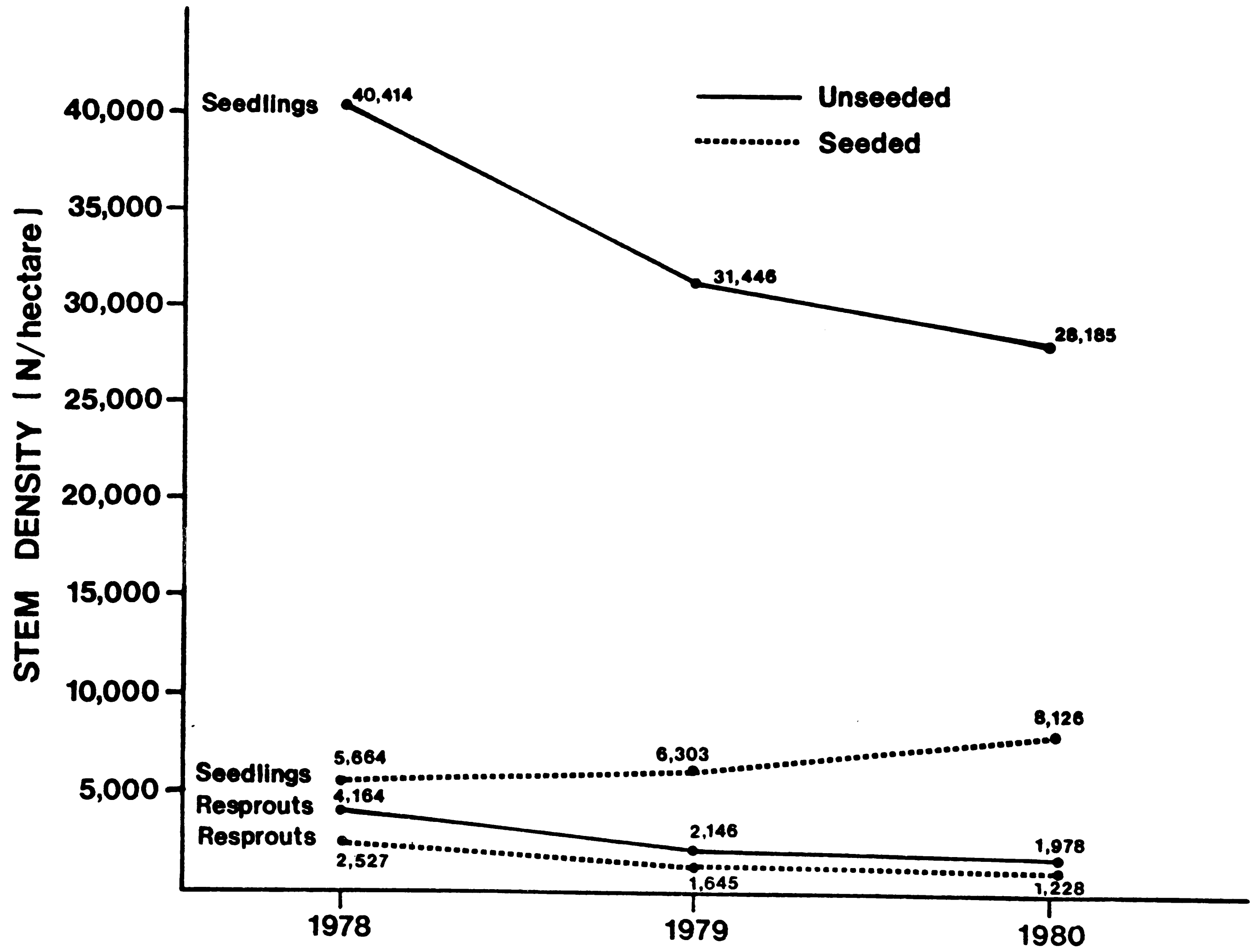

Figure 2. Seedling and resprout stem densities on seeded and unseeded right-of-way.

during the October 1977 seedbed preparation. Thus when the right-of-way vegetation was initially measured in September 1978, there were seven times as many seedlings and almost twice as many resprouts on the unseeded right-of-way as the seeded right-of-way. Mean resprout and seedling densities for the combined 3-year period remained highest on unseeded right-of-way, with 1119 and 13,501 stems/ac (2764 and 33,347 stems/ha), respectively. Seeded right-of-way supported a mean resprout density of 729 stems/ac (1800 stems/ha) and a seedling density of 2712 stems/ac (6698 stems/ha). However, in general, seedling densities on the seeded right-of-way increased over the 3-year period, while seedling densities on the unseeded right-of-way decreased as shading and competition for moisture, space, and nutrients increased (Fig. 2). Consequently at some point over the next few years, seedling densities of the two treatments should become approximately the same.

Woody Stem Height and Growth

The maximum height that vegetation is allowed to reach on TVA right-of-way before being considered a hazard to system integrity is 12 ft (3.66 m). Consequently reclearing operations are usually necessary within 3 years due to the long growing season and abundant rainfall in the region. In this study, there were two species (yellow-poplar and ash, four individual trees), that exceeded the 12 ft (3.66 m) height limit on the seeded right-of-way transects (Table 1). However, there were five additional species that would have exceeded the height limit in the fourth growing season because their heights ranged from 10.5-11.8 ft (3.20 to 3.61 m). On unseeded transects, eight tree species, comprised of 30 individual trees, exceeded the height criterion, while a total of 13 other species had individual trees with heights ranging from 9.8 to 11.8 ft (3.0 to 3.6 m).

The reader should note that vegetation on the seeded portions of the right-of-way was damaged severely during the October 1977 seedbed preparation. The intensive tractor disking removed the majority of annual woody growth that had developed on those portions of right-of-way since the initial clearing of the right-of-way in March 1977. Unseeded portions were not subjected to this treatment and consequently had more species and individual trees that exceeded or approached the height constraint. However, the tree growth on the unseeded right-of-way was not considered to be a significantly greater maintenance problem than seeded treatments during the first reclearing operation.

As expected, the annual mean growth and height of stump resprouts were significantly greater than that of seedlings because of the well-established resprout root systems. On unseeded right-of-way, mean heights of 3.7 and 6.3 ft (1.13 and 1.91 m) were calculated for seedlings and stump resprouts, respectively. In comparison, seeded right-of-way supported seedling and resprout heights of 2.8 and 5.7 ft (0.85 and 1.73 m). As before, these treatment growth differences can be explained on the basis of removal of first-season annual growth during seedbed preparation.

Reclearing Economics

Only about 60% of a new right-ofway is seeded under TVA's current ground cover restoration program. These seeding operations, which presently cost

Table 1. Top 20 Seedling and Resprout Species, Ranked by Greatest Mean Height in Meters, Occurring on Seeded and Unseeded Watts Bar-Roane Transmission Line Right-of-Way, 1978-1980.

Seedlings: Species	Seedlings: Mean Height	Seedlings: Mean Growth	Seedlings: Max. Height	Seedlings: (N>3.7 m)[a]	Resprouts: Species	Resprouts: Mean Height	Resprouts: Mean Growth	Resprouts: Max. Height	Resprouts: (N>3.7 m)
SEEDED									
Sweetgum (*Liquidambar styraciflua*)	1.33	0.51	2.50	(0)	Ash (*Fraxinus* sp.)	3.75	0.47	3.75	(1)
Smooth sumac (*Rhus glabra*)	1.24	0.42	3.45	(0)	Smooth sumac	2.55	0.81	2.68	(0)
Flowering dogwood (*Cornus florida*)	1.15	0.40	1.82	(0)	Oak	2.43	0.46	2.43	(0)
Black willow (*Salix nigra*)	1.13	0.77	1.49	(0)	Black willow	2.34	0.70	3.61	(0)
Sycamore (*Platanus occidentalis*)	1.12	0.31	2.20	(0)	Yellow-poplar	2.02	0.47	4.50	(2)
American hornbeam (*Carpinus caroliniana*)	1.11	0.28	1.85	(0)	Black cherry	1.97	0.44	3.20	(0)
Privet (*Ligustrum* sp.)	1.09	0.53	1.09	(0)	Red maple	1.95	0.48	3.20	(0)
Scarlet oak (*Quercus coccinea*)	1.07	0.24	1.07	(0)	Sweetgum	1.63	0.52	1.74	(0)
Virginia pine (*Pinus virginiana*)	1.06	0.24	1.46	(0)	Blackgum	1.54	0.45	3.40	(0)
Empress tree (*Paulownia tomentosa*)	1.01	0.46	1.75	(0)	Empress tree	1.50	0.31	1.51	(0)
Sugar maple (*Acer saccharum*)	0.98	0.25	1.40	(0)	White oak (*Quercus alba*)	1.48	0.30	2.74	(0)

Table 1. Continued.

Seedlings: Species	Mean Height	Mean Growth	Max. Height	(N>3.7 m)[a]	Resprouts: Species	Mean Height	Mean Growth	Max. Height	(N>3.7 m)
Oak (Quercus sp.)	.94	0.26	1.32	(0)	Sourwood (Oxyodendron arboreum)	1.37	0.56	2.10	(0)
Blackgum (Nyssa sylvatica)	.93	0.36	2.90	(0)	Persimmon (Diospyros virginiana)	1.22	0.33	2.14	(0)
Yellow-poplar (Liriodendron tulipifera)	.91	0.27	5.15	(1)	Winged sumac	1.13	0.38	2.15	(0)
Hawthorn (Crataegus sp.)	.90	0.48	0.90	(0)	Hickory (Carya sp.)	1.07	0.27	2.02	(0)
Red mulberry (Morus rubra)	.89	0.27	1.56	(0)	American hornbeam	1.07	0.45	1.14	(0)
American beech (Fagus grandifolia)	.85	0.38	0.85	(0)	Winged elm	0.84	0.37	0.84	(0)
Red maple (Acer rubrum)	.82	0.24	3.25	(0)	Sassafras	0.73	0.31	0.98	(0)
Redbud (Cercis canadensis)	.81	0.27	1.90	(0)	Flowering dogwood	0.67	0.32	1.09	(0)
Winged elm (Ulmus alata)	.80	0.32	1.60	(0)	Unknown	0.60	0.34	0.60	(0)
UNSEEDED									
Devil's-walkingstick (Aralia spinosa)	3.00	0.76	3.00	(0)	Chestnut oak (Quercus prinus)	3.25	0.47	3.25	(0)
Smooth sumac	1.88	0.58	5.00	(6)	White ash	3.00	0.46	3.00	(0)
Sweetgum	1.66	0.50	3.60	(0)	Sugar maple	2.83	0.58	3.80	(1)
Black locust (Robinia pseudoacacia)	1.65	0.49	2.00	(0)	Black cherry	2.69	0.57	5.50	(4)

Table 1. Continued.

Seedlings					Resprouts				
Species	Mean Height	Mean Growth	Max. Height	(N>3.7 m)[a]	Species	Mean Height	Mean Growth	Max. Height	(N>3.7 m)
Sycamore	1.57	0.41	3.40	(0)	Black willow	2.30	0.80	2.30	(0)
Empress tree	1.57	0.50	1.57	(0)	Serviceberry	2.27	0.38	4.10	(1)
Green ash (_Fraxinus quadrangulata_)	1.52	0.37	3.35	(0)	Red maple	2.25	0.49	7.55	(8)
Yellow-poplar	1.51	0.40	5.34	(13)	Redbud	2.22	0.47	3.00	(0)
Slippery elm (_Ulmus rubra_)	1.40	0.38	1.89	(0)	Flowering dogwood	2.04	0.41	3.41	(0)
Sassafras (_Sassafras albidum_)	1.36	0.41	3.32	(0)	Yellow-poplar	1.99	0.56	6.50	(4)
White ash (_Fraxinus americana_)	1.36	0.41	1.82	(0)	Sourwood	1.99	0.52	3.65	(1)
Winged sumac (_Rhus copallina_)	1.29	0.42	3.10	(0)	Black oak (_Quercus velutina_)	1.99	0.32	3.00	(0)
Pine (_Pinus_ sp.)	1.28	0.40	2.36	(0)	Winged sumac	1.99	0.66	2.68	(0)
Flowering dogwood	1.27	0.45	2.85	(0)	Slippery elm	1.95	0.49	1.95	(0)
Virginia pine	1.25	0.28	1.65	(0)	Scarlet oak	1.94	0.58	4.34	(1)
Blackgum	1.23	0.37	3.00	(0)	Sassafras	1.93	0.43	3.32	(0)
Apple (_Malus_ sp.)	1.14	0.18	1.15	(0)	Sweetgum	1.83	0.49	2.96	(0)
Hackberry (_Celtis occidentalis_)	1.12	0.30	1.12	(0)	Green ash	1.81	0.33	3.25	(0)

Table 1. Continued.

Seedlings					Resprouts				
Species	Mean Height	Mean Growth	Max. Height	(N>3.7 m)[a]	Species	Mean Height	Mean Growth	Max. Height	(N>3.7 m)
Serviceberry (*Amelanchier* sp.)	1.10	0.32	2.32	(0)	Hickory	1.74	0.35	3.25	(0)
Black cherry (*Prunus serotina*)	1.08	0.28	5.00	(1)	Carolina buckthorn (*Rhamnus caroliniana*)	1.67	0.45	1.74	(0)

[a]The maximum height that vegetation is allowed to reach on TVA transmission line rights-of-way before maintenance is required is 3.7 m (12 ft).

$200/ac ($500/ha), are required primarily where rights-of-way cross wooded areas. The remaining 30% traverse lands such as cultivated fields, pastures, streams, and highways. Thus it would cost approximately $160,000 to restore ground cover on the 37 mi (60 km) of wooded right-of-way (174 ft (53 m) wide)) usually associated with 62 mi (100 km) of right-of-way. Fowler et al. (1981) reported that volunteer vegetation had stabilized 95% of an unseeded new right-of-way crossing a wooded area in east Tennessee. He suggested that only the 5% of such corridors which were actively eroding should be seeded to fescue grass. Thus utilization of volunteer vegetation as ground cover could potentially cut restoration costs by $147,000 along the 37 mi (60 km) of wooded rights-of-way per 62 mi (100 km) of newly constructed right-of-way (53 m (174 ft) wide).

In this study both seeded and unseeded portions of the study right-of-way were recleared during March-April of 1981 using rotary mowing equipment. Although seedling and resprout densities, and the number of problem trees, were higher on the unseeded right-of-way (Table 1), reclearing costs ($40/ac ($100/ha)) were the same for both treatments. This situation may be explained by the growth stage of the woody vegetation on the study right-of-way. At the time of reclearing, the diameter of the woody stems was not large enough to pose a problem for the rotary mowing equipment. However, if reclearing had been delayed for another year of so, maintenance expenditure for the unseeded right-of-way would probably have exceeded that of the seeded treatment since both rotary mowing and hand clearing with chain saws would have been necessary along the corridor. The amount of hand clearing required on the unseeded right-of-way would have been considerably more than on the less dense seeded right-of-way.

Clearly, reduction of stump resprout densities is the key to lowering the costs associated with subsequent reclearing operations on new right-of-way. However, while seedbed preparation reduces resprout densities, it would probably be more cost efficient to treat the stumps with herbicides when the right-of-way is initially cleared and then allow volunteer vegetation to develop as the dominant ground cover. This procedure would reduce ground cover restoration costs by 80 to 90%, and the treated stumps would be eliminated permanently. These types of considerations could easily be integrated into corridor clearing operations once the basic application details are devised.

CONCLUSIONS

This study is the last phase of a research effort designed to evaluate the economics and environmental consequences of incorporating volunteer vegetation into TVA's ground cover restoration program for new transmission line rights-of-way. During the first phase of this research effort, Beeman et al. (1979) concluded that the Kentucky-31 fescue grass seeded along new right-of-way was replaced within 6 years by volunteer plant communities. Next, Fowler et al. (1981) examined the composition of vegetation that volunteered along a new TVA right-of-way immediately after initial shearclearing and prior to seedbed preparation. This right-of-way traversed a wooded area. Fowler documented 137 species of volunteer plants, estimated ground cover values of 71%, calculated standing crop biomass to be 2631 lbs/ac (2947 kg/ha) ovendried and concluded that the invading vegetation had effectively checked erosion along 95% of the study right-of-way. Both Fowler and Beeman concluded that the volunteer plant communities provided valuable food and cover for wildlife populations using the rights-of-way. This research project complements those earlier investigations and provides the final information needed to make sound management decisions regarding modification of TVA's current ground cover restoration program on new rights-of-way.

Fowler et al. (1981) also speculated that the seedbed preparation process might reduce future maintenance costs by reducing the number of seedlings and resprouts. The data presented in this study indicate that woody regrowth stem densities are indeed reduced but that the present TVA policy of reclearing right-of-way on a 3-year cycle prevents the vegetation from getting large enough to pose a serious problem for the rotary mowing equipment. However, these conclusions are based on a spring cleared right-of-way and the erosion control potential of volunteer vegetation on fall cleared right-of-way would be much less desirable, particularly if ground cover restoration measures were planned for the following spring. These studies do indicate that seeding operations are often hard to justify over an entire new right-of-way on the basis of erosion control and reduction of future maintenance costs. It appears that in many cases ground cover restoration costs would be cut substantially by taking advantage of volunteer vegetation on right-of-way. Clearly utilities should consider incorporating volunteer vegetation into their ground cover restoration programs.

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RIGHT-OF-WAY MAINTENANCE TO REDUCE COSTS AND INCREASE VEGETATIVE DIVERSITY AND WILDLIFE HABITAT--A DEMONSTRATION

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ABSTRACT.--A demonstration area on the upper Coastal Plain of Mississippi was established to determine right-of-way maintenance costs and to improve wildlife habitat. Maintenance methods studied were winter and spring prescribed burning, selective spring mowing, and selective summer basal spraying. All methods controlled unwanted woody growth. Selective herbicide spraying and mowing did not increase abundance of wanted shrubby growth more than unselective prescribed burning. Spring maintenance did not kill woody growth more effectively than winter maintenance. Prescribed burning increased the abundance of legumes, while use of more than one maintenance method increased wildlife habitat diversity. Cost per acre for prescribed burning was \$5.22; for selective mowing, \$8.70; and for selective basal spraying of herbicide, \$97.16. Utility companies can achieve effective maintenance and reduce costs by using prescribed fire and selective mowing as maintenance methods.

INTRODUCTION

Utility companies strive to provide electricity at the most economical rate. Right-of-way (ROW) maintenance costs are incurred to insure reliable transmission. Various studies have presented conflicting results as to which maintenance methods are most economical (Huntley 1980). In addition, utilities face increased concern over the environmental effects of ROW construction and maintenance. Since ROW through forested land increase edge effect and habitat diversity, the management of ROW to further enhance wildlife habitat has been recommended.

In the Southeast, ROW research has determined which maintenance methods best increase wildlife food production while controlling woody growth. In Alabama, Arner (1959) first used prescribed burning to increase wildlife food production on ROW. Numerous studies have been conducted in Mississippi. Arner et al. (1976) summarized some of these studies and concluded that winter prescribed burning was cheaper and produced more food plants than mowing or spraying with herbicides. Huntley (1977) and Huntley and Arner (1981) reported the effects of winter burning, mowing, disking, hand clearing, selective basal spraying, aerial spraying, fertilizing, and

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seeding on ROW vegetation at three study sites. They found that of the methods tested, prescribed burning and mowing were the most economical.

Other research has documented wildlife usage of ROW. Eastern wild turkey (Meleagris gallapavo silvestris) in North Alabama favored winter mowed ROW for nesting sites (Everett et al. 1981). Although only 0.6% of the study areas was ROW, 37% of the discovered nests were in the mixed herbaceous, low brushy habitat provided by ROW. Ladino and Gates (1981) and Gates and Dixon (1981) discuss the effects of ROW and different maintenance practices on wildlife populations in Western Maryland. Betsill et al. (1981) reported on the effects of ROW maintenance on cottontail rabbit (Sylvilagus floridanus) populations in South Carolina.

Utilities seem willing to implement wildlife management plans (Lancia and McConnell 1976, Fowler et al. 1976), and a technical assistance manual on the management of transmission line ROW for fish and wildlife is now available (U.S. Fish and Wildlife Service 1979). However, implementation of these programs has been slow because of high cost and difficulty in obtaining cooperators to administer the plans. These problems may be solved if cost-effective management programs administered by utilities could be developed and demonstrated.

This paper reports the results obtained from one such demonstration area. The objectives of the study were to demonstrate the feasibility of using multiple maintenance methods to improve wildlife habitat and to provide cost data on each method.

Study Area

The demonstration area was on a Tennessee Valley Authority (TVA) 161 kV transmission line ROW located in the Upper Coastal Plain of Mississippi. The ROW averages 100 feet (30.48 m) in width and the study area was 0.75 miles (1.2 km) in length, encompassing 9.1 acres (3.68 ha). The ROW was constructed in 1967 and maintained by mowing in 1972 and 1975. Vegetation consisted of native woody growth, forbs, and grasses. Sweetgum (Liquidambar styraciflua) and winged sumac (Rhus copallina) were the most abundant woody species. The surrounding forest was mixed pine-upland hardwoods. Loblolly pine (Pinus taeda), shortleaf pine (Pinus echinata), and sweetgum were most abundant. Large oaks (Quercus spp.) and hickories (Carya spp.) occurred along small intermittent drainages.

METHODS

Maintenance treatments were winter prescribed burning, spring prescribed burning, spring mowing, and summer basal spraying applied respectively on March 16, April 8, April 13, and first week of August 1977. Mowing and basal spraying were used in a selective manner to control only the unwanted woody growth, tree species that would soon grow into the conductors. Treatments were intermixed to increase vegetative diversity and were assigned to particular sites depending on differences in ROW topography and vegetation (Fig. 1). Strip-head fires were utilized and fire lanes were plowed with a small crawler tractor and fire plow. A low volatile ester of 2,4,5-T with 4 pounds of acid equivalent per 1 gallon was used for basal spraying. A mixture of 1 pint herbicide per 4 gallons of diesel fuel was applied to the basal 1 foot of all unwanted woody stems. A medium-sized farm tractor and rotary cutter were used for mowing vegetation to a height of 7 inches (17.8 cm).

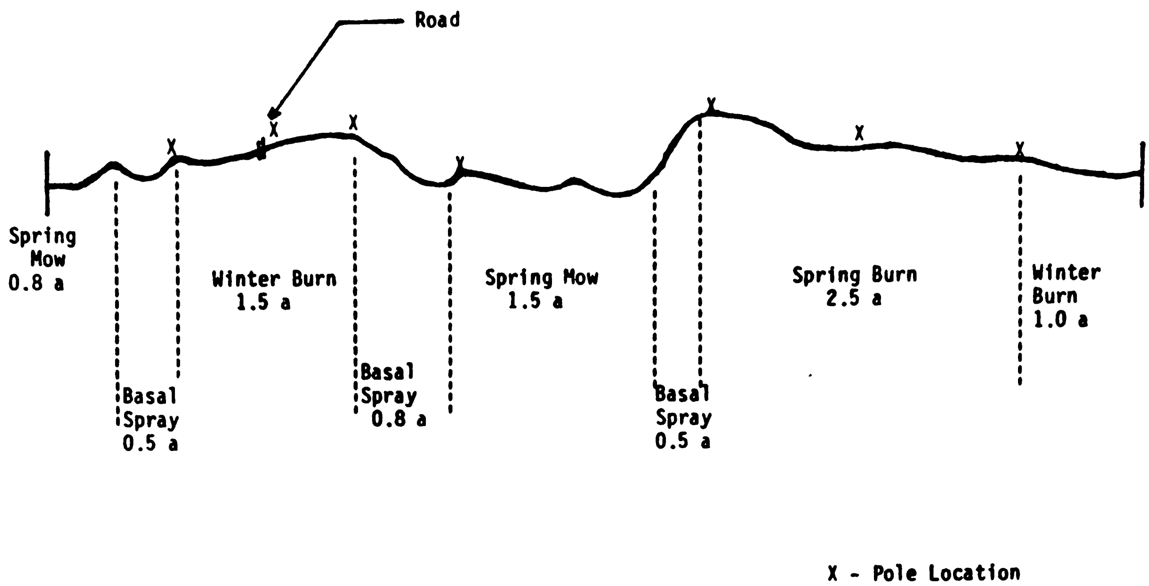

Figure 1. Profile of a utility ROW with acreage maintained by four methods, Winston County, Mississippi.

Spring treatments were applied during leaf development of woody species in an attempt to increase root-kill and prevent sprouting. Spring burning was conducted when sweetgum leaves were one-fourth to one-half full size, and the area was mowed when leaves were one-half to three-fourths fully developed.

Vegetation was sampled in 1977 and 1978, using the line interception method (Canfield 1941) to estimate coverage by different communities and abundance of legume and woody stems. Each maintenance treatment was sampled with 6 systematically placed 100-foot (30.48 m) line transects. Communities along each 5-foot (1.52 m) segment of the transect were identified. Communities were defined differently during the two sample periods because woody coverage was measured individually in 1977 but included in the community concept in 1978. Plant communities were identified by the species or group of species that covered over 50 percent of each line segment.

The cost of each treatment was based on actual labor and equipment used during field maintenance. Costs of travel, administration, and overhead were not included. The time spent during each type of maintenance is given so that these additional costs can be added to the field costs given in this report.

RESULTS

Community Coverage

The 1978 method was the most appropriate for determining community coverage because woody species were included in the community concept. Fifty-four community types were recognized in 1977 and 52 in 1978 (Huntley 1980). To facilitate comparisons between treatments, communities were aggregated into vegetative groups with different values as wildlife food and cover (Table 1). Communities were defined differently and 1977 and 1978 data should not be compared.

Winter-burned areas had the greatest coverage, 7.7% and 4.8% in 1977 and 1978, respectively, of legume dominated communities. Coverage of preferred grasses was highest in the basal-sprayed areas in both years. Other grass coverage was highest in the spring-mowed and spring-burned treatments. Other grass communities were dominated by bluestem (*Andropogon* spp.) which has little value as wildlife food. Differences in pre-treatment abundance had a greater impact than treatments on bluestem coverage. Common ragweed (*Ambrosia artemissiifolia*), an excellent wildlife food, was abundant 1 year after winter burning.

Unwanted woody growth was killed by basal spraying with 2,4,5-T. Coverage was effectively reduced after 1 year, but in 2 years pine coverage increased because of rapid seedling growth. Other treatments controlled woody growth but only above ground parts were killed. Sprouts from hardwoods and shortleaf pine root stocks, as well as new pine seedlings, developed and grew rapidly. Winged sumac and smooth sumac (*Rhus glabra*) dominated communities in the winter-burned areas counted for the greatest wanted woody coverage, 26.5%. Shrubs and small tree species were considered wanted woody growth.

Line transects were a very efficient method for determining community coverage, yearly changes in vegetation, and differences between treatments. The entire demonstration area was sampled in 8 hours.

Abundance of Legume and Woody Stem

The greatest number of legumes per 100-foot (30.48 m) transect, 123 and 126 in 1977 and 1978, respectively, occurred in the winter-burned areas. The other treatments ranked according to legume abundance were spring-burned, spring-mowed, and basal-sprayed. Legume abundance decreased after application of herbicide (Table 2).

Basal spraying with 2,4,5-T root-killed most sprayed stems, but controlling pine was a problem. Pine increased to pre-treatment levels 2 years after treatment because very small seedlings were not detected and new seedlings became established. Abundance of wanted woody stems was as great in the non-selective spring and winter burns as in the selectively basal-sprayed and spring-mowed areas. Burning promoted the development of sumac, the most abundant shrubby species.

TABLE 1

Percent coverage of different community groups on a utility ROW in 1977 and 1978, respectively, one and two growing seasons after maintenance, Winston County, Mississippi.

Community[a] Groups	Treatments							
	1977[b]				1978[b]			
	Basal Spray	Spring Mow	Spring Burn	Winter Burn	Basal Spray	Spring Mow	Spring Burn	Winter Burn
Legumes	0.3	0.5	1.5	7.7	1.8	1.8	4.3	4.8
Preferred Grasses	27.3	24.3	12.3	4.7	19.0	10.5	5.7	4.5
Other Grasses	33.2	49.8	53.0	25.0	24.7	62.3	69.2	22.2
Ragweed	0.0	0.0	2.3	19.3	0.0	0.0	0.0	0.0
Other Forbs	0.0	1.7	6.0	11.0	0.0	1.5	7.3	16.5
Vines	9.7	2.3	0.0	8.2	18.2	8.5	1.8	9.7
Rubus	4.7	3.7	4.5	4.7	3.7	4.3	3.7	11.7
Wanted Woody	11.2	6.8	14.8	15.0	20.7	10.2	3.0	26.5
Unwanted Woody	3.0	20.8	5.5	4.5	12.7	0.8	5.0	1.7
Dead Vegetation	10.6	0.0	0.0	0.0	1.0	0.0	0.0	2.3

a Various communities were grouped together according to dominant species in the community.

b Due to different definition of communities do not compare 1977 to 1978 data.

Table 2. Average number of woody and legume stems that intersected a 100-foot line transect on a utility ROW after various treatments, Winston County, Miss.

Category	Basal Spray			Spring Mow		Spring Burn		Winter Burn	
	1977[a]								
Unwanted Woody	Pre-Trt.	After-Trt.	1978	1977	1978	1977	1978	1977	1978
Pine	7.5	3.8	10.0	10.0	16.3	6.7	6.3	1.2	1.5
Sweetgum	4.2	1.2	1.3	6.0	6.3	3.3	5.2	2.0	4.0
Total	14.2	6.3	13.5	19.2	27.5	12.5	18.2	8.3	10.5
Wanted Woody									
Winged Sumac	18.2	13.2	18.0	10.3	12.8	20.2	19.8	18.0	10.8
Total	25.0	18.8	26.8	14.3	19.2	28.5	28.0	26.5	32.5
Legumes	56.8	34.2	44.7	47.8	67.3	85.3	122.8	123.0	126.3

a 1977, one growing season after treatment except basal spray where pre-treatment and after-treatment data are given; 1978, two growing seasons after treatment

Cost of Maintenance

To determine costs, the following per hour rates were used:

1.	Fire lane plowing, equipment and operator	$24.00
2.	Mowing, equipment and operator	12.00
3.	Labor for herbicide application	6.50
4.	Labor for prescribed burning	4.50
5.	Additional supervision for selective treatments	2.50

Selective treatments require additional supervisory cost because workers must distinguish between wanted woody species and unwanted species. Also, additional supervision is needed to assure proper field implementation. Labor costs for herbicide application were higher than for prescribed burning because it is harder work.

Time spent and cost per acre were as follows:

	Cost/ac
1. Prescribed burning	
a. Fire lane plowing, 0.12 hr/ac	$ 2.88
b. Labor, 2 men, 0.26 hr/ac	2.34
Total	$ 5.22
2. Selective mowing	
a. Equipment and operator, 0.6 hr/ac	$ 7.20
b. Additional supervision	1.50
Total	$ 8.70
3. Selective basal spraying	
a. 2,4,5-T ester, $21.80/gal, 0.9 gal/ac	$19.62
b. Diesel fuel carrier, $1.05/gal, 26.7 gal/ac	28.04
c. Application and supervision, 5.5 hr/ac	49.50
Total	$97.16

On the Coastal Plain, prescribed burning and mowing on a 3-year cycle would probably control unwanted woody growth. The cycle for selective basal spraying could be longer if the treatment was successful in establishing shrub-dominated ROW. After 1 treatment, basal spraying did not increase shrubby growth and light-seeded unwanted species--mostly pines and sweetgum--rapidly reseeded the ROW.

Cost of prescribed burning was greatly reduced by using strip-head fires rather than backfires. On a nearby research area where both back and head fires were used, the latter reduced the cost of burning $12.15 per acre (0.4 ha). To ensure control, cross fire lanes were plowed at 500 foot intervals. Cross lanes can be plowed around wooden utility poles to prevent damage.

The amount of time and money saved by selective mowing as compared to complete mowing depends on the density and distribution of unwanted woody stems. Where wanted woody growth and herbaceous growth were predominant, a substantial amount of time was saved. Sites with abundant wanted woody growth were chosen to be basal sprayed because these sites had the greatest potential for development of shrubby growth. Density of unwanted stems on the sprayed areas was also higher than the average ROW density.

DISCUSSION AND SUMMARY

The purpose of this study was to demonstrate how 4 maintenance methods, spring and winter prescribed burning, selective mowing, and selective basal spraying, could be used to reduce costs and to enhance wildlife habitat on the Upper Coastal Plain of Mississippi. Results clearly indicate that utilities could reduce costs by using prescribed burning and selective mowing for ROW maintenance. Prescribed burning increased the abundance of legumes, which are preferred wildlife food plants, and both methods maintained the ROW in a mixture of low bushy and herbaceous vegetation. Such habitat is beneficial to a variety of wildlife including 4 popular game species: wild turkey, cottontail rabbit, bobwhite quail (*Colinus virginianus*), and white-tailed deer (*Odocoileus virginianus*). The ROW provided a type of habitat not available in the surrounding forest.

Selective mowing and prescribed burning can be easily applied for ROW maintenance in the South. Mowing is already the predominant method used and could be applied in a selective manner with additional training and supervision. Prescribed burning is a widely accepted forest and wildlife management practice. Adverse impacts from smoke emissions would be minimal because ROW are linear-shaped and most ROW in forested areas are not near heavily-populated areas. Coordination with fire control agencies would be essential, and announcement to local landowners and the general public would be desirable. When conducted under proper conditions, fire is not likely to escape onto surrounding land, and liability agreements with landowners are a possibility.

The cost of maintaining the 9.1 acre (3.68 ha) demonstration area was $23.29 per acre (0.4 ha). Maintenance cost could be reduced to $6.76 per acre if selective mowing was substituted for the basal-sprayed treatment. In this case, 4.1 acres (1.66 ha) would be mowed and 5.0 acres (2.02 ha) would be burned. The benefits gained by selective basal spraying do not justify the higher cost. Wildlife habitat is not improved because burning and mowing at 3-year intervals also provide brush dominated areas. Also, selective basal spraying is not expected to decrease maintenance cost by increasing shrubby growth because the most abundant shrubby species, sumac, blueberry (*Vaccinium* spp.), and blackberry (*Rubus* spp.), are promoted by disturbances such as fire (Oosting 1942, Duvall 1962, Gill and Healy 1974). Where dense patches of shrubby growth are already established, a few unwanted woody stems could be economically controlled by basal spraying. Three of these patches, covering about 0.2 acres (0.08 ha), were present on the demonstration area.

Spring treatments are not recommended because they destroy wildlife nests and do not control woody growth any better than winter maintenance. Using fewer maintenance treatments will also simplify ROW management planning. Apply the 2 recommended treatments, winter prescribed burning and selective mowing, in different years so the entire ROW will not be maintained the same year. This type maintenance will ensure that brushy habitat will be available throughout the maintenance cycle. Everett et al. (1981) found that wild turkey nesting on ROW was greatly reduced the first year after mowing.

The field cost of maintaining the demonstration area with prescribed fire and selective mowing on a 3-year cycle would be $2.26 per acre (0.4 ha) per year. Mowing a greater percentage would increase costs, but mowing the entire area would cost only $2.90 per acre per year. These economical methods will greatly reduce maintenance costs and provide productive wildlife habitat. Wildlife food production can be increased by fertilization and establishment of food plots but such practices are costly, and consumers of electricity should not have to pay the additional expense. High cost practices should not be utilized unless the additional costs are assumed by the chief beneficiaries.

This study demonstrated that ROW management plans that are simple to administer, reduce maintenance costs, and improve wildlife habitat are feasible.

ACKNOWLEDGEMENTS

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THE ROLE OF CHEMICALS IN MANAGEMENT OF ROADSIDE VEGETATION

Larry D. Voorhees[1]

ABSTRACT.--A survey of State Highway departments indicates that mechanical mowing of highway rights-of-way has decreased dramatically over the past ten years, while use of herbicides and growth retardants showed a marked increase. Although a wide variety of pesticides are used (46 herbicides or growth retardants and 8 insecticides), only a few are common to many states. The most common herbicide (applied in 66% of the reporting states) is 2,4-D, used to control broadleaf species. Roundup, a very broad spectrum, nonselective herbicide, is used in 57% of the states. Drift to nontarget areas was the primary problem encountered when using herbicides. Toxicity and effects of chemicals on wildlife are discussed as well as recommendations to minimize potential adverse environmental effects.

INTRODUCTION

Controlling vegetation on highway rights-of-way is necessary to (1) maintain adequate visibility, particularly at intersections, (2) prevent obstruction of guardrails and traffic signs, (3) eliminate noxious weeds, (4) prevent breakup of the pavement edge, (5) maintain a groundcover resistant to erosion, (6) minimize fire hazard, and (7) minimize drifting snow and snow removal problems. The high cost of fuel, labor, and equipment associated with mechanical mowing of highway rights-of-way make the use of pesticides an attractive, viable alternative. This study documents the extent of pesticide use in the United States for managing roadside vegetation and the potential adverse environmental effects associated with this specific use of pesticides. Ways to minimize such effects are recommended.

METHODS

Chemical Use Survey

A survey on the use of herbicides, growth retardants, and insecticides in roadside maintenance was administered to each State Highway Department through the American Association of Highway Transportation Officials.

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Forty-four states and the District of Columbia reported. Data from the District of Columbia were eliminated because their rights-of-way are almost entirely urban in character.

RESULTS

General Statistics

More than 6 million acres (2.4 million hectares) of roadside are maintained along 830,000 miles (1.3 million km) of state-operated highways in 44 states. General maintenance practices are listed in Table 1. Annually, 38 states spend about $182 million to manage roadside vegetation. An average of 19% of the budget is used for pesticide treatments, principally herbicides. Fertilizers, mowing, and mechanical removal of trees and brush account for 3%, 49%, and 18% of the budget, respectively.

Table 1. Relationship of maintenance practices on state highway rights-of-way.

Maintenance	Number of Responses	Acres/Hectares
Mowing	42	4,032,200 (1,632,000)
Growth retardants	14	44,800 (18,100)
Selective herbicides	37	819,600 (331,700)
Nonselective herbicides	29	124,100 (50,200)

Trends in Roadside Maintenance

Although mowing has decreased in 39 states over the past ten years, rights-of-way acreage receiving growth retardants and herbicides showed a marked increase. Thirty-three percent of the states had increased the use of growth retardants; 65% had increased the use of herbicides. Use of herbicides and growth retardants save some states (primarily in the southeast) about $40/acre ($100/ha) annually. Four states had decreased their use of growth retardants, reporting that results were too erratic to justify the high cost of materials and equipment. Vermont eliminated the use of growth retardants. Reduction in the use of herbicides (six states) was most dramatic in Wisconsin where, prior to 1971, the entire right-of-way received broadcast sprays. Wisconsin now uses herbicides for spot treatment only. No states had completely eliminated the use of herbicides.

Pesticides Used

A total of 54 pesticides are used throughout the United States--46 herbicides and growth retardants, and eight insecticides. Eight pesticides are common to at least 25% of the reporting states (Table 2). More than one-half (56%) of the pesticides are used in only one or two states. The most common herbicide was 2,4-D, (applied in 66% of the states) used to control broadleaf species. Roundup, a very broad spectrum, nonselective herbicide, was used in 57% of the states. Alaska is the only reporting state that does not use pesticides to manage roadside vegetation.

Table 2. Pesticides used on highway rights-of-way in the United States.

Pesticide[a]	Alabama	Alaska	Arizona	Arkansas	California	Colorado	Connecticut	Delaware	Florida	Georgia	Hawaii	Idaho	Illinois	Indiana	Iowa	Kansas	Kentucky	Louisiana	Maine	Maryland	Massachusetts	Michigan	Minnesota	Mississippi	Missouri	Montana	Nebraska	Nevada	New Hampshire	New Jersey	New Mexico	New York	North Carolina	North Dakota	Ohio	Oklahoma	Oregon	Pennsylvania	Rhode Island	South Carolina	South Dakota	Tennessee	Texas	Utah	Vermont	Virginia	Washington	West Virginia	Wisconsin	Wyoming	Total	% of states reporting
Atrazine																												X									X					X			X							4	9
Amizine																	X							X						X					X			X													5	11
Amitrole					X		X													X	X	X										X					X							X			X				9	20
Ammate									X															X																									X		3	7
Ansar 560					X																																														1	2
Asulox								X						X																			X	X																	4	9
Atratol 80W																												X									X														2	5
Borate-chlorate																X																									X										2	5
Bromacil			X													X		X		X			X	X			X							X		X					X				X	X	X	X	X	X	16	36
Bromoxynil											X																																								1	2
Casoron																												X					X	X			X										X		X		6	14
Chloflurenol																																															X				1	2
Cygon								X																																											1	2
DSMA																																				X															1	2
Dalapon									X							X				X	X		X		X							X	X		X	X				X									X		12	27
Devrinol								X																																						X				2	5
Diazinon																																													X						1	2
Dicamba									X			X	X	X	X												X						X									X		X		X	X				11	25
Dinitro compounds			X																									X																							2	5
Diquat									X																X																										2	5
Diuron	X							X												X	X	X	X		X							X	X				X	X				X					X		X		14	32
Embark																						X											X					X									X		X		5	11
EPTC																																	X																		1	2
Fenac			X																																																1	2
Fenavar											X										X																														2	5
Igran																																												X							1	2
Kelthane																																						X													1	2
Krenite	X			X				X									X	X			X	X			X					X		X	X				X	X				X			X	X	X	X	X		19	43
MSMA	X			X												X	X	X						X	X											X						X									9	20
Malathion																																						X													1	2
Maleic hydrazide																	X			X									X			X	X				X									X	X				8	18
Methoxychlor																					X																	X													2	5
Orthene								X																																											1	2
Oryzalin					X				X																								X							X		X	X				X				7	16
Paraquat													X					X																																	2	5
Phytar 560			X																																																1	2
Picloram	X											X	X	X	X	X							X	X			X					X			X			X			X			X			X		X	X	17	39
Pramitol				X																							X						X	X							X	X	X			X				X	9	20
Pronamide																																															X				1	2
Ronstar								X																																							X				2	5
Roundup			X	X	X			X				X	X	X		X	X	X		X				X		X		X		X			X		X	X		X		X		X	X			X	X		X		25	57
Sevin							X	X													X																									X						4	9
Simazine				X	X		X	X					X							X		X				X							X	X			X	X									X		X		14	32
Spike			X					X					X		X										X		X						X									X	X				X		X		11	25
Tedion							X																																												1	2
Treflan																																	X																X		2	5
Triclopyr																																	X																		1	2
Trimec															X												X																								2	5
Ureabor			X												X																			X																	3	7
Velpar								X	X				X	X	X							X			X													X					X						X		10	23
XP pellets																									X																										1	2
2,3,6,TBA																X																																			1	2
2,4,5-DP																																															X		X		2	5
2,4-D	X							X	X			X	X	X	X	X	X	X		X		X	X		X	X	X	X		X		X	X		X		X	X		X	X					X	X		X	X	29	66
Total	5	0	7	5	5	b	4	13	7	b	b	6	8	6	7	8	6	6	b	8	7	7	5	6	9	3	7	6	1	4	b	7	17	5	6	6	8	2	b	4	6	8	5	5	2	9	19	2	15	4		

[a]See appendix for synonyms or similar formulations referred to in response to survey.

[b]Data not available.

Problems Associated with Pesticide Use

Drift of sprays to nontarget areas was reported in 12 states. "Unpopular with the public" was the second greatest concern (eight states), followed by misapplication (incorrect rates or choice of pesticide), difficulty in applying the pesticides at the proper time, and liability for accidents even though the pesticide was applied according to instructions and regulations. Nine states reported "none," "very few," or "minor" problems.

ENVIRONMENTAL EFFECTS

Although very few impacts from the use of pesticides for highway rights-of-way maintenance are reported in the literature, their use in other situations (e.g., agriculture, forestry) indicates the potential for many undesirable side effects. Impacts from pesticide use may not be restricted to the rights-of-way themselves. Sprays drift to nontarget areas. Highway rights-of-way often act as ditches carrying run-off of water-soluble chemicals and contaminated soil particles. Rights-of-way cross a wide range of habitats and land-use types and come into close contact with natural areas, agricultural lands, and urban environments.

The effects of pesticides depend upon several factors, including (1) toxicity, (2) rate of application, (3) method of application, (4) time of application, (5) movement of the pesticide through the ecosystem, (6) persistence of the pesticide and its metabolites in the environment, and (7) bioconcentration. Basically, organisms can be affected by pesticides either directly, through toxicity, or indirectly, by some change in the ecosystem.

Direct Effects

The severity of the direct effects of a pesticide depends on both the inherent toxicity of the pesticide and the way in which it is used. Pesticides exhibit a wide range of toxicity to animals. Insecticides as a class, however, are generally more toxic to wildlife than are herbicides and growth retardants (Figure 1). Diazinon, one of the more toxic insecticides used, is gaining widespread acceptance for the control of agricultural and household pests. Residues of diazinon in food for human consumption have already been detected in the United States (Johnson and Manske 1977), Canada (Smith et al. 1975), and elsewhere (Dick et al. 1978). Methoxychlor is only one-sixth as toxic as aspirin (NIOSH 1979); yet, waters have become so contaminated with this chemical that the Environmental Protection Agency has set maximum contaminant levels to protect human health (CEQ 1980).

Herbicides have, with a few exceptions, relatively low toxicity to mammals (Figure 1). However, some, such as treflan, can be highly toxic to fish and invertebrates at extremely low concentrations (U.S. EPA 1974). Similarly, some forms of 2,4-D, used extensively in managing roadside vegetation, are also toxic to fish (Niering 1978). The hazard of such herbicides is important and must be carefully evaluated when using them in areas with high erosion.

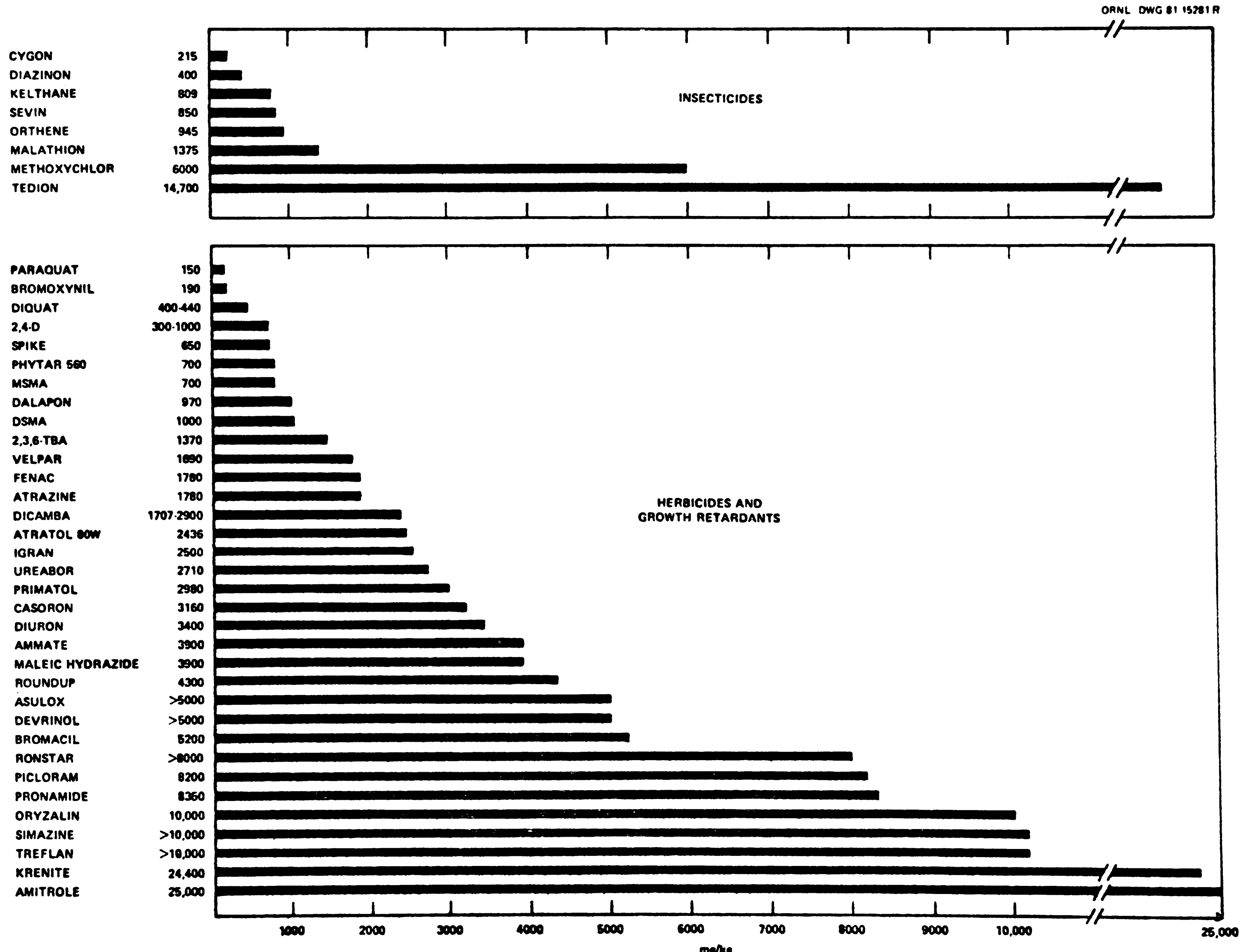

Figure 1. Relative toxicity (acute oral LD_{50}) of pesticides to rats. The shorter the bar the more toxic the chemical if ingested (Farm Chemicals Handbook 1981, Weed Science Society of America 1979).

Often more than one herbicide is used to control weeds, and as revealed by the survey, mixing several herbicides for a single application is a common practice. Some herbicide combinations could produce a greater than additive toxicity (synergism) resulting in an unexpected hazard to wildlife (USFWS 1980). Since toxicity studies are usually conducted for a single pesticide only, few data are available on this potential hazard.

Indirect Effects

Toxicity to wildlife can also occur indirectly as a result of managing vegetation with herbicides (U.S. EPA 1974). For example, several herbicides increase concentrations of substances (e.g., potassium nitrate) produced naturally by plants to levels that are poisonous to the animals ingesting them. Additionally, some naturally poisonous plant species which wildlife avoid become palatable following sublethal doses of certain herbicides.

Herbicides may reduce or eliminate resistance of plants to attack by pests. For example, certain varieties of red clover and oats lost their resistance to pest nematodes when exposed to low levels of 2,4-D (Webster 1967). In other situations, serious pest infestations followed the use of herbicides, thus requiring the application of still another pesticide (Fox 1964). Herbicides can also promote certain fungal diseases which may affect the very plants the herbicide is designed to protect (Katan and Eshel 1972).

The continued use of a herbicide to rid an area of an unwanted weed may actually promote the incidence of other weed species. For instance, the use of 2,4-D to control broadleaf weeds may lead to infestations of foxtail grasses (*Setaria*) and crab grasses (*Digitaria*) (Brown 1978). Also, dock (*Rumex*), knotweed (*Polygonum*), and bindweed (*Convolvulus*) appeared after applications of simazine or diuron; plantain (*Plantago*) after diuron; chickweed (*Cerastium*) after dalapon or amitrole; and brambles (*Rubus*) after simazine, diuron, or casaron (Schubert 1972). Canada thistle (*Crisium arvense*) appeared after general terbacil treatments in Michigan, and dandelions (*Taraxacum*) appeared following simazine treatments in Massachusetts (Brown 1978). The appearance of such species illustrates unexpected changes in community composition and can be particularly troublesome for managers of highway rights-of-way if the herbicides lead to the appearance of noxious weed species which they are charged with controlling. A classic case of unintentional results from use of herbicides was one from a New Jersey roadside in which 19 foliar applications of herbicides destroyed attractive broadleaf flowering plants. The result was a relatively spray-resistant cover open to tree invasion, requiring continuous maintenance (Dill 1962, 1963).

Populations (ecotypes) of weed species differ in their susceptibility to herbicides. For example, dalapon has a wide range of effectiveness for nine ecotypes of yellow foxtail (*Setaris lutescens*) and 16 ecotypes of giant foxtail (*S. faberii*) from different locations in Maryland (Santelmann and Meade 1961). Of ten ecotypes of Canada thistle collected in four states of the northwestern United States, one from Idaho was especially tolerant to amitrole and 2,4-D (Hodgson 1970). Field bindweed (*Convolvulus arvensis*) also expressed ecotypic variation to 2,4-D

(Whitworth 1964). Such wide ranges of susceptibility can, in time, lead to the development of resistant populations.

The greatest inadvertent environmental effect of using pesticides for roadside management is to change the composition of the plant community to the extent that it affects habitat available to wildlife. Herbicides can affect mammal populations by altering their food supply. For example, pocket gophers (Thomomys talpoides), which prefer forbs to grasses, were found to have a diet of 82% forbs on an untreated range where plant composition was 75% forbs and 25% grasses (Kieth et al. 1959). After applying 2,4-D for two years, the plant composition changed to 91% grasses and 9% forbs and the gopher diet changed to about a 50-50 mixture of grass and forbs. Although there was no evidence of 2,4-D toxicity to gophers, the population declined 87% compared to untreated areas. Somewhat similar situations have occurred among mice (Mus musculus and Peromyscus maniculatus) and voles (Microtus ochrogaster) in Indiana following treatment of a clover field with the insecticide cygon (Barrett and Darnell 1967), and among grey partridge (Perdix perdix) chicks following treatments of their habitat with herbicides (Southwood and Cross 1969). Highway rights-of-way provide attractive, secure nesting cover for several species of game birds (Voorhees and Cassel 1980, Joselyn 1969). Domestic hens pastured on grass sprayed with MCPA and 2,4-D showed no signs of ill health nor loss in weight, but the birds consumed more water (Dobson 1954). More importantly, egg production was reduced by 25% with MCPA and 15% with 2,4-D for a 3-week period after the spraying.

Herbicides can also indirectly affect aquatic organisms through habitat alteration. Simazine applied experimentally to ponds to control the weed Potomogeton fuliosus and all filamentous forms of algae also lowered the pH of the water and drastically changed the species composition of bottom-dwelling invertebrates (U.S. EPA 1974). Decomposition of aquatic weeds in highway drainage ditches following extensive treatment with herbicides can lower the oxygen saturation of the water, adversely affecting many aquatic organisms in receiving systems (Brown 1978).

MINIMIZING ENVIRONMENTAL EFFECTS

The effects of pesticides on nontarget plants and animals and the unanticipated side effects to an ecosystem in general warrant a few specific recommendations regarding their use in managing roadside vegetation.

Frequent and widespread use of herbicides can affect vegetation over very wide areas in a short period of time, eliminating wildife and wildlife habitat (Way 1969). Usually the problem is not toxicological, but ecological in terms of scale and intensity of use. For instance, the total destruction of a small area of vegetation on one occasion might be less serious for wildlife than the selective destruction of vegetation over a wide area at regular intervals (Andres et al. 1978). Consequently, nonselective broadcast sprays may be ecologically unsound. Only the minimum area should be treated. Streams and other water bodies should be avoided when applying pesticides designed for upland areas, and the dangers of runoff and erosion should be considered.

Select the pesticide that is least dangerous to fish and wildlife (Figure 1), recognizing that its toxicological properties vary with the taxon. Factors such as bioaccumulation, persistence, and rate of application should also be considered. For example, Figure 2 illustrates the persistence of activity in soils of herbicides used in highway roadside maintenance. The persistence of picloram in soil can delay reinvasion of many herbicide-sensitive species for several years (Carvell 1976). If 2,4-D and picloram produce the same desired effect, it may be advisable to use 2,4-D even though it is relatively more toxic. Pesticides should be applied at recommended rates only, following all label instructions. Application should be avoided during nesting periods of birds or other times of principal use of the area by wildlife.

Application method, carrier, and formulation should be chosen so as to minimize wildlife's contact with chemicals. Emulsions are more toxic than oil solutions or suspensions for application in aquatic habitats. Granules often concentrate the effect of the toxicant. Drifting can be reduced by regulating the particle size of the spray, the time of application, and by using a relatively new technique called electrostatic spraying (Law 1980). Electrostatic spraying not only reduces drift but is expected to effectively reduce the volume of active ingredients released to the environment by at least 50% (Law 1980).

Other, more natural methods, such as fire or biological control should be considered. With fire, air pollution can be a problem in terms of total suspended particulates and visibility. However, such effects can be minimized through proper management and time of application. Biological control permits self-perpetuation and a high degree of host plant selectivity, especially when weed-feeding insects or plant pathogens are used (Andres et al. 1978). CEQ (1980) emphasizes greater use of natural pest control techniques in lieu of chemical pesticides. U.S. EPA (1980) recently announced a new program to encourage the use of a class of pesticides called biologicals. Although the control of pests by natural enemies will develop further, it is unlikely to make the use of chemical pesticides entirely unnecessary. Therefore, care must be taken in their selection and application.

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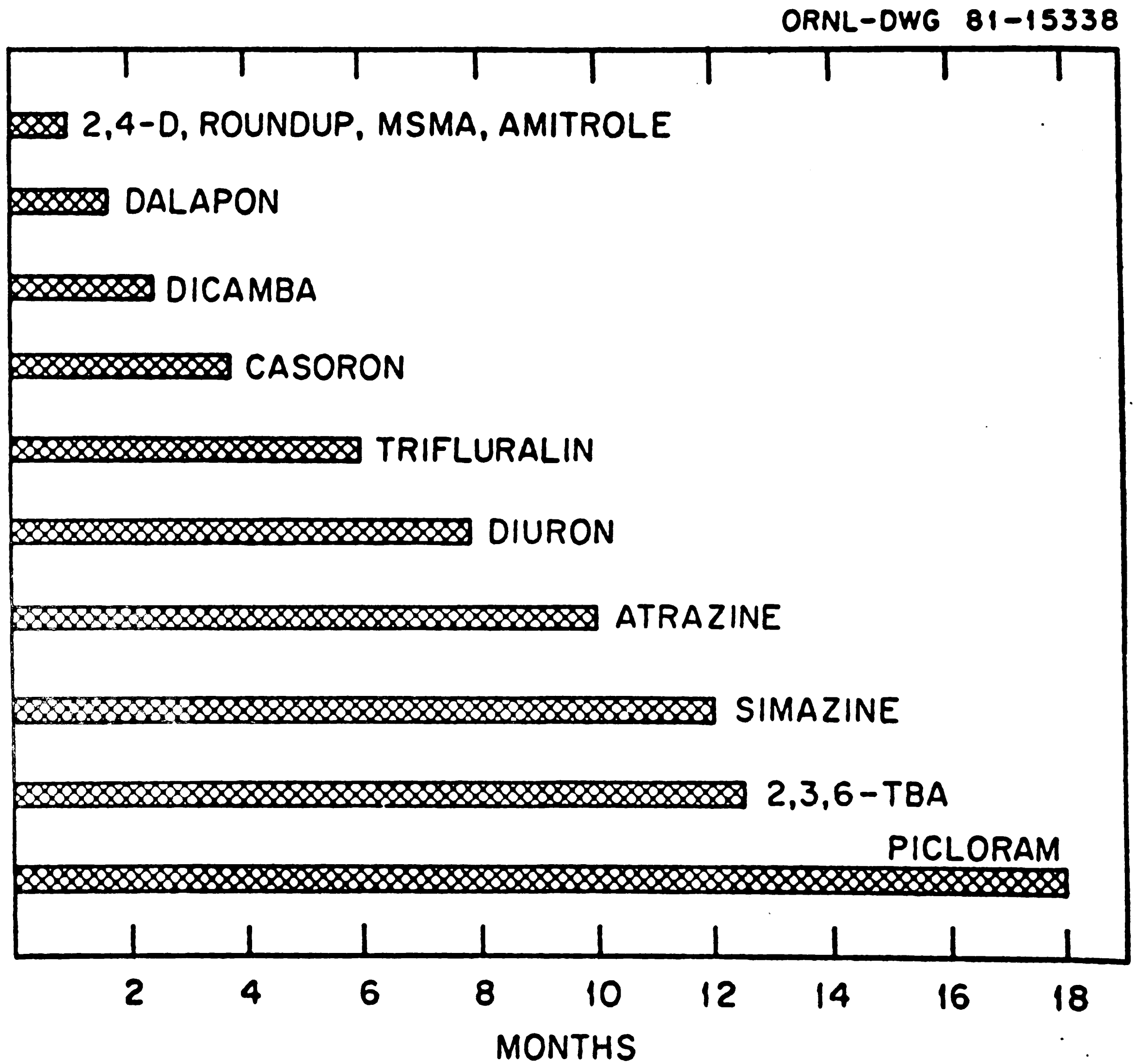

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APPENDIX

Synonyms or Similar Formulations for Pesticides Listed in Table 2

Atrazine = Aatrex, Primatol A
Amizine
Amitrole = Amizol, Aminotriazole
Ammate = Ammonium sulfamate
Ansar 560
Asulox
Atratol 80W
Borate-chlorate
Bromacil = Hyvar XL, Urox B
Bromoxynil
Casoron = Dichlorobenil
Chloflurenol = Maintain
Cygon
DSMA (disodium methanearsonate)
Dalapon = Dowpon
Devrinol = Napropamide
Diazinon
Dicamba = Banvel
Dinitro compounds
Diquat
Diuron = Krovar, Karmax, Urox D
Embark = Mefluidide
EPTC = EPTAM
Fenac
Fenavar
Igran = Terbutryn
Kelthane = Dicofol
Krenite = Fosamine ammonium
MSMA (monosodium methanearsonate)
Malathion
Maleic hydrazide
Methoxychlor
Orthene
Oryzalin = Surflan
Paraquat
Phytar 560 = Cacodylic acid
Picloram = Tordon
Pramitol = Prometon
Pronamide = Kreb
Ronstar = Oxadiazon
Roundup = Glyphosate
Sevin = Carbaryl
Simazine = Princep, Primatol S
Spike = Tebuthiuron
Tedion
Treflan = Trifluralin
Triclopyr = Garlon
Trimec
Ureabor
Velpar = Hexazinone
XP pellets
2,3,6,TBA (trichlorobenzoic acid)
2,4,5-DP
2,4-D = MCPA, Envert, Weedone, 2,4-D Invert

NEW YORK STATE PUBLIC SERVICE COMMISSION'S POLICY ON THE MANAGEMENT OF ELECTRIC TRANSMISSION RIGHTS-OF-WAY VEGETATION

James J. de Waal Malefyt[1]

ABSTRACT.--In 1980, the New York State Public Service Commission adopted a policy statement on the role of herbicides in managing vegetation on electric transmission rights-of-way. It also adopted regulations for approval of aerial spraying plans, long-range management plans, annual maintenance plans, and ordered improvements in herbicide applicator training programs. The PSC found that the continued use of selective techniques for herbicide application was reasonable from engineering, economic and environmental viewpoints. The policy statement and regulations were formulated to reduce deferred maintenance, increase system reliability, and to address the desire of some of the public to ban herbicide applications. An adequate inventory of vegetation and related resources and criteria for choosing vegetation management techniques was stressed as was the training of applicators in plant identification and herbicide application near sensitive areas. No basis was found for restricting specific herbicides beyond those imposed by EPA and other state agencies. A review of herbicide applicator proficiency is reported. Lists of target plants, applicator training procedures, specifications to protect sensitive areas, and proper supervision and monitoring were found to be common elements of utility training programs for applicators. Outlines of long-range, systemwide rights-of-way management plans and annual maintenance programs are presented. Such plans and programs will be reviewed in utility rate cases, management audits, and on rights-of-way.

INTRODUCTION

In 1978, the New York State Public Service Commission (PSC) asked its Office of Environmental Planning to analyze herbicide use on electric utility ROW. Following this evaluation, the PSC issued for public comment a draft policy statement on the role of herbicides in managing vegetation on electric transmission rights-of-way (ROWs). It was adopted in final form in 1980 (NYS PSC 1980a). The policy statement was written in

1 New York State Department of Public Service, Albany, NY 12223.

response to tree-fault outages on bulk transmission systems, deferred vegetation maintenance, moratoriums on herbicides by utilities, complaints against aerial broadcast spraying of herbicides, and increased public concern about herbicides.

The PSC determined that properly controlled herbicides are very useful for managing ROW vegetation and emphasized that herbicides should be used selectively. The PSC found that an adequate inventory of ROW vegetation and related resources is an indispensable first step in selecting either chemical or mechanical techniques for controlling vegetation on a particular ROW segment. Adequate training of herbicide applicators can offer increased assurance that herbicides are applied safely and effectively. The PSC also concluded that preparation of systemwide transmission ROW management and annual maintenance programs should lessen the amount of deferred vegetation management. Regulations for approving aerial herbicide applications on ROWs were also adopted.

HERBICIDES AND ROW MANAGEMENT OBJECTIVES

The principal ROW vegetation management objective endorsed by the PSC is the growth of low-growing, relatively stable plant communities that are compatible with electrical system reliability requirements, aesthetically appealing, beneficial to wildlife, and need relatively little maintenance over the life of a ROW. Using herbicides is one way to achieve this objective and is commonly used by New York State utilities. The New York State Attorney General, the Atlantic Chapter of the Sierra Club, and several other public organizations argued for gradually abandoning herbicide use on utility ROWs. However, the PSC found no compelling evidence for discontinuing the present role of herbicides as a useful tool of utility ROW vegetation management, provided their use is limited to proper situations and made subject to adequate controls. The PSC also concluded it has no basis for singling out any registered herbicide for special consideration or restriction beyond those actions taken by the Federal Environmental Protection Agency or New York State's Department of Environmental Conservation regulations. It did, however, take additional precautionary measures to protect sensitive areas adjacent to ROWs from possible herbicide contamination.

PROTECTING SENSITIVE AREAS

The PSC required the electric utilities to establish a voluntary notification system between the utilities and the field offices of the Department of Environmental Conservation and Health. This would allow these agencies to provide guidance and assistance in protecting nearby populated areas, potable water supplies and sources, crops, bodies or courses of water, and recreation and other sensitive areas from herbicide contamination. The utilities were also ordered to show cause why they should not institute training programs for herbicide applicators working in sensitive areas. All utilities responded and demonstrated that each had satisfactory procedures or specifications to protect sensitive areas. Field observations by PSC staff, however, revealed minor deviations from such specifications, and consequently the PSC ordered the utilities to work with staff to improve training programs and supervision in this area.

ACCEPTABLE HERBICIDE APPLICATION TECHNIQUES

It has been the PSC's policy in environmental certification of major electric transmission facilities under Article VII of the Public Service Law to approve site-specific management techniques that are based on a vegetation inventory, environmental concerns and cost-effectiveness. In one instance, the PSC ordered a utility to resume an approved vegetation management program for applying herbicides basally and to cut stumps when the utility changed to a "non-chemical" program after the suspension of 2,4,5-T in 1979. The PSC has generally accepted the various herbicide application techniques used by New York State utilities, but the aerial application of herbicides by helicopter has, however, received more scrutiny than any other technique to date.

Only two of the major investor-owned electric utilities in New York have used the aerial technique in the past several years. Consumer complaints, involvement of the State Attorney General, and field investigations by OEP led to several PSC actions with respect to one utility in 1977. The PSC required the utility to: (1) prepare appropriate statements and plans to justify aerial spraying on a site-by-site basis indicating vegetation conditions to be treated, access conditions, and measures taken to insure that non-target resources such as streams would not be contaminated; (2) prepare plans under the direction of trained ROW management professionals to institute an ecologically and economically sound long-range, system-wide ROW vegetation management program as the basis for continued use of herbicides; and (3) prepare a draft environmental impact report concerning the potential termination of aerial spraying and substitution of alternate means of ROW management.

Due to relatively low costs and utility-reported high effectiveness on ROW sites with extensive tree coverage or which are economically inaccessible, the PSC did not terminate aerial herbicide applications. Because it continues to be a controversial treatment method, the PSC issued rules and regulations in 1980 concerning this technique (NYS PSC 1980b). They supplanted orders which formerly applied only to Niagara Mohawk Power Corporation. Any electric utility must now submit plans with suitable maps and charts justifying its choice of the aerial technique on a site-by-site basis. Plans must describe vegetation to be treated, access conditions, measures to insure that non-target resources will not be fouled, and how the technique will achieve the utility's ROW vegetation management goals for the affected ROW and system as a whole. Such information must be filed with the PSC 60 days before spraying begins and is approved if not acted upon within 45 days.

Only one utility challenged the PSC on this subject, asserting the PSC was exceeding its jurisdiction and encroaching on an area delegated to the Department of Environmental Conservation. The PSC said that, under the Public Service Law, it must ". . . take steps to assure that transmission ROW are maintained in a way that strikes the proper balance among reliable service, low cost, and protection of the environment. Reviewing aerial spraying plans is one such step, for improper spraying cannot only cause damage off the ROW, but also interfere with the ROW management goal of fostering the growth of stable, low-growing communities of vegetation" (NYS PSC 1980b).

To date, only Niagara Mohawk Power Corporation has submitted aerial spraying plans for PSC approval for ROW maintenance. Criteria submitted by the utility allow aerial spraying if the site is covered by: (1) 65 to 100% woody undesirables; (2) 30 to 65% woody undesirables, and woody desirables cover less than 15% of the site; (3) 30 to 100% root-suckering undesirables where stem-foliar treatment would result in the same loss of woody desirables; and the site (4) has 30 to 100% of the limbs from side trees encroaching upon the wire security zone (on ROW less than 75 feet (23 m) wide it may be justifiable to treat the entire ROW); and (5) is not reasonably accessible to ground equipment. In addition, helicopter shut-off zones have been established for environmentally sensitive and intensive land use areas as follows: 50 to 100 feet (15-30 m) from a wetland or stream, 25 to 100 feet (8-30 m) from road crossings, and 250 feet (76 m) from parks, golf courses, etc.

SYSTEMWIDE, LONG-RANGE ROW MANAGEMENT PLANS

In 1977, the Secretary of the PSC wrote each major utility suggesting that it prepare and submit a long-range, ROW system management plan. Prior to this, the PSC staff had distributed guidelines on such plans and made presentations at informal ROW management symposia. By mid-1979, only one utility had prepared a PSC-ordered and approved systemwide plan and two others had made partial submittals. In its proposed and final opinion (NYS PSC 1979; 1980b), the PSC gave several reasons for requiring such plans. Field observations by its staff and documentation by utilities in rate cases and by utility consultants provided the PSC with evidence that ROW maintenance for many transmission facilities was not being planned or conducted on a consistent, systematic basis. Out-of-control ROW vegetation conditions could be attributed, in part, to inadequate planning and budgeting for ROW management and to the lack of comprehensive, long-range plans. Other causes included herbicide moratoriums, utility labor/management problems, inadequate vegetation inventories, and public resistance to tree removal programs.

Thereafter, the PSC issued rules for preparing long-range ROW management plans and annual maintenance programs for electric transmission systems. The preparation and availability of the plans and programs offer a basis for early warnings of deferred maintenance. The PSC would then be in a position to take suitable preventive or corrective actions before ROW vegetation gets out of control. The PSC also instructed its environmental staff to involve themselves systematically and routinely in rate cases and management audits to examine all aspects of transmission ROW maintenance. Utilities were ordered to prepare their own maintenance programs and maintain adequate records for periodic examination by staff.

Long-range ROW management plans for electric transmission systems were required by PSC for 34 kV systems and above, except where located entirely on public streets or roads. The utilities were required to generally describe their ROW system and company organization as it relates to ROW management. A short history of past ROW management programs, practices and issues was required to set the framework for the goals and objectives of the new plans. The primary goal of the plans, of course, is to maintain transmission systems free of tree-caused interruptions. Most utilities have adopted a reciprocal goal to suppress tall-growing trees by encouraging the development of relatively stable, low-growing plant communities. Other goals listed by the utilities are to reduce herbicide usage by a specific amount, improve access roads on certain ROWs, landscape ROWs in specific residential areas, and to prevent unauthorized ROW use.

Determinations of ROW treatments based on vegetation and other types of inventories were required along with determinations of maintenance schedules or cycles. Various ROW management techniques were required to be described, including justifications, costs, effectiveness, environmental impacts, and other concerns for each technique. Discussion about the influence of vegetation density, type and height on treatment selection was also urged.

The approach for preparing annual maintenance plans and schedules for individual ROWs and the steps to implement them to achieve long-range goals was also suggested. In their responses, the utilities have identified criteria for selecting ROW for treatment followed by a description of the program designed to accomplish the specific objectives. This includes determination of work force size, type (i.e., company versus contractor), equipment and materials, training needs, and monitoring and evaluation programs. As a minimum, the PSC required the utilities to specify the types and frequencies of regular ROW inspections. Specific quantitative criteria relating to clearances between conductors and vegetation and the corresponding range of time in which vegetation maintenance must be performed was required. Additionally, annual schedules must be prepared by the utilities based on the results of ROW inspections.

The approximate funding levels needed to accomplish annual and multi-year ROW management planning goals were required by the PSC. Significant increases in funding could then be analyzed with respect to future rate cases and management audits. Curiously enough, since 1977, when the PSC first requested long-range plans, four of the seven major New York State electric utilities have substantially increased transmission management budgets to fund "accelerated" vegetation maintenance programs which are projected to result in low cost, sustained, cyclical maintenance programs.

Examples of standardized inspection reports, vegetation treatment reports, inventory forms, cost account sheets, etc., are required of each plan. The PSC ordered the retention of herbicide application reports for three years and for other records to be retained for a period consistent with the maintenance cycle. Only records summarized annually were expected to be retained permanently by the utilities. By imposing these requirements, the PSC intends to allow utilities to develop their own maintenance programs, but yet ensure that adequate records are maintained so that staff may periodically review them and report to the PSC. Other sections of the plan should address unresolved management issues, research activities, possible landowner notification procedures, and provisions for periodically reviewing, evaluating and revising the long-range plan.

HERBICIDE APPLICATOR TRAINING

PSC Opinion 80-40 (NYS PSC 1980b) ordered the seven investor-owned electric utilities to work with staff to improve their herbicide applicator training programs. Earlier, Opinion 80-15 (NYS PSC 1980a) ordered the utilities to show cause why they should not be required to institute a training program in: (1) fundamental plant species identification; and (2) application techniques in critical or sensitive areas on or adjacent to a ROW, for all herbicide applicators. The PSC proposal was based on field evidence gathered by its staff which showed excessive amounts of desirable vegetation had been eliminated by some faulty herbicide applications. The continual eradication of desirable ROW vegetation by herbicide applicators who lack knowledge and experience in distinguishing wanted from unwanted vegetation is inconsistent with the concepts, goals, and practices of ROW management endorsed by the PSC.

Staff found considerable variation in plant identification knowledge between herbicide applicators. As expected, there was a tendency for new applicators to be less proficient. In one case, an applicator on the job for one week was estimated to have misapplied the herbicide 30 to 40% of the time. With experienced and well trained applicators, misapplication was estimated at 10% or less. Misapplication not only wastes expensive herbicide, but defeats a secondary aim: to increase desirable shrubs. Plant identification problems centered on "look alike" plants. For example sumac (Rhus spp.) was confused with tree-of-heaven (Ailanthus altissima) and low- and tall-growing species of the same genus were confused with each other (i.e., choke cherry (Prunus virginiana) and black cherry (Prunus serotina). Most of the problems encountered by staff could be attributed to the short-term and seasonal employment of many herbicide applicators. The obvious, practical solution to this problem appears to be in the amount of training given to unskilled applicators by crew foremen and utility supervisors. Alerting applicators to unfamiliar woody species based on vegetation inventories would also aid in the solution.

All utilities were found to have procedures or specifications which, if followed, should protect sensitive areas such as residential areas, streams, and croplands. Staff found considerable differences, however, in the buffering margin (spray restriction) near streams: it ranged from 20 to 100 feet (6-30 m). Minor confusion about company specifications, restriction or allowable deviations were also found among crews and supervisors. However, in both situations, staff found no violation of herbicide label instructions or significant ecological damage.

CONCLUSION

Following many years of increasingly specific attention to ROW management issues and staff investigation of particular problems, the NYS PSC adopted a requirement for unified and integrated management of ROW resources. All seven investor-owned utilities subject to these PSC regulations have submitted long-range ROW management plans for PSC review and approval. Most of the smaller utilities have initially committed themselves to accelerated vegetation management programs of three to five years duration, followed by a lengthening of the maintenance cycle and increased use of selective techniques. The larger utilities are planning to treat individual ROWs on an average of every six to eight years. As a result of these new regulations, utilities have focused more attention to ROW management on a systemwide scale and have committed themselves to specific goals with revised budgets and management strategies to accomplish their objectives. The development of long-range ROW management plans should also make it easier for utilities to justify budget changes in PSC rate proceedings. Also, for the first time, most utilities will be recording changes in ROW vegetation composition, herbicide usage, and vegetation treatment techniques to measure the success of their plans in relationship to the PSC policy on herbicide and vegetation management of electric transmission ROW.

ACKNOWLEDGMENTS

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SPIKE 80W AS AN ALTERNATIVE

Rexford T. Myers[1]

ABSTRACT.--During the dormant season, contract right-of-way maintenance crews perform extensive basal spray work on transmission rights-of-way. Basal spraying involves the use of tremendous amounts of fuel oil (as a herbicide carrier). Experiments are currently being conducted on Public Service Indiana property using Spike 80W, a total vegetation control herbicide to eliminate this cost. Testing was done using several application techniques; banding, spot treatments, and combinations of banding and spot treatments. Due to the highly concentrated nature of the herbicide solution, treatments can be done quickly and effectively, with savings in time and cost.

INTRODUCTION

As the cost of living and inflation have risen, the cost of chemical growth control has sky-rocketed over the past several years. The primary factors in this cost increase are the cost of herbicides and the fuel oil carrier required by many herbicides.

The basic year-round herbicide program for utility companies utilizes basal spray application during the dormant season. This season lasts from mid-October to mid-April (in Indiana). Utility companies, with extensive rights-of-way, consume tremendous amounts of fuel oil during the winter months; for example, 1 gallon of Banvel 520 (Velsicol Chemical Corp.) is mixed with 33 gallons of fuel oil, and applied at from 50-250 gallons per acre (depending on brush size and density).

To reduce some of these costs, Public Service Indiana has tested application techniques for Spike 80W (Elanco Chemical Co.) to control rights-of-way brush. Spike 80W is a total vegetation control herbicide; i.e., it will kill all forms of vegetation having roots extending into the treated area. The Environmental Protection Agency has registered Spike 80W for use on utility rights-of-way applied in bands, or as a spot treatment. To prevent damage off the right-of-way, the manufacturer recommends that bands be applied no closer than 40 feet (12 m) from the right-of way edge. If techniques can be found to kill all of the brush on the right-of-way using Spike 80W, great savings can be obtained.

1 Carolina Power and Light, Raleign, NC 27602.

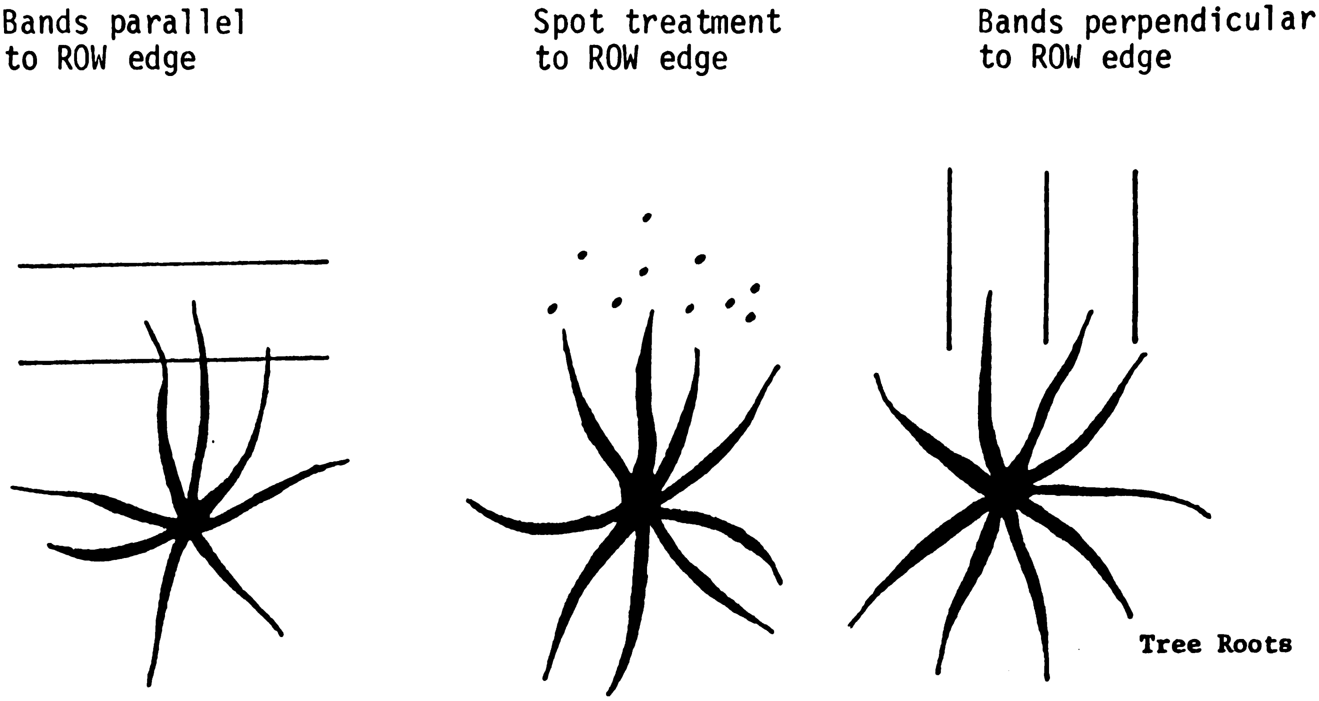

Figure 1. Methods of treatment evaluated.

APPLICATION METHODS

Public Service Indiana established 6 test plots on April 16, 1981, to evaluate different methods of applying Spike 80W to control brush along the edge of the right-of-way and to evaluate damage off the right-of-way.

Test Location

Six test plots are located on the edge of a 175-foot (52.5 m) wide right-of-way at Riverwood Generating Station, Riverwood, Indiana (about 15 miles (24 km) northeast of Indianapolis). The generating station is a small coal-fired plant, with several wide transmission corridors on plant property. Down the center of the right-of-way, we placed bands of Spike 5 feet (1.5 m) apart at the rate of 3 gallons per linear mile of a 1 lb Spike 80W/1 gal. water mixture, or the equivalent of 5 pounds of Spike per acre.

The 40-foot (12 m) zone on the east edge of the right-of-way was divided into six plots, 99 feet (30 m) wide (See Figure 2). The corners were marked with stakes, and each plot was labeled with a letter, A to F.

Test A: Bands were applied perpendicular to the right-of-way edge eight feet (5 m) apart, with half the bands alternating to within 16.5 feet (5 m) of the right-of-way edge at the rate of 5 pounds per acre of Spike applied in a 1 lb:1 gal. mixture with water.

Test B: The entire area was spot treated. The herbicide solution was mixed at the rate of 4 pounds of Spike in 1 gallon of water. The solution was applied to the ground at the base of the brush, with one 4 ml "spot" for each 2 inches (5 cm) of brush diameter (one "spot" for a 2-inch stem, and three "spots" for a 6-inch (15 cm) stem).

Test C: Bands were applied perpendicular to the right-of-way edge 16.5 feet (5 m) apart to within 16.5 feet (5m) of right-of-way edge at the rate of 5 pounds per acre of Spike applied in a 1 lb:1 gal. mixture with water.

Test D: Bands were applied perpendicular to the right-of-way edge 33 feet (10 m) apart to the right-of-way edge, at the rate of 5 pounds per acre of Spike applied in a 1 lb:1 gal. mixture with water, and the intermediate areas were spot treated. The herbicide solution for spot treatment was mixed at the rate of 4 pounds of Spike in 1 gallon of water. The solution was applied to the ground at the base of the brush, with one, 4 ml "spot" for each 2 inches (5 cm) of brush diameter.

Test E: Bands were applied perpendicular to the right-of-way edge 33 feet (10 m) apart to the right-of-way edge at the rate of 5 pounds per acre of Spike applied in a 1:1 mixture with water.

Test F: Bands were applied perpendicular to the right-of-way edge 33 feet (10 m) apart to within 16.5 feet (5 m) of right-of-way edge and 5 pounds per acre of Spike applied in a 1:1 mixture with water.

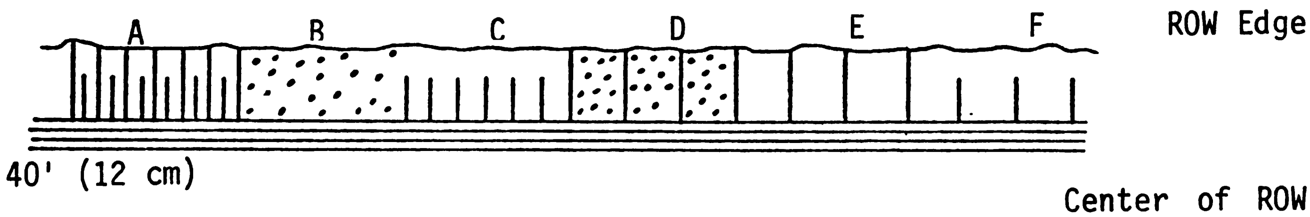

Figure 2. Test treatments.

Equipment

Band Treatment. A 3/4-ton, four-wheel drive spray truck was used for this test with a boom on the back pumper of the truck with straight stream nozzles located 5 feet (1.5 m) apart (the recommended band spacing). To achieve the recommended rate of 5 pounds of Spike per acre, 3 pounds of Spike were added to 3 gallons of water, and then applied at 3 gallons per linear mile (a single band 5280 feet (1610 m) long equals .6 acre (.24 ha). The output of one nozzle (at 10 P.S.I.) was .15 gallons per minute. At a ground speed of 3 miles per hour, the proper rate was obtained using this calibration. Bands could be applied by the truck driving down the right-of-way, or hand applied with the basal spray wand. The bands applied perpendicular to the right-of-way in the test areas were applied with the normal basal spray wands on the end of 300 feet (91 m) of hose connected to the spray truck. The adjustable nozzle was set on a straight stream. This eliminates the need to use backpack sprayers.

Spot Treatment. A Chem-Spot Applicator (Chem-Trol, Inc.) was used for this portion of the test. The Chem-Spot Applicator is a hand-triggered gun which delivers 4.0 or 8.0 ml of mix for each depression of the trigger. The chemical suspension is carried in a backpack container.

RESULTS

On October 9, 1981, with the assistance of Mark Walker (Northern Division Forester for Public Service Indiana), the test area was observed after one growing season. The bands in the middle of the right-of-way gave a predictable 98% kill.

Test A: Brush between the bands were 95% dead. Only one off right-of-way tree was killed (a six-inch (15 cm) (DBH) White ash (*Fraxinus americana*), six feet off right-of-way at the end of a band).

Test B: On right-of-way brush was 75% dead. Half of one off right-of-way tree (eight-inch White ash, 3 feet off right-of-way) was killed.

Test C: Brush between the bands was 40% dead. Brush less than head high was not affected unless it occurred within a couple of feet of a band. There was virtually no control (5%) between the end of the bands and the right-of-way edge.

Test D: On right-of-way brush 100% dead. There was much off right-of-way damage, up to 8 feet off right-of-way. (The brush on this plot was dense and large right up to the edge of the right-of-way).

Test E: Brush between the bands was 40% dead. Only very slight evidence of off right-of-way herbicidal damage (leaf discoloration).

Test F: Fifty percent of the on right-of-way brush was dead. There was no evidence of off right-of-way damage.

DISCUSSION

Prior to full utilization of one or more of these techniques, some further testing needs to be done.

1. Control may be obtained in the second and third growing season between the wider spaced bands. These tests need to observed for 2 more years.

2. Tests should be made, replicating the more promising tests (A and B).

3. Several additional tests should be made:
    a. Bands 8 feet (2.4 m) apart to within 8 feet (2.4 m) of right-of-way edge;
    b. Spot treat to within 8 feet (2.4 m) of right-of-way edge;
    c. Compare application time between spot treatment and bands;
    d. Make all of the same tests as above, but at several reduced rates;
    e. Test bands down the right-of-way should be established at wider spacing, and at reduced rates.

CONCLUSIONS

Based on this single growing season evidence, several conclusions can be drawn:

1. Bands 8 feet (2.4 m) apart effectively control brush, as demonstrated in Test A.

2. Bands 16 feet (4.8 m) or farther apart are not effective without intermediate spot treatments (at least in one growing season). (Test areas C, E, and F).

3. Bands up to the right-of-way edge can cause damage up to 8 feet (2.4 m) off the right-of-way. (Test areas A, B, C, and E).

4. Resistance species (not 100% killed in one growing season) are Red Bud (Cercis canadensis), Silver Maple (Acer saccarinum), Wild Cherry (Prunus serotina), and Red Elm (Ulmus rubra). Spike 80W appeared to have no effect on Sassafrass (Sassafrass albidum).

5. White Ash (a normally very difficult species to control) appears to be very susceptible to Spike.

6. Due to the highly concentrated nature of the herbicide solution, and the small amount applied per acre, right-of-way can be treated quickly and without the need for large amounts of water.

THE USE OF D-LIMONENE AS AN ADJUVANT FOR FOLIAGE TREATMENTS OF WOODY PLANTS

W. E. Chappell[1] and P. L. Hipkins[2]

ABSTRACT.--A solution of D-limonene in water has proved an effective wetting agent and emulsifier in combination with 2,4-D or picloram-2,4-D in experiments in Virginia, Georgia and Florida. A 0.5-2.0% solution of D-limonene can be used in the foliage season with good results. When used with fosamine, picloram, triclopyr, and dicamba for summer woody plant control, D-limonene acts as an odor-masking and wetting agent. It is equally effective for both aerial and ground applications.

INTRODUCTION

D-limonene is a derivative of citrus peel oil (4-isopropenyl-1-methyl cyclohexane). Cide Kick[R], the product used in these studies, is sold by the J. L. B. International and Chemical Company and contains 100% D-limonene and emulsifiers. D-limonene has also been sold under the names "S.A. 77," "Cuticle Cutter," and perhaps other trade names. Mainly used for its emulsifying and wetting qualities in spraying plants, D-limonene masks pesticide odors and is relatively non-toxic to plants when used below 10% concentration in water. This compound is an excellent adjuvant for aquatic weed control and has also increased herbicidal effectiveness when mixed with several common herbicides (Adams and Boha 1979; Steward 1979). Its wetting properties enhance the effectiveness of herbicides for woody plant control (Jacoby 1981; Pepper et al. 1981; Soteres et al. 1981).

EXPERIMENTS

To determine if the foliage and stem-wetting qualities of D-limonene combined with certain herbicides would enhance penetration and eventual kill of woody plants, studies were conducted in cooperation with the Appalachian Power Company, Roanoke, Virginia. In August 1980, near Bluefield, Virginia, 20 acre plots were sprayed with two mixtures.

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Experiment 1

In August 1980, near Bluefield, Virginia, 20 acre plots were sprayed with the following mixtures. (1) Mixture A - Krenite 3 gal, 2 qts Cide Kick, and ½ pt Crop Spray Oil in 22 gal water/acre, and (2) Mixture B - Krenite 3 gal, 2 qts WK Surfactant, and ½ pt Crop Oil in 22 gal water/acre. Applications were made by a helicopter equipped with a Microfoil Boom using .060" diameter nozzles. Results are presented in Table 1.

Table 1. Percentage kill of various species on 9/23/81 following the August 1980 aerial application.*

Species	Mixture A	Mixture B
Red Maple	98	58
Wild Cherry	99	62
Yellow Poplar	100	72
Ash	100	65
Dogwood	100	75
Hickory	100	66
Buckeye	98	58
Aspen	100	76
Oaks (mostly red, black and white)	100	81
Birch (black)	100	88
Vine Maple	100	65
Hackberry	100	84
Hornbeam	100	81
Brambles (various)	100	85
Poison Ivy	100	85
Average: All Species	99.6	73.0

*A percentage kill of 100% means there was no new growth (including root suckers) on any stems during the 13-month period between the application and the examination date.

Experiment 2

During July 22-24, 1981, 11 treatments of brush control herbicides containing various adjuvants and drift control agents were applied with a hydraulic sprayer equipped with a T-Jet industrial 15° flat jet nozzle. One-eighth acre plots were sprayed with various mixtures using a volume of 100 gal (378.5 l) per acre, and compared with an adjacent area that was treated with a mixture of 2,4-DP 2.5 gal plus Tordon 101 3 gal in water at 25 gal per acre. The mixtures and results are presented in Table 2.

Table 2.

Treatments/100 gal water/A		Amount/acre	% Control* 6/3/81
1)	Banvel 720 +	2 gal	77
	Cide Kick	1 gal	
2)	Banvel 720 +	½ gal	64
	Garlon A +	½ gal	
	Cide Kick	½ gal	
3)	Garlon E +	2 gal	98
	Cide Kick	1 gal	
4)	Garlon A +	1 gal	73
	Banvel 720	1 gal	
5)	Trimec +	3 gal	97
	Cide Kick	1 gal	
6)	Roundup +	1 gal	94
	Banvel 720 +	1 gal	
	Cide Kick	1 gal	
7)	Krenite +	1 gal	98
	Cide Kick	1 gal	
8)	Krenite +	1 gal	100
	Garlon A + gal H_2O	1 gal	
	Cide Kick	1 gal	
9)	2,4-DP +	1 gal	83
	Garlon A	1 gal	
10)	2,4-DP +	1 gal	87
	Tordon 101 +	1 gal	
	Cide Kick	1 gal	
11)	2,4-DP +	1 gal	95
	Banvel 720 +	1 gal	
	Cide Kick	1 gal	
12)	Commercial Application**		60
	2,4-DP +	2½ gal	
	Tordon 101 (Helicopter)	3 gal	

*All treatments contained thickening agents for drift control.

**Microfoil boom - 25 g/A without thickening agent.

DISCUSSION

Both aerial and ground applications of woody plant herbicides mixed with D-limonine resulted in good control, but the aerial applications had the most striking differences in percentage kill of all species, as shown in Table 1. In view of the extreme height of the brush and the species involved, a 99.66% kill is extremely high. The D-limonene addition--instead of Surfactant WK--was the only variable, and it effected herbicide absorption and movement into all portions of the plants, which resulted in excellent species control.

In the ground applications containing D-limonene, there was a tendency toward increased kill as compared to those mixtures without D-limonene. D-limonene is also an effective odor inhibitor which is especially important in highly populated areas.

SUMMARY

From the results of these studies the use of D-limonene as an adjuvant is worthy of further investigation to determine its proper concentration, needed use, and effects on the actions of other herbicides.

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RIGHT-OF-WAY VEGETATION PRODUCED BY AERIAL, SELECTIVE BASAL, AND GROUND FOLIAR HERBICIDE APPLICATIONS

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ABSTRACT.--Vegetative cover produced by aerial, selective basal, and ground foliar spray techniques was compared on nine electric transmission rights-of-way (ROWs) in New York State. A high degree of floristic similarity was found in tree, shrub, and herbaceous components between all techniques. Total tree cover varied only slightly, 26 to 30%, between techniques. Total shrub cover ranging from 21 to 46% was not significantly different (P = 0.05) between techniques owing to dominance of polycormous and root-suckering species on all ROWs. The cover values of individual shrub species, however, were dissimilar between aerial-treated ROWs and those treated by the other two techniques. Total herbaceous cover, 16%, was significantly lower on selective-basal-treated ROWs and cover value of individual species was dissimilar between basal-treated and ground-foliar-treated ROWs.

INTRODUCTION

The specific effects of common herbicide application methods on desirable non-target vegetation on electric utility rights-of-way (ROWs) have become of increasing interest and importance in recent years. Unfortunately, very little documented information from reserach studies is currently available, although the need and value of ecological information to ROW management was recognized by Egler in 1954. From the research reports that are available (Bramble and Byrnes, 1974; Carvell and Johnston, 1978; Johnston and Bramble, 1979; Niering and Goodwin, 1974; Perala and Sorenson, 1979) it appears reasonable to assume that aerial broadcast spraying and ground foliar spraying should produce a herb-grass dominated community with few shrubs. Selective basal-sprayed ROWs should be dominated by shrubs to a greater degree. To check these assumptions, this study was made on ROWs which were under commercial spray maintenance.

METHODS AND MATERIALS

This study is based on data from a comprehensive study made in New York State to evaluate the environmental effects of ROWs (Asplundh Environmental Services, 1977). Row maintenance histories were obtained from

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cooperating utilities. The results, therefore, reflect conditions which existed at the time as the result of treatments which had been applied as needed by commercial applicators (Table 1). The three application methods used are (1) aerial - application from an aircraft, usually a helicopter, using a fixed boom sprayer and covering both target and non-target plants on the entire ROW; (2) selective basal - application under low pressure to the lower stem and base of selected target plants, only; and (3) ground foliar - application under high pressure to foliage and stems of target plants.

Table 1. Herbicide treatments which were commercially applied by utilities to control undesirable trees on the ROWs within a 7-year period before data collection.

ROW No.	Spray Application Method	Date Applied	Herbicide Used
1 (6)	Aerial	1970	Tordon 101
2 (9)	Aerial	1973	Tordon 101
	Selective basal	1969	(2,4,5-T)
3 (20)	Aerial	1974	Tordon 101
1 (5)	Selective basal	1974	Tordon 155
	Selective basal	1970	(Tordon 155)
2 (16)	Selective basal	1972	Tordon 155
	Selective basal	1971	(Tordon 155)
3 (21)	Selective basal	1975	Tordon 155
	Selective basal	1971	(Tordon 155)
1 (17)	Ground foliar	1969	Tordon 101
2 (18)	Ground foliar	1970	Tordon 101
3 (19)	Ground foliar	1971	Tordon 101

The study was restricted to mesic ROW habitats well distributed over the state. Mesic habitats are defined as moderately moist sites with well-drained soil and cover the majority of ROW acres in contrast to the more restricted xeric and hydric habitats (Johnston and Bramble, 1979). Vegetation data were collected on rectangular, one-fifth acre (0.08 ha) sample plots extending across the ROW. To locate plots, a preliminary study was made and a map prepared to show plant communities and habitats. One plot was located on each habitat area in a typical plant community and the plot size and shape was designed to include a representative sample of the community. This process has been referred to as subjective "stratified" sample selection by plant sociologists (Braun-Blanquet, 1964).

Abundance and cover estimates for each plant species were made by means of a modification of the method of Braun-Blanquet (1964). The term "constancy" is used to indicate the percentage of ROWs on which a plant species occurred out of the total number of ROWs studied for each application method. A comparison was made of the degree of similarity in the floristic composition of ROW vegetation produced by the three techniques by means of Sorenson's quotient of similarity (QS) between two groups of populations (Sorenson, 1948). For quantitative similarity comparisons, a modification of Sorenson's quotient was used. A threshold value of 40% was taken as acceptable similarity (Mueller-Dombois and Ellenberg, 1974).

RESULTS

Floristic Composition and Cover Value For Trees

A total of 32 tree species was found on the 9 ROWs. An average of 7 species per ROW was typical for ground-foliar treated ROWs, while aerial- and slective basal-treated each averaged 12 species. When floristic composition for all species was compared using Sorensen's quotient, all paired comparisons of treatments produced quotients between 40 and 47%, indicating floristic similarity among tree species for all methods (Figure 1).

Total cover values of all dominant trees combined for each of the three application methods varied by 3.8%, or less (Table 2). The amount of tree cover did not show a correlation between length of time between treatment and data collection. When paired comparisons of cover values for 12 highly constant tree species were made by means of Sorensen's modified quotient of similarity (QS), a dissimilarity appeared between cover values for ground foliar-treated ROWs and the other two methods (Figure 1).

Table 2. Mean cover values and constancy of common tree species on ROWs maintained by three application methods (each cover value is the mean of 3 replications).

Tree species[a]	Aerial		Selective Basal		Ground Foliar	
	Cover Value	Constancy	Cover Value	Constancy	Cover Value	Constancy
	%	%	%	%	%	%
Black cherry	2.7	66	4.4	66	8.4	66
Flowering dogwood	--	--	.07	100	.02	33
Gray birch	1.8	66	1.4	100	4.2	33
Large-toothed aspen	.01	33	.5	100	--	--
Pin-cherry	8.5	100	12.5	33	.5	100
Quaking aspen	2.2	100	1.2	66	10.0	66
Red maple	1.2	100	1.0	66	6.7	66
Red oak	.2	66	.05	66	.03	33
Serviceberry	.1	33	.2	66	--	--
White ash	.8	66	.03	33	.2	66
White pine	8.4	66	.02	33	.03	33
Yellow birch	.4	33	5.9	100	.05	66
Total	26.3		27.3		30.1	

[a]Common names are based on Gray's Manual of Botany, 1950.

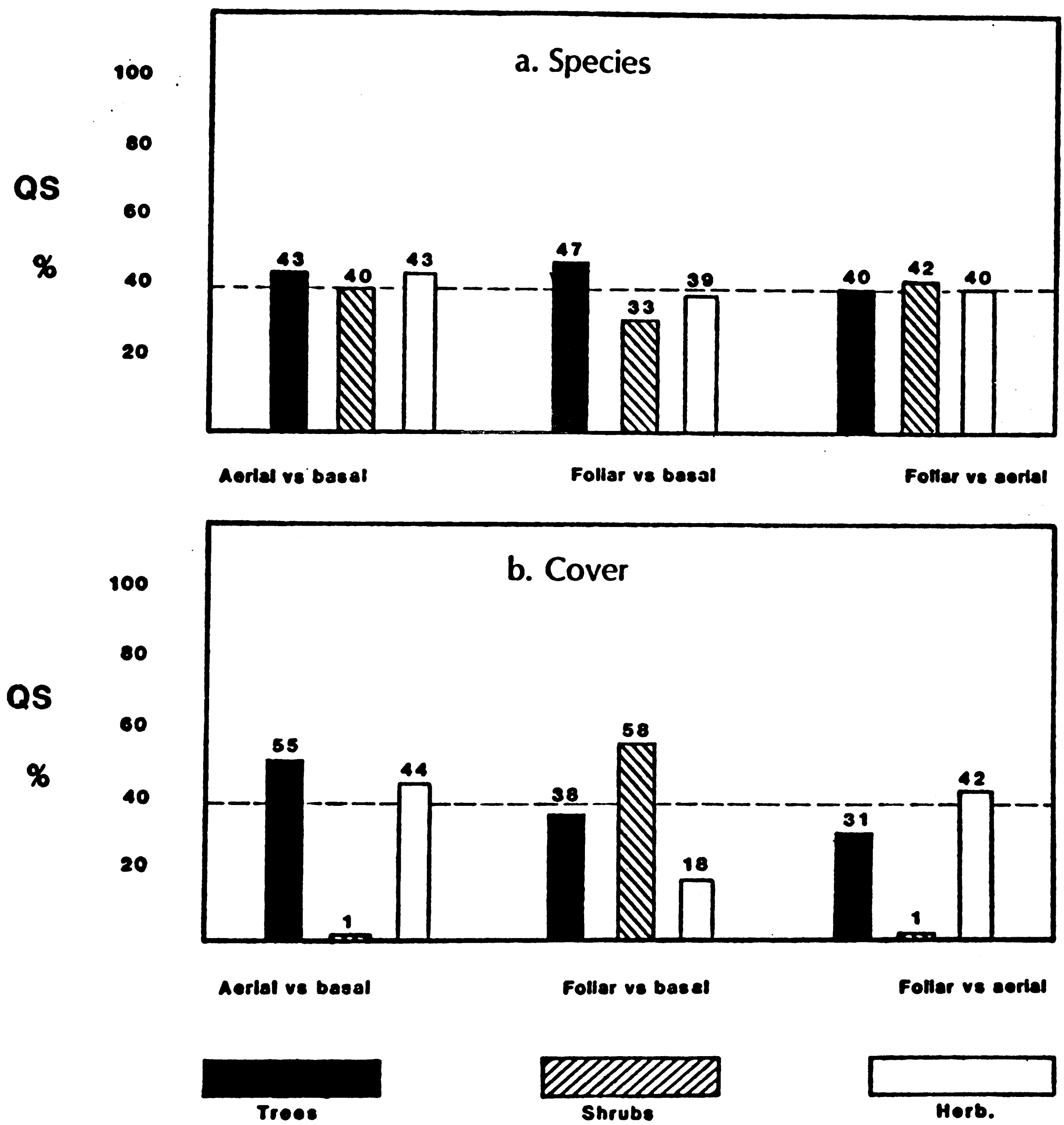

Figure 1. Comparison of species composition and cover percent of trees, shrubs, and herbaceous plants between methods using Sorensen's quotient of similarity (QS).

Species Composition and Cover Value of Shrubs

A total of 33 shrub species was found on the 9 ROWs with the lowest number, 11, on ground foliar-treated ROWs as compared with 21 species on the aerial-treated ROWs and 22 on selective basal-treated ROWs. The floristic similarity varied from a QS of 33% for foliar- as compared with basal-treated ROWs to 42% for foliar- compared to aerial-treated ROWs (Figure 1). The high constancy of suckering species of *Rubus*, *Spiraea*, *Rhus*, and *Vaccinium* was the primary reason for such similarities. The highest similarity, 42%, was between aerial- and ground foliar-treated ROWs, both of which cause similar disturbances; the lowest was between basal-treated ROWs and the other two methods (33% and 40%).

When only highly constant shrub species were compared, a somewhat different picture emerged, since only 3 shrub species had a constancy of 66% or higher on ROWs maintained by the ground foliar method (Table 3). They were blackberry (*Rubus allegheniensis*), spiraea (*Spiraea latifolia*), and shrubby willow (*Salix* spp.). These are species of open areas which spread vigorously by rhizomes or shallow roots and tend to form patches. In contrast, 7 species had a constancy of 66% or higher on ROWs treated with selective basal sprays (Table 3). These were blackberry, blueberry (*Vaccinium* spp.), gray dogwood (*Cornus racemosa*), raspberry (*Rubus idaeus*), spiraea, staghorn sumac (*Rhus typhina*), and teaberry (*Gaultheria procumbens*). Six species had a constancy of 66% or higher on ROWs treated with aerial applications. These were blackberry, blueberry, dewberry (*Rubus flagellaris*), maple-leaved viburnum (*Vibernum acerifolium*), spiraea, and staghorn sumac.

Table 3. Comparison of mean cover values and constancy of common shrub species on ROWs maintained by three application methods (each cover value is the mean of 3 replications).

Shrub species[a]	Aerial Cover Value	Aerial Constancy	Selective Basal Cover Value	Selective Basal Constancy	Ground Foliar Cover Value	Ground Foliar Constancy
	%	%	%	%	%	%
Blackberry	2.3	100	18.4	100	26.7	100
Blueberry	.03	66	.2	66	.03	33
Dewberry	12.7	100	--	--	.03	33
Gray dogwood	9.2	33	.05	65	--	--
Maple-leaved viburnum	.9	66	.03	33	--	--
Raspberry	1.0	33	.9	66	16.7	33
Shrubby willow	.02	33	.03	33	1.7	66
Spiraea	8.5	100	.2	66	.7	100
Staghorn sumac	.8	66	.4	66	--	--
Teaberry	--	--	.9	66	--	--
Total	35.5		21.1		45.9	

[a]Common names are based on Gray's Manual of Botany, 1950.

There was a higher total shrub cover for all 33 species present on ground foliar-treated ROWs (46.4%) and on aerial-treated ROWs (37.5%) than on ROWs maintained by selective basal sprays (28.4%). This was due primarily to high values for species of *Rubus*, *Spiraea*, and *Cornus* which spread underground by means of rhizomes (polycormy), or by root suckers. However, owing to large variations in cover values between ROWs, these differences were not significant at the 0.05 level when tested by the analysis of variance. As only one ground foliar treatment, and mostly one for aerial, was needed to control tall-growing trees over the 7-year period prior to data collection (Table 1), shrub species had time to spread. This appeared to be the probable reason for a high correlation of cover with length of time since treatment for ground foliar-treated ROWs (r=0.96), and medium correlation for aerial-treated ROWs (r=0.67). There was no such correlation on selective basal-treated ROWs.

When the cover value for 10 common species were compared for the three treatments by means of Sorensen's quotient of similarity modified for quantitative evaluations, the paired comparisons between aerial and the other two treatments produced a very low quotient of only 1.0% (Figure 1). Selective basal-treated ROWs, however, were similar to those treated by ground foliar sprays (QS 58%), primarily owing to high cover values for blackberry for both methods (Table 3).

Species Composition and Cover Value of Herbaceous Species and Grasses

There were 74 herbaceous species and genera recorded on the 9 ROWs; only those with a constancy of 66% or with appreciable cover values are listed in Table 4. Data were collected from June through August. When species composition for all species were compared by Sorensen's quotient (QS), all treatments showed a floristic similarity of 39% to 43% (Figure 1). This is also shown in Table 4 where 5 of the dominant species occurred with a constancy of 66% or higher for all three methods.

Herbaceous species with a constancy of 66% or higher on aerial-treated ROWs were aster (*Aster* spp.), bracken (*Pteridium aquilinum* Kuhn), cinquefoil (*Potentilla* spp.), goldenrod (*Solidago* spp.), haircap moss (*Polytrichum* spp.), pearly everlasting (*Anaphalis margaritacea*), sheep sorrel (*Rumex acetosella*), strawberry (*Fragaria virginiana*), trout lily (*Erythronium americanum*), and yarrow (*Achillea millefolium*). Many of the same species, plus a few others, had a constancy of 66% or higher on selective basal-treated ROWs. These were aster, bracken, cinquefoil, goldenrod, haircap moss, hayscented fern (*Dennstaedtia punctilobula*), sheep sorrel, strawberry, violet (*Viola* spp.), whorled loosestrife (*Lysimachia quadrifolia*), and wild lily-of-the-valley (*Maianthemum canadense*). Essentially the same group of species had a constancy of 66% or higher on ground foliar-treated ROWs. They were aster, bracken, goldenrod, haircap moss, spring beauty (*Claytonia virginiana*), strawberry, trout lily, and wild lily-of-the-valley.

There was a significant difference at the 0.05 level when tested by ANOVA in the cover value of the 18 common species between selective basal-treated ROWs (15.9%) and both ground foliar- (75.6%) and aerial-treated ROWs (49.7%) (Table 4). No correlation was shown between length of time

Table 4. Comparison of mean cover values and constancy of common herbaceous species and grasses on ROWs maintained by three application methods (each cover value is the mean of 3 replications).

Herbaceous and Grass species[a]	Aerial		Selective Basal		Ground Foliar	
	Cover Value	Constancy	Cover Value	Constancy	Cover Value	Constancy
	%	%	%	%	%	%
Herbaceous:						
Aster	7.3	100	.5	100	5.0	100
Bracken	8.3	66	2.7	100	17.7	100
Cinquefoil	3.1	100	2.0	66	--	--
Goldenrod	9.3	100	2.3	100	3.7	100
Haircap moss	13.2	100	1.0	66	5.8	66
Hay-scented fern	--	--	.5	100	--	--
Pearly everlasting	.03	66	--	--	.1	33
Sheep-sorrel	.3	66	1.0	66	.3	33
Spring-beauty	.1	33	--	--	.4	66
Strawberry	4.7	100	4.3	100	.7	66
Trout-lily	2.2	66	.2	33	25.0	66
Violet	.2	33	.08	100	.03	33
Whorled loosestrife	.8	33	.9	100	--	--
Wild lily-of-the-valley	.1	33	.2	100	16.7	66
Yarrow	.06	100	.2	33	.2	33
Total	49.7		15.9		75.6	
Grasses:						
Mixed grass species	26.7	100	19.3	100	8.3	100
Panic-grass	.1	33	1.7	66	--	--
Poverty grass	8.3	33	--	--	--	--
Sedge	.3	66	1.8	66	.7	100
Wild oats	.2	33	--	--	.3	33
Total	35.6		22.8		9.3	
Herbs and grasses:						
Total	85.3		38.7		84.9	

[a]Common names are based on Gray's Manual of Botany, 1950.

since treatment and data collection. When the contributions of the 18 common species to cover were compared to Sorensen's modified quotient, the selective basal- vs ground foliar-treated ROWs produced a low quotient of 18% (Figure 1). On the other hand, there was a QS of 42% between aerial- and ground foliar-treated ROWs as might be expected owing to similar cover disturbance caused by both. An unexpected similarity was shown by aerial- and selective basal-treated ROWs (QS 44%) that was due to similarity in cover value for five of the species common to both (Table 4).

Grass was an important component of vegetation for ROWs treated by all three methods, with least importance on ground foliar-treated ROWs (Table 4). When the cover values for herbs and grasses were combined, the total value was lowest for the selective basal- ROWs which is what is usually expected, and the difference between selective basal-treated ROWs was significantly different at the 0.05 level when tested by ANOVA.

DISCUSSION

A highly important factor in development of vegetation on ROWs has been the spread of dominant species either by rhizomes or shallow roots which produce suckers. The large number of dominant species that spread vegetatively on ROWs maintained by all 3 methods studied gives emphasis to this point. These include shrub species of Rubus, Vaccinium, Cornus, Rhus, and Spiraea; as well as herbaceous species of Solidago and Aster, and plants such as bracken, hayscented fern, and trout-lily.

Egler and Foote (1975) referred to colonial species on ROWs and stressed the importance of their vegetative spread. Carvell and Johnston (1978) described the importance of plants which spread vegetatively on ROWs in New Jersey and New Hampshire. Braun-Blanquet (1964) pointed out the advantage of vegetative increase in rhizomes (polycormy) in competition between species and in sociological development. On the ROWs in this study which had been repeatedly disturbed by herbicide spraying, polycormy and root suckering has been the distinct advantage over spread by seed and helps to account for the dominance of a number of species and most of the similarities in vegetation between different treatments.

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PLANT GROWTH REGULATOR INFLUENCE ON CHAPARRAL AND NATIVE GRASSES

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ABSTRACT.--Plant growth regulators were tested for effectiveness in reducing vegetative growth of native plants. Certain plant regulators were effective for a broad species range, while others were more species specific. Native grasses have been reduced approximately 50% in height and weight by an annual treatment of melfluidide or chlorflurenol in locations with less than 23 in (58 cm) of annual rainfall. Resprouts of chamise (Adenostoma fasciculatum) and manzanita (Arctostaphylos glandulosa) at 2 years after burning were more responsive to spring applications than to dormant timed treatments. Differences with chemicals and species response were found. Chamise showed from 41 to 50% growth reductions at 2 years after Krenite treatment.

INTRODUCTION

Plant growth regulators have a potential as an alternate method of reducing native vegetation growth, and thus causing less litter and fuel along roadsides, rights-of-way, and firebreaks. The degree of vegetation maintenance varies depending on economic and public pressures, but long-term evaluations indicate that it is necessary.

MH, extensively tested for growth control of grasses, has given variable responses (Foote and Himmelman 1971; Yemn et al. 1962). Elkins and Suttner (1974) tested several growth regulators on tall fescue (Festuca arundinacia) as possible means of reducing roadbank mowings in Illinois. Color changes of foliage and reductions of seedheads have been associated with certain chemical treatments (Elkins 1974; Street 1980). In our studies, effects on flowering of grasses were observed; but no long-term studies were conducted for possible changes in plant communities.

Chamise (Adenostoma fasciculatum) and manzanita (Arctostaphylos spp.) are frequently occurring root crown sprouting shrubs of semiarid mountain

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slopes of California (Conrad and Radosevich 1978). Brush growth is periodically removed from firebreaks by hand or by mechanical equipment. After clearing, a grass cover often develops. Brush conversion to grass is also used to increase grazing capacity. For these situations, herbicides have been used to permanently eliminate the brush (Graves and Radosevich 1980; McHenry et al. 1981; Johnson et al. 1980). Plant growth regulators have been investigated for only the reduction of brush growth. Brush and grass were tested on separate locations. Certain chemicals were best adapted for brush growth suppression, while others were primarily active for reducing grass growth.

METHODS

Grass Experiments

Natural Population Locations. Chemicals selected for evaluation for growth control on grasses and shrubs are listed in Table 1. Locations with dense grass stands were staked with individual plots, on either 9 or 41 sq m in area, replicated 4 times. Smaller plots were treated with a CO pressurized backpack sprayer, and the larger plots with a trailer sprayer with multiple spray tanks and a 6-nozzle boom. The spray was applied at 1123 l/ha. Leaf color was rated on a scale of 1 to 10, with 1 indicating no color change and 10 a severe brown color. Leaf blade and flower stalk (panicle) heights were periodically measured. The numbers of inflorescences (spiklets) were counted as an index of seed number. At maturiity, a 3 X 3 ft (1 X 1 m) swath was cut with a cycle bar mower; this sample was further dried in a forage dryer before weighing.

Table 1. Chemicals tests for growth regulation responses on grasses and chaparral.

Common	Product	Chemical
chlorflurenol	Maintain CF125, CF125	Methyl 2-chloro-9-hydroxyfluorene-9-carboxylate
maleic hydrazide, MH	Slo Gro	Diethanolamine salt of 6-hydroxy-3-(2H) pyridazinone
	Kerb	N-1 (1-1-dimethylpropynyl)-3-5-dichlorobenzene
dikegulac	Ro7-6145 (Atrinal)	sodium 2,4:4,6 bis-O-(1-methylethylidene)-α-L-xylo-2-hexulofuranosonic acid
	PP528	ethyl 5-(4-chlorophenyl)-2H-tetrazol-2-ylacetate
CIPC	Chloro IPC	isopropyl N-(3-chlorophenyl) carbomate
	Krenite	ammonium ethyl carbomoylphosphonate
mefluidide	Embark	N-[2,4 dimethyl-5[[(trifluoromethyl) sulfonyl]amino]phenyl]acetamide

Planted Populations Grasses

Mixed grass stands with a predominance of ripgut grass (Bromus diandrus), red brome (Bromus rubens), common foxtail (Hordeum leporinum), and wild oats (Avena fatua) were mowed and spread. The seed and straw were then soil incorporated. Pre- and post-planting sprinkler irrigations supplemented the rainfall, and resulted in good growth. Plots were of 9 sq m in size and replicated 5 times. Treatments were made on two dates in consecutive years. Wild oats were 4 in (10 cm) in height with 1 stool on the 1-15-74 treatment date. For the 2-19-74 treatment date, wild oats were 10 in (25 cm) in height and well stooled. In the second year, wild oats were 7 in (18 cm) in average height with 3.2 stools on 12-30-74. On the 1-14-75 treatment date, wild oats were 12 in (30 cm) in height. Leaf color, height, and mass at maturity were determined as before.

Chaparral Experiments

Soboba Burn Location. The Soboba fire of 8-27-74 covered 17,700 acre (7156 ha) in the San Jacinto mountains of the San Bernadino National Forest. Areas were selected for uniformity of root sprout regrowth of chamise or manzinita. The burned dead stubs were removed, and plots 89 sq m in size were replicated 4 times for each species. The plots were sprayed at 1123 l/ha with a hand-held boom and a backpack, CO sprayer. The 1-23-76 spray was applied over dormant foliage, while the 5-14-76 application was to foliage of the spring growth flush. Krenite and PP528 were applied with 0.25% X-77 and Ro7-6145 with 0.25% ACR 4031 (a special wetting agent for Atrinal). Four terminal shoots on 4 plants per plot were marked for growth measurement. Plant heights were measured on random selection of 5 plants per plot.

Thomas Mt. Location. Red shank (Adenostoma sparcifolia Torr.) at Thomas Mt. location in the San Jacinto mountains was cut between 5-31-77 and 6-7-77 to remove all top growth. The plots were replicated 6 times with regrowth treated on 8-31-77. Procedures and growth evaluations were the same as in the Soboba tests.

All data were subjected to an analysis of variance with the mean differences separated by Duncan's Multiple Range Test. Capital letters following the mean values permit population separation at the .01 significance level.

RESULTS

Native Grasses

Natural Populations. Chemicals selected from 2 years of field screening were compared in 1974 at 7 locations (Table 2). The rainfall in these locations ranged from 20 to 70 cm. Growth reductions from a single treatment occurred only at certain locations with 25 cm or less rainfall. Kerb and CIPC were dropped from the 1975 trials because these chemicals, developed as herbicides, had too small a safe concentration range for use as plant growth regulators. Six of eight locations showed significant growth reductions for Embark, CF125 plus MH, and CF125 in that order of effectiveness for the 1975 tests. Color ratings averaged for 1974 and

1975 trials are shown in Table 3. The CIPC, MH, and Kerb treatments caused a more chlorotic leaf color than the other treatments.

Table 2. Location of natural grass populations and the percent height reduction at maturity as influenced by chemical growth control treatments and by rainfall.

		Location						
		San Luis Obispo	Irvine	Chino I	Chino II	Riverside I	Riverside II	Riverside III
		Rainfall, cm						
		Sept-Dec						
		27.2	4.6	3.8	3.8	3.8	3.8	3.8
		Jan-May						
		51.6	20.3	21.3	21.3	16.0	16.0	16.0
		Date treated						
		12/7/73	1/23/74	1/25/74	1/24/74	1/15/74	2/19/74	4/18/74
Chemical	kg/ha	Height reduction, %						
CF125	2.2	19.0	26.0	32.5A[a]	11.9	35.1CD	50.3DE	14.9B
CF125	3.4	17.4	38.9		34.7	41.7DE	66.8G	
CF125 + MH	1.1 + 3.4	13.5	8.8	35.0B	30.2	39.0DE	53.0DE	
MH	3.4	12.1	19.7		44.3	35.5CD	45.6C	
MH + 24D	3.4 + 0.6	16.6	18.6		49.0	46.7DE	57.8F	
Kerb	0.6		42.5		14.2	16.3B	25.4B	
CIPC	4.5		4.9		2.8	42.6DE	41.9C	
Ro7-6145	6.7				13.8			
Embark	1.1						56.9F	64.9A
Embark	2.2					47.7DE	68.4H	74.9A
		Height, cm						
Control		97.8	36.5	67.7	68.8	106.6	113.2	101.0
Control Population				A		A	A	B

[a]Treatment means in the same column not followed by the same letter are significantly different at the .01 level according to Duncan's Multiple Range Test.

Table 3. Color ratings of 1974 and 1975 averaged for natural grass populations at 1 to 2 months after treatment.

Chemical	Rate kg/ha	Color[a] rating
Control	—	1.2C[b]
CF125	2.2	2.7ABC
Embark	1.1	3.2ABC
CF125 + MH	1.1 + 1.1	3.3ABC
CF125	3.4	3.5ABC
Embark	2.2	3.8ABC
CIPC	4.5	3.9AB
MH	3.4	4.3AB
Kerb	0.5	4.7A

[a]Scale, 1 = no change, and 10 = severe color change.

[b]Treatment means not followed by the same letter are significantly different at the .01 level according to Duncan's Multiple Range Test.

Planted Populations. The growth reductions for 4 grass species are shown in Table 4. The effectiveness of the chemicals is generally consistent for all species. Embark most often caused the greatest height reduction with CF125 plus MH, and CF125 being slightly less effective. The results of the initial 12-30-74 treatment are shown in Table 5. Color was acceptable at 53 days after treatment. CF125 granular showed no advantage over the CF125 EC spray, and dry weight was not reduced by the lower CF125 rates or by Embark. Plot height and dry weight were significantly correlated at the 0.05 level. The numbers of panicles and spikelets were not influenced. The 1-14-75 series of treatments in Table 6 shows a generally poor color response. However, Embark at 1.1 kg/ha was acceptable for color and showed reduced heights for plot and wild oats, as well as giving fewer spikelets per panicle. Plot dry weights were reduced, and they were significantly correlated with plot height (0.8194) at the 0.05 level. MH alone was not effective. Both CF125 rates resulted in undesirable color, but caused reductions in height and weight and fewer spikelets per panicle. Combinations of CF125 and MH, at a total rate lower than CF125 alone, showed better color but less reduction in growth. The numbers of panicles did not show statistical reductions, but the consistent reduction of spikelets supports the possibility of fewer seeds per panicle.

Table 4. Influence of growth regualtor treatments on the height at maturity of four grass species growing together in planted populations.

		Treatment date							
		1/15/74				2/19/74			
		Grass species							
		Avena fatua	Bromus diandrus	Bromus rubens	Hordeum leporinum	Avena fatua	Bromus diandrus	Bromus rubens	Hordeum leporinum
Chemical	Rate kg/ha	Height, cm							
CF125	2.2	86D-H[a]	71D	46A-E	43BCD	86BC	67AB	44B	36ABC
CF125	3.3	78F-I	61E	42B-G	32B-E	78BCD	39BC	32BC	29BC
CF125 + MH	1.1 + 1.1	76G-I	48F	36B-G		75CD	53BC	36BC	29BC
MH	3.4	83E-G	62E	42C-G	31B-E	82BCD	56BC	37BC	38ABC
Embark	2.2	67I-K	40GH	27D-H	23DE	67DE	34C	28BC	23C
Kerb	0.5	93B-G	63E	48A-D	54AB	98B	60BC	40BC	20C
ClPC	4.5	89C-G	62E	37C-H	34B-E	89BC	52BC	35BC	31ABC
Control	--	117A	80ABC	57AB	70A	116A	97A	66A	58A

[a]Treatment means in each column not followed by the same letter are significantly different at the .01 level according to Duncan's Multiple Range Test.

Table 5. Color, height, and dry weight of planted mixed grasses and height, number of panicles, and numbers of spikelets per panicle of wild oats after December 30, 1974, growth control treatments.

		Mixed grasses			Wild oats		
	Rate	Color Rating	Mean plot ht., cm	Mean plot dry wt. gm/m^2	Height cm	No. panicles $/100cm^2$	No. spikelets /panicle
Chemical	Kg/hr	53 days	133 days	135 days	135 days	135 days	135 days
CF125	2.2	2.0CD[a]	54.1B	737.2ABC	87.4BC	10.7ABC	5.7
CF125	3.4	3.1A	53.4B	632.6C	67.6C	6.7BC	7.2
CF125 + MH	1.1 + 1.1	3.2B	54.7B	588.2C	81.0BC	12.9AB	6.7
Embark	1.1	1.9BE	60.5B	727.4ABC	90.0BC	17.3A	5.6
Embark	2.2	3.1A	59.0B	700.4ABC	82.4BC	13.1AB	7.0
CF125 granular	2.2	1.1DE	72.5AB	694.4ABC	102.2B	5.6BC	8.9
CF125 granular	3.4	1.1DE	63.9B	551.0C	109.6AB	4.3C	8.8
Control	--	1.0E	93.9A	974.0AB	134.4A	9.9ABC	13.3

[a]Treatment means in each column not followed by the same letter are significantly different at the .01 level according to Duncan's Multiple Range Test.

Table 6. Color, height, and dry weight of planted mixed grasses and height, numbers of seed stalks, and numbers of spikelets per panicle of wild oats after January 14, 1975, growth control chemical treatments.

		Mixed grasses			Wild oats		
Chemical	Rate kg/ha	Color rating 64 days	Mean plot height cm 122 days	Mean plot dry wt. gm/m^2 122 days	Mean ht cm 126 days	Panicles no./100cm^2 126 days	Spikelets no./panicle 126 days
Embark	1.1	3.0D-I[a]	95.5B	817.4A-D	62.7CD	18.4ABC	6.9BC
Embark	2.2	5.0A-G	81.2B-E	624.6B-E	52.3DEF	18.7ABC	6.0C
Embark + MH	1.1+1.1	4.4A-H	68.8DEF	554.6DEF	53.1DEF	12.1A-D	5.0C
Embark + MH	1.1+2.2	5.6A-E	70.8DEF	634.8B-E	48.6D-G	18.8AB	6.0C
Embark + MH	1.1+3.4	5.6A-E	66.0EFG	407.2EFG	46.3D-G	14.5A-D	5.8C
Embark + MH	2.2+1.1	6.3AB	63.0EFG	508.0DG	43.1EFG	17.1A-D	4.3C
Embark + MH	2.2+2.2	5.7A-D	66.8EF	450.0EFG	47.3D-G	24.7A	5.4C
Embark + MH	2.2+3.4	6.6AB	59.6EFG	353.4EFG	41.5FG	10.9BCD	4.9C
MH	3.4	2.2GHI	127.2A	884.8ABC	90.4AB	11.5BCD	11.7B
CF125	2.2	5.0A-G	71.2DEF	802.6A-D	46.1D-G	4.9CD	3.5C
CF125	3.4	5.7A-D	72.8C-F	581.8CDE	49.4D-G	6.1BCD	5.5C
CF125 + MH	0.6+0.6	2.4F-I	93.0BC	959.0A	75.1BC	10.5BCD	7.0BC
CF125 + MH	0.6+1.1	3.5B-I	89.2BCD	889.0ABC	61.6CD	10.1BCD	5.0C
CF125 + MH	1.1+1.1	5.3A-F	75.6B-F	778.0A-D	56.2DEF	7.6BCD	4.4C
CF125 + MH	1.1+0.6	4.2A-G	75.4B-F	928.2AB	60.9DE	6.9BCD	4.0C
Embark + CF125	1.1+1.1	6.8A	53.2FG	225.4FG	31.5G	9.2BCD	3.5C
Embark + CF125	0.6+1.1	5.6A-E	61.4EFG	418.0EFG	40.3FG	13.1A-D	4.6C
Embark + CF125	0.6+2.2	5.8A-D	55.2FG	361.6EFG	38.3FG	6.1BCD	4.7C
Embark + CF125	1.1+0.6	6.4AB	63.0EFG	488.2D-G	50.9DEF	8.5BCD	5.8C
Embark + CF125	1.1+2.2	6.1ABC	43.8G	214.2G	39.0FG	4.1CD	3.6C
Control	—	1.6HI	132.2A	988.8A	94.8A	11.3BCD	19.1A

[a]Treatment means in each column not followed by the same letter are significantly different at the .01 level according to Duncan's Multiple Range Test.

Chaparral

Influence of time of treatment. Comparisons of dormant and spring dates of treatment show greater growth reductions from applications over the spring growth (Table 7). Manzanita did not respond to any chemical with the dormant 1-23-76 applications. Spring treated manzanita, on 5-14-76, showed shoot growth reductions at 5 months from Krenite at the 0.6 and 0.8% sprays and Ro7-6145 with the 0.75 and 1.0%. PP528 was not effective on manzinita.

Table 7. Comparisons of growth control from January 23, 1976, sprays, over dormant growth, with applications on May 14, 1976, over spring growth, on chamise and manzanita at the Soboba burn location.

		Shoot growth, cm						
		Treated 1/23/76			Treated 5/14/76			
	Conc.	Chamise		Manzanita	Chamise		Manzanita	
Chemical	%	6/30	9/21	9/17	6/30	10/15	8/9	10/12
1. Krenite	.2	16.6A[a]	16.7AB	10.4	16.6A	39.7BC	3.8AB	6.2A
2. Krenite	.4	8.1AB	6.3BC	11.3	8.1AB	28.2B	3.4AB	2.7A-D
3. Krenite	.6	9.5AB	10.9ABC	11.3	9.5AB	18.5D	.5B	-.3D
4. Krenite	.8	5.1B	4.0C	12.5	5.1B	19.4D	1.1B	-.6D
5. Ro7-6145	.5	12.4AB	12.7ABC	12.0	12.4AB	40.9BC	4.3AB	4.9ABC
6. Ro7-6145	.75	10.6AB	10.2ABC	9.9	10.6AB	38.0BC	1.0B	1.6BCD
7. Ro7-6145	1.0	6.9B	7.1BC	12.4	6.9B	40.8BC	.7B	1.0CD
8. PP528	.25	4.5B	3.7C	10.0	4.5B	52.5AB	6.4A	7.0A
9. PP528	.5	5.8B	6.0BC	7.7	5.8B	37.5BC	4.7AB	5.7AB
10. CK	—	16.4A	20.9A	8.8	16.4A	62.1A	6.0A	6.1A

[a]Means not followed by the same letter are significantly different at the .01 level according to Duncan's Multiple Range Test.

Duration of effects. Only Krenite sprays of 0.4, 0.6 and 0.8% reduced manzanita shoot growth at 515 days after the 5-14-76 treatment (Table 8). Shoot dieback was frequently observed with the 0.8% conc. The final evaluation of red shank at 267 days after treatment showed a regrowth reduction with Ro7-6145 at 0.8 and 1.0% and with Krenite at the 0.4 and 0.8% sprays (Table 9). Chamise treated on 5-14-76 showed no shoot growth reduction at 414 days for Ro7-6145 (Table 10). However, all Krenite treatments and PP528 at 0.5% were then reducing shoot growth. Shoot growth responses were erratic at 661 days with 0.2 and 0.8% Krenite and 0.5% PP528 showing reductions. Plant height at 661 days from the spring treatment date showed smaller plants for all Krenite and PP528 treatments. Less reduction in plant height resulted from the 0.5 and 1.0% Ro7-6145 sprays. Final evaluations at 825 days showed continued plant height reductions from Krenite and PP528 treatments, with the 0.8% Krenite spray giving the greatest reduction.

DISCUSSION

Single applications of Embark or Maintain CF125 resulted in approximately 50% reductions in height and weight for annual grasses in low rainfall areas. Height and weight were significantly correlated. Differences in

Table 8. Growth control responses of manzanita at Soboba burn location II following May 14, 1976, spray treatments.

	Conc.	Shoot growth, cm Days after treatment		
Chemical	%	368	424	515
Krenite	0.2	6AB[a]	12AB	10AB
Krenite	0.4	3ABC	5CD	3BC
Krenite	0.6	1BC	3DE	2C
Krenite	0.8	-3C	0E	-1C
Ro7-6145	0.5	5AB	11AB	11A
Ro7-6145	0.75	2ABC	10AB	9AB
Ro7-6145	1.0	2ABC	9BC	9AB
PP528	0.25	7A	13AB	11A
PP528	0.5	5AB	9ABC	10AB
Control	---	7A	14A	14A

[a]Means not followed by the same letter are significantly different at the .01 level according to Duncan's Multiple Range Test.

reductions between early and late treatment dates were not great. All applications were made before the grass was taller than 12 in (30 cm). Treatment at heights of from 6-8 in (15-20 cm) appears desirable for the grass species which were tested. A similar degree of response to the chemicals was observed on the various grass species in naturally occurring locations and the locations which were planted and which received early season supplementary irrigation. Combinations of Embark and CF125, at levels below the total for either chemical applied alone, were frequently the most effective rate. MH alone was not effective. Repeated applications were not tested. Locations which normally received more than 10 in (25 cm) of rainfall sometimes contained perennial grasses and did not demonstrate a persistent growth reduction. Where there is sufficient soil moisture for summer growth, the Embark CF125 combination treatment might be appropriate for a repeat treatment.

Table 9. Growth control of red shank at Thomas Mt. location.

Chemical	Concn. %	Growth plants, cm Days after treatment 106	156	257
Ro7-6145	0.6	11AB[a]	10A	14BC
Ro7-6145	0.8	9B	8B	12B
Ro7-6145	1.0	8B	7BC	9AB
Krenite	0.4	9B	8BC	11AB
Krenite	0.8	4B	3C[b]	6A
Control	---	14A	13A	19C

[a]Means not followed by the same letter are significantly different at the .01 level according to Duncan's Multiple Range Test.

[b]Shoot dieback occurring.

Manzanita was less responsive to the applied chemicals than were chamise and red shank. Spring treatment dates showed a greater response than treatment of dormant plants. This might be attributed to a greater chemical uptake by the young foliage. With chamise, it appears that plant height could be reduced for 2 years by a single 0.4% Krenite spray. Krenite at 0.8% caused shoot dieback which might be acceptable. Further observations showed no loss of chamise or red shank plants. Manzanita shoot growth control from 0.8% Krenite was approximately 1 year.

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Table 10. Growth control responses of chamise at Soboba burn location II following May 14, 1976, spray treatment.

		Shoot growth		Plant height	
		cm		cm	
	Concn.	Days after treatment			
Chemical	%	414	661	661	825
Krenite	0.2	5.0A[a]	0.4AB	53CD	63CD
Krenite	0.4	0.0AB	4.3ABC	48E	48ABC
Krenite	0.6	3.6AB	14.5C	45E	43AB
Krenite	0.8	-4.0A	-3.6A	31E	37A
Ro7-6145	0.5	13.1C	12.1BC	69BC	72DE
Ro7-6145	0.75	16.7C	15.9C	83AB	83E
Ro7-6145	1.0	15.2C	14.1C	69BC	73DE
PP528	0.25	8.4BC	9.1ABC	59CD	63CD
PP528	0.5	-0.1AB	0.8AB	58CD	58BCD
Control	—	14.4C	14.3C	89A	88E

[a]Means not followed by the same letter are significantly different at the .01 level according to Duncan's Multiple Range Test.

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GRASS GROWTH REGULATION PROPERTIES OF S-ETHYL DIPROPYLTHIOCARBAMATE (EPTC) - A THREE-YEAR STUDY

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ABSTRACT.--Discovery of the grass growth suppression properties of s-ethyl dipropylthiocarbamate (EPTC) in 1979 has led to extensive studies on the practical use of this compound for use on highway rights-of-way and other areas that require extensive mowing. Applications of 4.0-8.0 lbs/acre have reduced seedhead formation on KG 31 fescue, creeping red fescue, bluegrass, and other species by 95-99%. Treated areas did not require mowing the entire growing season. March and April proved the best time of year for suppressing cool season grasses by using granular applications of EPTC (Eptam 10-G). Other species are also being studied for response to EPTC. Combinations of granular formulations of EPTC with Dicamba and other selective broadleaf and preemergence herbicides were also studied for annual and perennial grass and weed control.

INTRODUCTION

In most of the eastern half of the United States, seed stalks from tall fescue constitute the major reason for early mowing along highways and other rights-of-way. Most broadleaf weeds are easily removed with herbicide treatments. Other grasses usually do not present a problem since they do not grow tall enough to require mowing.

Grass growth regulators such as dethanplamine salt of 6-hydroxy-3-(2H) pyridazinone (maleic hydrazide) and mefluidide (Embark) have long been used for reducing the height of seedheads on tall fescue. Maleic hydrazide has been used for many years, and performs well when applied before the seedheads begin to form in the spring. Weather conditions, such as the occurrence of rain within a few hours after application, will reduce its effectiveness. Embark , a grass inhibitor, also reduces seedhead formation sufficiently to reduce mowing costs, but has been erratic under some conditions. Both of these compounds sometimes discolor the grasses. Earlier reports from this institution (Link et al. 1980, Link et al. 1981, Link et al. 1981) showed that s-ethyl dipropylthiocarbamate (EPTC) would reduce seedhead formation almost 100% when applied as a 10% granular formulation in March or April under Virginia conditions. In 1979, preliminary studies showed that reates of 4-8 lbs ai/acre of EPTC 10% granular would inhibit seed stalk formation of tall fescue with little or no effect on the other vegetative growth of this species.

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In 1980, a rate/time study was begun to determine the most efficient and economical means of applying EPTC for reducing mowing requirements. EPTC has little or no effect on annual or perennial broadleaved weeds; therefore, some herbicidal applications are necessary to maintain control of all vegetation height. In 1981, the studies were expanded to include mixtures of herbicides with granular EPTC and spray applications of herbicides following EPTC applications. The findings of these experiments in 1979, 1980, and 1981 follow.

1979 Experiment

Several compounds with known or suspected grass growth inhibitory properties were applied, as exploratory treatments, to single turf plots 3600 sq ft in size on a highway median near Shawsville, Virginia, during Spring 1979. The turf plots consisted of tall fescue (Fig. 1) (85%), common bluegrass (10%), and various broadleafed breeds (5%). Liquid materials were applied in 70 gal. of water/acre with a knapsack sprayer equipped with a Sprying Systems 8008 nozzle. Granular materials were weighed and applied uniformly with a hand-held cyclone-type seeder over the plots. The treatments were made on April 10, 1979, and evaluated on June 27, 1979. (See Table 1).

Striking differences were found on K-31 tall fescue in seedhead reduction, blade length, and turf discoloration. All treatments reduced the height of seedheads as compared to the untreated check. The discoloration (tip burn) was very slight in all treatments. The EPTC plots, in particular, remained a lush green throughout the 1979 growing season.

1980 Experiments

A rate/date of application experiment was conducted near Shawsville, Virginia, during Spring 1981. Six rates were applied on April 23, 1980, and 8.2 lbs of 10% EPTC granules were administered on seven application dates. The results are presented in Tables 2 and 3.

In this study, rates of 2-16 lbs ai/acre indicated that 6 lbs or more was necessary to achieve good seedhead inhibition. Grass blade length was slightly reduced in all cases. The percent of tip burn was less in the best EPTC plots than in the untreated plot.

EPTC application between late February and late April resulted in acceptable seedhead suppression in Virginia. The early (February 20 and March 6) applications resulted in delayed growth, but by June, there was no apparent difference in grass growth.

Another 1980 experiment was designed to compare various inhibitor formulations. Treatments and results are shown in Table 4. Combinations of some of these treatments also appeared favorable for grass seedhead regulation.

1981 Experiments

In 1981, commercial applications were made on ten dates in ten Virginia locations. In these large scale tests (2-3 acres each), certain broadleaf

Table 1. Efficacy of plant growth regulators applied 4/10/79 to highway turf at Shawsville.

Compound used	Formulation	Rate lbs (ai)/A	Average Seedheads/Ft^2	Average Seedhead Height (CM)	Average Blade Length (CM)	Average Tip Burn (%)
1. PP-333[a]	Wettable powder	2.0	25.8	53.8	31.7	11.9
2. PP-333	Wettable powder	4.0	20.0	41.4	23.0	7.5
3. PP-33	Granular	2.0	17.6	46.6	32.5	6.1
4. PP-333	Granular	4.0	22.8	32.2	26.7	22.7
5. EL-72500[b]	Wettable powder	2.0	19.4	67.3	33.8	11.1
6. EL-72500[b]	Wettable powder	4.0	24.4	52.9	19.5	13.4
7. EPTC[c]	10% granule	4.0	14.2	89.9	47.9	4.9
8. EPTC	10% granule	8.0	0.1	50.0	44.9	2.5
9. Embark[d]	10% granule	0.375	7.2	65.6	38.9	8.3
10. Maleic hydrazide[e]	Liquid	4.0	4.0	68.2	43.7	3.3
11. Untreated	--	--	31.6	100.1	42.7	11.8

[a]Experimental Compound from ICI Industries

[b]Experimental Compound from E. I. Lily

[c]Commercial formulation from Stauffer

[d]Melfluidide from 3-M Company

[3]Commercial formulation from Uniroyal

Table 2. Growth inhibition in KY-31 tall fescue in highway turf.

Rate (ai/A) 4/15/80	Seedheads/ft^2	Avg. Seedhead Ht (cm) 6/24/80	Avg. Blade Length (cm)	% Tip Burn
2 lb	8.0	63.5	48.0	7.6
4 lb	12.0	40.1	42.4	8.0
6 lb	2.4	23.5	31.5	12.3
8 lb	3.4	26.0	32.6	13.3
12 lb	2.1	25.2	33.5	15.1
16 lb	0.1	22.0	31.6	18.4
Check	17.3	100.6	58.4	8.6

Table 3. Growth inhibition in KY-31 tall fescue in highway turf.

Date 8.2 lbs/A	Avg. Seedheads/Ft^2	Avg. Seedhead Ht (cm)	Avg. Blade Length (cm)	% Tip Burn
2/20/80	3.4	79.4	43.0	2.1
3/6/80	1.8	66.7	34.1	4.5
3/20/80	3.4	67.9	34.8	3.4
4/3/80	1.5	72.6	32.5	6.1
4/17/80	6.3	52.7	33.9	8.9
5/1/80	20.9	51.2	35.8	8.2
5/16/80	24.5	79.1	27.8	8.6
Check	25.0	91.0	36.9	5.3

herbicides and other additives were used. Effective seedhead reduction was obtained at all locations when various mixtures were applied before May 1 (Table 5).

The focus of the 1981 studies was to examine EPTC effectiveness in commercial applications and to compare the effects of odor inhibitors and herbicides on EPTC. Truck-mounted, battery-operated Herd seeders were used for eight commercial applications on one-acre plots (12' X 3600') during March and early April. The mixtures and results are listed in Table 5.

Except for the two applications in Virginia, all treatments were satisfactory. Where broadleaf weeds were a problem, the grass suppression was masked. Mowing was necessary to keep the weeds down when a suitable herbicide was not applied. The spray application of Dicamba at 1/4 lb/acre and 2 lbs of 2,4-D resulted in effective weed control, and mowing was unnecessary. Dicamba granular applications were unsatisfactory for weed control when mixed with granular EPTC or applied separately.

To reduce the objectionable odor of the EPTC granules, D-limonene, a citrus oil derivative (Brand name: CideKick) was used and did not interfere with seedhead inhibition.

Other 1981 experiments and results are listed in Tables 6 and 7.

DISCUSSION

EPTC has been used in crop weed control for more than 20 years, but its growth-regulating properties in certain grasses had not been reported before the authors' discovery in 1979. As shown in Table 1, the 8 lb rate resulted in 99% control of the number of seedheads; the height of the remaining stems, <1%, was only slightly reduced. This indicates that either the growth stage of Kg-31 fescue at the time of treatment was not uniform, or a low percentage of the plants were EPTC-resistant. In 1980, a study designed to determine if the stage of growth as determined by seasonal phenomenon would affect the response. A rate study was also incorporated during the Spring, 1980.

As shown in Table 2, the EPTC rate was most effective between 6 and 16 lbs/acre. Here again, even the highest rate did not completely eliminate seedhead growth; it was reduced to a point where the final height was not enough to require mowing. In the date of application study, there was little difference in the number of seedheads produced during the period between 2/20 and 4/17.

SUMMARY AND CONCLUSIONS

A three-year study using granular EPTC at 6-8 lb ai/acre resulted in excellent control of tall fescue seedheads. Other general conclusions from these studies are as follows: (1) EPTC granular can be applied in the spring over a 6-8 week period; (2) application can be made without regard to weather, except high winds; (3) there is no residual problem; (4) it does not affect shrubbery or other woody plants; (5) application can be made with any type granular applicator, providing accurate calibration

Table 4. Growth inhibition in KY-31 tall fescue in 1980.

Treatment 4/1/80	Rate (ai/A)	Avg. Seedheads/ft^2 6/12/80	Avg. Seedhead Ht (cm)	Avg. Blade Length (cm)	Avg. % Tip Burn
PP-333 + EPTC	1.0 lb + 4.0 lb	2.3	53.3	29.1	2.7
PP-333	2.0 lb	14.8	46.0	23.3	4.5
PP-333 + Melfluidide	1.0 lb + 0.25 lb	0.8	37.4	26.9	1.1
PP-333 + Melfluidide	2.0 lb + 0.125 lb	2.6	31.2	24.2	3.6
Melfluidide	0.375 lb	1.1	24.3	31.2	7.0
Check	--	27.8	90.9	37.1	7.3

Table 5. 1981 applications.

Area/Location	Mixture Applied	Subsequent Treatment	% Seedhead Reduction	Weed Control
1. Norfolk (Eastern VA)	8 lb EPTC (2/15/81)	Dicamba + 2,4-D	95	100
2. Richmond (Eastern VA)	8 lb EPTC (3/15/81)	----	96	0
3. Fredericksburg (Eastern VA)	8 lb EPTC (3/15/81)	Dicamba + 2,4-D	99	95
4. Culpepper (Central VA)	8 lb EPTC (3/15/81)	Spray Dicamba + 2,4-D	95	90
5. Staunton (Central VA)	8 lb EPTC (5/1/81)	----	75	0
6. Salem (SW VA)	8 lb EPTC (5/15/81)	----	50	0
7. Bristol (Western VA)	8 lb EPTC (3/20/81)	----	97	0
8. W. Chester, PA	8 lb EPTC (4/15/81)	Dicamba granular	95	50
9. W. Chester, PA	8 lb EPTC (4/15/81)	Dicamba spray	99	95
10. Blacksburg (Western VA)	8 lb EPTC + d-limonene	(Cide Kick)	95	0

Table 6. A comparison of three grass inhibitors for seedhead reduction in KY-31 tall fescue, applied 4/8/81, Shawsville, Virginia.

Chemical	Rate (ai/acre) lb	Seedheads per ft (5/26/81)	Seedheads per ft (7/15/81)
Eptam[R] 10-G	6.0	1.5	1.7
Eptam[R] 10-G	8.0	0.7	0.9
MH-30[R]	4.0	2.8	1.5
Embark[R]	0.375	1.8	1.8
Check	--	24.2	32.8

Data derived from 3 replications of each treatment, 5 samples per rep.

Table 7. A comparison of two rates of Eptam[R] applied to mowed and unmowed stands of KY-31 tall fescue, applied 3/18/81, Blacksburg, Virginia.

Chemical	Rate (ai/acre) lb	Seedheads per ft (6/24/81)		Seedheads per ft (7/15/81)	
		Mowed	Unmowed	Mowed	Unmowed
Eptam[R] 10-G	6.0	0.6	1.7	1.4	1.9
Eptam[R] 10-G	8.0	1.1	1.1	1.3	1.2
Check	--	15.9	18.4	29.6	27.4

Data derived from 3 replications of each treatment, with 5 samples per replication.

and even coverage can be made; (6) D-limonene effectively counteracts the odor of EPTC without receiving efficacy; and (7) mowing before treatment has no effect on results.

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BIOLOGICAL PROCESSES IN THE CONTROL OF RISK TREE SPECIES ON RIGHTS-OF-WAY IN FORESTED MOUNTAINS: PACIFIC NORTHWEST

Richard D. Taber[1] and Stephen D. West[1]

ABSTRACT.--An investigation of biological controls for rights-of-way management began in 1970 in western Washington, and is continuing. The results are applicable, with allowance for local variation, in other temperate forested regions, where risk species must be controlled, wild herbivorous mammals exist, and soils tend to be deficient in nitrogen and humus.

The main biological controls considered are plant-plant competition, mammalian herbivory, and ungulate trampling. The aim is a self-perpetuating ecosystem of nonrisk species, maintained at minimal expense.

INTRODUCTION

Once the location and width for an electric transmission line right-of-way have been determined, measures for construction and maintenance must be undertaken. Integral to construction and maintenance are the removal and subsequent suppression of any trees capable of growing sufficiently tall to interfere with the transmission line conductors. Trees with this potential are called <u>risk species</u>.

Several methods for control or suppression of risk species on established rights-of-way are in use, but by far the most common in the Pacific Northwest is periodic broadcast herbicide spraying. The resulting plant community varies, but in forested mountains where soils are typically deficient in available nitrogen, ground cover is incomplete. The presence of ample bare ground provides a ready seedbed for risk species that border the right-of-way. As tree seedlings become established and begin to grow toward the wires, another broadcast application of herbicide is applied. While there are many variations, the basic pattern itself, the repeated broadcast application of herbicide, is common.

With increasing public resistance to the use of herbicides, particularly on the forested mountains so frequently used as municipal watersheds, some alternate method of risk species control on rights-of-way is desirable.

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DISCUSSION

A method is being developed that is effective, economical, and minimizes the need for herbicides. The factors and processes being investigated are those that have strong influences on the structure of Pacific Northwest forests.

The problem of risk species control is being approached as an exercise in integrated pest situation management (IPSM). Successful IPSM programs reduce pest-situation conflict to tolerable levels through the most cost effective combination of factors. The principal factors being investigated are those involved in the pressures exerted against plants by other plants, commonly referred to as competition, and the pressures exerted against plants by animals, commonly referred to as control.

Plant Competition

Grasses are effective agents in denying sufficient soil moisture, nutrients, and light to risk species. If a seed falls on bare ground and germinates, it has a good chance of sending its root into the soil. If, however, it germinates on a bed of wet, lodged grass stems, its attempts to send a root down to soil level may well fail. Therefore, a heavy cover of herbaceous vegetation capable of keeping a sufficient proportion of seeds above the surface of the soil will tend to discourage invasion by risk species.

A young seedling, germinating in the wet season and succeeding in sending its root into the soil, must find sufficient moisture in the soil to survive. If there is already a well-established herbaceous community on the right-of-way with a fully developed root system, then soil moisture in the upper levels of the soil will be depleted rapidly, and many seedlings of risk species will be unable to extend their roots rapidly enough to obtain sufficient moisture for survival. The same reasoning for soil moisture can be applied to other nutrients. An investigator who has much experience in attempting to establish forest trees in old fields in New England describes the effectiveness of grass as a competitor (Richards 1973:81): "In competition (for moisture and nutrients) grass species appear to be expecially effective for at least two reasons: (1) the dense, fibrous root systems characteristic of grass facilitate rapid and effective moisture absorption, (2) grasses can draw moisture down to and endure a greater soil moisture stress than most woody plant seedlings (Lane and McComb 1948)." The newly germinated seedling of a risk species has a small amount of foliage on a short shoot. If it is on open ground, it receives ample light for growth and development. But if it is overtopped by a luxurient stand of herbaceous vegetation, it can easily be suppressed. And during winter rainstorms, if a heavy mat of sodden grass stems falls over it, available light will be effectively reduced.

If the biomass of such plants as grasses, already established on a right-of-way, can be increased both below and above ground, competitive pressure against newly germinated seedlings of risk species will be increased, and the established right-of-way vegetation will be more effective in minimizing the invasion of risk species. Such an increase in below- and aboveground biomass can be achieved in nitrogen deficient soils by applying nitrogen fertilizer. An example can be taken from plot studies on Cedar River Watershed on the west slope of the Washington Cascade Mountains. Table 1 shows grass production with and without fertilization on two soil types under different growing conditions: an average and a moist summer. Both of these soils are nitrogen deficient. Application of urea at the rate of 112 kg of nitrogen/ha resulted in marked increases in above-ground biomass for both soils and both growing conditions. Since below-ground biomass is proportional to above-ground biomass, fertilization also increased root system biomass. As a result, nitrogen fertilization increased the potential ability of the established vegetation to exclude risk species. In the development of an IPSM program, results like these are worthy of deeper investigation and refinement.

Table 1. Effect of nitrogen fertilization on grass production on a western Washington right-of-way.

Soil Type	Average Year		Moist Summer	
	Control (kg/ha)	Fertilized (kg/ha)	Control (kg/ha)	Fertilized (kg/ha)
Everett	785	2805	2245	3370
Alderwood	2245	5615	2805	8980

NOTE: Fertilizer applied at 112 kg nitrogen/ha. Grass mixture - annual and perennial rye, Kentucky bluegrass, and alta fescue.

Animal Control

The pressures that can be exerted by animals on the survival or growth of tree seedlings are widely recognized as damage to forest regeneration, but these pressures have not been deliberately employed in the control of risk species on rights-of-way. Animal control in the form of seed predation, seedling and sapling consumption, and trampling can have great importance in IPSM programs against risk species invasion.

Many different species of animals, both invertebrates and vertebrates, feed upon seeds and have a potential for reducing the number of seeds on a right-of-way. Some quantitative observations of seed predation on trees of economic importance have been made (Lawrence and Rediske 1959, 1962; Radvanyi 1966). By following the fate of seeds marked with radioactive coatings, loss rates approaching 50% have been documented (Table 2).

Herbivores such as snowshoe hares (*Lepus americanus*), mountain beavers (*Aplodontia rufa*), and microtine rodents (*Microtus* spp.) use seedlings of risk species as food, eating it on the spot (hares), clipping and carrying it away for underground consumption (mountain beavers), or eating the stem bark at ground level (microtine rodents). Larger herbivores such as porcupines (*Erethizon dorsatum*), black-tailed deer (*Odocoileus hemionus*), and elk (*Cervus elaphus*) feed upon larger seedlings and saplings, often retarding their development. It is commonplace for conifer plantations established in grassy, old fields to suffer heavy, and sometimes total mortality, to bark-girdling by microtine rodents. A well developed grass-forb meadow on a right-of-way should support a population of microtine rodents that will girdle tree seedlings. And if soil nutrient deficiencies are remedied by fertilization, resulting in enhanced grass growth, the population of microtine rodents will increase.

Table 2. Fate of radioactive coated white spruce seed.

Destructive Agent	No.	Percent
Mice and voles	640	35.2
Chipmunks	172	9.5
Shrews	53	2.9
Insects	31	1.7
Seeds Destroyed (1819 total)	896	49.3

Modified from Radvanyi, A. 1966. For. Sci. 12:307-315.

Seedlings that have been fertilized are more attractive to herbivores than unfertilized seedlings (Mattson 1980). Nitrogen fertilization, or the permanent establishment of nitrogen-fixing species in the right-of-way plant community, will increase the attractiveness of seedlings as food for herbivores and intensify browsing pressure against risk species.

Trampling by hoofed mammals affects vegetation in obvious ways, such as the establishment of bare soil trails. It also has more subtle effects, such as weighting the competitive advantage in favor of a particular group of plants in the community to the detriment of another group. Our studies have focused on the quantitative effects of elk and deer, mainly by trampling, in several forest communities in western Washington (Hanley and Taber 1980). Comparing plant communities inside game-proof exclosures with those subject to use by deer and elk, it was found that trampling favored grass-like and rosette plants over other forbs and shrubs (Hanley and Taber 1980).

The mechanics of trampling by wild animals has seldom been quantified, but this has been done for hoofed livestock and for humans (Spedding 1971, Anderson 1973). Downward and lateral hoof forces result in the compaction, puddling, and displacement of soil. Trampling breaks down the loose, porous structure (crumb) of the surface soil and so reduces infiltration of water, root penetration, and air diffusion (Steinbrenner 1951; Krucera 1958; Anderson 1973). This compaction reduces the ability of germinating seedlings to become established, particularly in the face of a plant community already in place (Buckman and Brady 1969). Where soils are fine textured and the water table is high, a common occurrence in local depressions in the mountains, heavy trampling by hoofed animals can cause puddling. This is a physical working of the soil surface in a wet condition that reduces pore space to the point that it is virtually impervious to air and water. The increase in topsoil density, and thus reduction in moisture availability, may last for months (Gradwell 1966). On steep slopes, characteristic of forested mountains of the Pacific Northwest, soil stability is easily disrupted. Physical pressures can cause downslope movement and the formation of terraces.

The principal wild ungulates that can be expected to affect rights-of-way by trampling in the Pacific Northwest are deer and elk, which average about 45 kg and 225 kg respectively. On one intensively studied right-of-way in western Washington, considerable seasonal variation was found in the presence of deer and elk on the right-of-way, as estimated by the pellet-group count method (Table 3). On this right-of-way the most intensive trampling will occur in winter, when both deer and the larger, seasonally mobile elk are present.

Table 3. Seasonal densities[a] of deer and elk in forest, right-of-way edge, and right-of-way center. Cedar River Watershed, western Washington.

Season	Deer			Elk		
	Forest	Edge	Center	Forest	Edge	Center
Dec-Feb	0	42	7	48	89	71
Mar	0	53	3	16	9	51
Apr-May 15	0	19	3	9	9	9
May 15-Jun 15	0	30	18	0	0	0

[a]Individuals/km^2 on the basis of pellet-group counts.

CONCLUSION

The pattern of Integrated Pest Situation Management that is being developed for the exclusion of risk tree species from electric power rights-of-way employs both competition (plant vs. plant pressures) and control (animal vs. plant pressures). Establishment and maintenance of a meadow-like plant community will shift the competitive advantage against risk tree species and provide a favorable habitat for herbivores. Nitrogen fertilization will enhance both competition and control functions.

As the work progresses, screening of a wide variety of plants, and their use in combinations, will provide data on optimal treatments for the span of sites and soils that characterize rights-of-way in the study region. At the same time, different animal species, important as agents of control, will be known more thoroughly, and procedures for enhancing their control function will be sought.

The development of a sound, biologically-based, system of risk tree species management is considered feasible for most or all rights-of-way sites in the study region.

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POTENTIAL ROLE OF ALLELOPATHY IN ROW VEGETATION MANAGEMENT

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ABSTRACT.--Recent investigations into the chemical defenses of plants indicate that these mechanisms play a role in the development and maintenance of biotic communities. Many low growth plant communities, considered desirable by rights-of-way (ROW) managers, may exhibit allelopathic characteristics which could be exploited to maintain low plant growth on ROWs. This paper briefly reviews research in allelopathy and describes the potential for applying research results to ROW management objectives. A proposal for utility-supported research in allelochemics is offered.

INTRODUCTION

The term, "allelopathy", was coined by Molish (1937) to refer to detrimental and mutually beneficial biochemical interactions between all types of plants, including microorganisms. Recent authors (Rice 1974, Rietveid 1979, Fisher 1980) define allelopathy as any direct or indirect harmful effect of one plant on another through the production and release into the environment of chemical compounds. In a more recent review, Rice (1979) revised his earlier definition to include reciprocally beneficial biochemical effects, thereby accepting the original definition of Molish. Since most authors continue to favor the limitation to harmful effects definition, the term, "allelopathy," as used in this paper, will be restricted to harmful or negative plant biochemical interactions.

Plant scientists are divided over the relationship between allelopathy and competition. While plant competition for light, water, space and nutrients has been accepted as a reason for plant distributions and associations, chemical inhibition, or interference, has not received similar consideration, nor has it been widely studied until recently. In a recent review of 405 publications, 346 of the references were published between 1968-1978 (Rice 1979). Some biologists do not consider allelopathy to be a component of competition, and Muller (1969) has proposed the term "interference" to include both allelopathy and competition. This author disagrees and does not see the need for the new term, thereby accepting plant chemical defenses as one of the competitive strategies which has been evolved by plants. When evaluating existing or future vegetation,

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the plant scientist can ill afford to fragment the sum total of plant competitive devices into neatly named compartments. To analyze or manage vegetation, one must be able to recognize all the interactions which give certain plant species advantages over other species. This is especially true in ROW vegetation management.

While the term "allelopathy" is recent, and most of the research has been conducted during the past two decades, observations on the effects of allelopathy have a much longer history. The harmful effects of dew washing off red pine (*Pinus densiflora* Sieb. & Zucc.) onto crops were noted in a 300-year-old Japanese document (Rice 1979). In the first century A.D., Pliny the Elder described the failure of plant growth under walnut (*Juglans regia* L.), and De Candolle described the phenomenon in 1832 (Fisher 1980). Of the North American species studied, black walnut (*Juglans nigra* L.) is the most notable and historic (Cook 1921). Juglone, the active chemical ingredient of walnut, has been known for decades (Gries 1943). Despite the early observations and research on allelopathic effects, plant chemical defenses received scant attention from plant scientists. The lack of interest, until recently, in research on the role of allelopathy in the development and maintenance of plant communities is a perplexing mystery.

The intent of this paper is not to fully explore or review the mechanisms, actions and species of allelopathic plants, but to discuss the potential application to ROW vegetation management. Readers with a more compelling interest in the broader subject of allelopathy are referred to excellent reviews by Rice (1974, 1979), Rietveid (1979) and Muller (1966, 1969).

ALLELOPATHY

Plants produce many chemical compounds to fulfill the primary objectives of growth, development, and reproduction, such as chemicals for photosynthesis and respiration. At the same time, the plants also produce "secondary chemical compounds." Whether or not these chemicals are metabolic by-products, many of these secondary compounds have been shown to be advantageous to the plant; e.g., in inhibiting herbivory and attracting pollinators. Allelopathic literature shows that plant chemicals have harmful effects on other plants through a variety of actions, including effects on cell elongation, structure of root tips, growth, membrane permeability, mineral uptake, cation exchange, stomatal opening, photosynthetic rate, respiratory rate, protein synthesis, metabolism, enzyme activity, and water transport. Chemical analyses of the active agents have revealed a wide range of responsible compounds--normally forms of phenolics, terpenes, and coumarins. The effects of these compounds have been demonstrated in laboratory bioassays, and to a much lesser extent in field bioassays. The latter test is more important, since a chemical produced by one plant and harmful to another is of no ecological significance unless the chemical is operative in the environment. This field test should be a key research feature on the allelopathic potential in ROW vegetative management.

ALLELOPATHIC PLANTS

The most common procedure in identifying allelopathic plants is either to macerate a plant suspected of allelopathy in an aqueous solution or to collect plant run-off water from leaves, stems and roots, and apply this solution to seeds or seedlings of standard bioassay plants growing in potting soil or prepared laboratory media. The germination rate or amount of growth of the experimental plants is compared to control samples. In a few cases, soil taken directly from the field is used for both experimental and control groups. In even fewer cases, the bioassays are conducted in field situations.

Since many plant chemicals are not released to the environment under natural conditions, and since the actions of soil microorganisms can chemically change compounds released by plants, the laboratory tests can only be taken as a preliminary test for allelopathy. In addition, the plants used to detect allelopathy may never grow in the same plant communities as the plant which produced the allelopathic chemical. Therefore, the extensive list of allelopathic plant species described in the literature may not be accurate when applied to the actual environments of the plant communities. The best preliminary test for allelopathy is analysis in the field of plant associations and distributions which will indicate some type of competitive stress. Competitive variables, including allelopathy, can be investigated in more detail. Then, before allelopathy can be utilized as a ROW management option, field effects must be verified by additional research.

APPLICATION TO ROWs

Fisher (1980) produced a short list of allelopathic plants important in forestry (Table 1). Since many of the species in the table are considered desirable ROW vegetation, or affect undesirable vegetation, the list may be used as a basis for discussion on allelopathic potential in ROW management.

Table 1. Some allelopathic plants, the chemicals produced, and plants they are reported to affect.

Allelopath	Compound	Plants affected
Sugar maple	phenolics	yellow birch
Hackberry	coumarins	herbs, grasses
Walnut	Juglone (phenolic)	trees, shrubs, herbs
Juniper	phenolics	grasses
Sassafras	terpenoids	elm, maple
Laurel	phenolics	black spruce
Bearberry	phenolics	pine, spruce
Sumac	phenolics, terpenoids	Douglas fir
Rhododendron	phenolics	Douglas fir
Elderberry	phenolics	Douglas fir
Aster	phenolics, terpenoids	sugar maple, black cherry
Goldenrod	phenolics, terpenoids	sugar maple, black cherry
New York Fern	phenolics	black cherry
Bracken fern	phenolics	Douglas fir
Fescue	phenolics	sweetgum
Short husk grass	phenolics	black cherry

(Modified from Fisher 1980)

From this short list, it is apparent that allelopathic research has primarily been directed at the effects of allelopathy on valuable species in forestry and agriculture. Since none of the references listed in any review on allelopathy has mentioned ROWs in the titles, it is apparent that the utility industry has not seized on the fact that plants can be used to suppress other plants by allelopathy and/or competition for nutrients, space, water or light. The reasons for this omission need not be elaborated here because the future should be more encouraging than the past.

However, the potential must be noted and emphasized. If plants, by allelopathy or other means, can suppress tall-growing vegetation, they should be encouraged on ROWs to reduce expensive dependence on chemical and mechanical maintenance of vegetation. If benefits are available, and are to be derived from allelopathy, then a proper research program must be instituted to (1) identify plant communities of desirable height which appear to suppress the growth of tall trees, and (2) develop methods of propagating or encouraging those communities on ROWs. At this stage of applied research on ROW vegetation, it is not necessary to determine the type or nature of the suppression, just that suppression does occur and can be inexpensively encouraged on ROWs. Later research can seek further definition or refinement of the preliminary, but workable, results.

PROPOSED RESEARCH

A list of candidate species already exists in the literature and can be used as a beginning point. Species on the list which possess the characteristics of desirable ROW vegetation can serve as the initial experimental group for further testing. These species should be tested in the laboratory and in field situations using soil bioassay techniques. Additional field studies could also enumerate the degree of suppression by a statistical analysis of adjacent plant communities which different in their ability to suppresss tree growth.

The final step would be to investigate the applicability of the initial results to ROW conditions. In this phase, different manipulative techniques normally available to ROW managers could be tested to see which techniques actually encourage the spread of the desired vegetation. These techniques could range from selective herbicides, timed mechanical disturbance, controlled burning, or direct seeding or planting after site preparation.

CONCLUSION

The purpose of this paper was not to define precisely a long-term research proposal for utility funding, but to alert the industry to the potential benefits of long-term vegetation management options which would not run afoul of EPA fact or fancy and would not increase the public ire. The time, space, author, and audience are not suited to a scholarly (and lengthy) discourse on the chemical nature or ecological significance of allelopathy; but they are suited for the introduction or reintroduction of an idea whose time has come. The stable, low growth plant communities investigated and encouraged by Frank Egler since 1949 (Egler 1949, Egler and Foote 1975, Pound and Egler 1953, Neiring and Egler 1955) include the concept of allelopathy; the present author merely takes advantage of a "catch word" so enjoyable to fund-raisers and funders alike. If allelopathy is the term which will stimulate and encourage good applied research on ROW vegetation, then let is be used.

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BOTANICAL STUDIES IN THE STABILITY OF NON-DIVERSITY: *Taxus canadensis*

Frank E. Egler[1] and John P. Anderson[1]

ABSTRACT.--This paper is one in a series of long-term interpretive non-ecolometric studies of one-species-predominant plant-communities, based on small pure patches, varying from 1 to 100 feet (.3-30 m) across. At present, about 100 different such herb, shrub and tree social groups are under investigation which already have given promise of interesting continuity. All such patches are on the lands of Aton Forest, an 1100-acre (446 ha) private research area in the beech-birch-maple-hemlock Zone of northwestern Connecticut. This descriptive and interpretive research is intended to elucidate the relative stability of these communities with respect to competition (withdrawal and use of water nutrients and light by plants) and allelopathy (input of natural herbicides by plants). Thus, we are revealing the relative roles of Relay Floristics (classical Clementsian "plant succession") and Initial Floristic Composition (herbs, shurbs, and trees starting at one time, but becoming physiognomically predominant at different times) in vegetation development.

INTRODUCTION

Taxus canadensis, Yew, is a prostrate evergreen shrub growing about 18 inches (46 cm) high. Locally rare, it is known from less than 10 stations. It is found in lower slope forests, on highly variable sites, from steep slopes to flat terraces, and from rock to deep soil. The yew is known to be highly palatable to deer and is fragile. The very limited trespassing for this study snapped off several branches. The plant would be very vulnerable to trampling by cattle or conservationists. Effect of such pruning is unknown.

DISCUSSION

The location of the patch is on the U.S. Geological Survey South Sandisfield (Massachusetts-Connecticut) quadrangle of 1958. It lies in Compartment B 52-2 (original division of the Town of Norfolk), in a parcel that had been cut for charcoal before 1850, then pastured until 1934, with lumbering in 1926-28. The surrounding forest is mature, 50-80 years old,

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60-70 feet tall, 6-24 inches in diameter, predominantly hemlock with sugar maple, yellow birch, beech, black cherry, white ash, in that order of abundance.

The patch exists on a huge boulder placed directly in the streambed of Doolittle Lake Brook (locally known as Brummagem Brook, Brummagem being a corruption of Birmingham, the iron town of England). The boulder rises abruptly to 6-9 feet (2-3 m) on all sides and is 10 x 20 feet (3 x 6 m) at the base, with an essentially flat summit. The rock is in almost full shade, lying mainly below hemlock branches. The entire summit is covered with a mat of Taxus 8 x 25 feet (2.4 x 4.6 m), 12-18 inches (30.5-46 cm) high, with prostrate branches to 3 feet (.9 m) long and 1/2 inch (1.3 cm) diameter, growing to the edge of the rock and hanging over the edge. Below the Taxus is a 5% coverage of Polypodium vulgare, the normal rock-covering in this region. These plants are growing in a medium of leaf and needle litter 3 in (7.6 cm) deep, composed of hemlock and yew, together with some hardwood materials. There are no seedlings of trees and shrubs in the patch, except for one two-stemmed 6-foot (1.8 m) Corylus rostrata, in the northwest quadrant. Present growth of the yew seems vigorous. New growth is 2-4 inches (5-10 cm) long. No disease is noticed.

The history of the patch is most significantly related to the fact that its steep sides make it inaccessible to deer. In winter, with the brook frozen or with heavy-crusted snow, deer have apparently been able to browse and kill off the marginal yew that they can reach. Apparently, no deer has walked on the top. No other such inaccessible rock is known on Aton Forest. No known seed source exists within 500 feet (152 m), and yew is essentially absent from Aton Forest. Although this rock had been known for over 25 years, the summit yew was not specifically observed or studied until 1981. No estimate can be given for the age of the colony, which might have started from a single bird-carried fruit deposited coincidentally in the surface duff of a Polypodium clone.

No conversion to a mono-predominant plant-community is necessary.

Future developments cannot be involved with any peripheral extension of the clone; it already occupies the entire rock summit. A once-a-century flood conceivably could wash over the top and remove the mat of duff and yew, completely or in part. There is no present indication whatever of an invading relay of any tree or shrub seedlings, although the rock is in the seed-shadow of hemlock, sugar maple, and yellow birch, with other trees in the near vicinity. If the community remains stable, there is a reasonable implication that Taxus is allelopathic to many other forest species, but not for certain ferns. Controlled laboratory testing of yew for phytotoxins is now needed to verify the presumption of allelopathy based on field interpretation.

SUMMARY

In conclusion, the total absence of yew from all of Aton Forest except for a very few deer-excluded areas (themselves extremely different in edaphic substrata) strongly implies that but for the herds of white-tailed deer, yew could be one of the commonest forest shrubs, thus changing the physiognomy of the forest understory to a very marked degree, as well as the

ability of the forest to reproduce itself. Deer-exclosure studies on a variety of sites would be very revealing of academic and applied problems in vegetation science and vegetation management.

A PRELIMINARY STUDY OF THE USE OF JELLIED FUEL AND HAND-HELD TORCHES FOR RIGHTS-OF-WAY MAINTENANCE

Dale H. Arner[1], William W. Elam[2], Danny R. Hartley[1], and Jim W. Lipe[1]

ABSTRACT.--Jellied fuel and a hand-held propane torch were field tested and evaluated to determine their effectiveness in the selective control of undesirable woody plants on utility line rights-of-way. The propane torch was effective in setting back woody vegetation (root kill and/or top kill of woody plants) by application of the flame for 20 seconds per stem. Application of the flame for 5 seconds was not as effective. The use of a jellied fuel mixture of gasoline and diesel fuel was as effective as the propane torch applied for 20 second periods.

INTRODUCTION

Government concern and regulations for the use of chemical herbicides have dictated the investigations of other means for controlling undesirable woody vegetation on utility line rights-of-way (ROW). Prescribed burning has been used successfully on ROW in the Southeastern United States (Arner 1959, Arner et al. 1976) where the plowing of fire lanes did not cause undue soil erosion. However, other techniques are needed on the steeper slopes and rough areas where the plowing of fire lanes would cause considerable soil erosion. Safe burning on ROW is limited by weather factors which reduce the ROW acreage that can be managed by prescribed burning (i.e. burning should be restricted to one to two days after rain, a steady wind of low velocity etc.).

Another method of treating undesirable vegetation may be through the use of jellied fuel. At present, jellied fuel is being used in aerial application for forest site preparation by several timber companies in the southeastern United States. The use of direct intense heat on individual woody stems after periods of heavy rainfall or snowfall had not been thoroughly explored, although the use of hand held torches for controlling undesirable woody vegetation in forest stands was described by Cavanagh and Weyrick (1978) and the use of such torches on ROW was investigated and reported by Olson et al. (1979).

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This study was initiated to determine the feasibility of using jellied fuel and hand held torches selectively on undesirable woody vegetation in steep areas where the plowing of fire lanes is not desirable.

METHODS AND MATERIALS

Three jellied fuels were used in the trials: (1) gasoline (2) diesel fuel and (3) a 3:1 diesel fuel to gasoline mixture. The jelling agent used was alumagel, a commercial product of Witco Chemical Organics Division of New York, N.Y. Alumagel is an aluminum soap developed to gel nonpolar solvents without use of heat and contains about 7% free fatty acids. Gels made with aluminum metallic soap characteristically show good stability to heat and storage (Witco, 1978).

Metallic soaps can form solvent gels when used in amounts of 0.5 to 5 percent of system weight. Laboratory tests were run to determine which jellied fuels possessed the proper viscosity to be applied with a hand-held pressure type garden sprayer. The various fuel mixtures were then tested in the field using a hand pump pressure sprayer of 1½ gallon capacity equipped with a standard nozzle. In the field, the jellied fuels were ignited with a standard type drip torch, and the difficulty of ignition and explosive aspects was noted and recorded. Moisture conditions under which the trials took place varied from immediately after a heavy rainfall to one day after a heavy rainfall.

A hand held propane torch of 500,000 BTU capacity which produced a flame of 3,500° F was used selectively on undesirable woody plants. Three treatments were tested and evaluated where the flame of the torch was held on the basal portion of woody stems for (1) 5 seconds (2) 10 seconds and (3) 20 seconds.

The propane torch or jellied-fuel was applied to pine and hardwood stems ranging from 0.75" to 3" (1.91 cm to 7.62 cm) in diameter at the base of the stem. The pine species treated were short leaf pine (*Pinus echinata*) and loblolly pine (*Pinus taeda*); the hardwoods tested were sweet gum (*Liquidambar stryraciflua*) and oak (*Quercus* spp.). The treatments were conducted during the summer of 1981. Topkill and plant mortality were determined by the methods of Olson et al. (1979).

RESULTS AND DISCUSSION

The 3:1 diesel fuel to gasoline mixture proved to be the best fuel. When mixed at a 1.75 to 2.00 percent solution with the jelling agent it could be successfully sprayed with the equipment used. It was relatively easy to ignite, was non-explosive, and had the desired characteristics of not burning out quickly.

When the gasoline gel was sprayed on woody vegetation in the field, hazardous conditions were created for ignition. The gasoline vaporized and showed a tendency to explode and jump from stem to stem when ignited. It also burned up too quickly for the maximum effective kill for the amount of energy released. The time-temperature relationship is important in killing woody plants. When only diesel fuel was mixed as a gel, there was difficulty in igniting the treated stems, especially under the wet, high humidity conditions of the test.

Preliminary results indicated no significant difference in root kill when the gasoline-diesel fuel gel was field tested, but it was effective in setting back woody vegetation by either top killing or root killing (Table 1).

The time involved in treatment with jellied-fuel varies with conditions existing on ROW. Scattered woody growth on rough, steep ground will naturally take longer to treat with either propane torch or jellied-fuel. Recorded time of treatment with jellied fuel showed that 89 stems were treated in 3/4 of an hour.

It appears the major benefit of using jellied fuel is that fuel can be applied rapidly and in the quantity desired to the target vegetation during periods of wet weather. Direct application around the base of the woody stem will in all probability increase woody plant mortality over that of the conventional prescribed burning technique. The increased fuel plus the localization should allow a heat build up that would penetrate the bark better and achieve a better kill. The cost of alumagel was $1.97/pound. We obtained another similar thickening compound from an army ammunition plant for $ .07/pound.

Table 1. A comparison of the effectiveness of the use of the propane torch and jellied fuel in "setting back" woody vegetation. The diameter of the basal area of the trees ranged from 1.91 cm to 7.62 cm.

	PROPANE TORCH Hardwoods			JELLIED FUEL
	5 sec	10 sec	20 sec	
Top or root kill	9	42	29	7
Not killed	7	4	3	0
Total	16	46	32	7
Prop. killed	0.56	0.91*	0.91*	1.00*

*P ⩽ 0.05; Fisher's Exact Probability Test

	Pines			
Top or root kill	39	44	60	79
Not killed	30	28	10	14
Total	69	72	70	93
Prop. killed	0.65	0.61	0.86*	0.85*

*P ⩽ 0.05; Chi-square Test of Independence

Field testing with the propane torch showed no significant difference in root kill or top kill for the three times of application in pine or hardwood. However, when top kill and root kill were combined, statistical analysis showed that application of flame by the propane torch for a period of 20 and 10 seconds was significantly more effective in setting back hardwood woody plant growth than the 5 seconds time interval of flame application. In pines, the 20 second interval of flame application was the only effective time interval (Table 1).

It was found that every 20 minutes the propane torch used one gallon of fuel which cost $1.00/gal. The estimated cost for fuel was 0.8¢ per stem for a 10 second interval of torch application and 1.7¢ per stem for a 20 second interval.

It appears evident that both of these treatments can be applied as economically as selective spraying with herbicides when the woody plants are few and scattered on the ROW. However, if jungles of woody stems cover the ROW, any selective treatment of undesirable woody plants becomes far too expensive. Based on our study, it appears that the initial treatment for such areas in the Southeastern United States should be broadcast spraying of a herbicide followed by seeding of partridge pea or annual lespedeza. The ROW can then be maintained selectively by either herbicide, torch, or jellied fuel. This was a preliminary study; field trials and investigations are continuing at Mississippi State University.

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USE OF PRESCRIBED BURNING FOR MANAGING RIGHTS-OF-WAY IN CENTRAL NEW ENGLAND--PRELIMINARY RESULTS

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ABSTRACT.--Fifteen one-half acre (.2 ha) plots , fifteen two-third acre (.27 ha) plots, and two 10-acre (4 ha) blocks were burned to determine costs; effectiveness in controlling tree growth; changes in herbaceous vegetation; and periods during the spring, summer and fall, when fire can be used effectively. Under average conditions in spring, costs of labor and equipment for prescribed burning are approximately $20 per acre on 250 ft (76 m) wide rights-of-way. First year results indicate that, although woody stem heights were reduced by killing tops, the total number of stems increased due to resprouting and seedling establishment on all burns. However, on the areas burned in the early part of the growing season (late May, early June), the increase in woody stems is less than on the unburned controls. With mid-April burns there was a marked increase in density and flowering of forbs. On the mid-October burns, increases in flowering and seed production were also obtained but to a lesser extent. Shrubs, ferns, and mosses decreased after burning in spring, summer and fall. Mid-April burns were the most cost effective and covered nearly all the surface area of the plots, but also resulted in the greatest number and the most rapid height growth of tree sprouts. Overall the burns in spring (May) when the hardwoods are partially leaved out appear to be the most favorable for reducing hardwood stems and increasing the cover of grasses and forbs. Summer and fall burns are increasingly less effective in costs and coverage because of increasing green growth, shorter day lengths for drying, and a tendency for fire to smolder in the duff or downed woody material. At this point prescribed burning appears to have considerable potential for managing right-of-way vegetation, but it is apparent that single fires will not adequately control hardwood tree growth. In addition, there is a real shortage of trained operators to apply this technique.

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INTRODUCTION

The use of herbicides to control woody vegetation on rights-of-way has recently come under close scrutiny for a variety of reasons. There is concern for the health of humans, wildlife, and non-target plants as well as potential contamination of water supplies. The cost of herbicide application has continued to increase, while at the same time, there is evidence to suggest herbicide resistant tree species are continuing to increase on some rights-of-way (Egler 1979).

Fire is a natural phenomenon which has modified vegetation for eons, and there is considerable evidence that with burning, grass species and forbs are favored over shrub and tree growth (Kucera 1981). In the past fifteen years, there has been a gradual increase in use of prescribed fire for a variety of land management purposes including prescribed burning on rights-of-way in the South (Arner 1979). There has been little research on the use of fire for managing rights-of-way in the Northeast.

Since 1970 there has been a fire research program at the University of New Hampshire in which prescribed burns have been conducted on a variety of vegetation types at different times of the snow-free season. We found that, in general, forest fuels would only burn in spring or fall but that grasses and some forbs and shrubs would burn during the entire snow-free season, provided two to five days had passed since the last rain. These initial trials led to the present study which was started in 1979 and is only partially completed. The objectives of this paper are to present a progress report on the costs, effectiveness in controlling tree growth, and changes in herbaceous vegetation from prescribed fires conducted at five different periods during the snow-free season of the year.

METHODS

Prescribed fires were conducted in mid-April, late May, mid-July, late August, and mid-October on 15 half-acre (.2 ha) plots on a 250 foot (76 m) wide, 345 kV transmission line near Rochester, New Hampshire. In each burning period three plots were burned; one on well-drained sandy soils, one on heavy poorly-drained silt loams, and one on an intermediate soil type. There were two one-half acre (.2 ha) control or unburned plots on each soil type. The first three plots were burned in mid-July 1979, and the last three plots at the end of May and early June 1980 (Table 1).

A second series of 15 plots, each approximately two-thirds acre (.27 ha) in size, was established and burned from mid-July 1980 to the first of June 1981. These plots are in abandoned agricultural clearings in the Rochester Ranger District of the Green Mountain National Forest, Vermont. The burning schedule was similar to that of the right-of-way plots. On these plots the soils were similar but the vegetation was somewhat different. One set of 5 plots and a control or unburned plot were mostly grassy and open, the second set was characterized by dense stands of shrubs, mostly meadowsweet (*Spiraea latifolia*), and the third set was characterized by scattered thickets of tree saplings and many tree seedlings. During each of the five burning periods, one of each vegetation type was burned (Table 1).

Within each category of soil (New Hampshire rights-of-way) or vegetation (Vermont agricultural clearings) the time of burning or designation as unburned control was assigned randomly. The plots were usually burned between two and five days after a soaking rain, with good drying conditions and winds of 5-15 mph. Usually the downwind or uphill side of the plot was burned first in a narrow strip and then the fire was allowed to back into the wind or downhill (Fig. 1). Sometimes successive strips were ignited so that the fire burned both as head fires (with the wind or uphill) and as backing fires. Ignition was by means of a handheld drip torch and the edges were patrolled with portable back-pack pumps (Indian tanks). On the right-of-way plots, an attempt to get complete fire coverage of the surface area was made by going back over the area and igniting unburned patches. On the Vermont plots, which were burned by crews from the Green Mountain National Forest, there was no re-ignition.

Prior to burning, all of the stems of tree species were counted on each plot. For each stem, the height [(less than one ft (.3 m), one to six ft (.3-1.8 m), or over six ft (1.8 m)], as well as whether the stem was a single or one of a clump of sprouts (multiple), was recorded. After the burns the tree stems were counted again in the summers of 1980 and 1981.

A measure of frequency of occurrence of herbaceous species as well as shrubs and bare ground was obtained by randomly dropping a one-eighth in (.3 cm) diameter steel pin 600 times on each right-of-way plot. Each plant species that the steel pin touched was recorded. Although data is available for individual species, for purposes of this report the data have been aggregated into six groups: grasses and sedges; forbs; shrubs; ferns; moss; and bare ground.

In order to establish techniques for burning areas larger than the one-half or two-thirds acre research plots, and to estimate costs for management sized operations, two 10-acre (4 ha) units on the 345 kV right-of-way were burned with a four-man crew using the hand tools described above. One unit was burned in August of 1979, and the other in April of 1981.

Attempts were made to determine if the species composition of the grasses could be changed by the addition of grass seed after burning. On twenty-one 10 square yard subplots within the one-half acre burn plots and on ten locations in the April management burn, a grass seed mixture was sown over the recently burned ground surface. The mixture was one-quarter creeping red fescue (*Festuca rubra*), one-quarter Kentucky bluegrass (*Poa pratensis* L.), one-quarter perennial rye grass (*Lolium perenne*) and one-quarter white Dutch clover (*Trifolium repens*).

RESULTS

Surface Area Burned

The proportion of surface area which was burned varied between different seasons of burning and from plot to plot, depending on drainage and the nature of the fuels (Table 1). In mid-April, prior to the start of the growing season, virtually all of the fine fuels are cured and there is the least amount of shade. Fires at this time of year burn from 80-95% of the surface; the only areas missed are those under standing water, wet

Table 1. Schedule of prescribed burning dates for thirty plots on power line rights-of-way and abandoned agricultural clearings in New Hampshire and Vermont.

Abandoned Agricultural Clearings in Vermont

A series - open grassy	Date burned	4/13/81	6/1/81	7/14/80	9/8/80	11/7/80	Control
	Plot number	A4	A6	A1	A3	A2	A5
	Size (acres)	0.6	0.6	0.6	0.6	0.6	0.6
	Percent burn	89.5	62.5	49.1	36.1	<20	---
B series - dense shrubs	Date burned	4/13/81	6/1/81	7/15/81	9/8/80	11/7/80	Control
	Plot number	B3	B5	B2	B4	B1	B6
	Size (acres)	0.6	0.6	0.6	0.6	0.6	0.6
	Percent burn	83.8	61.5	15.0	72.7*	<10	---
C series - scattered thickets of tree saplings and many tree seedlings	Date burned	4/13/81	6/1/81	7/14/80	9/8/80	11/7/80	Control
	Plot number	C1	C4	C5	C3	C6	C2
	Size (acres)	0.6	0.6	0.6	0.6	0.6	0.6
	Percent burn	93.2	63.5	35.3	10.7	<5	---

Power Line Rights-of-Way in New Hampshire

A series - heavy poorly-drained silt loams	Date burned	4/17/80	5/27/80	7/20/79	9/1/79	10/23/79	Control	Control
	Plot number	A7	A4	A1	A6	A2	A3	A5
	Size (acres)	0.54	0.53	0.46	0.56	0.72	0.54	0.61
	Percent burn	75.2	>65	69.5	48.5	73.3	---	---
B series - well-drained sandy soils	Date burned	4/17/80	5/27/80	7/20/79	9/1/79	10/23/79	Control	Control
	Plot number	B5	B3	B1	B4	B2	B6	B7
	Size (acres)	0.51	0.55	0.42	0.69	0.66	0.43	0.37
	Percent burn	84.5	>80	92.2	54.5	86.8	---	---
C series - intermediate sandy loams	Date burned	4/17/80	6/6/80	7/20/79	9/1/79	10/30/79	Control	Control
	Plot number	C2	C6	C5	C1	C4	C3	C7
	Size (acres	0.51	0.55	0.42	0.69	0.66	0.56	0.50
	Percent burn	84.5	>80	92.2	54.5	86.8	---	---

*Percent burn is abnormally high because of mowing and drying of fuels before burning.

Figure 1. Power lines were burned by igniting strips across the right-of-way and allowing the fires to back into the wind.

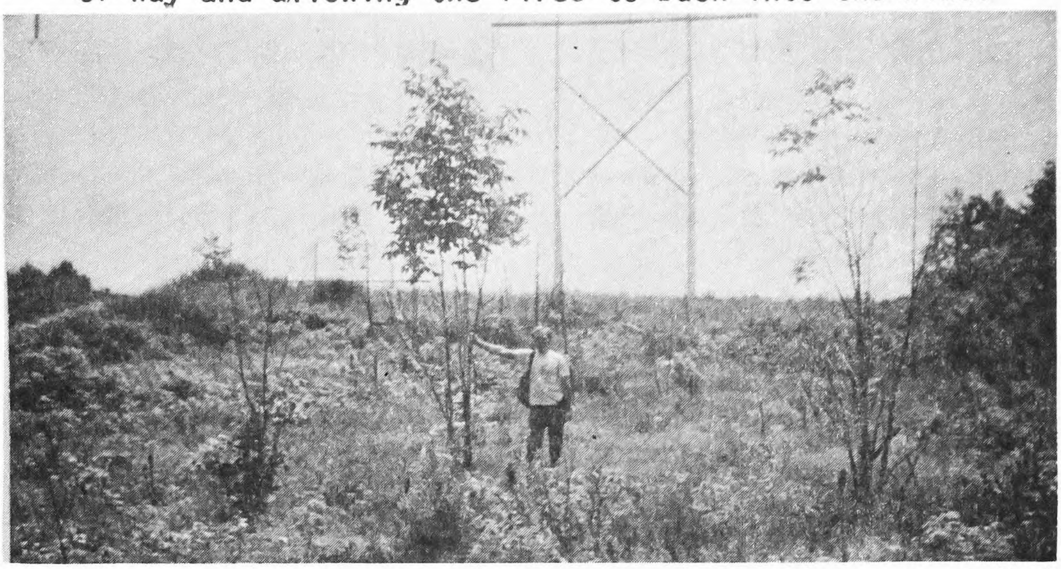

Figure 2. Prescribed fires increased the accessibility and visibility on the rights-of-way but did not kill many of the hardwood stems more than one inch in diameter.

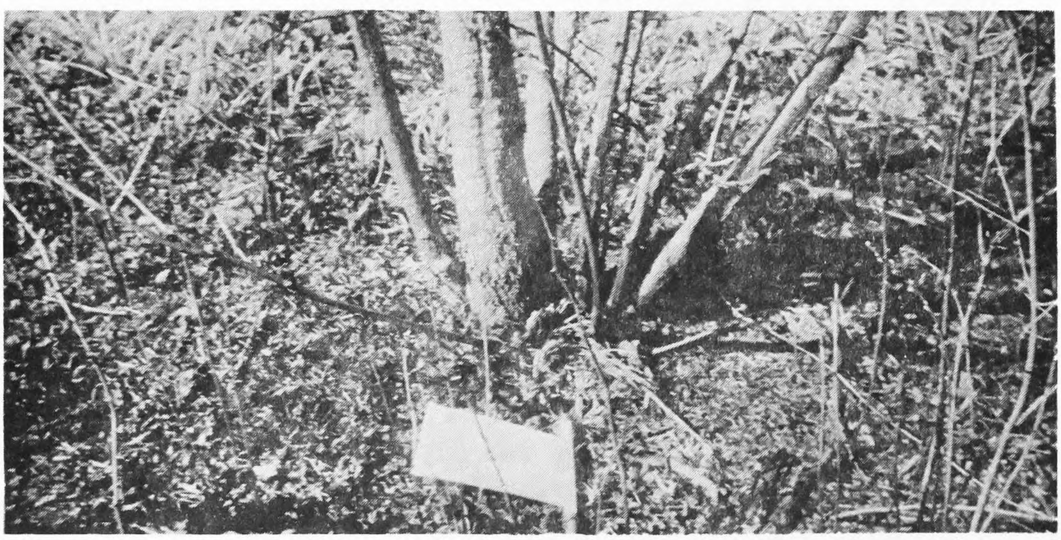

Figure 3. Resprouting after injury by fire increases the number of tree stems and insulates the inner stems from control by fire.

depressions, and hummocks or patches of vegetation surrounded by rock or bare ground.

The fires in late May also cover a large proportion (50-75%) of the surface. Fuels are still mostly dry and exposed, and the long day length results in favorable drying conditions. By the end of May many new leaves are partially or fully developed, producing areas of shade such as in clumps of raspberry (Rubus spp.), meadowsweet, or thickets of tree saplings which will not burn completely.

In the middle and latter part of the growing season (July and August), there is a considerable development of new green vegetation; hence, much of the fuel does not dry out, and the areas covered by the fires (10-50%) are considerably lessened. During these months it is possible to get individual clumps of grass in sunny exposed areas to burn, but the fires do not spread into other fuels, and it is difficult or impossible to burn shady areas, patches of fern, shrubs, goldenrod, or areas of tall grass.

By mid-October the plots on the power line rights-of-way in New Hampshire have had frost, leaf fall, and some curing of the fine fuels, and the fires will cover from 73 to 80% of the surface ara. Bristly dewberry (Rubus hispidus) remains green and unaffected by the frost and it considerably retards combustion and the spread of the fires. At the higher elevation research plots in Vermont, the fall is characterized by heavy dews, frequent showers, and sometimes snow by the middle of October. As a result, the fuels seldom dry and the area that can be burned is very low (5-10%).

Changes in Tree Stem Density With Burning

Counts of tree stems on the power line right-of-way plots before burning are incomplete and therefore unreliable. This analysis is based on the stem counts before and after burning on the Vermont study areas. On these areas the number of stems increased on all the burned plots and on the unburned control plots as well (Fig. 4). However, the increase in tree stem density was least (76%) on the plots burned in the early part of the growing season (June 1). The density of stems on the unburned plot increased by 110%. Increases in tree stem density in mid-April (169%), mid-July (161%), and late August (129%), were all larger than on the unburned plot and about twice that of the early growing season (June 1) burn. The mid-October burn plots had an increase in stem density of 77%, but this was probably due to factors other than burning, since only 5-10% of the surface area was covered by fire. The October plots had the largest density of stems over 1 ft tall, which may have provided enough shade to inhibit the development of seedlings under 1 ft tall, as suggested in the last column of Figure 4.

The increase or decrease in tree stems after burning is due to several factors. Many hardwood saplings are girdled by the heat and the tops are killed. The roots and lower stem remain alive, however, and produce new sprouts, usually more than one. The fires will normally girdle and top-kill stems less than one-inch (2.5 cm) in diameter, but saplings with stems more than one-inch in diameter are not consistently top-killed. Most seedlings and saplings of conifers: white pine (Pinus strobus), balsam fir (Abies balsamea), red spruce (Picea rubens), and hemlock (Tsuga canadensis) are killed outright by the fires and do not resprout. Many tree seedlings, especially sugar maple (Acer saccharum), are killed by the fires. Some of these may resprout, but usually only with a single weak stem. In areas where the fires burn hot or smolder in moss (Polytrichum spp.) or duff, the soil surface is exposed and paper birch (Betula papyrifera), willow (Salix spp.) and aspen (Populus tremuloides) often start from seed.

The most abundant tree species on the Vermont plots are black cherry (Prunus serotina), red maple (Acer rubrum), choke cherry (Prunus virginiana), apple (Malus spp.), and sugar maple. All except sugar maple increased due to resprouting after burning. The density of sugar maple (seedlings) decreased after both the spring dormant and early growing season fires.

When the tallest stems are girdled and resprout, or in some cases are killed outright, the average height of the tree stems decreases and the burned areas become more open and less shady despite the increased density of tree stems due to resprouting (Fig. 2). The shift from single stems to multiple stems (i.e., sprout growth) is greatest in the April, June, and July fires when the largest proportion of the surface area is burned (Fig. 3).

Changes in Tree Stem Density One-Two Years After Burning

From the power line right-of-way research plots, data are available to analyze the change in the density of tree stems between the first and second growing seasons after burning (Fig. 5). There was an increase in the density of tree stems on all of the plots, burned as well as control, but the increase was least (33%) on the plots burned in the early part of the growing season. The overall pattern is similar to that observed on the Vermont study areas (Fig. 4).

If one examines the proportions of single and multiple stems in the seedlings less than 1-ft (.3 m) tall in Figure 5, it is possible to see an increase in the proportion of single stems in 1981. This is probably due to some tree sprouts being eliminated due to competition and shading, and to establishment of seedlings on areas of bare soil. In the mid-July burns the fires were hot and burned the humus in several places. These have been seeded in by paper birch in particular, and this accounts for the large increase in seedlings in 1981. The proportion of stems less than 1 ft (.3 m) tall did not increase on the early growing season burns.

Changes in Ground Vegetation

The 1981 growing season was a very favorable one with ample, well distributed rains and an early warm spring. As a result the relative frequency of all five categories of vegetation: grasses and sedges, forbs, ferns, shrubs, and moss on the control plots increased (Fig. 6), and the relative frequency of bare ground decreased. To fully understand the changes in these categories of vegetation, one must look at net change, or the change in relation to the control plots as depicted in Figure 7 and discussed below.

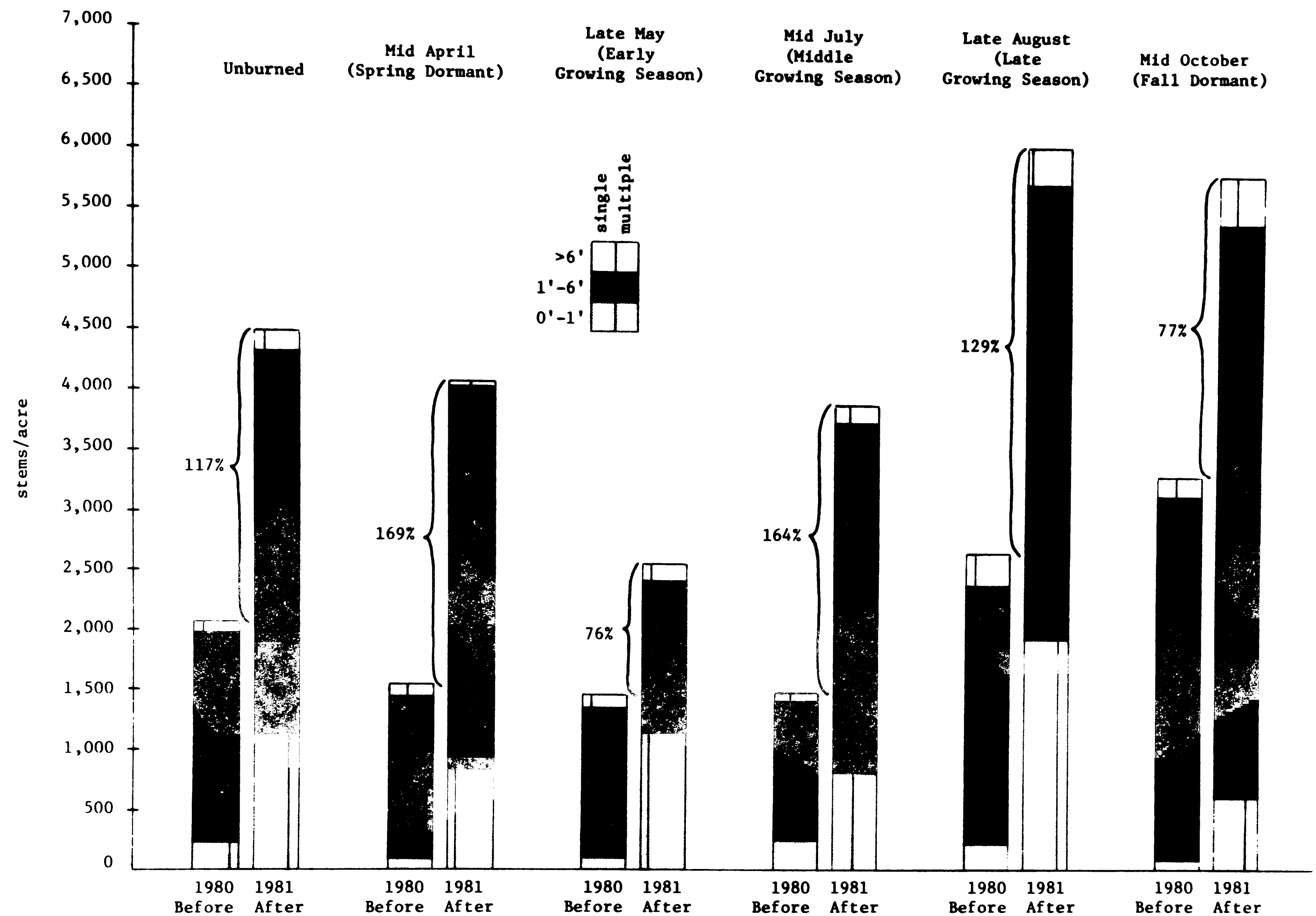

Figure IV. Change in the number and heights of tree seedlings, saplings and sprouts as the result of prescribed burning in abandoned agricultural clearings in the Green Mountain National Forest of Vermont.

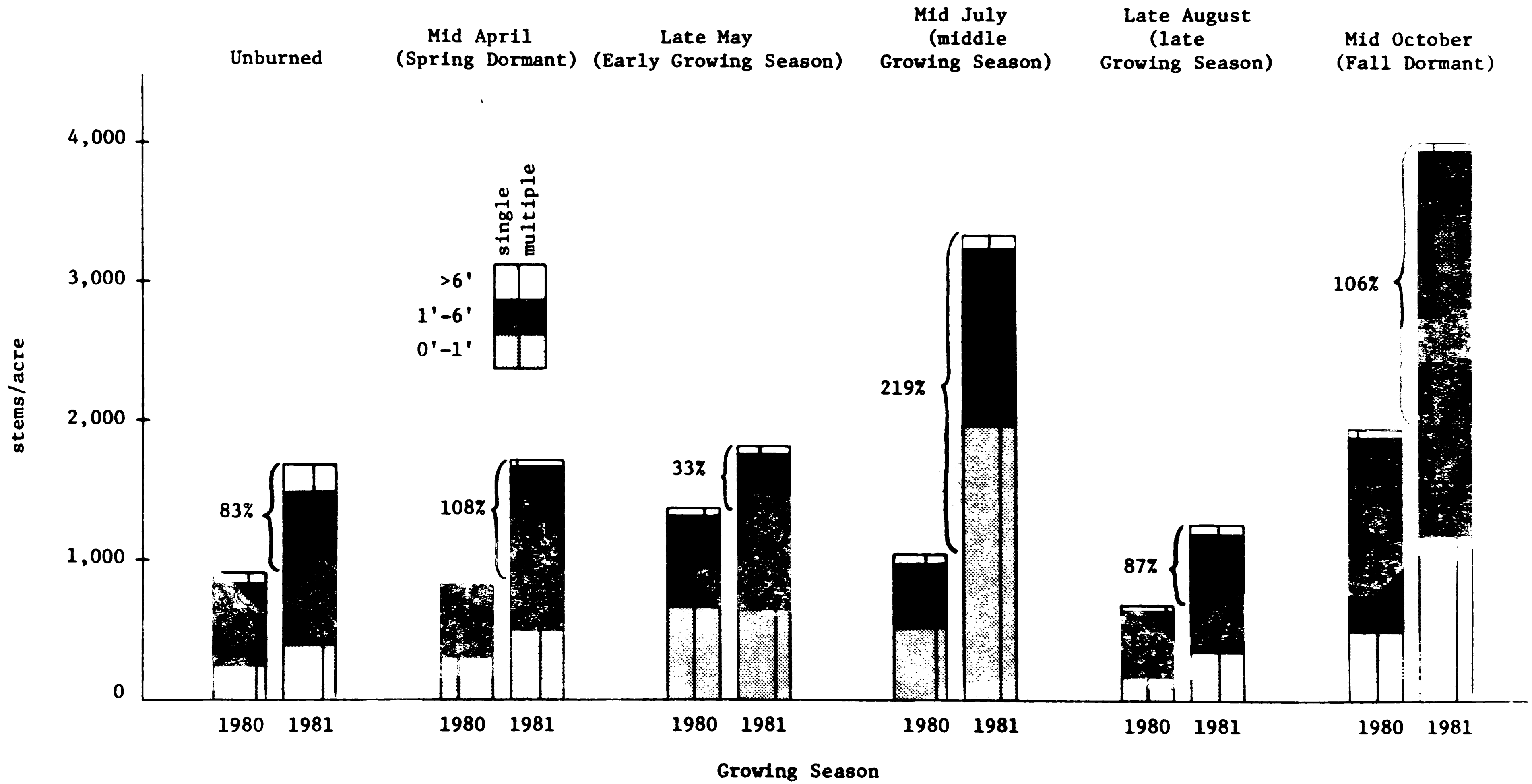

Figure V. Changes in the number and heights of tree seedlings, sapling and sprouts between the first and second growing seasons after prescribed burning on power line rights-of-way in New Hampshire. (Plots burned from July 1978 to May 1980. Tree stems counted in September 1980 and 1981).

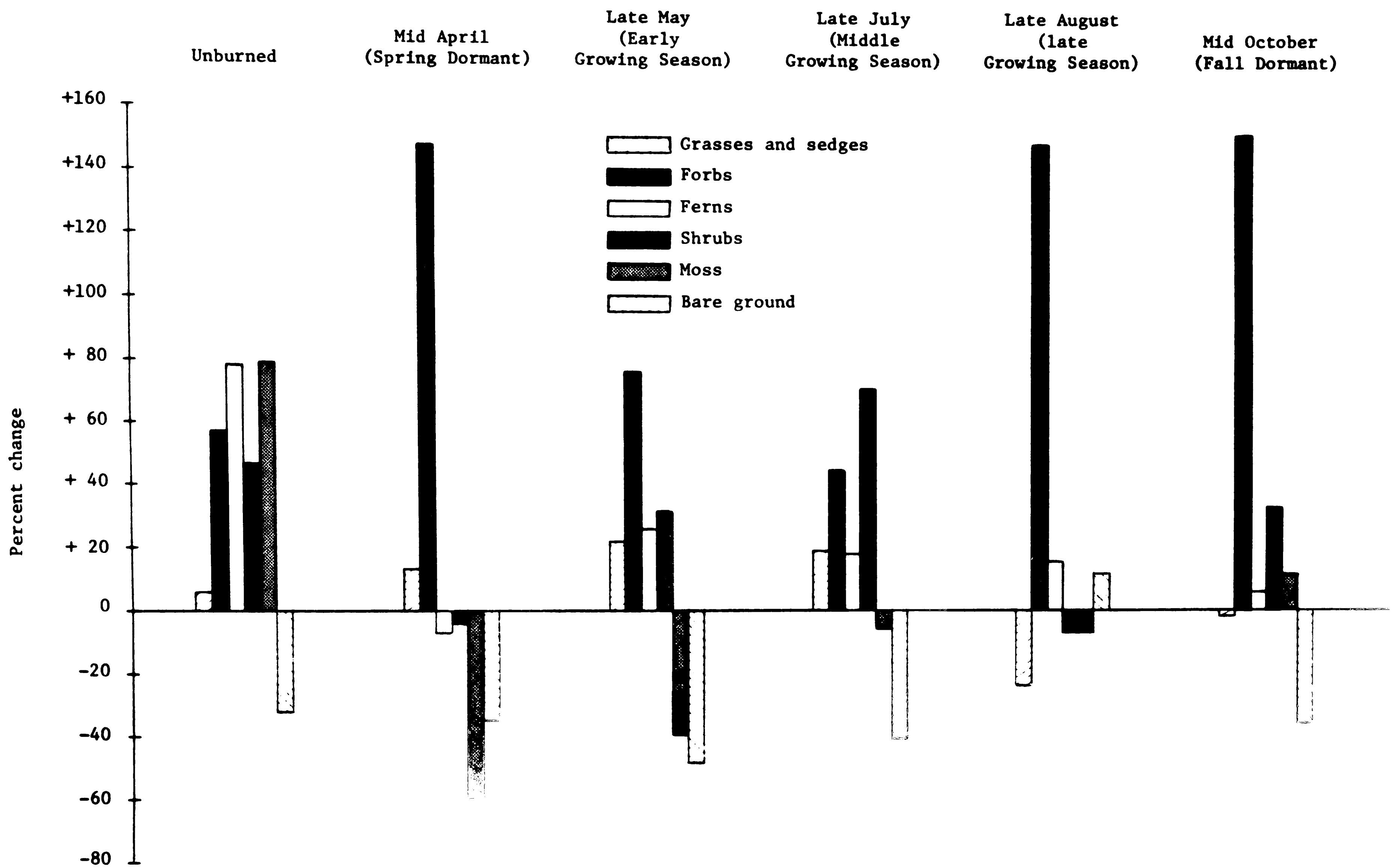

Figure VI. Changes in relative frequency for six categories of ground vegetation, one growing season following prescribed burning on a power line right-of-way in New Hampshire.

Grasses and Sedges. The relative frequency of grasses and sedges increased in the spring (dormant), early and mid-growing season fires, and decreased in August and October burns. For grasses alone, the largest increase was in the late May burns. The major grass and sedge species on study plots are little bluestem (*Andropogon scoparius*), *Danthonia spicata*, *Carex pensylvanica* and Kentucky bluegrass. Little bluestem tended to increase when burned in April, May, or July, but decreased when burned in August or October. There was no visible change in the species composition of grasses as a result of sowing a grass seed mixture on 31 small patches after burning.

Forbs. The relative frequency of forbs increased dramatically after the spring and fall dormant season fires, and from burning in August, late in the growing season. There was a moderate increase in forbs from burning early in the growing season, but a decrease with the mid-July fires. The principal forbs on the research plots are goldenrods (*Solidago* spp.), whorled loosestrife (*Lysimachia quadrifolia*), sheep sorrel (*Rumex acetosella*), and asters (*Aster* spp.). The goldenrods and asters, both perennials, seemed to flourish after dormant season fires. The first year after burning there is a remarkable increase in flowering, and on the heavier soils this flowering effect has persisted for two growing seasons. Sheep sorrel and whorled loosestrife, also perennials, increased with the early and late growing season fires.

Ferns. The relative frequency of ferns decreased after burning in all five burning periods. This is a rather surprising result because all of the ferns appeared to resprout after burning, and in many cases it was difficult to get ferns to burn at all. In some areas white-tailed deer (*Odocoileus virginianus*) browsed the resprouting bracken fern (*Pteridium aquilinum* L.) as the new fronds unfolded. However, the decrease in ferns could not be attributed to any one species.

Shrubs. Except for the mid-July period the relative frequency of shrubs was always reduced by burning. In particular, sweetfern (*Comptonia peregrina*) decreased after the spring and fall dormant season fires, and broadleaf spirea, or meadowsweet, decreased after the early and late growing season fires (May and August). The increases in shrubs with the mid-July burns were due to increases in dewberries (*Rubus flagellaris*, *Rubus hispidus*), blackberry (*Rubus allegheniesis*), and red raspberry (*Rubus idaeus*), all of which, although classified as shrubs in this analysis, are really trailing brambles.

Moss. There is a surprising amount of moss on the prescribed burn and the unburned control plots on the New Hampshire rights-of-way and on the abandoned agricultural clearings in Vermont. On both areas the principal species are *Polytrichum* spp., but there are some *Sphagnum* spp. on poorly drained areas. Fire reduced the relative abundance of moss in all the burning periods. The moss was consumed by the fire in some cases, while in others it was killed by heat scorch. New seedlings of various grass species and sheep sorrel were often observed in areas of burned or scorched moss.

Bare Ground. A category of "bare ground" was used to describe those areas where the steel pin used in sampling did not touch living vegetation.

Thus, bare ground included rock, mineral soil, pieces of wood and dead leaves. The frequency of "bare ground" decreased for all of the burning periods except in the late August burns. The increases and decreases in relative frequency for the bare ground category appear to be inversely proportional to the increases and decreases in grass and sedge (Fig. 7).

Differences in Height and Vigor on Tree Sprouts

On both the New Hampshire and the Vermont study areas, it was observed that resprouting of tree stems was markedly different depending on the time of burning. The sprouts of trees burned in the early part of the growing season (late May) were much shorter and less vigorous than sprouts from the spring dormant season or other periods of burning. On the power line study areas the first year sprouts of red oak (*Quercus rubra*), red maple, aspen, black cherry and gray birch (*Betula populifolia*) are only about half as tall on the May burns (Table 2). Although no measurements are available, visually, the differences in sprout height and vigor between the spring dormant (mid-April) and early growing season (late May) burns in Vermont were even more pronounced. White-tailed deer browsed the shorter, thinner sprouts from the early growing season burn and this may have increased the difference.

Table 2. Differences in height growth of tree sprouts during the first growing season after prescribed burning in mid-April and late-May on power line rights-of-way in New Hampshire.*

Time of Burn	mid-April	late May
Plot A	(36)**35.5"	(26) 18.9"
Plot B	(26) 29.5"	(42) 19.0"
Plot C	(32) 29.2"	(18) 15.8"
All Plots	(94) 31.7"	(84) 18.3"
Red oak	(24) 29.8"	(25) 15.9"
Red maple	(11) 39.1"	(12) 18.9"
Aspen	(17) 26.5"	(1) 13.0"
Black cherry	(20) 32.0"	(9) 23.6"
Gray birch	(12) 30.0"	(14) 18.9"
Other	(10) 38.6"	(23) 18.0"
All Species	(94) 31.7"	(84) 18.3"

*Representative stems were selected for measurements; in clumps, the tallest and shortest sprouts were measured.

**(n) the number of stems measured.

DISCUSSION

The results of this research are obviously incomplete. The response of the vegetation to prescribed burning is still occurring, and more time is

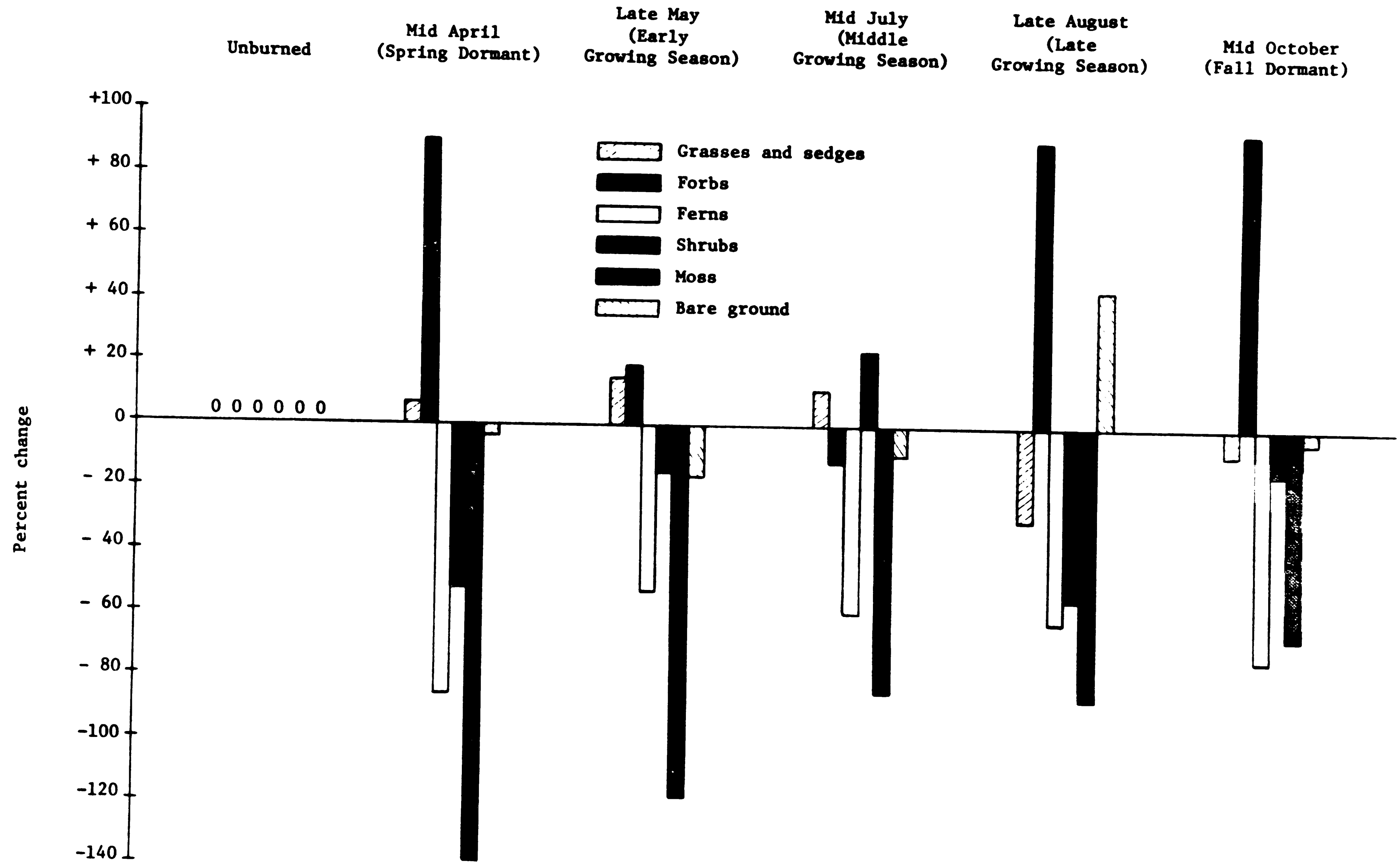

Figure VII. Net change (in relation to unburned controls) of relative frequency for six categories of ground vegetation, one growing season following prescribed burning on a power line right-of-way in New Hampshire.

needed to more fully evaluate the types as well as the duration of change. The data for many individual plant species are extremely variable from plot to plot, and therefore they had to be aggregated (as in Figs. 4-7) to depict the overall patterns of change.

Time of Prescribed Burns

In many respects prescribed burning is easiest to accomplish in the spring before the onset of the growing season. At this time most of the fine fuels are dry or dormant, the day length is increasing and good drying conditions prevail. The ground is saturated so that the fires do not burn deep and there is usually an abundance of water nearby. The fires spread well and burn uniformly so that most of the surface area is covered. However, while it appears that some increase in grasses and sedges, and a large increase in forbs can be obtained, trees (except conifers) respond to these early season fires by resprouting vigorously if they are injured or it their tops are killed. The result is that that are more tree stems than before burning, and in subsequent years the rate of increase is greater than on the unburned areas.

Burning in the early part of the growing season has the greatest potential for managing rights-of-way and other open areas where a reduction in, or elimination of tree species is desirable. Prescribed fires in this season are somewhat more difficult to conduct than in early spring because the new leaves on the forbs, shrubs, and trees produce shade, and the new green foliage of grasses, sedges, and forbs reduce flammability. However, the longest days and the best drying conditions occur at this time, and much fine fuel from the previous year is still not decomposed. The result is that early growing season fires cover much of the surface area (i.e., from 50 to 70%). The trees that resprout from these fires produce short, thin sprouts, apparently because most of the stored energy and nutrients have been already used in producing the spring growth. In Vermont, white-tailed deer were exceptionally fond of these new sprouts and browsed on them intensely all summer, thus assisting in controlling the height growth. The deer browsed 43.8% of the sprouts from early growing season burns, compared to 29.5% of the sprouts from other periods of burning.

In addition to reduced tree growth, the early growing season fires produced the largest increase in grasses and sedges, and the greatest reduction in the amount of bare ground. Burning at this time of the year is known to favor warm season grasses such as little bluestem, which occurred on many of the power line plots.

On the study areas in Vermont, where the phenological development in spring is later than on the coastal plain of New Hampshire, early growing season burns at the end of May or early June appear to be very effective. On the power line right-of-way research plots on the coastal plain of New Hampshire, prescribed fires in late May appear to be too late because by this time, the tree leaves are well developed and the humus layer in the soil has frequently dried out sufficiently to cause deep smoldering fires instead of light surface fires. On these areas, burning in the middle of May would probably be more effective, both because of decreased labor costs and increased effectiveness in reducing tree sprouts. As an initial approximation, it appears that early growing season fires are most effective when the leaves of hardwood trees are still developing, or have just reached full size and the soil and humus are still moist.

Burning in the middle of the growing season, late growing season, or in the fall dormant season, does not appear to be effective for managing power line rights-of-way. Fuels are very green and wet, and under normal conditions the fires do not cover more than 50% of the surface area. Also, the number and vigor of tree sprouts after burning are such that the total density of tree stems increases relative to the unburned areas. Occasionally drying conditions are such that summer and fall fires will cover much surface area, but usually the organic layers in the soil are also dry and the labor costs to extinguish smoldering fires is prohibitive. These mid and late growing season fires may also reduce the amount of grass, especially warm season grasses which are then at the peak of growth.

Reductions in Shrubs, Ferns, and Moss

Fire, no matter when it was tried, had the effect of reducing the relative frequency of shrubs, ferns, and moss (Table 7). The only exception was that in mid-July, shrubs increased due to an increase in trailing brambles as discussed above. The reduction in shrubs and ferns contributed to the more open aspect of the rights-of-way after burning (Fig. 2), and probably would result in better access for maintenance crews and future herbicide treatments.

It also appears that the reduction in shrubs, ferns and moss will reduce the actual numbers of (or future potential for) tree seedlings established on the rights-of-way, especially where the reduction is accompanied by an increase in grasses and sedges. On the rights-of-way studied, the shrub and fern patches appear to act as "tree-seedling nurseries," where seedlings of semi-shade tolerant species such as black cherry, red oak, red maple, black birch (Betula lenta), white ash (Fraxinus americana), and sugar maple become established in the partial shade. Mosses, which frequently occur with shrubs and ferns, appear to provide moist seedbeds which protect tree seedlings from drought in the first critical years. By the time the seedlings grow above this "nursery cover" they are several years old, well established, and some are difficult to control with either fire or herbicides. These views are contrary to Neiring and Goodwin's recommendation that stable shrub communities be maintained to reduce tree invasion on rights-of-way (Neiring and Goodwin 1974).

Economics of Prescribed Burning

Since burning the small research plots did not provide useful information on the economics of prescribed burning, two 10-acre (4 ha) blocks were burned in an attempt to obtain more useful cost figures.

The 10-acre (4 ha) block burned in August 1979 produced a cost of $17.50 per acre; this included labor (a 4-man crew), equipment rental, and fuel. Because of the date of burning, only about 45% of the surface area actually burned, and the labor and fuel costs were probably higher than normal because of attempts to re-light the fire in areas which would not burn readily.

Another 10-acre block was burned in April 1981 and the cost was approximately $20 per acre. This estimate also included labor, a four-man crew, equipment rental and fuel. The equipment used was a four-wheel drive pickup truck, 2 drip torches, 4 Indian tanks, a portable Floato-Pump and 800 ft of 1½ in hose. No overhead or administrative charges are included in these estimates. This fire was very successful in that it covered approximately 85% of the ground and was completed in an elapsed time of 4 hours.

In both fires, the burning crew was on foot and mobility was limited by the distance to water and/or the location of the protable pump and hose, which, although not used for control, had to be available for backup protection as a requirement of the commercial burning permit issued by the state of New Hampshire. More mobility will be needed to burn rights-of-way more economically as a regular management activity.

One of the results of prescribed burning, increased accessibility and visibility, may be useful in reducing costs and increasing effectiveness of herbicide applications. With increased accessibility and visibility, the spraying crews will be able to move over the rights-of-way faster and see and spray more of the trees, especially seedlings.

APPLICABILITY OF RESULTS

Overall the results of this study are probably conservative. There are three reasons:

1. The power line right-of-way plots are extremely irregular with uneven terrain, rocks, wet areas, and areas of major disturbance resulting from excessive bulldozer work when the power line was constructed 11 years ago. As a result, the fires did not cover the surface area well and many tree stems were protected by exposed mineral soil, rocks, standing water, and road edges. On more level or uniform rights-of-way where the sod has not been disturbed, the fires should be more effective in controlling trees and increasing grasses, sedges, and forbs.

2. The method used to measure relative frequency of herbaceous vegetation and shrubs may also contribute to a conservative interpretation of these results. When the narrow steel pin was dropped through the vegetation until it hit the ground, it was frequently touching more than one plant species, or the same species more than once. Whereas, every species that the pin touched was recorded, when the pin touched a species more than once, that species was only recorded once. Thus certain species with finely divided leaves, especially grasses and sedges, are probably underrepresented in the data; they probably are more abundant, and perhaps denser than the data indicate.

3. The crews that did the burning trials on the right-of-way where costs are estimated consisted of rather inexperienced university students and one professor with some prescribed burning experience. It seems logical to assume that a crew that is experienced and working with mobile equipment would be more efficient.

RECOMMENDATIONS

Additional trials of prescribed burning should be conducted during the early growing season and the summer. In this study the times of burning were chosen simply to bracket the snow-free season of the year, and more "fine tuning" as suggested above will undoubtedly be necessary.

Repeated prescribed burns on the same areas should also be tried. In conversations with fire ecologists and land managers around the country, the consensus seems to be that single fires do not accomplish very much. A 10-15% shift in species composition is all that can usually be expected. Repeated fires, however, often produce further changes in vegetation. Because of the central New England soils and short growing seasons, fires are probably not possible in consecutive years because there is not enough build-up in fuels. Some trials with fires repeated at 2-4 year intervals should be conducted.

There seems to be considerable potential for hybrid applications using combinations of prescribed fire and herbicides. An attempt should be made to use prescribed burning early in the growing season; i.e., mid-May, and then follow with a herbicide application on the same area in mid-summer, provided enough leaf surface area is present for chemical pickup. The prescribed burn would increase accessibility and visibility, and the reduction in foliage to be sprayed would save chemicals. The reduced costs of the herbicide application might compensate for the cost of prescribed burning. This hybrid application may maximize the effectiveness of both treatments.

Another combination that should be tried is alternating prescribed burning and herbicide treatments on approximately a 4-year interval. Since prescribed burning potentially costs less, the total cost of managing right-of-way vegetation may be reduced.

In the northeastern United States there is currently a shortage of people who are knowledgeable about prescribed burning, and possibilities of training such people in conventional schools and universities are limited. Skillful prescribed burners will have to be developed by training workers, such as firefighters, resource managers, loggers, and herbicide applicators. Additional training for these people may increase their employment opportunities. The dual use of equipment in idle seasons would also provide more income to pay capital overhead investments.

SUMMARY AND CONCLUSIONS

Prescribed burning in the early part of the growing season (i.e., May) reduces the rate of increase in tree stems below the rate of increase on unburned control plots, and improves visibility and accessibility. These changes last at least three years. Concurrently there is an increase in grasses, sedges, and forbs, and a decrease in shrubs, ferns, moss, and bare ground.

In contrast, prescribed burning in the spring and fall dormant seasons, and in the middle or later part of the summer growing season, results in an increase in the number of tree stems greater than on the unburned controls. On heavy soils, spring and fall dormant season burns result in spectacular increases of wildflowers for at least two years after burning. Prescribed burning of power line rights-of-way and other permanent openings is a safe economical means of managing the vegetation. Labor, equipment, and fuel costs are measured at about $20 per acre; however, there is a shortage of trained personnel to carry out these burns.

Additional studies are needed to determine the length of time that single early growing season fires are effective in reducing tree invasion; the effects of repeated prescribed fires on tree density and the amount of grass and sedge; and the effects of combining or alternating prescribed burning with conventional herbicide treatments.

ACKNOWLEDGMENTS

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AQUATIC IMPACTS

Don Gartman, Session Chairman

WATER QUALITY CONCERNS ASSOCIATED WITH PIPELINE STREAM CROSSINGS

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ABSTRACT.--During the construction of major pipelines, localized water quality degradation may occur due to instream construction activites and the discharge of water used for hydrostatic testing. Specific water quality concerns include the potential for increase in levels of suspended solids, and hence increase in turbidity; the potential for elevated levels of iron, oil, and grease; and the potential for localized erosion. This paper examines the water quality concerns associated with instream construction and hydrostatic test water discharge. For each of these activities several areas are addressed. First, the regulatory framework governing the activity is described. Second, a review of available literature associated with the water quality concern is presented. Third, impact assessment methodologies are developed, with examples given of the types of effects likely to occur. Finally, measures and procedures are presented which can be used to reduce potential effects associated with each of these activities.

INTRODUCTION

Major pipeline corridors usually involved the crossing of perennial streams and rivers. Instream construction activities at pipeline river crossings may in turn result in temporary water quality degradation, principally in the generation of increased levels of suspended sediments. Pipelines also require hydrostatic testing to ensure pipeline and weld integrity. Uncontrolled discharge of water used for hydrostatic testing can also result in temporary water quality degradation and erosion. This paper evaluates these water quality concerns.

INSTREAM CONSTRUCTION

Regulatory Background

Under Section 404 of the Clean Water Act of 1977 (33 USC 1344) a permit may be required for the placement of fill material over a buried instream pipeline. The U.S. Army Corps of Engineers issues these permits under existing regulations (33 CFR 323) and may require either a general or an individual permit, depending on the type of crossing. Specific water

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quality performance standards pertaining to dredge and fill activities have not been established under the Clean Water Act.

Literature Review

Few published data are available that describe the water quality effects associated with stream crossing construction activity (e.g., increases in levels of suspended solids and turbidity). Crabtree et al. (1978) presented the results of pipeline construction monitoring for three small creek crossings in Michigan. Hay (1972) investigated suspended sediment levels downstream of stream crossing construction activities in a shallow Michigan trout stream, and Landeen and Brandt (1975) investigated the increases in suspended sediment levels associated with instream pipeline construction (draglines) on two rapidly flowing Alaskan rivers. Other specific field monitoring data are unavailable for pipeline stream crossings, based upon a review of data available from the U.S. Soil Conservation Service, U.S. Geological Survey, U.S. Army Corps of Engineers, and other agencies.

Methodologies for Impact Analysis

Overview. A general methodology for the evaluation of construction-related effects of river crossings would include the following sequential steps. (1) Classify stream or river crossings as perennial or intermittent, based on USGS or other available maps. Because intermittent creeks or streams can be trenched during dry periods, eliminate these crossings from further analysis. (2) Determine the specific type of construction methods to be used for major or minor perennial crossings. (3) Assemble background characteristics of individual crossings (if available) or "generic" characteristics of typical crossings. These may include mean stream velocities and depths, mean particle size, previously recorded suspended sediments levels, and other factors. (4) Estimate the levels of suspended solids which could be generated instream during construction activities. (5) Compare the estimated levels during construction to recorded average and maximum levels to determine the level of signifi cance; and (6) Determine the need for mitigation and/or monitoring to control construction-related effects, and develop measures as appropriate.

Potential Construction Methods. The particular type of trench and fill operation at stream crossings depends upon the crossing width and depth and underlying streambed materials. Intermittent streams are usually crossed using spread equipment (backhoes) during periods of low or no flow. In minor perennial streams, half the flow can be temporarily diverted and the pipeline trenched "dry" with the aid of dewatering wells, or draglines can be used from the shore or floating positions. Major perennial streams are trenched by dredging (bucket or hydraulic cutterhead) or directionly drilled (tunneled underneath the riverbed). In bayous or wetlands, backhoes or draglines on movable barges are used. Table 1 shows average trench and fill rates for these types of equipment.

Table 1. Estimated dredge and fill rates during stream crossing construction.

Equipment	Capacity (Cu. Yd)	Rate (Cu. Yd./Hr.)
Backhoe	1½ to 2	150
Backhoe (on pontoons/barge)	2 to 2½	100
Dragline	2½	60-80
	2	100
	3	120-150
Dragline (on barge)	2	250
Dragline (on marsh buggy)	2	100
Bucket dredge	4	320
Hydraulic dredge (Cutterhead)	20"	420
	24"	750
	30"	1040

Sources: Northam 1980; Pendarius 1980; Williams 1980.

Estimation Methodologies

Method of Analysis. A precise estimation of the instream construction effects at a particular crossing requires detailed information related to stream bed material characteristics, stream velocity and depth, mass transfer rate, and other factors. Such data are usually not available for the number of crossings being evaluated. Therefore, expected crossing effects can be estimated for "generic" crossing types, each having assumed typical stream characteristics; e.g., minor perennial streams and major perennial streams.

Minor Crossings. To estimate the effect of dredge and fill activities at minor perennial streams, the following first order rate equation can be applied to account for the settling of particles, and hence reduction in level of suspended solids, downstream (longitudinally) of trenching operations. It is assumed that complete mixing would take place due to the width and depth at most minor crossings.

$$Cx = (Co)\, e^{-kt}$$

$$= (Co)\, e - \frac{vs}{d} \quad \frac{x}{u}$$

where:

Cx	=	Concentration of suspended solids at some distance x downstream
Co	=	Initial concentrations of suspended solids in the water column at the trenching site
vs	=	Settling velocity
d	=	Depth
x	=	Distance downstream
u	=	Current velocity
k	=	Reaction rate
t	=	Time

Average depth and current velocity can be estimated from U.S. Geological Survey records for crossing at or near existing gaging stations for months when construction would take place. Bed material size characteristics can be estimated from U.S. Geological Survey Water Resources Data and foundation boring logs at nearby bridge crossings, if available.

Knowing the estimated mean particle diameter, settling velocity can be estimated from available nomographs; e.g., Schubel (1978). To estimate the initial concentration of suspended solids (Co), a mass discharge rate must be determined. This can be accomplished by first estimating a specific weight (Trask 1931) for the particle size in question. Using the applicable trench and fill rates (Table 1) and assuming that at least one-half of a given trench or fill cycle could occur within the water column, a mass discharge rate (e.g., kg per sec) can be estimated.

Recent investigations by the U.S. Army Corps of Engineers (Schubel et al. 1978) indicate that an average of 1% of the mass discharge will become suspended in the water column at or adjacent to a typical river dredge and fill site. Therefore, the initial concentration, Co, is given as 0.01 times the estimated mass discharge rate.

Major Crossings. At a major crossing, due to the depth and width of the stream the plume would not be completely mixed across the streambed. The plume would disperse, not only longitudinally, but horizontally across the stream. Based upon work completed by Okubo (1971) a typical rate of horizontal spread in rivers is given as 0.5 cm/sec. The dispersion of the plume is then given as:

$$Cx \qquad \frac{Co}{u(.5\frac{x}{u})d} \qquad e^{-kt}$$

$$\frac{Co}{(.5)(x)(d)} \qquad e - \frac{vs}{D/2} \qquad \frac{u}{x}$$

The same worst case settling velocity (to mid-depth of the river) and mass discharge rate can be used for this type of crossing.

An additional factor to be considered is the effect of turbulence in suspending, or resuspending particles discharged into the stream. It is reasonable to assume that no solids would remain suspended unless at least some of the turbulent eddies have upward velocity components exceeding the fall velocity of the solid (Bagnold 1966). According to Bagnold (1954) the ratio of fall velocity, w, to shear velocity, v*, indicates whether sediment will be moved by bedload, via saltation, or as suspended particles. To evaluate this ratio, fall velocities for four classes of particles can be determined: gravel and cobbles, sand, silt, and clay. Shear velocities are determined for major and minor river crossings using the following equation:

$$v^* = (v) \quad (\sqrt{g}) \frac{n}{1.49\ (r)^{1/6}}$$

where:

v*	=	Shear velocity
v	=	Mean current velocity
g	=	Gravitational constant
n	=	Mannings number
r	=	Hydraulic radius

If the ratio of fall velocity to shear velocity is less than about 1, it is likely that this class of particles will remain in suspension due to turbulence (Bagnold 1954).

Finally, it should be noted that these estimates assume a typical bed material size based on mean particle diameter. A very small fraction of finer materials could travel downstream a greater distance before settling entirely to the stream bottom (assuming no resuspension), where the materials would ultimately continue to travel downstream as bedload.

To estimate a worst case travel distance the estimated settling velocity for an assumed "fine" fraction; e.g., silt or clay, can be combined with the expected current velocity to give a maximum settling distance downstream, assuming that there are no intervening reservoirs and that no induced settling by adsorption or aggregation with other particles takes place.

This estimation methodology has been used to estimate the levels of suspended solids generated during the crossing of typical major and minor crossings in Colorado and Wyoming.

Table 2 presents the results for major and minor crossing, and indicates the assumptions used to estimate typical background conditions.

These estimates have assumed a typical bed material size based on mean particle diameter. A very small fraction of finer materials could travel downstream a greater distance before settling entirely to the stream bottom (assuming no resuspension), where the materials would ultimately continue to travel downstream as bedload. For example, in the minor perennial crossing type, a worst case estimate for transport of a fine silt fraction (diameter of 0.008 mm and settling velocity of 0.005 cm/sec) would give a maximum settling distance of about 1500 feet downstream. For the major perennial crossing type, this worst case settling distance would be over 20,000 feet downstream assuming no intervening reservoirs and no induced settling by adsorption or aggregation with other particles.

Results also indicate that resuspension of fine silts and clays could occur in major rivers as a result of stream turbulance, assuming current velocities of up to 2.5 ft/sec. Particles would eventually settle downstream in pools, reaches of low stream velocity, or reservoirs. Estimation of levels resuspended sediments in minor streams due to turbulence cannot be accurately made because high suspended solids concentrations could increase fluid density, and correspondingly decrease shear velocity; e.g., the turbulence could be dampened by high suspended solids concentrations (Vanoni 1946 and Hino 1963).

Table 2. Estimated increase in level of suspended solids at typical stream crossings.

Crossing Type	Distance Downstream (feet)	(m)	Suspended Solids (mg/l)
Major Perennial	50	15	8900
	100	30	3500
	200	60	3000
	500	150	80
	1000	300	3
	2000	600	<1
Minor Perennial	50	15	1200
	100	30	140
	200	60	3
	500	150	<1

Assumed Background Conditions:

Construction rate	=	150 cu yd/hour
Mean particle diameter	=	0.082 mm
Specific weight	=	1378 kg/m^3
Settling velocity	=	0.3 cm/sec
Mass discharge rate	=	8.4×10^7 mg/sec
Average current velocity		
Major	=	36.6 cm/sec
Minor	=	15.2 cm/sec
Average depth		
Major	=	91 cm
Minor	=	15.2 cm

Mitigation Measures

In most situations, the generation of elevated levels of suspended solids as a result of pipeline construction would not constitute a significant adverse impact, since (1) Pipeline trench and fill activities would be temporary in nature and no permanent water quality alteration would occur; (2) Existing short-term levels of suspended solids in many streams and rivers may already exceed the temporary level estimated to occur during pipeline construction. Beyond 100 to 200 feet (30-60 m), pipeline construction may not increase levels above naturally occurring historical maximums; and (3) The great majority of disturbed sediments would settle within short distances downstream.

In cases where crossings involve unique or pristine streams, or sensitive habitats are present, adverse impacts may occur. Measures to avoid or reduce construction-related effects would include (1) scheduling of construction activities to take place during periods of no flow or lowest flow; (2) use of directional drilling (e.g., tunneling beneath the river to avoid instream disturbance entirely); (3) use of check dams or diversions to conduct trenching "dry" on one-half of the river; (4) use of straw bale filters, firmly anchored to the stream bed, to reduce instream levels of suspended solids; and (5) use of silt screens or curtains at major river crossings.

HYDROSTATIC TEST WATER DISCHARGE

Regulatory Background

The discharge of pollutants from point sources, included hydrostatic test water, into waters of the United States is unlawful without a permit issued pursuant to the National Pollutant Discharge Elimination Systems (NPDES). Administration of NPDES permits may be transferred to individual states, if authorized by the Administrator of the EPA. At this time, uniform federal standards of performance for the discharge of hydrostatic test water have not been promulgated. Authorization for the discharge of test water would be required from either the EPA or from an authorized state.

Because hydrostatic test water discharge is a relatively small, one-time-only discharge, the issuance of an NPDES permit is a routine matter in most states. In states that have assumed NPDES permitting authority, the applicable state agency usually issues an authorizing letter, and does not require a large body of permit application material. If the regional EPA must issue the permit, the short form application is usually sufficient. States will usually attach certain mitigation conditions to the approval.

Literature Review

Little published information is available regarding hydrostatic test water characteristics. Pipelines are usually tested to 125% of maximum operating pressure, using water obtained from local ground or surface water sources. As a result of hydrostatic testing, the levels of suspended solids, iron, grease, and oil could potentially increase in the test water. Table 3 presents a summary of water quality monitoring data collected before and after hydrostatic tests, using ground, surface, and municipal waters. As expected, the constituent showing the greatest increase is iron.

Methodologies for Impact Assessment

Overview. A general methodology for assessment of the effects of hydrostatic test water discharge would include the following steps: (1) determine the approximate discharge locations; (2) estimate the maximum discharge volume, using the pipeline diameter times the distance between topographic high points; (3) estimate the discharge rate; (4) characterize the expected quality of discharge water using local data, (or Table 2), also considering possible anti-freeze compounds in cold climates; (5) evaluate the effects of increased flow and localized degradation in downstream water quality; and (6) develop mitigation measures necessary to meet local and regulatory requirements.

Typical Instream Effects. Without adequate treatment, the discharge of hydrostatic test water could increase the levels of turbidity, iron, oil,

Table 3. Hydrostatic test water analyses.

Parameter	Water Source									
	Pond		Well		Creek		River		Municipal	
	Fill	Dewater	Fill	Dewater	Fill	Dewater	Fill	Dewater	Fill	Dewater
Fe (mg/l)	0.56	13.2	0.2	14.0	1.3	1.3	0.2	2.6	2.7	0.4
TSS (mg/l)	69	61	8	120	-	-	-	-	-	-
SO_4 (mg/l)	17	142	-	-	-	-	26.8	30.3	8.0	7.2
Cl (mg/l)	0.8	0.7	-	-	-	-	52.5	36.0	4.0	3.0
F (mg/l)	0.4	0.4	-	-	-	-	0.4	0.4	1.1	1.1
COD (mg/l)	68.0	34.0	1.0	1.0	38.0	10.0	-	-	-	-
Hardness (mg/l)	64.0	60.0	-	-	-	-	48.0	40.0	26.0	26.0
Alkalinity (mg/l)	78.0	58.0	-	-	-	-	26.0	20.0	18.0	18.0
pH	7.3	7.3	7.7	7.9	5.8	6.3	6.9	6.6	7.6	7.5

Source: Young 1980.

and grease, and decrease the levels of dissolved oxygen in receiving waters. This would be especially significant in low flowing surface waters, which would have low assimilative capacities. Without adequate flow control, localized erosion could also occur at discharge sites. For a large volume of test water, uncontrolled (instantaneous) discharge over a short period could significantly increase local surface-water flow. Depending upon the specific discharge location, downstream uses, including recreation, aquatic habitat, or municipal water supply could be temporarily impaired.

Mitigation Measures. To reduce the temporary effects of hydrostatic test water discharge, the following measures can be used: (1) Whenever possible, hydrostatic test water should be disposed of on land, via evaporation pits or basins, with no surfacewater discharge; (2) If surfacewater discharge is necessary, watercourses with the greatest background flow (and assimilative capacity) should be selected; (3) To prevent erosion at discharge sites, test water should be released slowly, so that background flow levels are not significantly increased (e.g., beyond 5-10%); (4) Water should be discharged horizontally into a discharge diffuser pipe, to minimize flow velocity and prevent potential scour effects; (5) Water should be routed through detention basins prior to discharge to reduce the levels of suspended solids and iron; and (6) If grease and oil are present, water should be routed through one or more straw bale filters, in sequence, to reduce concentrations to acceptable levels.

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POTENTIAL IMPACTS OF RIGHTS-OF-WAY ON FISHES--ANALYSES FOR PLANNERS

Mike Busdosh[1]

ABSTRACT.--Most fish habitat potentially affected by rights-of-way (ROWs) in the western states is contained in perennial, temporally intermittent, and spatially intermittent streams. Considerations of space and time indicate modes of both avoidance and minimization. Impacts to spatially intermittent streams can be avoided by not constructing through the wet segments of the stream. Impacts to temporally intermittent streams can be avoided by not constructing during times of water presence. Potential impacts to perennial streams may be unavoidable but can be minimized. Recognition that streams contain heterogeneous habitat can allow minimization of potential impacts by avoiding important segments. Recognition that some habitat (as spawning areas) are used only seasonally can allow minimization of potential impacts by avoiding work at certain times. Each area's fishery must be ascertained to allow such actions, with particular attention given legally protected, sports, or commercial fishes. Such information should be obtained early enough in a project to allow planners leeway.

INTRODUCTION

Various aquatic habitats exist in the southwestern states and Rocky Mountain states that are crossed by rights-of-way (ROWs). Size of waterway is an obvious factor, but there are relatively few large rivers in the area, and these present their own unique problems. The great majority of waterways encountered are streams and small wetlands. Among these are perennial waters and intermittent streams. These intermittent wetlands are of two basic types: intermittent in time and intermittent in space.

Time-intermittent streams experience seasonal flow. Water is present during the rainy or snowmelt period, after which they dwindle to dryness. Space-intermittent streams are a common phenomenon in the Southwest. Most flow in these watercourses is subsurface, through the usually sandy alluvium. In certain areas impermeable bedrock projects through the alluvium to near the surface. Water is forced to and above the surface in such areas, which vary from a few meters to several hundred meters

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long. Beyond the bedrock area the alluvium again becomes sufficiently thick to allow the full stream to resume a subsurface flow.

The major types of ROWs are pipeline, transmission line, and transportation corridors. Pipelines are normally buried below scour depths in stream bottoms. Transmission lines, unless construction requires supports in the watercourse proper, normally affect streams only by vehicular traffic driving through the waterway. With the impacts of pipelines and transmission lines manifested only during construction, avoidance of fish is possible in the two types of intermittent streams. Were construction performed during the time temporally intermittent streams are dry, or at dry segments of a spatially intermittent stream, no direct effects on fishes would occur.

Perennial streams, by definition, have a continuity in space and time that precludes avoidance during construction of pipelines, transmission lines, or transportation corridors, a term encompassing many types of projects. These corridors often contain structures--bridges, roadways, embankments--which may allow temporal or spatial avoidance during construction, but whose permanent presence may cause impacts during operation and maintenance.

Environmental consequences potentially occur then, when dealing with any ROW project on perennial streams, with some transportation corridors on perennial or intermittent waters, and with any ROW project unable to temporally or spatially avoid intermittent waters. The best way to deal with a potential impact is to avoid it. When that is not possible, efforts should be directed at minimizing the likelihood of impacts, and then at minimizing the severity of the impact.

DISCUSSION

Two modes were used in the preceding text in the discussion of impact avoidance: spatial consideration and time consideration. These same ideas best express the two central themes in minimizing the likelihood and severity of impacts to fishes.

Spatial Considerations

Streams have an almost planar surface and western streams are often turbid, reducing our perceptions of depth and substrate variability. We know fish move in three dimensions; therefore, unless a stream shows marked habitat heterogeneity of large quiet pools separated by whitewater rapids, there is a subtle impression of uniformity. Ranges of fishes are reported between points A and B, or from river mile X to mile Y, and maps often show stream segments of several miles in which a certain fish is found. In truth these stream segments include habitat in which the fish is found, but contain other, often exclusive habitats as well. One advantage in minimizing potential impacts of a ROW is the nature of the ROW: a long, narrow strip. A stream is also a narrow strip, allowing the potentially impacted area--the intersection of the two strips--to be relatively small geographically. Moving a crossing site a few tens of meters may avoid directly impacting the habitat of an important or protected fish.

Some stream habitats are used only seasonally by fishes. A combination of avoidance in time and space could minimize impacts on those areas. Gravel bars are a commonly utilized spawning area in streams. If such habitat is determined to be a spawning area, a slight route change could avoid it. Backwaters are a common nursery area for young fish. Such individuals cannot yet deal with the current in the mainstream, or cannot effectively feed, or are subject to greater predation. If such backwaters can be avoided, or if they can be avoided during the time of year these juveniles are present, impacts can be avoided.

A working knowledge of what species of fish are present, and what habitat types exist and their distribution is necessary to examine potential impacts of a ROW on the fish fauna of a waterway. It is also unlikely that all impacts to all species can be totally avoided. Different characteristics of the species must be tabulated to allow tradeoffs within the subject of fishery impacts.

Time Considerations

Species may spawn at different times, through most of the seasons. Choices often have to be made among species in terms of potential impacting. After consideration of protected and sports or commercial species, such factors as abundance, commonness, and recruitment potential become meaningful. A species abundant in the area would likely have members that could move into an affected area. A common species would also probably have recolonizers, and, if not, the loss of individuals from the ROW would not likely jeopardize the population. Species with high recruitment potential would be expected to replenish their numbers at the first opportunity.

Consideration must be made of the relatively short time of disturbance with a pipeline or transmission line. Industrial projections of time needed to cross western rivers, as the White or Yampa with a pipeline, is within two weeks, and the time needed to cross streams is certainly less than that. Time of stress is limited. Construction of a roadbed or bridge in a transportation corridor could take longer and may have more impacts. Table 1 summarizes the potential impacts of construction, operation, and maintenance on streams by transportation lines, pipelines, and transportation corridors.

The natural dynamics of western waterways are meaningful in examining construction effects. Western streams are rarely, if ever, placid, steady, laminar flow waterways. Variation in monthly average flows may be an order of magnitude, flooding usually brings on scouring, and turbidity is often naturally high. Western fishes have adapted to such stresses, and their biology is often synchronized with these variations. On the one hand the fishes are "used to" stresses; on the other they could be negatively impacted by construction stresses occurring during periods streams are normally sufficiently constant to allow spawning or survival of fragile young.

A seemingly unrelated issue has become and will continue to be an important factor in ROW location: riparian vegetation. This perennial vegetation along western streams often contains the only trees in the area.

The combination of the physical presence of the trees, the shade of the canopy, and the presence of the surface water in the stream forms a particular habitat. Such physical effects as shading and higher humidity combine with biological effects of detritus input from leaves and insect habitat that contribute to the biology of the fish present. Much attention has been given riparian areas; indeed, a complete symposium, like this one, has been dedicated to the subject. The literature on fish habitats and requirements has frequent papers discussing riparian importance.

Table 1. Potential impact avoidance and minimization in waterways crossed by ROWs.[a]

Right-of-Way		Perennial	Intermittent	
			Spatial	Temporal
Transmission Line	Construction	+M,XM	+	X
	Operation-Maintenance	0	0	0
Pipeline	Construction	+M,XM	+	X
	Operation-Maintenance	0	0	0
Transporation Corridor	Construction	XM	+	X
	Operation-Maintenance	+M	+M	?

[a] + = impacts avoided by minor route change; X = impacts avoided by time activity; +M = impacts minimized by minor route change; XM = impacts minimized by time of activity; and 0 = no likely impact.

CONCLUSIONS

Avoidance of potential impacts is the first goal of ROW planning, from the consideration of fishery effects. Minimizing unavoidable impacts is the next step. A working knowledge of the fisheries and the habitat at potential crossings is essential to supplying solid input to planners and should be done very early in a project. Fishery impacts are only one component of biological impact, which is only one component of an impact statement package. Trade-offs are usually necessary. Waiting until certain routes are well-developed before discovering important fishery impacts has often been the result of hesitation to determine these potential impacts early in the game.

THE IMPACT OF A PIPELINE CROSSING ON THE BENTHOS OF A PENNSYLVANIA TROUT STREAM

Donald K. Gartman[1]

ABSTRACT.--In August 1980, Columbia Gas Transmission Corporation constructed a buried 14 inch (36 cm) natural gas pipeline across Bushkill Creek, a trout stream in Northampton County, Pennsylvania. Construction techniques were planned to minimize downstream sedimentation. Analysis of the benthic community on a pre- and post-construction basis in the area of the pipeline crossing noted a major increase in mean benthic densities within 30 days. Samples from the pre-construction period indicated 25 taxa with a mean density of 872/m^2. Samples taken from the same area 26 days after pipeline construction had a total of 27 taxa and a mean density of 5391/m^2. This extraordinary increase in macroinvertebrates was dominated by _Hydropsyche_ _spp_. which readily colonized the recently-exposed dolomite substrate, a result of blasting and trench excavation. Little impact in terms of benthic community and substrate changes were noted downstream.

Samples were collected monthly from August 1980 through July 1981, and compared with pre-construction data and previous studies on this reach of Bushkill Creek.

INTRODUCTION

The natural gas industry uses underground pipelines for gathering, transporting, and distributing this energy resource. There are over 1 million miles of natural gas pipeline in the U.S.; more than one-fourth belongs to the transmission line category (American Gas Association 1979). Pipelines are efficient, unobtrusive means of transportation, and have little environmental impact associated with pipeline operation. Pipeline construction, however, creates certain short-term disturbances on the natural systems through which it traverses.

When it is necessary to cross a stream with a pipeline, one construction technique is to excavate a trench across the stream-bed, place the pipeline in the trench, and backfill the trench with original stream-bed material or new gravel fill. This stream-crossing procedure usually

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causes an increase in sedimentation around the stream substrate immediately downstream from the excavated trench. The trench is usually constructed with a backhoe or clamshell dredge operating from shore or floating-barge as stream width dictates.

There are few published reports on the impact associated with pipeline crossings of streams and related aquatic communities. Hay (1972) studied the effects of sedimentation on the benthic fauna resulting from the construction of a sewer line across a Michigan trout stream. He found reductions in benthic densities immediately after instream construction, but the study did not include sampling to monitor how long it took for aquatic insects to recolonize the disturbed areas.

A study by the Michigan Public Service Commission (Crabtree et al. 1978) discussed the impacts of pipeline construction on Michigan streams and wetlands. The stream portion of this investigation concentrated on downstream sedimentation resulting from three pipeline crossing methods: "open cut," "flume," and "plow." The "open cut" method involves the excavation of a trench across the stream bed without diverting the stream flow from the work area. The "flume" method involves isolating the work area from the stream flow with a temporary cofferdam and flume pipes while the trench is excavated under the flume pipes. The "plow" method is limited to a small diameter pipe; a large blade or "plow" is pulled across the stream or mounted on the back of a bulldozer, and the pipe is pulled through the opening.

The Michigan study found that the least downstream sedimentation resulted from the "flume" method while the greatest amount was associated with the "open cut" method. Direct monitoring of the benthic communities was not included in this study, but was discussed relative to general impacts associated with siltation, turbidity, and aquatic life.

A Canadian study (Baddaloo 1978) assessed the effects of pipeline activity in streams in Ontario. The flume method of stream crossing was also found to result in lower turbidity and sedimentation concentrations downstream from the construction activity. Using the open-cut method, significant decreases in invertebrate populations were found three days after construction below the crossing. When the stream was sampled one year later, there were no significant differences between the pre- and post-construction benthos numbers. Recolonization had taken place.

None of the above studies attempted to resolve the question of how long it takes an area disturbed by a pipeline crossing to recover in terms of a time period of less than a year. In addition, the actual crossing area of the stream where the greatest amount of construction activity occurs has not received investigation regarding its potential as new riffle habitat.

The opportunity for such a study occurred when Columbia Gas Transmission Corporation constructed a 14-inch (36 cm) diameter pipeline crossing of the Buskhkill Creek in Northampton County, Pennsylvania. This excellent trout stream has a natural brown trout population (_Salmo trutta_). The Bushkill has received intensive benthic and chemical investigation by Dr. Patricia Bradt of Lehigh University (Bradt 1974, 1978). The pipeline was constructed in August 1980 using the open trench method.

STUDY AREA

Bushkill Creek has a drainage area of 206 km^2 and flows southeasterly, joining the Delaware River at Easton, Pennsylvania (Fig. 1). The main stream is approximately 21 mi (34 km) long with a gradient of 9 mi (14.4 m/km).

The upper portion of the stream flows over shale and slate substrate while the lower portion drains a limestone area, giving the stream favorable pH and alkalinity characteristics of a trout stream. Bradt (1978) reported a mean pH of 8.1 in spring sampling, and a mean of 85.6 mg/l total alkalinity in summer.

Highway construction near the stream in 1968-69 resulted in rechanneling 1.2 km of the streambed. Construction-related impacts included removal of canopy trees, raw bank exposure, and increased siltation (Bradt 1978). A cooperative effort among the Pennsylvania Highway Department, the Pennsylvania Fish Commission, the Pennsylvania Department of Forest and Waters, the Bushkill Watershed Association, local sportsmen associations, and other concerned citizens resulted in stream improvements and mitigation devices which included gabions, small dams, ground cover, and tree planting along banks. The "reconstruction" efforts were evaluated by Bradt in 1978 and were found to be successful in terms of increases in macroinvertebrate diversity, biomass, total numbers of taxa, and improved water quality.

The present study area is within the 1.3 mile section of the stream's designated "Fly-fishing-only," Fish for Fun Project of the Pennsylvania Fish Commission; only one trout 20 inches or greater in length may be kept per day.

METHODS

Surber samples (.09 m^2) were taken across the stream within the trench excavation area before construction and at monthly intervals after construction. Sample numbers varied from three to six each time, depending on stream flow and season.

In addition, sampling stations of Bradt's 1978 study were monitored twice and compared with post-construction data and the pipeline crossing station. Bradt's station 3 is located approximately 262 ft (80 m) upstream from the pipeline crossing, and her station 5 is about 1640 ft (500 m) downstream from the pipeline crossing (Fig. 2).

Samples were fixed in 95% ethanol for subsequent identification and enumeration.

RESULTS

A total of 59 taxa of benthic macroinvertebrates were collected from the riffle over the buried pipeline, while 38 taxa were collected from Bradt's downstream station number 5 and 32 taxa from her upstream station number 3. Figure 3 presents the mean numbers of benthic organisms per square meter from the riffle area over the pipeline on a pre- and post-construction basis. Samples from the pre-construction period indicated 25 taxa with a mean density of 872/m^2. Samples taken from the same area 26 days after pipeline construction had a total of 27 taxa and a mean density of 5391/m^2. This extraordinary increase in macroinvertebrates was dominated by Hydropsyche spp. $\bar{X}$ = 2129/m^2. In the pre-construction sample, Hydropsyche spp. was recorded at mean concentrations of only 346/m^2. An even larger increase in macroinvertebrate numbers was recorded in October with a mean of 9060/m^2 of which 52% were Hydropsyche spp. larvae.

Bradt's upstream station 3 was sampled in December 1980, and was found to have a mean benthic concentration of 3077/m^2. Her 1978 winter mean for this same area above the pipeline crossing was 2281/m^2, while the downstream station 5 had a December 1980 mean of 2303/m^2. Bradt's 1978 report noted 3260/m^2 at this location, suggesting some downstream perturbation. The pipeline crossing recorded 5283/m^2 with 26 taxa for the December 1980 sampling. Samples collected in April 1981 noted densities of 8497/m downstream from the pipeline at station 5 and 4286/m^2 at the upstream sampling point. Bradt's 1977 spring collections included 5358/m^2 for the downstream station and 6972/m^2 for the upstream station (Fig. 4). The pipeline crossing for this date recorded 6531/m^2 with 23 taxa.

Since it is generally accepted that relatively unstressed environments support communities with numerous species, the Shannon-Weaver index was chosen for comparison as recommended in the EPA Biological Field and Laboratory Methods (1973). Generally, $\bar{d}$ ranges between 3 and 4 with clean, favorable conditions, while $\bar{d}$ is usually <1 in polluted or stressed conditions (Wilhm 1970). However, the index is subject to "false low values" if one species has an extraordinary large number of individuals even in samples with many species.

Diversity estimates over the pipeline crossing during the study period ranged from 2.2 to 3.0, and number of taxa ranged from 10 to 35 (Fig. 5).

Bradt's 1978 study recorded mean diversity ranges from 2.0 to 3.2 at the upstream station and 2.9 to 3.4 at the downstream station. Sample diversities from the same areas in 1981 ranged from 2.3 to 3.4 at the upstream station and 1.7 to 3.2 at the downstream station. The lower reading of 1.7 was recorded in April 1981 when the benthic densities of 8497/m^2 were dominated by oligocheats (68% of total) which were associated with filamentous algae at this sampling location.

DISCUSSION

Blasting was required to open the streambed so a 7 ft (2.1 m) deep trench could be excavated to receive the pipeline. In addition, large pieces of dolomite from the east bank were removed to facilitate boring under the highway which parallels the stream. On the advice of the Pennsylvania Fish Commission, these large "boulders" were later placed in the stream crossing reach. These boulders created areas of quiet "pocket water" behind them, which could be used by the resident brown trout population (Fig. 6).

Water velocities were greatly altered in this section which previously had been a smoother "run" with less diverse water flow patterns.

The sampling results indicated that the recently-exposed stream substrate was rapidly recolonized by benthic macroinvertebrates, especially the net-spinning Hydropsychidae.

Müller (1954) studied a 500 ft (150 m) section of a stream (Skravelbäcken) in Sweden which had its streambed top cleared away along with its benthic community. Within 11 days, the benthos had recolonized to a density of up to $9240/m^2$. Waters (1965) noted that large portions of the benthic community were carried downstream everyday as "drift," a phenomenon which allows disturbed stream sections to be re-invaded rapidly. Allen (1975) in his study of Cement Creek, Colorado, noted that pans set in the stream bottom with various substrate sizes were colonized within 24 hours--with a total of 31 species observed in one pan.

Planning by biologists and pipeline engineers can result in successful stream crossings with little or no detectable long-term damage to aquatic communities or habitat. It is possible to create a more productive reach of stream at a pipeline crossing than existed there previously.

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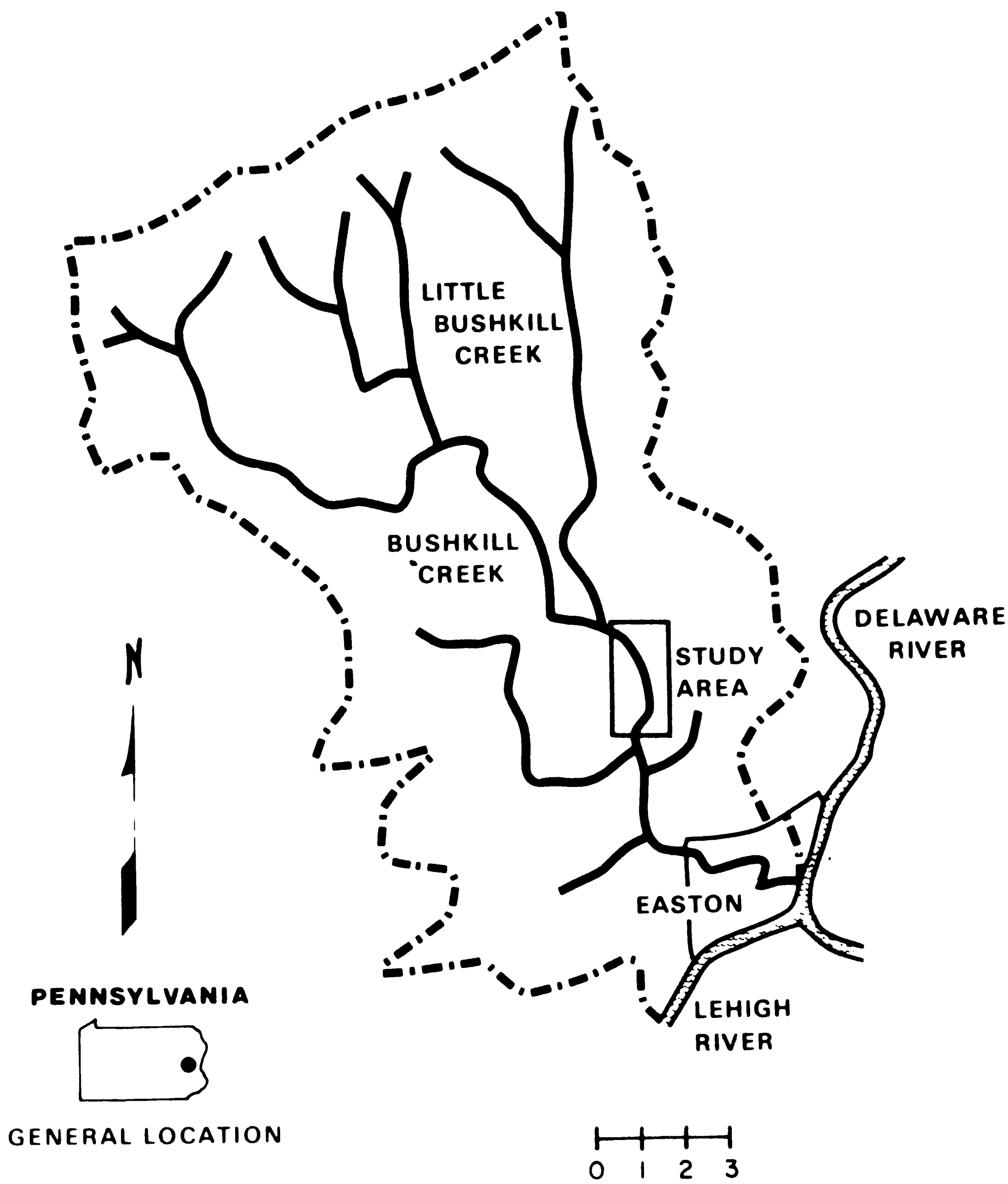

Figure 1. General location of pipeline crossing study area. Bushkill Creek, Northampton County, Pennsylvania.

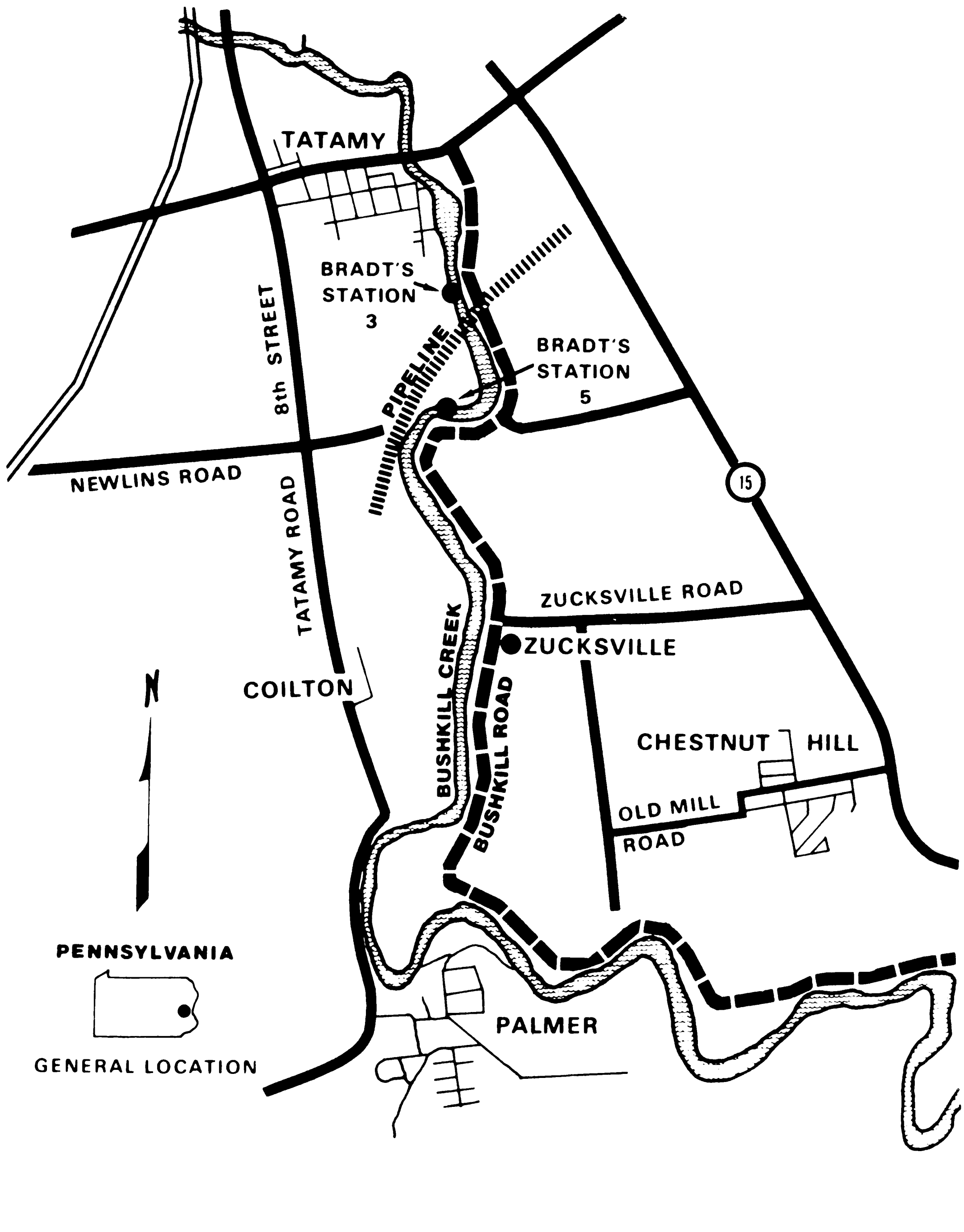

Figure 2. Pipeline crossing relative to Bradt's sampling stations, Bushkill Creek, Northampton County, Pennsylvania.

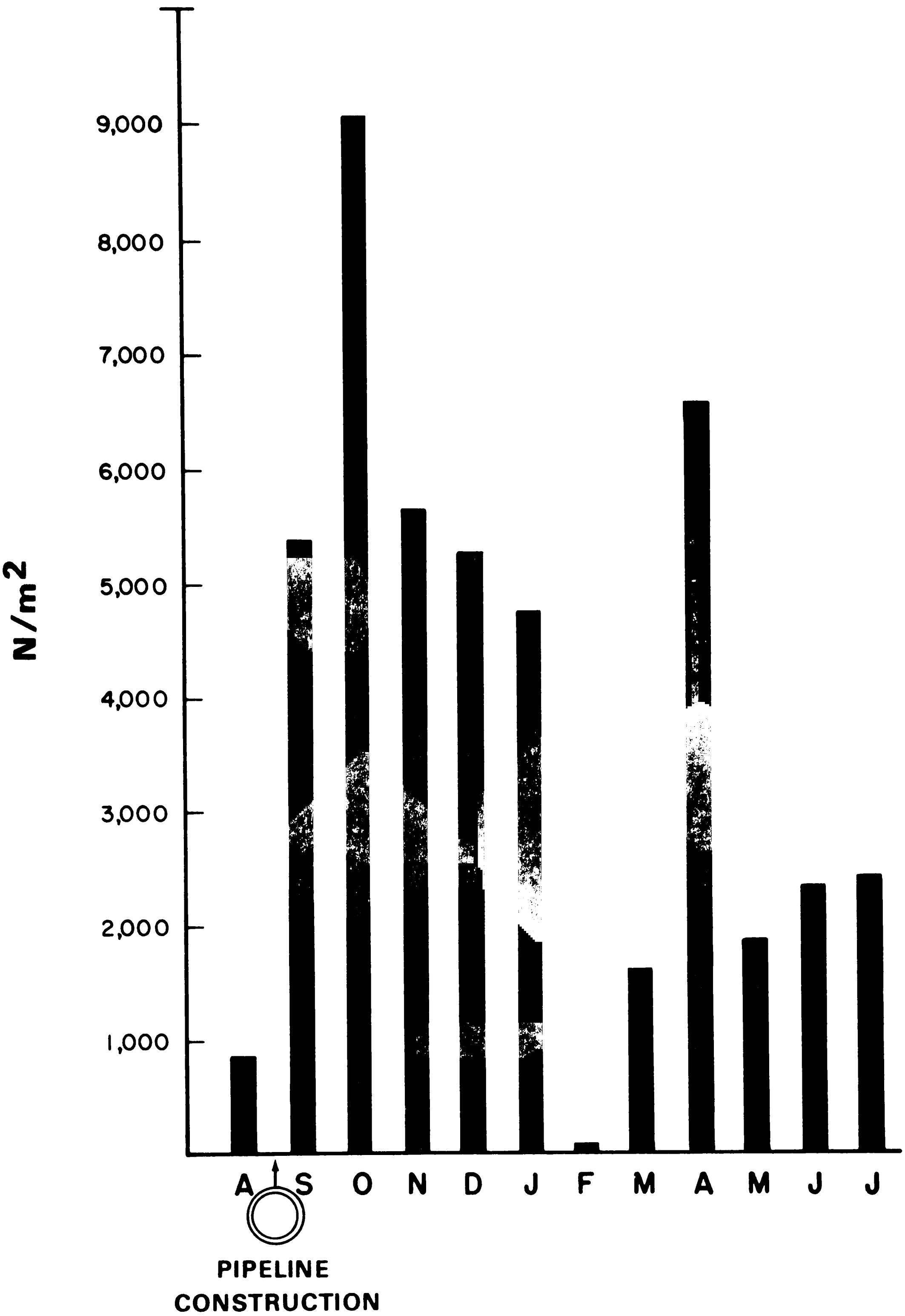

Figure 3. Mean numbers of benthic macroinvertebrates from pipeline crossing area, Bushkill Creek, Northampton County, Pennsylvania. August 1980-July 1981.

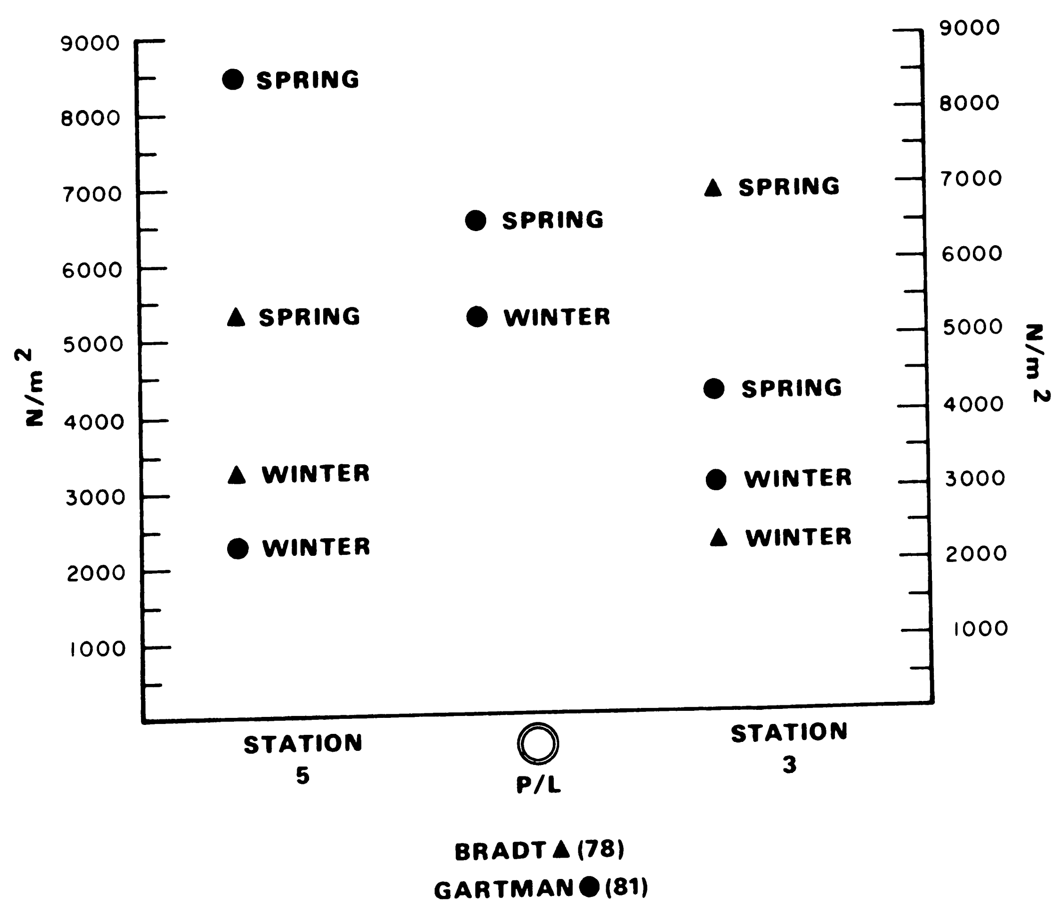

Figure 4. Comparison of mean benthic densities for Bradt (1978) and Gartman (1981) samples above, at, and below pipeline crossing. Bushkill Creek, Northampton, Pennsylvania.

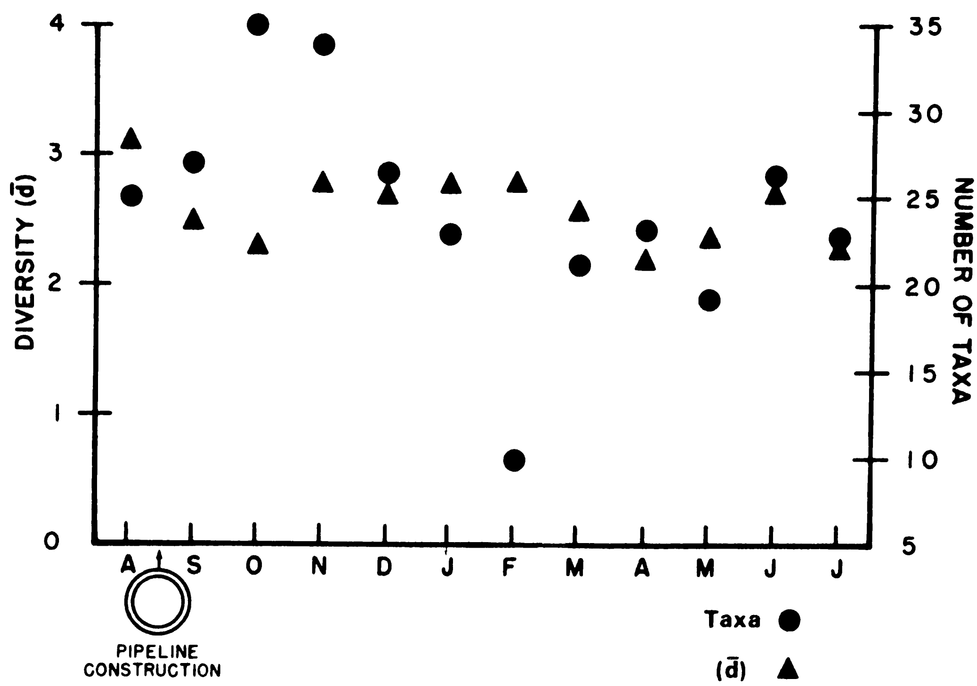

Figure 5. Shannon-Weaver diversity estimates (d̄) and number of taxa found from pipeline crossing area, Bushkill Creek, Northampton County, Pennsylvania. August 1980-July 1981.

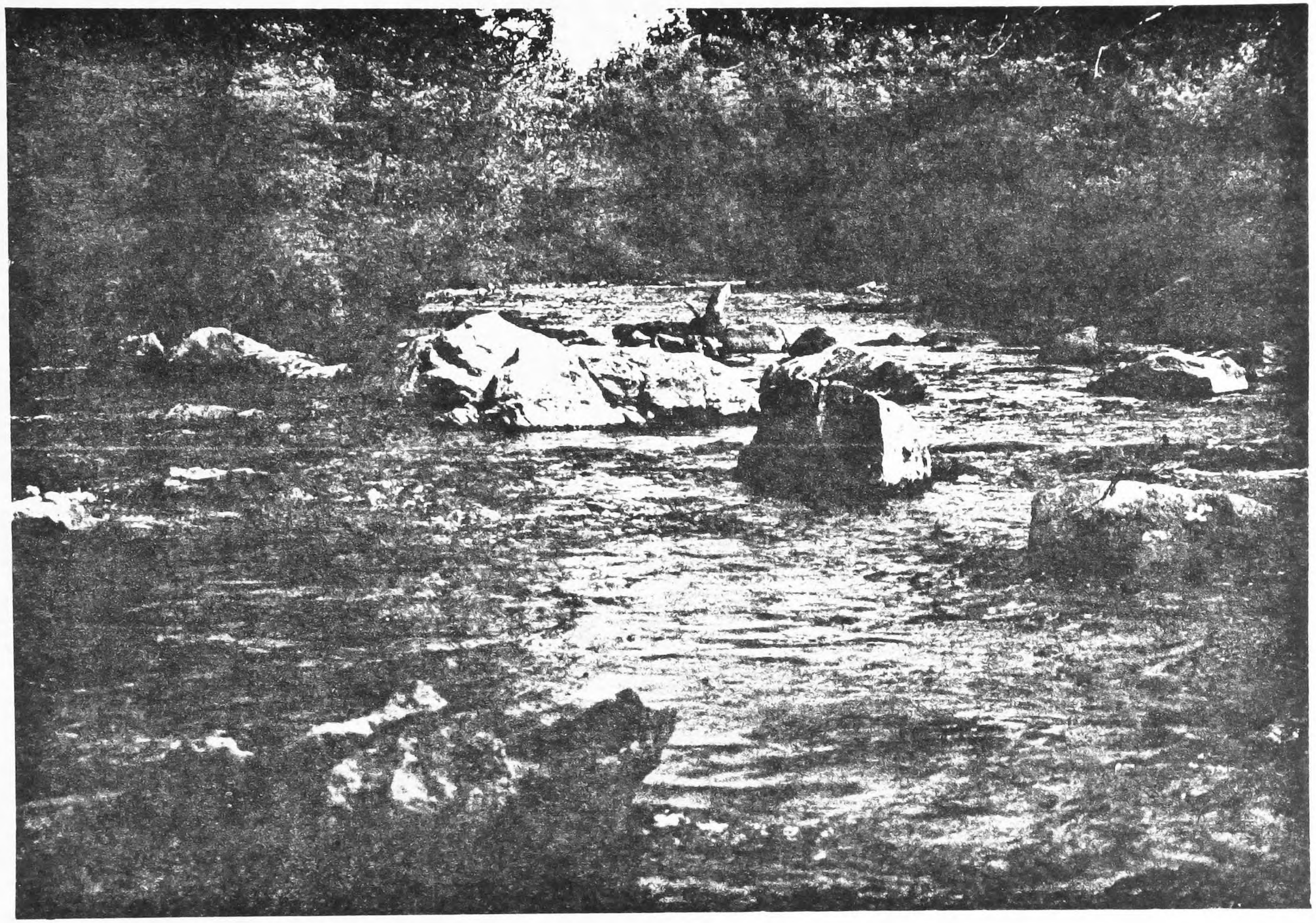

Figure 6. Bushkill Creek, Northampton County, Pennsylvania. May 1981. Pipeline crossing is in middle of photograph.

RESOLVING CONFLICTS BETWEEN TWO NATURAL RESOURCE USER GROUPS: PIPELINE RIGHTS-OF-WAY AND OFF-ROAD VEHICLES

Allen F. Crabtree[1]

ABSTRACT.--The process of environmental review and regulation of energy projects impacting on the natural environment is designed to anticipate problems and then to prevent them and/or to mitigate them to an acceptable level. Three pipeline crossings and an electric cable crossing of the upper Manistee River in northern lower Michigan were made between 1973 and 1976. In all cases the crossings were reviewed and designed to minimize impacts to the stream and to the uplands. Construction impacts were of short duration since innovative construction methods were used and the pipelines were installed in a common right-of-way.

Heavy use of the ROW by trail bikes and four-wheel off-road vehicles developed since 1976 and caused severe bank erosion and sedimentation of the river. Uncontrolled continuing heavy ORV use and resultant soil erosion could also have exposed the pipelines to rupture and release to the environment of crude oil, high pressure natural gas, and poisonous hydrogen sulfide gas. A cooperative effort to control ORV use and to repair the erosion and stream damage was successfully taken by the Michigan Department of Natural Resources, the Michigan Public Service Commission, the four utilities owning the pipelines, and local ORV and sportsmen's groups.

INTRODUCTION

The Mainistee River is a top quality trout stream with a self-sustaining population of brown and brook trout. Located in northern lower Michigan, it provides quality recreation for fishermen, canoeists, and campers.

One of the key limiting factors to a viable native fisher is the availability of suitable spawning habitat. The sandy soils in the watershed are prone to bank erosion. Gravel areas in the stream are subject to silting and sedimentation from this erosion, as well as from the often heavy bed load of sediment.

One hundred years ago the Manistee Rivershed was the scene for an active White Pine logging industry. The forest has regrown to open to moderate

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stands of aspen, oak, birch, and other hardwoods, with, in some areas, a vigorous understory of white pine. All that remains of this earlier era are the grey pine stumps scattered over the countryside and the foundations of the old logging camps. One of these camps, the "ghost town" of Deward, lies just north of a major oil and gas pipeline right-of-way which marks the latest development in this area.

The Manistee River crosses the northern Niagaran Trend, an area of intense oil and gas activity since early in the 1970's. In the Trend area, numerous oil and gas wells have been drilled and are being produced. In addition, flowlines and pipelines criss-cross the area, transporting hydrocarbons to processing plans and to market. A recent development in the area is the use of depleted reservoirs for underground storage of natural gas.

The Deward area is part of a large tract of state forest land heavily used by a wide variety of outdoor enthusiasts, including hunters, campers, hikers, cross country skiers, and both summer and winter ORVs. The Manistee River is popular with fishermen and canoeists.

UTILITY CONSTRUCTION

In 1973 Michigan Consolidated Gas Company applied for and received a certificate of public convenience and necessity from the Michigan Public Service Commission for construction of a 6 inch OD natural gas pipeline across the Manistee River at Deward to connect newly completed gas wells to market in lower Michigan. A special use permit for crossing the state forest lands and a stream crossing permit were obtained by the utility from the Michigan Department of Natural Resources. Staff worked closely with the utility in design, routing, and the construction of the pipeline to minimize the impacts on the forest and the stream. The pipeline was constructed using the open cut method and was buried 3 feet (1 meter) below the stream bed. The Manistee River is about 45 feet (15 meters) wide and 12-24 inches (30-60 cm) deep at this point. The banks were graded and reseeded following construction.

Shell Pipeline Corporation field an application with the Public Service Commission for construction of a 16 inch OD crude oil pipeline in 1975. Approval was granted by the MPSC, as well as by the MDNR, for the land and stream crossing, and the oil piepline was installed parallel to and about 75 feet (25 meters) south of the 6 inch OD gas line in a common ROW. The open cut method was again used, with restoration of the banks and ROW after construction.

On September 30, 1975, the Consumers Power Company filed an application with the MPSC requesting approval of a 3-1/2 inch OD sour gas lateral pipeline to transport sour gas from the State Frederic "A" 1-7 oil well on the east side of the Manistee River to a sour gas sweetening plant located on the west side of the river. Sour gas is the term used to describe natural gas which contains hydrogen sulfide, a poisonous and corrosive gas; H2S must be removed from the gas stream before it can be marketed. In this case, removal was to be accomplished by the amine solvent process at a central plant serving, at the time, two wells.

An environmental impact statement was prepared by the MPSC for the Frederic 7 pipeline as well as the sweetening plant and another pipeline, as part of the state's environmental review procedure under Governor's Executive Order 1974-4. It was submitted to the Michigan Environmental Review Board and reviewed by all state departments before being approved. Approvals were also given for the land and stream crossings and for the construction of the sour gas sweetening plant by the MDNR and the Michigan Air Pollution Control Commission, respectively.

To reduce impacts, several mitigative measures were included as part of the MPSC approval, including the requirement that the Frederic 7 pipeline be installed using a relatively new construction technique, the "plow" method. To reduce the width of the ROW, it was installed approximately 35 feet (11 meters) south of the 6 inch gas line and 35 feet (11 meters) north of the 16 inch oil line.

At the same time that the 3-1/2 inch Frederic 7 pipeline was installed, a 4 inch OD electric transmission cable was installed for the Top O' Michigan Rural Electric Company. This cable was plowed in parallel to the three pipelines and about 35 feet (11 meters) south of the 16 inch oil pipeline. The common ROW created by these four utilities is about 130 feet (43 meters) wide.

The plowing method of pipeline construction has been used to install pipelines of 10-12 inches (25-30 cm) OD in varied terrain in Michigan. The plow is attached to the rear of the bulldozer or installed on a special sled, and is then driven or winched across the stream cutting a narrow ditch and loosening and clearing materials down to the required depth of installation. The bulldozer or sled is then returned to the starting point, the pipeline is attached to the plow using a "shoe," and a second pass is made inserting the pipe into the ditch previously dug. Figures 1 through 6 illustrate the installation of the Frederic 7 pipeline across the Manistee River during the winter of 1975-76.

The plow method using a bulldozer is effective if the stream bottom is reasonably solid and the water is not deeper than about three feet (1 meter). In installing the Frederic 7 pipeline and the 4 inch electric cable, washed gravel was dumped into the stream bed to provide a firm bottom for the bulldozer (see Figure 7). At the request of the local MDNR fisheries biologist, the gravel was left in the stream as potential spawning habitat. When construction was completed, banks were stabilized with sacrete and slopes were graded and seeded (Figure 8).

OFF-ROAD VEHICLE USE

The utilities were installed down the banks and under the Manistee River at Deward in a manner to reduce the amount of soil discharged into the river at the time of construction and to prevent further bank erosion after construction. As so often happens, however, these measures, designed to deal with a known problem did not anticipate the actions of third parties.

Coinciding with, but unrelated to, the development of the oil industry in northern lower Michigan has been the growth of the use of off-road

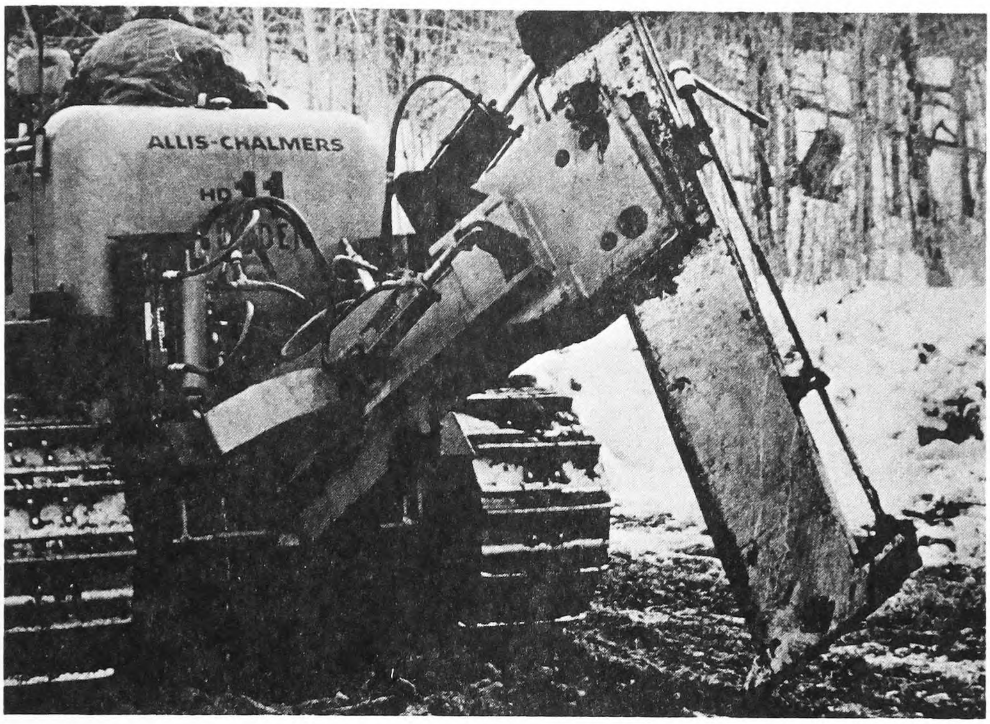


Figure 1. Plow and shoe attachment at rear of bulldozer. Note bullet nose shoe at bottom of plow. Pipe is attached to rear of shoe.

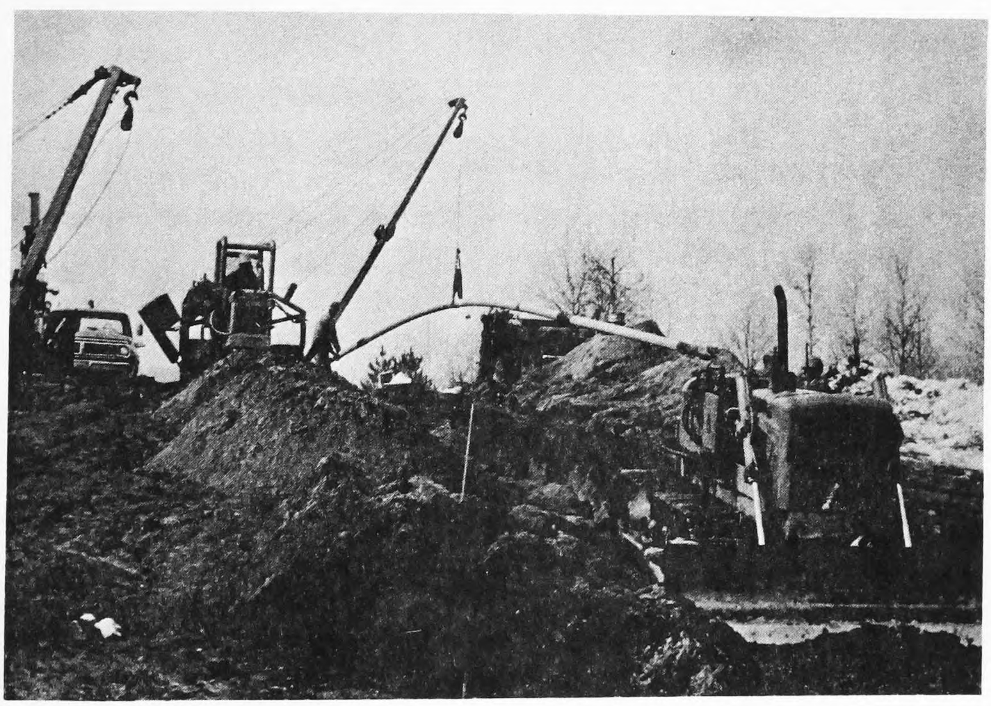


Figure 2. Three and one-half inch pipeline about to be attached to shoe of plough in preparation to pull through.

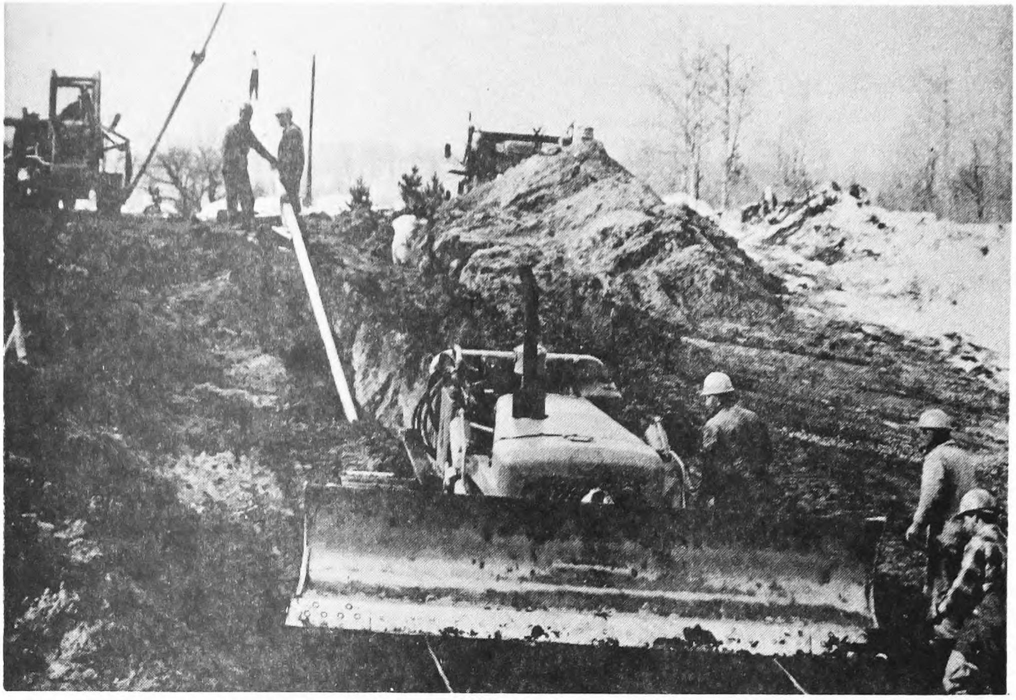


Figure 3. Attached pipe and plow is lowered into trench to proper depth and pull through commences.

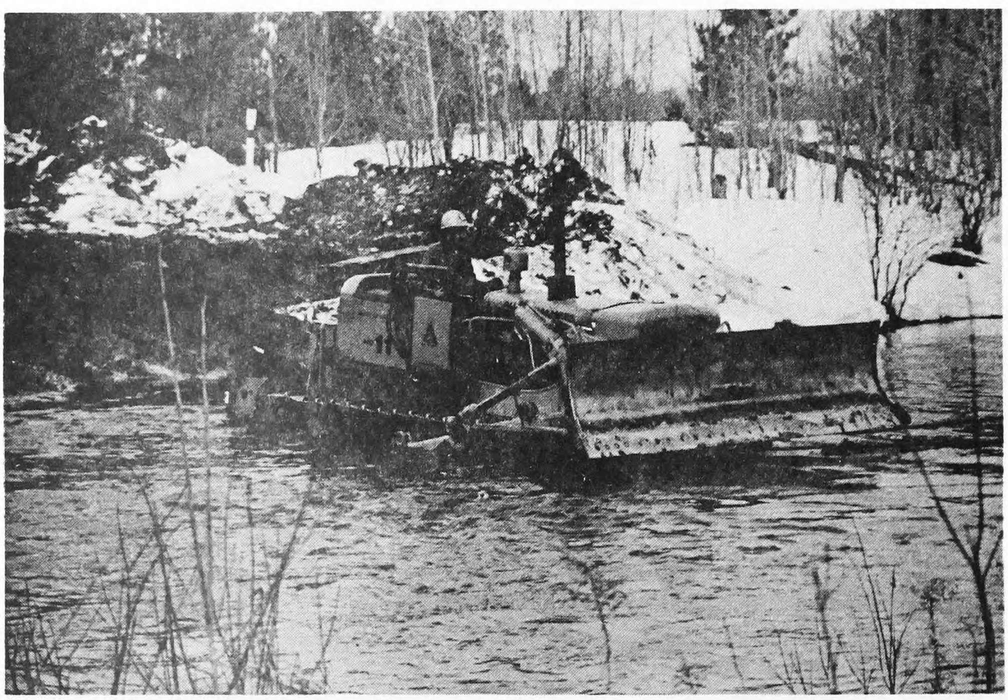


Figure 4. Bulldozer installing pipeline beneath bottom of Manistee River.

Figure 5. Pipleine laid beneath stream bottom and installation progressing up opposite bank.

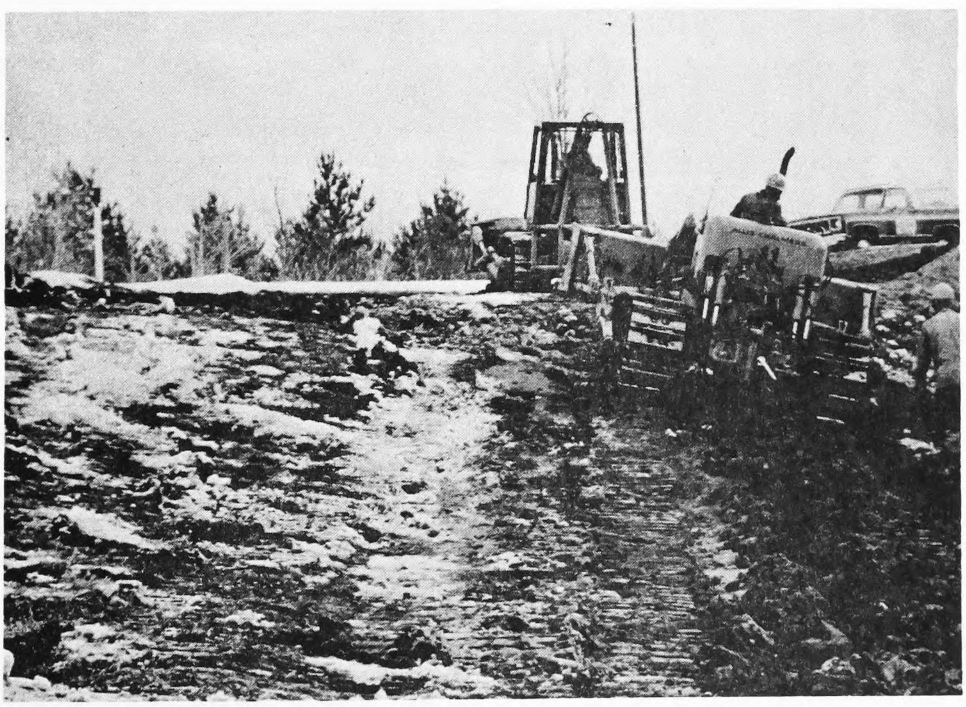


Figure 6. Installation of 3-1/2 inch pipeline to top of opposite bank. Note additional bulldozer to assist in pull.

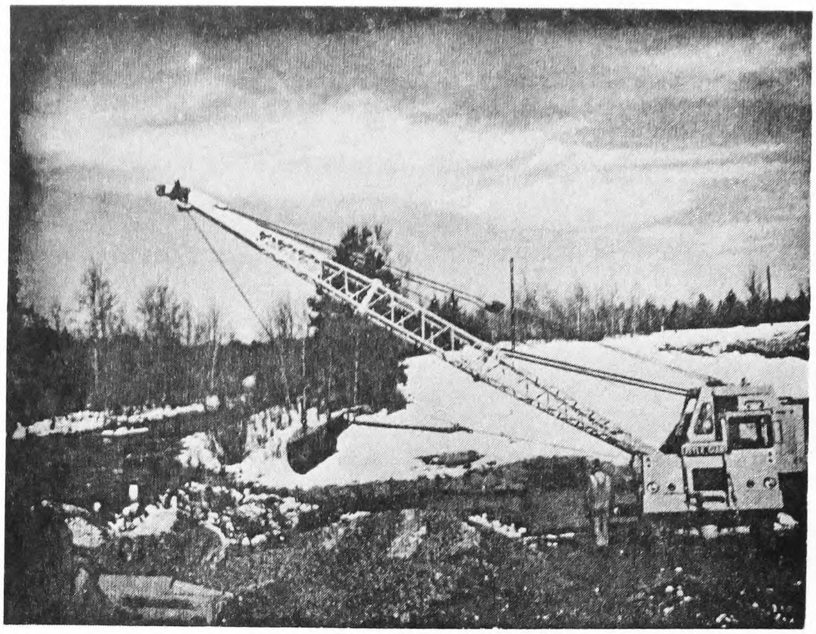


Figure 7. Washed gravel being dumped into stream bed to facilitate use of heavy tractor in river.

Figure 8. West river bank after reconstruction by Consumers Power.

vehicles for summer and winter recreation. Among the favorite areas for trail bikes, four-wheelers, and snowmachines are the large tracts of state land available in this part of the state. Especially attractive are the miles of pipeline and electric distribution and transmission line ROWs crossing these lands. The summer time use of these ROWs is a continual problem because of the disturbance to soils and vegetation, especially on hills and at stream crossings. While ORV use is often compatible with ROWs (and in fact ROWs are often routed to allow use in conjunction with an ORV trail system), there are areas which are sensitive to any type of disturbance and where ORV use can be very damaging.

It is unfortunate that the most sensitive areas are often the most attractive to the ORV user. The utility crossing of the Manistee River at Deward soon developed into one of the most heavily used ORV river crossings in this part of the state. There is a popular hill climb area east of the river, and an extensive, but unconnected, state-designated trail system to the west. The crossing became a popular route between these two, and in less than three years ORV use had stripped the banks along the ROW of all vegetation and had created a serious erosion problem. Attempts by the area forest manager and by the utility companies to control the problem by emplacing stumps and signs seemed only to provide a challenge to the ORVs. Figures 9 and 10 illustrate the condition of the crossing.

PROBLEM RESOLUTION

A number of factors combined to make the control of ORVs and or erosion at the Deward ROW difficult, including set patterns of ORV use and local soil and slope conditions. While enforcement options were opten to the state to restrict use of the ROW by ORVs, they had not been effective; there simply were not enough Conservation Officers to post one at the ROW on every busy weekend when ORVs were around. Attempts at designating ORV use areas and promulgating a state ORV use policy had met with limited success, but breaking old habits of use has proven difficult.

A request was made by the MPSC of the MDNR on October 9, 1979, to begin discussions on the problem. After field reviews and recommendations by MDNR fisheries and forestry staff, meetings between the two agencies began in the spring of 1980 to define their respective roles and design a comprehensive control program. A meeting with representatives of the four utilities was held on June 24, 1980. They were agreeable to a cooperative approach with each other and with the state to stop the ORV use at the Deward crossing and to restore and stablize the banks to prevent future erosion and loss of soil. A course of action was agreed upon and commitments of money, manpower, and equipment to accomplish the project were as follows:

1. <u>Administrative action</u>. The crossing point and an area of state land around the crossing point would be closed to all ORV use, using the power of the MDNR Director as land manager. The area would be posted and violators ticketed by Conservation Officers.

2. <u>Education efforts</u>. Local sportsmen's groups and ORV groups would be informed of the area closure and of the directing of ORV users to other

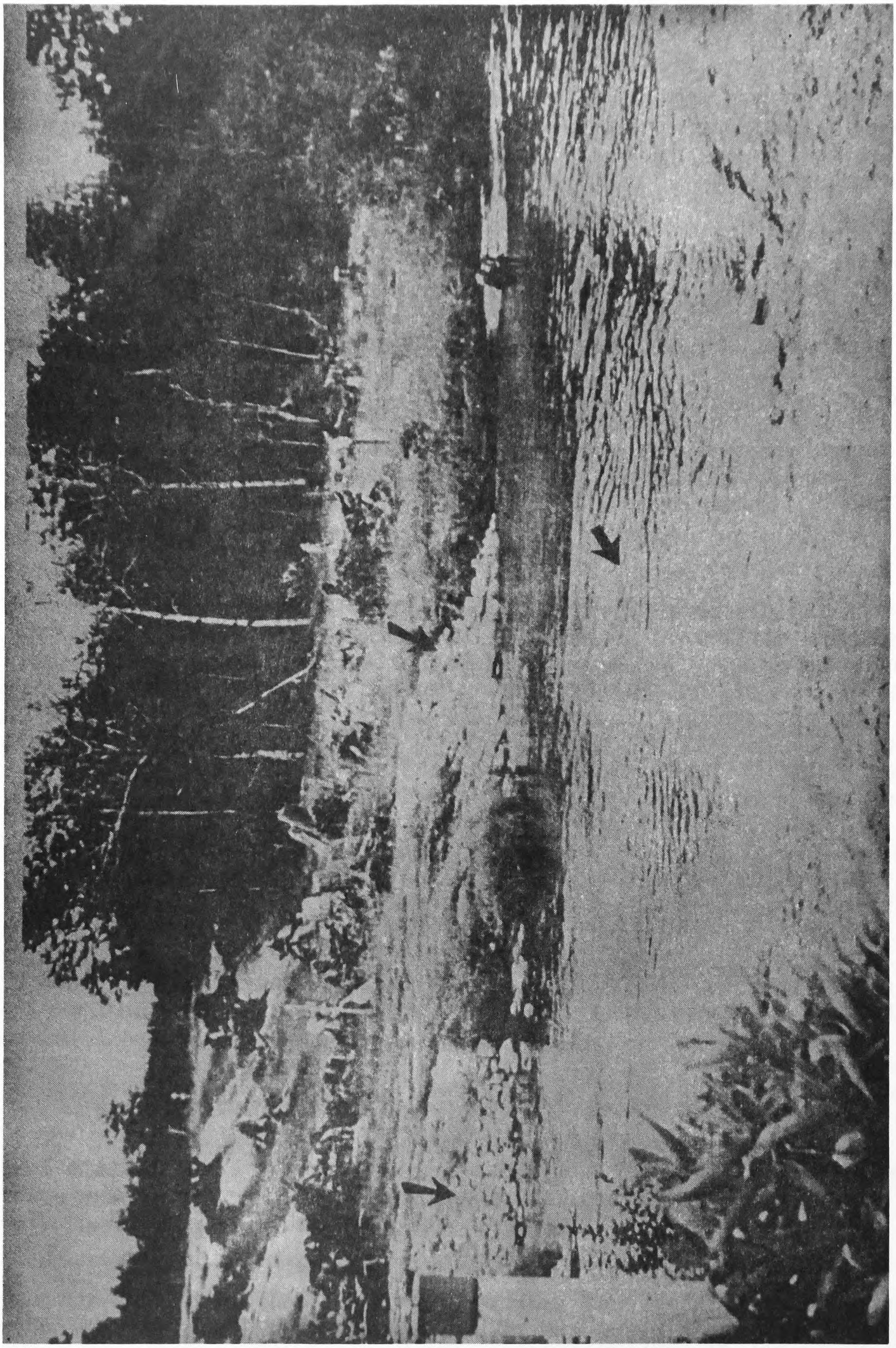


Figure 9. Bank erosion and stream sedimentation (arrows) at Manistee River crossing.

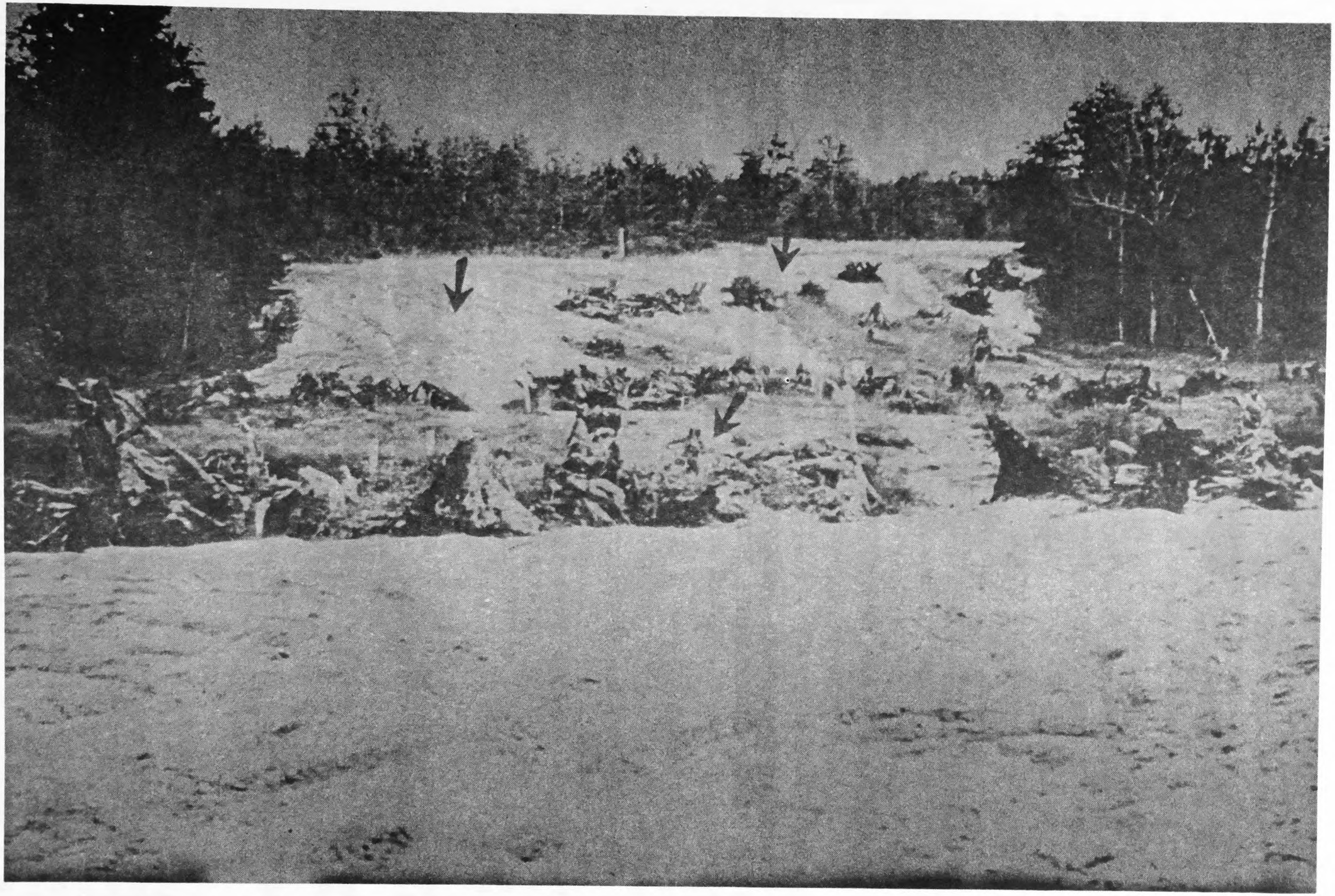


Figure 10. Arrows in background point out erosion on slopes adjacent to river. Arrow in foreground points to motorcycle rider who is negotiating his way through stump barrier.

designated areas on state land nearby where the potential on environmental damage was minimal.

3. Bank reconstruction and physical barriers. A substantial barrier to ORV use would be constructed at the crossing and banks would be reconstructed and stabilized.

A Director's Order was issued, effective August 11, 1980, closing an area 7 miles long and 1/2 to 2 miles wide on all motorized vehicles except on designated forest roads. This included the Deward ROW crossing and other sensitive areas, and effectively rerouted traffic along county gravel roads and away from the crossing area (Figure 11). The entire area was posted, barricades erected at roads into the area, and Conservation Officers assigned for the first few busy weekends to advise ORVs of the new order.

The Michigan United Conservation Club, Trout Unlimited, and local sportsmen's clubs, as well as several ORV clubs, were contacted. There were extensive press coverage and word-of-mouth discussion among members of groups affected.

Fisheries experts designed a package of in-stream devices to repair and stabilize the banks and to deepen the channel and scour out much of the sand and silt in the crossing area. Approximately 160 feet of stump or log jam was constructed on the west bank of the river at the crossing to stabilize the edge, add cover, and create a 2-3 foot (1 meter) drop-off into the river (Figure 12). A rock and log wing dam was installed on the east bank and upstream of the bank structure to direct the river flow and deepen the river channel at the crossing (Figure 13).

The in-stream structures were constructed by MDNR fisheries crews using local materials from the state forests nearby. Total costs for labor, supplies, and materials were $1,233.11 and were reimbursed to the state by Shell Pipe Lne Company and Top O' Michigan.

Consumers Power and Michigan Consolidated donated surplus river weights and placed them upland of the river crossing on either bank as an additional barrier to deter ORVs from eroding the slopes above the river. Consumers provided a double row of 12 inch weights, while MichCon provided 24 inch and 10 inch weights (Figure 14).

Work was completed on the barriers by the end of July, 1980.

SUMMARY

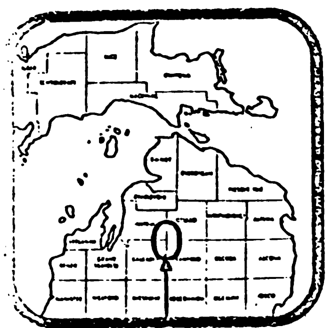
Two ORV seasons later, the Deward ROW crossing has healed itself and the barriers/closure combination have been effective in preventing further disturbance and erosion by ORVs. Whether it will stand the test of time is uncertain. This effort demonstrates, however, the difficulty in anticipating the whole realm of impacts from energy projects at the time that they are being planned and constructed. It also demonstrates the value of a cooperative effort by regulators, resource managers, and utilities in solving a common problem.

DIRECTOR'S ORDER II-80-5 STATES:

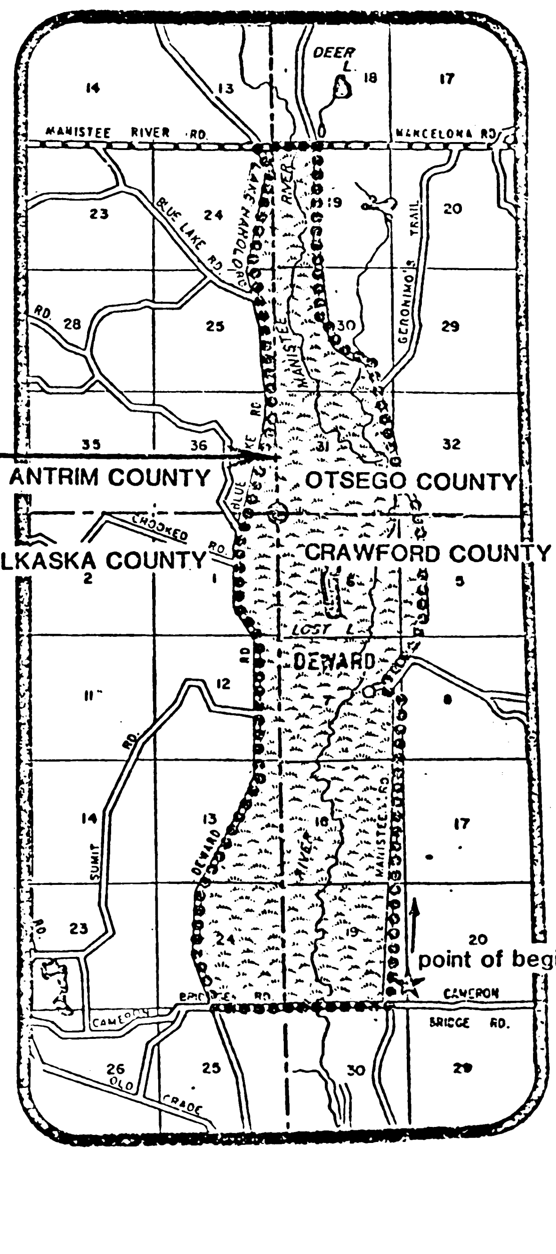
It is unlawful for any person to:

1. Use or operate a motorized vehicle except on designated forest roads;
2. Camp farther than 50 feet from roads open to motorized vehicle use;

Beginning at the intersection of Cameron Bridge Road and Manistee Road; thence northerly on Manistee Road to Mancelona Road; thence westerly on Mancelona Road to the county line common to Otsego and Antrim Counties, thence westerly on Manistee River Road to Lake Harold Road, thence southerly on Lake Harold Road to Blue Lake Road; thence southerly on Blue Lake Road to the county line common to Antrim and Kalkaska Counties; thence southerly on DeWard Road to Cameron Bridge Road; thence easterly on Cameron Bridge Road to point of beginning; except that vehicles used by the State of Michigan and oil and gas company lease holders may enter on official business.



THE AREA EFFECTED BY DIRECTOR'S ORDER II-80-5



north

Figure 11.

LOG AND STUMP FISH BANK STRUCTURE

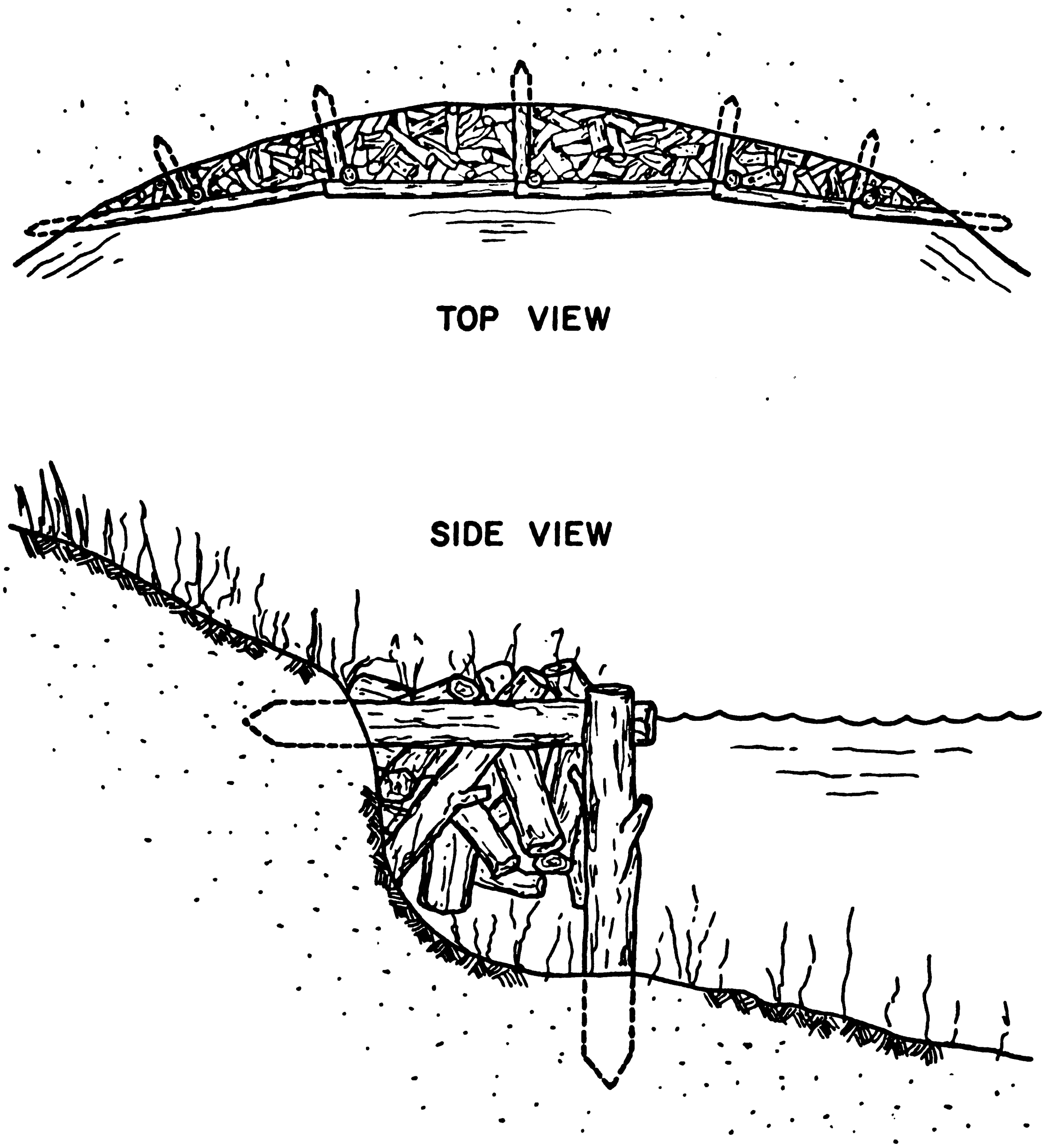


Figure 12.

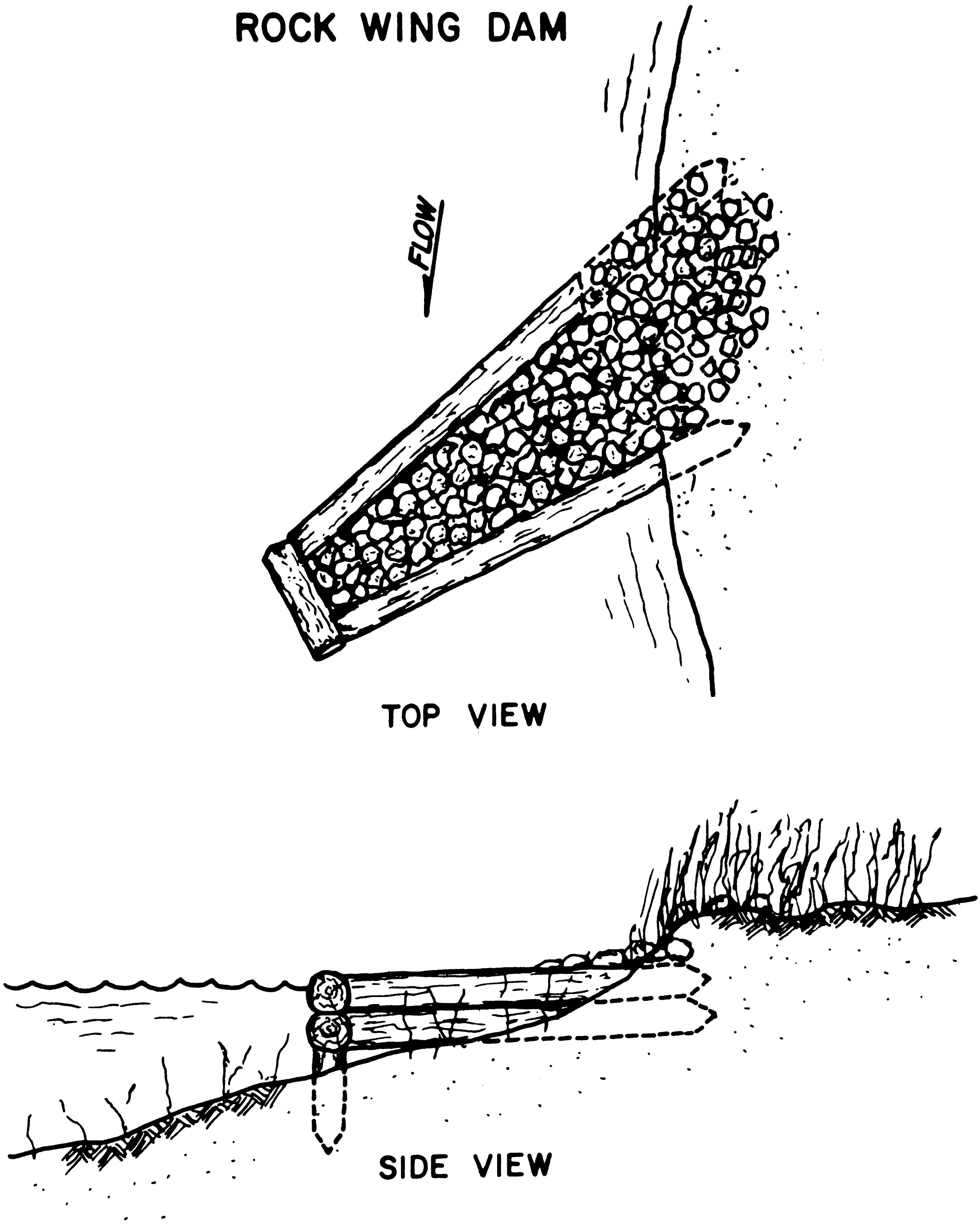


Figure 13.

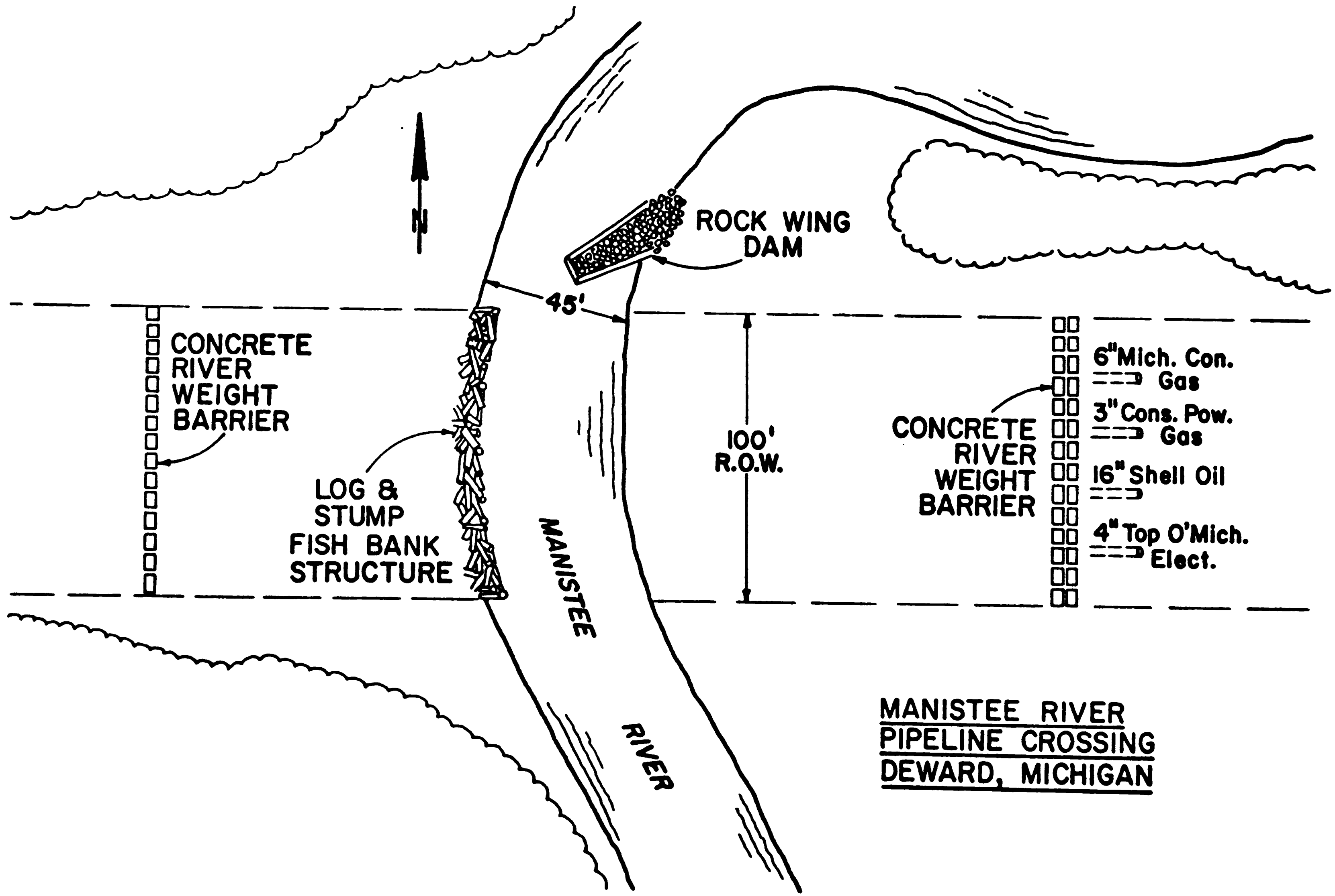

ROCK WING DAM
45'
CONCRETE RIVER WEIGHT BARRIER
LOG & STUMP FISH BANK STRUCTURE
N
MANISTEE
RIVER
100' R.O.W.
CONCRETE RIVER WEIGHT BARRIER
6"Mich. Con. Gas
3"Cons. Pow. Gas
16"Shell Oil
4"Top O'Mich. Elect.
MANISTEE RIVER
PIPELINE CROSSING
DEWARD, MICHIGAN

Figure 14.

ACKNOWLEDGEMENTS

I would like to thank Consumers Power Company for use of their photographs of the Frederic 7 pipeline construction, Ron Callen and his staff at the Michigan Public Service Commission for the ORV crossing pictures, and Donald Raymond of the Geological Survey Division, MDNR for his sketches.

EFFECTS OF PIPELINE CONSTRUCTION ON JUVENILES AND INCUBATING EGGS OF MOUNTAIN WHITEFISH (*Prosopium williamsoni* Girard) IN THE MOYIE RIVER, BRITISH COLUMBIA

Morris Zallen[1]

ABSTRACT.--The effects of construction and installation of a 194 mm O.D. (36 in) natural gas pipeline on the incubating eggs and juveniles of mountain whitefish (*Prosopium williamsoni*) were investigated at two crossings of the Moyie River, British Columbia. During November, 1980, prior to the pipeline installations, recently deposited whitefish eggs were quantitatively sampled in transects across the river at several locations upstream and downstream of the ROW crossings to a distance of 1 km. In addition, seining in pools below the crossings indicated that numerous young-of-the-year mountain whitefish were also present downstream of the ROW. Installation of the pipeline occurred during January, 1981, and involved ditching directly across the river. At each crossing, instream construction activities occurred intermittently during 5-6 days and maximum observed suspended sediment levels in the river were 1000-3000 ppm, decreasing rapidly several hours after construction. Approximately one month after the completion of the stream crossings, a re-examination of habitats containing whitefish eggs revealed no significant increase in mortality of eggs downstream of the crossing sites compared to control areas, while juvenile whitefish continued to utilize most pool habitats downstream of the ROW.

INTRODUCTION

One of the major environmental concerns related to construction activities near watercourses is the impact of suspended sediments and sedimentation on downstream fish resources, including juvenile fish and incubating eggs. These potential concerns have been identified in the environmental assessments of numerous construction projects, including pipeline and highway related developments (e.g., Peterson et al. 1978; Foothills Pipe Lines (South Yukon) Ltd 1979; Miles et al. 1979).

Although many studies have documented the effects of long-term chronic sedimentation in watercourses (e.g., from erosion and run-off), relatively few field studies have directly examined whether significant impacts due to sedimentation occur from major instream construction activities. The

1 ESL Environmental Sciences Limited, Vancouver, British Columbia.

present investigation documents the results of a sampling program for eggs and juveniles of mountain whitefish (Prosopium williamsoni Girard) prior to and after the installation of a 914 mm O.D. (36 in) pipeline at two locations in the Moyie River, British Columbia. The pipeline crossings investigated were in a segment of the Alaska Highway gas system prebuild project. The specific objectives of the program were to determine whether mortality of whitefish eggs below the pipeline crossings increased and juvenile whitefish vacated pool habitats below the crossing sites after construction.

STUDY AREA

The Moyie River is located within the Columbia River watershed in southeastern British Columbia, and it flows south into the Kootenay River in Idaho (Figure 1). In the study area, the Moyie River channel ranged from approximately 10-40 m wide and consisted of a series of relatively long pools and riffles. Water depths in riffles were less than 0.5 m; water depths in pools usually ranged from 1-1.5 m, but were occasionally greater than 2 m.

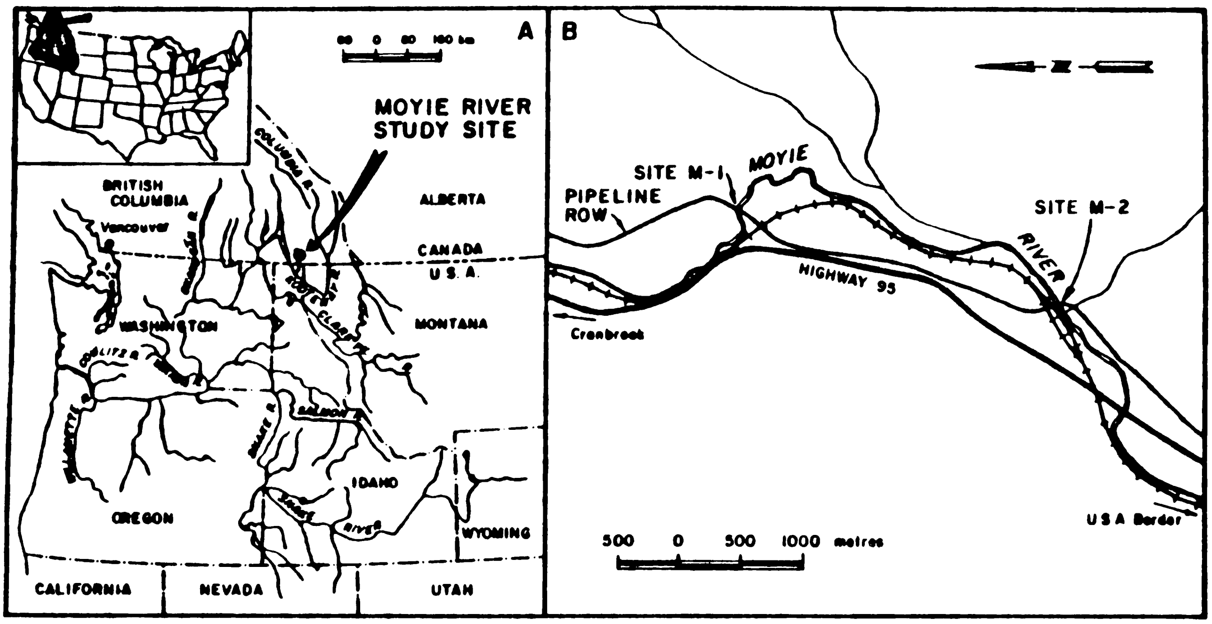


Figure 1. A - Columbia River drainage showing location of Moyie River study site and B - pipeline crossing locations (map from: Trefethen 1972).

METHODS

The two stream crossings (M-1 and M-2) were located over 3 km (1.9 mi) apart, and were both sampled for the presence of fish eggs and juvenile fish. Fish eggs were collected in a series of transects across the river, located at various distances up to approximately 1 km (.6 mi) downstream of each crossing. Control stations upstream of each pipeline crossing were also sampled. Deep pools and other low water velocity areas which were considered unsuitable spawning habitat for mountain whitefish were not sampled for egg presence.

Eggs were collected by excavating a 1.5 m (5 ft) wide band of substrate (to a depth of approximately 10 cm) across the river. This excavation was completed in 2 m (6.6 ft) segments using garden cultivators and a 2 m (6.6 ft) drift net (1.2 mm mesh) held immediately downstream of the excavation site for collection of uplifted eggs. Each 2 m x 1.5 m excavation area was considered an individual sample quadrat. Bottom substrate type and water depths were also recorded along the majority of transects. Average current velocities (m/s) across transects with high egg numbers were measured using a Teledyne-Gurley current meter held at 60% of the stream depth.

During the winter (March 1981) program, only selected stations upstream and downstream of crossings M-1 and M-2 (previously identified during the fall program as important spawning grounds) were re-examined since the primary objective of this study phase was to determine the percentage egg mortality above and below the pipeline right-of-way. In order to increase the sample size of eggs for statistical evaluation of mortality, some additional quadrats (1.5 x 2 m) were sampled in areas adjacent to the March transects.

In the March survey, the percentage of dead eggs (white-opaque) was determined for each quadrat containing 20 or more eggs. In quadrats with fewer than 20 eggs, the eggs were pooled with adjacent samples until a sample of at least 20 was obtained prior to determining percentage mortality. Methods used for analysis of mortality estimates are described in the following section.

During both the fall and late winter programs, juvenile fish were collected with a 45 m (148 ft) beach seine, and were released following identification and measurement of fork length. Sampling sites during both programs are described with the results.

RESULTS

The total numbers of whitefish eggs found in each transect above and below crossings M-1 and M-2 during November, 1980, are indicated in Table 1. There was a large degree of variability in the total number of eggs found between transects and sites. At sites M-1 and M-2, the total number of eggs collected in transects varied from 0 to 254 (0-10.5 egg/m^2) and 0 to 393 (0-32.8 eggs/m^2), respectively.

One of the major factors affecting whitefish egg distribution in the Moyie River appeared to be substrate type. In each instance when egg numbers were relatively high, the substrate was composed largely of loosely-compacted cobble over gravel. Current velocity and water depths also appeared to influence the spawning locations of whitefish. Figure 2 shows egg distributions in relation to river depth and current velocity at transects with highest egg numbers below crossings M-1 and M-2. In general, some eggs were deposited in areas with moderate current, but numbers were highest where both the depth and water velocity were at or near the maximum for that transect. Highest egg numbers in each transect occurred in water with average velocities of approximately 0.6 to 0.9 m/sec, although eggs were also found in habitats with current velocities ranging from 0.4 to 1.2 m/sec. Most eggs were collected from water depths ranging from 0.28 to 0.43 m, and were infrequently found in areas as shallow as 0.15 m.

Table 1. Eggs collected at Moyie River pipeline crossings M-1 and M-2, November, 1980.

Distance from Crossing[a]	Channel Width (m)	Total Eggs Per Transect	Average No. Eggs per m
M-1			
170 U	22	49	5.4
55 D	16	17	1.9
80 D	25	254	10.5
200 D	16	1	0.3
230 D	19	0	0
310 D	18	30	2.5
330 D	10	0	0
400 D	10	1	0.3
510 D	14	0	0
600 D	22	0	0
680 D	15	0	0
700 D	12	0	0
800 D	13	6	0.7
890 D	27	12	4.0
1060 D	30	0	0
M-2			
19 U	20	7	1.2
25 D	14	6	0.7
200 D	14	0	0
300 D	30	0	0
460 D	38	393	32.8
500 D	24	52	4.3
615 D	26	76	5.1
715 D	14	189	12.6
850 D	16	1	0.3
1000 D	24	121	13.4

[a]Meters downstream (D) or upstream (U) from crossing.

All of the eggs collected during November were in an early developmental stage. No distinct embryo was evident within the eggs, and only 2 dead eggs were observed (identified by opaque outer membrane) in all of the samples collected (n = 1215). No spawning fish were observed during the fall survey, although several females with retained eggs were captured. It appeared that spawning had been completed a few weeks prior to this program, and the observed distribution of eggs in the stream appeared to be typical of mountain whitefish and other species which are broadcast spawners in midstream areas, rather than nest or redd builders (Thompson and Davies 1976).

Juvenile (young-of-the-year) whitefish were particularly abundant in pools below the crossings during November. In nine seining efforts, 86% of 367 whitefish captured were between 7-10 cm and had hatched earlier in the spring.

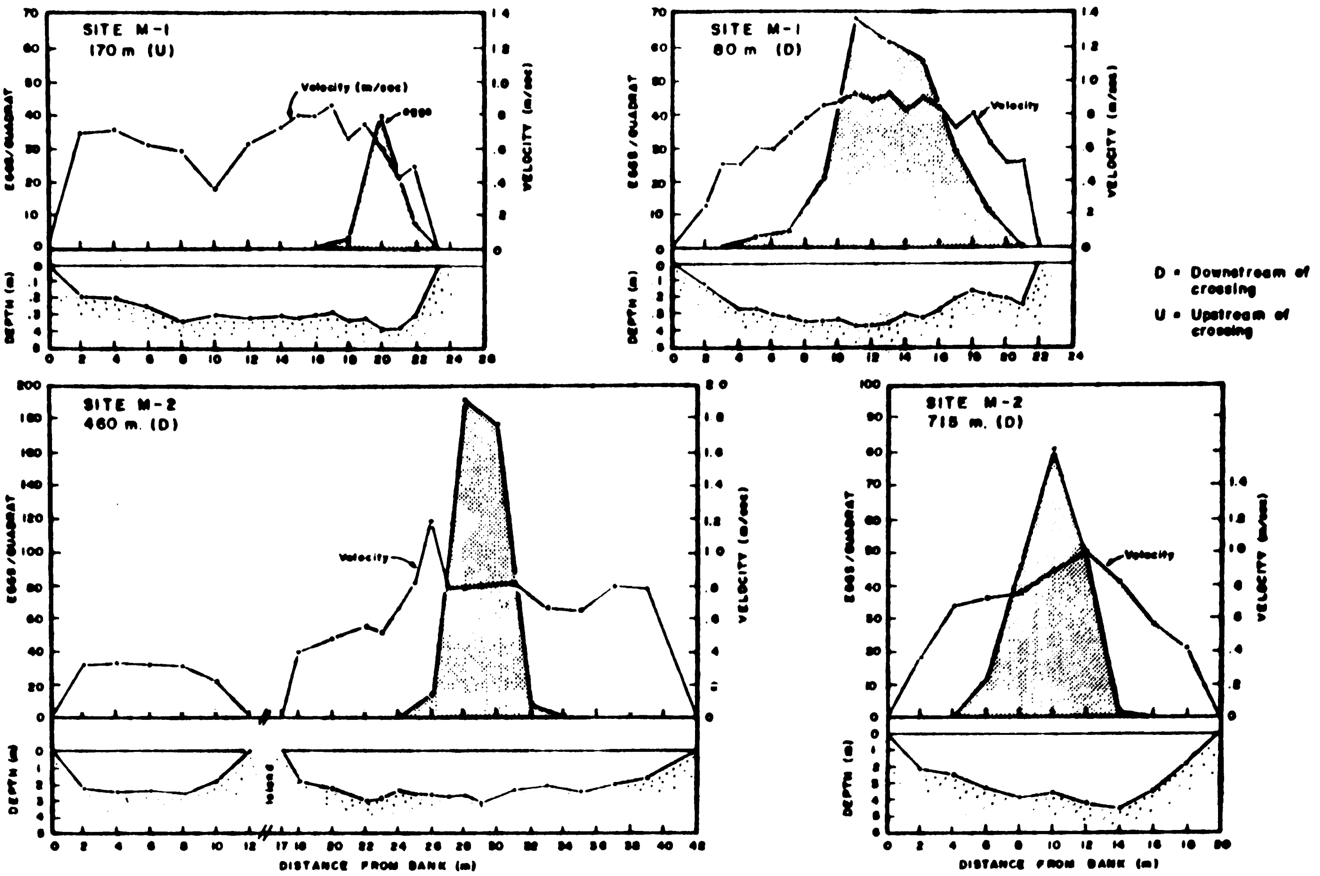


Figure 2. Distribution of mountain whitefish eggs in relation to average current velocity and water depth in transects with highest egg numbers at each Moyie River crossing.

POST CONSTRUCTION

Magnitude of Instream Disturbances

The second study of whitefish eggs and juveniles was initiated approximately one month after completion of the stream crossings on the Moyie River. Although a detailed program to document sediment increases associated with instream activities was not initiated, the construction engineer (Quadra Engineering International Ltd., Calgary) collected a series of water samples for suspended sediment determination at crossing sites during the pipeline construction, and these data provide some indication of the magnitude of the sediment load which resulted from construction activities (Figure 4).

Construction methods at each site were similar and involved ditching directly across the river channel, laying in the pipe, and backfilling the trench. No flumes or major river channel diversions were employed to direct river water away from construction activities. Equipment workers within the river channel included a back-hoe, clam-shell dredge, and dozers. Other smaller vehicles crossed the river as required throughout the construction period. In addition to equipment-related disturbances, ditches near the river were often pumped directly into the river during welding and other tie-in operations.

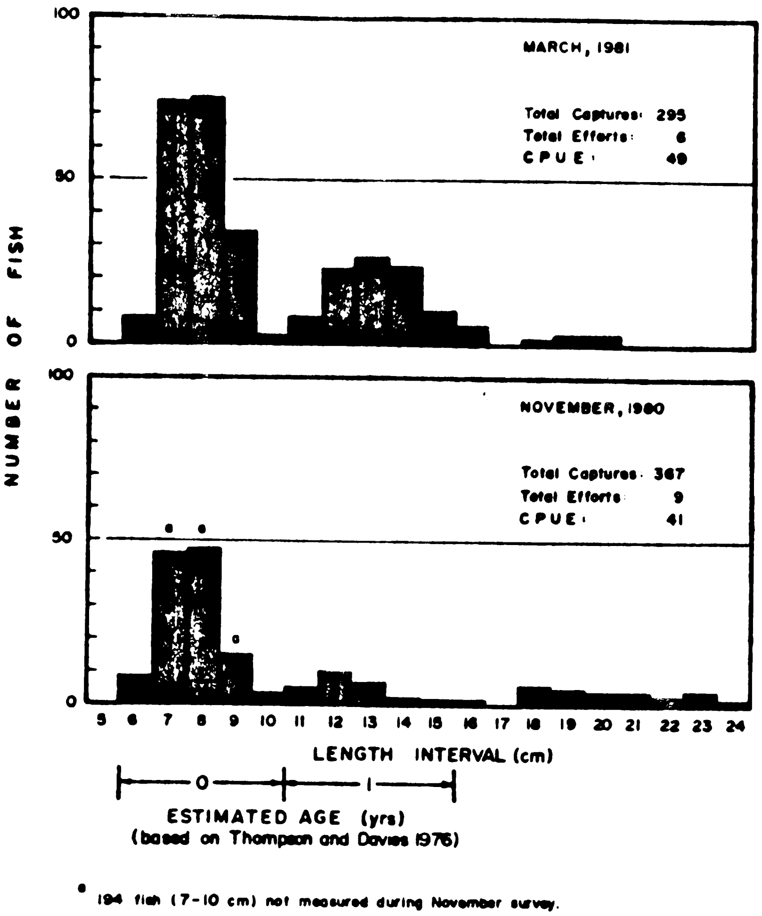


Figure 3. Length-frequency distribution of mountain whitefish captured by seines during November and March surveys downstream of Moyie River crossings M-1 and M-2.

Construction in the Moyie River at crossing M-1 occurred between January 25 and February 2, 1981. Surface "grab" samples of water were collected at selected distances downstream of the crossing site during and after various instream activities between January 26 and 29 (Figure 4). The highest measured suspended sediment concentration (1080 mg/L, 10 m (30 ft) downstream) appeared to result from in-river operations on January 27. Construction of Moyie River crossing M-2 occurred during the period from January 19 to 26, 1981. High levels of suspended solids appeared to result from in-river ditching and clamming, but the highest measured sediment levels (2680 mg/L) were recorded followed pumping out of the ditches. Although sediment levels 1 km (.6 mi) below each crossing reached approximately 100-300 mg/L during various disturbances, they returned to relatively low levels (<10 ppm) with 24 hours, and in some cases, suspended sediment levels returned to background levels only a few hours after the disturbances (Figure 4).

Whitefish Egg Mortality

In early March, following construction activities, the pattern of egg distribution across each transect remained virtually identical to that observed during the fall program, with highest egg numbers occurring near mid-stream sites where current velocity and water depth were near maximum.

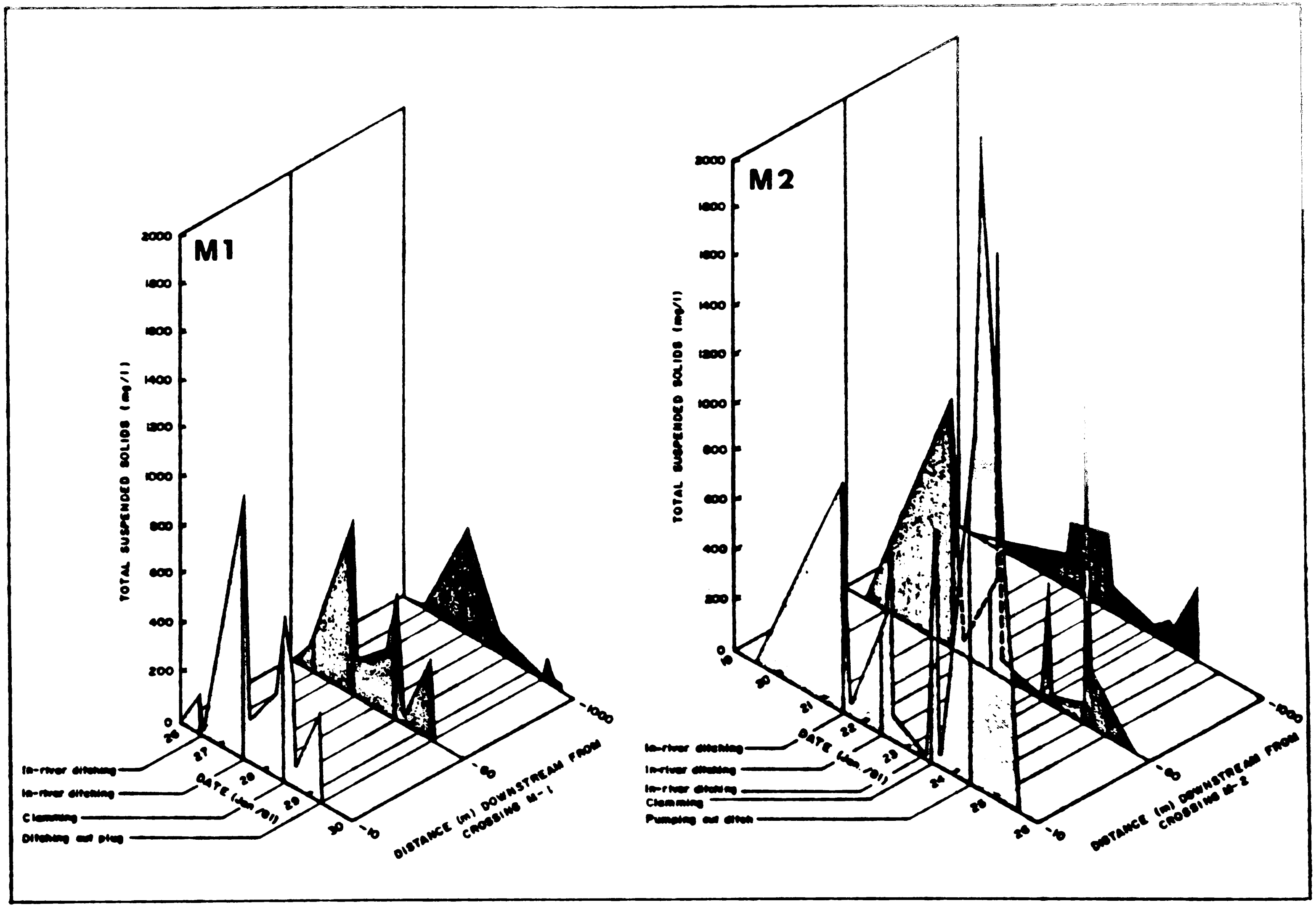


Figure 4. Measured levels of suspended solids of crossing M-1 and M-2 during pipeline installation. (Samples collected by Quadra Engineering International Ltd.).

These eggs were at the "eyed" stage (at least 4 months old) and had a prominent yolk sac and visible fins on the developing embryos.

One method used to evaluate the effects of pipeline construction on the survival of whitefish eggs was to determine if the numbers of eggs was lower in samples collected below crossings. The average number of eggs per m present before construction was compared to average numbers of eggs per m upstream and downstream of these crossings after construction (Table 2). These statistical analyses were limited to those transects having more than 10 eggs, in order to eliminate all marginal spawning habitats. Although the average number of eggs/m^2 in transects decreased after construction compared to pre-construction densities, the reduction in numbers was greatest at sites upstream of the pipeline crossings, although these differences were not statistically significant (Student's t-tests: $p<0.05$). In addition, comparison of upstream and downstream sites in March indicated that pipeline construction did not have a measurable effect ($p<0.05$) on overall egg numbers.

Table 2. Average number of eggs in transects with over ten eggs before and after pipeline construction.

	Mean No. of Eggs/m^2	SD[a]	No. of Transects With at Least 10 Eggs
Pre-construction			
Upstream and downstream sites	9.3	9.21	10
Post-construction			
Upstream sites	3.8	3.70	6
Downstream sites	4.9	2.53	5

[a]Standard deviation.

The numbers of dead (opaque) eggs present in samples collected above and below the pipeline crossings were also compared to assess whether or not instream construction activities had a significant effect on the survival of whitefish eggs (Table 3).

The maximum proportion of dead eggs (8.7%) was observed at the site upstream of crossing M-1, while the number of dead eggs ranged from only 2.2-5.7% at sites downstream from the pipeline crossings. Student's t-test comparisons were completed between all of the combinations of stations (21) to determine if there were any significant differences in whitefish egg mortality which could be attributed to pipeline construction. The "control" station upstream of all pipeline disturbances on the Moyie River (M-1 + 170) had a significantly higher mean egg mortality than most sites downstream of the crossings ($p<0.05$ to $p<0.01$). The other "control) site above crossing M-2 (M-2 + 30), although located over 3 km downstream of crossing M-2 also had significantly fewer dead eggs ($p<0.05$) than the site above crossing M-1. However, there were no significant differences ($p>0.05$) between egg mortalities at the station above M-2 (M-2 + 30) and other sites downstream of this crossing.

Table 3. Summary of mortality in egg sample replicates from crossings M-1 and M-2.

Station	Replicate Mortality[a] (percent)	X ± SD
M1 + 170 m[b]	15.0/9.1/3.7/8.3/ 12.5/10.4/2.0	8.7 ± 4.6
M1 - 80 m	0.0/6.7/3.8/3.3/	3.5 ± 2.7
M2 + 30 m[b]	9.5/0.0/4.7/1.6/ 4.3/6.5/5.0/5.0	4.6 ± 2.9
M2 - 450 m	4.5/0.0/2.3/9.1/ 0.0/10.0/7/7	4.8 ± 4.2
M2 - 615 m	4.0/2.7/1.8/0.0/ 0.0/5/5/6.1	2.9 ± 2.5
M2 - 715 m	3.5/0.0/4.0/4.8 2.9/0.0/0.0	2.2 ± 2.1
M2 - 1000 m	9.5/0.0/13.0/0.0 4.3/10.3/2.9	5.7 ± 5.2

[a]Each replicate represents a sample of at least 20 eggs (see Methods).
[b]Upstream from crossing.

Whitefish Presence

The March fish sampling program was initiated to determine if mountain whitefish (predominantly juveniles) were still relatively abundant in pools downstream of the crossing sites. The results of this seining program are compared to the fall catches in Table 4.

Table 4. Comparisons of whitefish captures in seines below crossing sites before and after pipeline construction.

	SITE M-1		SITE M-2			
	Distance Downstream (m)					
Date	380 m	700 m	700 m	1400 m	1500 m	1600 m
Pre-Construction (November)	34	17	37	29	26	2
Post-Construction (March)	3	2	111	135	17	27

Although it was difficult to duplicate fishing effort at each site, each effort consisted of a single sweep across each pool with the 46 m series. On this basis, there was no substantial difference in the numbers of whitefish present in the Moyie River before and after construction. While fish numbers declined at two sites below crossing M-1, increased numbers of fish were collected at three out of four sites below crossing M-2.

The length-frequency distribution of fish captured during the March seine survey was similar to that observed during November, and young-of-the-year (7-10 cm) were dominant during both surveys (Figure 3). When the results from all sites were combined, the catch of whitefish per unit effort (CPUE) downstream of the crossings was similar during both the March (CPUE = 49) and November (CPUE = 41) surveys.

DISCUSSION

The results of this study indicated that instream construction activities related to the installation of a 914 mm O.D. (36 in) pipeline did not appear to contribute to mortality of whitefish eggs downstream of the crossings. The percentage of dead eggs in samples and the egg densities were generally not significantly different in samples collected below the crossings compared to undisturbed sites above the pipeline ROW. However, the mortality in one upstream "control" area was significantly higher than in most other areas sampled, despite the fact that it was located upstream of all pipeline-related disturbances. No obvious explanation for this anomoly was apparent during the sampling program, although a natural event such as rainfall and resultant river scouring could have affected this site more seriously than the other downstream areas. The average number of eggs/m in all transects declined during the period from November to March, but these differences were probably attributable to natural mortality caused by predation, disease, and abrasion. For example, Stalnaker and Gresswell (1974) and Dahlberg (1979) suggest that total egg mortality from spawning to hatching for whitefish and other species which do not prepare spawning nests or protect their eggs is commonly in the order of 90%. Therefore, the maximum observed reduction in the average number of eggs in transects below the crossing sites (40%) is well within the anticipated range of natural egg mortality. However, the trend observed during the present investigation cannot be extrapolated to other species such as trout, which bury their eggs in interstitial gravel. These species usually have a much higher survival rate to hatching (Dahlberg 1979), and may also be more susceptible to sedimentation.

The presence of numerous juvenile whitefish in some pools below crossings M-1 and M-2 following pipeline construction also suggested that instream activities had little effect on fish presence. Although the concentrations of suspended solids measured during construction (1,000-3,000 ppm) approached levels which may be potentially injurious to some fish (Nobble 1978; Miles et al. 1979), the relatively short-term nature of the disturbance probably minimized any significant effects on fish in downstream areas. Fish may have temporarily vacated some of these downstream pool habitats, particularly near crossing M-1, since numbers of fish collected from the two pools examined declined between November and March. However, it is also possible that these fish may have naturally moved downstream during this period.

CONCLUSION

In conclusion, this study has documented that in instances where major instream construction activities occur for relatively short periods, such as during pipeline installations, downstream spawning grounds of mountain whitefish and fish habitat utilization may not be seriously affected, even though relatively high levels of suspended solids and turbitities occur.

The sampling methods employed in this study were also relatively simple to execute and should be applicable to many types of stream crossings, including situations where other species may be present. If more post construction studies were completed in conjunction with future stream crossings, a more complete understanding of the direct impacts of pipeline installations on aquatic resources could be developed, particularly if these investigations included monitoring of the physical effects of instream construction activities as well as biological observations such as those described here.

ACKNOWLEDGEMENTS

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AQUATIC BIOLOGICAL IMPACTS OF INSTREAM RIGHT-OF-WAY CONSTRUCTION AND CHARACTERISTICS OF INVERTEBRATE COMMUNITY RECOVERY

Betty Dehoney[1,2] and Eugene Mancini[1,3]

ABSTRACT.--Two major impacts associated with the construction of a pipeline through an aquatic habitat are the disturbance of habitat through the removal of substrate and the increase in stream siltation/turbidity. Quantities of macroinvertebrates that would be affected through substrate removal are estimated. The potential secondary impact of invertebrate removal on fish productivity is also estimated. Impacts from increases in siltation/turbidity are discussed for all life cycle stages of fishes and macroinvertebrates. It was concluded that the egg and larval stages of fishes and macroinvertebrates would be the most adversely affected by increases in siltation/turbidity due to their relative immobility. Adult fishes would likely vacate the affected area at least temporarily, although increased siltation could disrupt reproduction by covering potential spawning grounds. Recovery of the area would be dependent upon the time needed for silt to be removed from the substrate, but after the silt has been removed recovery should occur fairly rapidly (less than 6 weeks).

INTRODUCTION

In the preparation of various environmental impact documents for right-of-way projects (e.g., pipeline, transmission lines), a thorough analysis of the biological effects of instream corridor construction is required. The two physical construction effects which would be expected to precipitate detectable biological impacts are stream siltation/turbidity and habitat disturbance (temporary benthic substrate removal). While few, empirical, right-of-way instream construction impact data exist (Tsui and McCart 1981, Gartman 1981), other available data make it possible to accurately estimate biological damage anticipated from such activities.

This paper will discuss only those impacts associated with the construction of a pipeline corridor through an aquatic habitat. Although some

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transmission lines, railroads, roads) are similar in nature, there are significant differences in the extent of impact. Facilities associated with transmission lines are seldom placed within stream habitats. Roads, bridge supports, and culverts permanently replace natural substrate with man-made material, while a buried pipeline only temporarily removes natural stream substrate.

DISCUSSION

Construction of a pipeline right-of-way through a river or stream can kill, injure, or at least displace, members of the invertebrate community in the affected area. The magnitude of the impact is dependent upon several factors including (1) season of construction, (2) size of stream, (3) width of corridor, (4) construction procedures, (5) quality of habitat, and (6) metamorphic stage of the invertebrates.

Benthos

Since the standing crop of benthic macroinvertebrates varies seasonally (Table 1), the biomass anticipated to be loss to construction impacts also varies seasonally, although no consistently predictable trend is indicated. It should be noted that measurable standing crop, as indicated in Table 1, normally includes only the upper few centimeters of substrate. Since normal pipeline construction procedures include digging the corridor below scour depth, a somewhat greater standing crop could be affected than is indicated.

The life history of affected macroinvertebrates also determines the extent of biological impact. Virtually all aquatic insects inhabiting stream or river substrate have a terrestrial adult stage. The period of emergence from immature to adult stage results in a decreased standing crop within the stream. Even after successful reproduction there is a lag period before instream biomass increases to pre-emergency levels. In fact, the eggs of many species deposited during the fall months do not hatch until the following spring.

Two parameters not directly associated with invertebrate standing crop but, nevertheless, affecting the total loss of benthos include the size of the stream and the width of the crossing corridor. Obviously, a large stream corridor would disrupt a greater amount of habitat than a small one, thereby affecting a greater portion of the benthic community.

Habitat quality also affects the standing crop of benthos. Permanent streams, as compared to intermittent or ephemeral waters, sustain a higher standing crop of invertebrates due, primarily, to constant substrate inundation. If an intermittent drainage is crossed during the "dry" season no significant impact would be anticipated.

Table 1. Standing crop (mg dry weights/m^2) of macroinvertebrates reported from several aquatic systems.

	Early Spring	Spring	Summer	Late Summer	Autumn	Winter	Mean or Annual
Tornillo Creek, Texas[1]		1,592	74	1	1,168	656	698
Black River, Missouri							625
Yōrō River, Japan[1]						4,470	
Spring Creek, Pennsylvania[1]		5,822	2,025		3,544	6,582	3,038
South Willow Utah[1]		21,198			3,874	18,722	
Factory Brook, Massachusetts[2]							744
West Creek, Quebec[3]							2,210
Mississippi River, Mississippi[4]							4,243-4,534
West Fork[5]	450-1,094	890-3,334	731-1,322	1,108-1,310	37-184	13-100	697

[1]Bane and Lind 1978; [2]Neves 1979; [3]Mackay and Kalff 1969; [4]Ragland 1974; [5]Dehoney 1978.

It has also been demonstrated that riffle habitat tends to be more biologically productive than pool habitat (Parrot 1975, Hynes 1970). Of parallel interest is the fact that heterogeneous substrates (e.g., cobble, rubble, and unconsoldiated substrates mixed with detritus) maintain higher benthic densities than homogeneous substrates like silt or bedrock (Mackay and Kalff 1969, and others). Right-of-way construction through riffle and/or heterogeneous substrate habitat, therefore, would be expected to have concomitantly greater impacts than construction through pool and/or homogeneous substrate areas.

Stream Sedimentation and Turbidity

Although direct habitat disturbance has an immediate impact on aquatic biota, stream sedimentation can result in more extensive biological impacts. River crossing construction activities increase sedimentation and turbidity as a result of distrubance or removal of riparian ground cover, heavy equipment traffic, and dredging in the river channel. Cordone and Kelley (1961) and Stern and Stickle (1978) have completed extensive reviews of the literature regarding the biological effects of increased sedimentation and turbidity. It has been found that an increase in sedimentation can affect productivity throughout all trophic levels (Karr and

Schlosser 1978, Stern and Stickle 1978, Peters 1967, Cordone and Kelley 1961, Gangmark and Bakkala 1960, and many others).

Although sustained periods of exposure to high suspended solids under laboratory conditions have been shown to cause adult and juvenile fish mortality (Herbert and Merkens 1961, Herbert and Richards 1963, and several studies reported in Stern and Stickle 1978), increases in ventilation (Horkel and Pearson 1966), physical damage to gills and other exposed tissues (Herbert and Merken 1961, Ellis 1944 in Cordone and Kelley 1961), plus other behavioral effects, it has been shown that under natural conditions (Peters 1967, Herbert et al. 1961, Burnside 1967) fishes do not remain in areas of high turbidity. Further, elevated turbidity levels anticipated to last for only a few hours after the completion of construction, and to affect a relatively small section of river or stream within approximately 1020 feet (300 meters) (or less) of the dredging activity.

It is also believed that sediment affects the flow of water through gravel, preventing the removal of metabolic waste and entrance of oxygen (Cooper 1965, Sheridan and McNeil 1968, Meehan and Swanston 1977 and others). Shelton and Pollock (1966) found that if 15-30% of the interstices in gravel were filled with sediment, there was an 85% mortality of salmon eggs. The sediment may also act as a physical barrier to the fry, even if they do hatch successfully. Sedimentation can also disrupt reproduction by covering spawning grounds (Karr and Schlosser 1978), making them unavailable for reproduction.

Macroinvertebrates would be affected more from the deposition of suspended solids than from increased turbidity. The primary impacts of stream siltation on aquatic invertebrates would be gill membrane abrasion, smothering, and/or loss of acceptable substrate habitat as a result of substrate in-filling. Casey (1959 as reported in Cordone and Kelley 1961) found that siltation for about a quarter of a mile downstream from a dredging operation eliminated macroinvertebrates. There was a 50% reduction in numerical abundance one mile below the dredge. Not only do macroinvertebrate populations decrease when sedimentation increases (Tebo 1955), low level sedimentation can alter species composition (Conlan and Ellis 1979, Rosenberg and Wiens 1978). Conlan and Ellis (1979) found that a 1 cm layer of wood waste resulted in a reduction in biomass and the loss of the majority of suspension feeders with the affected area becoming dominated by deposit feeders. Rosenberg and Wiens (1978) noticed that sediment additions resulted in different drift rates for various invertebrates. White and Gammon (1977) reported that increases in suspended solids resulted in increased drift rates to more than double the normal rate. Since an increase in sedimentation results in a decrease in habitat diversity by filling in the substrate interstices, macroinvertebrate standing crop has been found to decrease (Williams and Mundie 1978, Allan 1975, Barber and Kevern 1973).

Regardless of the construction schedule it is anticipated that a large volume of macroinvertebrates would be killed as a result of dredging and downstream sedimentation impacts. Tsui and McCart (1981) have recently completed a study concerning the effects of a stream crossing by a pipeline on benthic invertebrates. They reported a general reduction in the diversity of benthic communities downstream from the crossing, but the reduction was subtle and statistically insignificant. A substantial reduction, up to 74%, of benthic standing crop was noted at downstream stations.

Mollusks, in addition to insects, may also be adversely affected by stream siltation. Ellis (1936) reported a general increase in mortality of mussels affected by silt, and many species of snails and mussels specifically avoid silt-substrate areas (Pennak 1978).

Data summarized from Neves (1979), Bane and Lind (1978), Dehoney (1978) and Ragland (1974) suggest that "typical" freshwater benthic invertebrate dry weight estimates range from 1 to over 21,000 mg/m^2 (Table 1). For assessment purposes a mean dry weight biomass of 16 g/m^2 has been assumed for all potentially affected macroinvertebrate populations. For each 3 meters (92.8 m) of river crossed, the dry weight of eliminated benthic invertebrates would equal approximately 1.5 kg.

Migration and Spawning

At those streams and river crossing locations where construction coincides with fish migration periods, there is a possibility that instream activity would interfere with pre- or post-reproductive migration. Such interference has been reported in the literature (EPA 1976), and the severity of the impact would depend upon the spawning behavior of the species involved, the suspended solids increase anticipated, and the delineation of the downstream area to be affected.

In the smaller streams and rivers where instream construction would be completed within a few days, or less, it is likely that migration would be temporarily suspended. Since most fishes migrate over a period of several days or weeks (Geen et al. 1966), migration would be expected to resume shortly after the completion of construction and the settling of suspended materials.

In wide rivers where construction would last for several weeks and would precisely coincide with initial migration periods, spawning could be limited to unaffected downstream areas. This, however, would be an unlikely impact since construction activity usually is confined to a relatively small area along the pipeline crossing transect. It is likely that migrating fishes would use unaffected transect areas as migration corridors and would avoid construction areas along the transect.

Secondary Impacts

The anticipated secondary impacts of invertebrate removal on fishes which rely on them as a food source are summarized in Table 2. This summary assumes that a fish would be approximately 15% efficient in converting its food to flesh (Russell-Hunter 1970). It should be noted that a 15% estimate is liberal. These data indicate that approximately .23 dry weight kg of fish flesh would be lost for every 3 meters of river crossed. This secondary impact on local fishes would be localized, short-term, and of limited biological significance since these fishes would be expected to simply move a short distance upstream or downstream in order to feed.

Recolonization

There are three main avenues for recolonization of denuded streambed areas by macroinvertebrates and these include (1) the phenomenon of "drift," (2) immigration from undisturbed substrate areas, and (3) aerial dispersal. Recovery of affected areas would be expected to occur primarily as a result of invertebrates drifting from unaffected upstream areas (Williams 1977). This phenomenon has been studied extensively (Anderson and Lehmkuhl 1968, Hynes 1975, Minshall and Winger 1968, Townsend and Hildrew 1976, Waters 1961, 1964, and 1972 and others). Townsend and Hildrew (1976) reported that 82% of the colonization of experimentally introduced substrate was from drifting invertebrates. Waters (1964) stated that the "downstream drifting of some stream invertebrates is a mechanism fully sufficient to return disturbed populations to normal or capacity levels in a short time." He reported that some organisms that exhibited high drift rates (such as Baetis sp. and Gammarus sp.) returned to normal conditions in a day or two, at least during the summer months when drift rates were high. However, if the drifting rate of an abundant species is not high, another species may attain densities higher than pre-existing levels. Waters (1964) concluded that a 14-day interval was sufficient for a return to normal densities.

Table 2. Estimates of macroinvertebrate and equivalent fish flesh biomass which may be lost as a result of river crossing construction.

River Width (meter)	Macroinvertebrate Biomass (kg, dry weight)	Fish Biomass (kg, dry weight)
3	1.5	.23
6	3.0	.46
9	4.5	.69
12	6.0	.92
15	7.5	1.15
30	15.0	2.30
60	30.0	4.60
300	150.0	23.00

NOTE: See text for discussion of assumptions.

Townsend and Hildrew (1976) reported that representatives of most benthic species arrived within three days of the introduction of uncolonized habitat to a natural streambed. They reported a longer period of time for recolonization (30 days) to return to the average naturally-occurring density, but they were using a new substrate, which may account for the difference.

Although the period for recolonization of natural substrates to normal densities has been reported to occur in less than 6 weeks (Waters 1964, Townsend and Hildrew 1976), recolonization after pipeline construction may take longer. Alteration of the substrate type or infilling of substrate interstices with silt could affect the species composition and density of organisms recolonizing the affected area. Depending upon hydrologic conditions, silt would be expected to be removed from the substrate during subsequent "scouring-flow" periods (e.g., spring run-off).

Recolonization should occur fairly rapidly after the silt has been removed from the substrate. Tsui and McCart (1981) concluded that it "appeared that stream-crossing by pipeline can have an impact on the water quality and biota of the stream. However, the nature of this impact is both short-term and non-residual. Proper post-construction stream bank protection and erosion control will substantially reduce the ecological impacts of stream crossings."

SUMMARY

It is anticipated that there would be no significant impact to indigenous fish populations when river crossing construction schedules do not coincide with critical fish migration or spawning activity. If, however, construction coincided with spawning activity it would be likely that egg and larval mortality would be limited to the relatively small affected area (less than 300 meters downstream) and should be considered a localized, short-term impact with no detectable population level effect.

Regardless of the construction schedule it is anticipated that these invertebrate impacts would be localized, short-term, and significant. Rainstorm activity would be anticipated to scour the silt deposits from the natural substrates and, thus, make the substrates available for macroinvertebrate recolonization as reported by Gore and Johnson (1979). There are anticipated to be no secondary impacts on local fishes since they would either feed in unaffected areas or they would feed on available invertebrates in the affected areas.

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ENVIRONMENTAL EVALUATION OF WATER CROSSING TECHNIQUES FOR PIPELINE CONSTRUCTION IN CANADA

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ABSTRACT.--Although pipeline construction is a temporary surface disturbance, it can also cause long-term negative environmental impacts if proper precautions are not taken. This paper focuses on excessive sedimentation resulting from watercourse crossings and includes a review of existing practices, including vehicular crossing methods and pipe installation methods (both wet and dry). The most common pipe installation techniques include (1) wet crossings; (2) wet crossing with downstream sedimentation controls; (3) fluming; and (4) slip boring. There is no preferred technique. It is important to match an appropriate technique with the environmental sensitivity of each water crossing.

INTRODUCTION

Canada is active in hydrocarbon exploration and development. Consequently, thousands of miles of pipelines are laid each year to gather these hydrocarbons, process them, and transport the products to market. Construction projects may range from small diameter gathering systems to larger diameter interprovincial/international systems. These pipelines traverse a variety of landscapes ranging from wilderness, to farmland, to urbanized areas.

In recent years, there has been a greater awareness of the potential environmental impacts from pipeline construction, especially those related to water crossings. The major concern is that of increased sediment loading (sedimentation) and its impact on stream biota and water quality. Impacts on stream biota can be either direct, causing injury, disease or death to organisms and/or indirect, altering the environmental requirements. The ultimate impact on water quality is to reduce it to a state that is unsuitable to downstream users. As a result there has been considerable dialogue between government and industry to examine pipeline construction techniques which will minimize sedimentation.

Generally, the impacts on water quality are well understood. Impacts on stream biota are not as well understood, since the extent of direct and

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indirect impacts can depend upon a number of factors, such as concentration, nature of material and exposure time, the distance transported and deposition. Normally, direct impacts are short-term construction related. Indirect impacts may be short- or long-term depending upon the characteristics of particular crossings such as scour and rehabilitation techniques.

The purpose of this paper is to provide environmental managers with a practical guide for determining the most suitable water crossing techniques depending upon watercourse sensitivity and engineering/cost factors. An ideal environmental management process for pipeline water crossings is presented in Figure 1. This paper focuses on the first two items of step 5 for Canadian watercourses not large enough to require a barge.

The extent of sedimentation and its impact depends on the substrate material, the velocity and volume of flow, stream morphology, and the extent and duration of digging within a watercourse. For example, crossing a watercourse with a muddy substrate will generate more sediment than one with a gravel substrate.

For fishery sensitive watercourses, the best protective measure is to avoid critical times (spawning, migration) and important habitats (spawning beds, overwintering areas).

Any method can be good or bad depending upon the crossing location. In general, a good pipeline crossing has the following characteristics: low, gently sloping banks that are well vegetated and stable; relatively slow-moving water; pipeline crosses watercourse at right angles; pipeline crosses in straight reach of watercourse; sandy, gravelly or rocky substrate; and non-braided section of watercourse.

Prior to selecting an appropriate water crossing technique it is necessary to classify watercourse sensitivity (See Figure 2). The life cycle of fish can determine sensitivity at time of construction. Since environmental managers may not always get their preference for scheduling construction, the issue becomes one of selecting a crossing technique which will minimize sediment loading.

PIPELINE WATER CROSSINGS

A pipeline water crossing has two main components-the actual pipe installation and vehicular crossings. Vehicular crossings involve the necessity for all construction equipment to pass through, over, or around the watercourse. Pipe installation normally consists of stringing, welding, weighting, trenching, lowering in and backfilling, although some of these steps may be missing or replaced depending upon the actual crossing technique.

Vehicular Crossing Techniques. The vehicular crossing methods used include fording, swamp mats, culverts, and bridges. These are described and evaluated in Table 1. Fording is the most common but it it not recommended for moderate or high sensitivity watercourses. The installation of culverts or placement of swamp mats are reasonably cheap improvements. Temporary bridges usually are expensive but are effective in minimizing

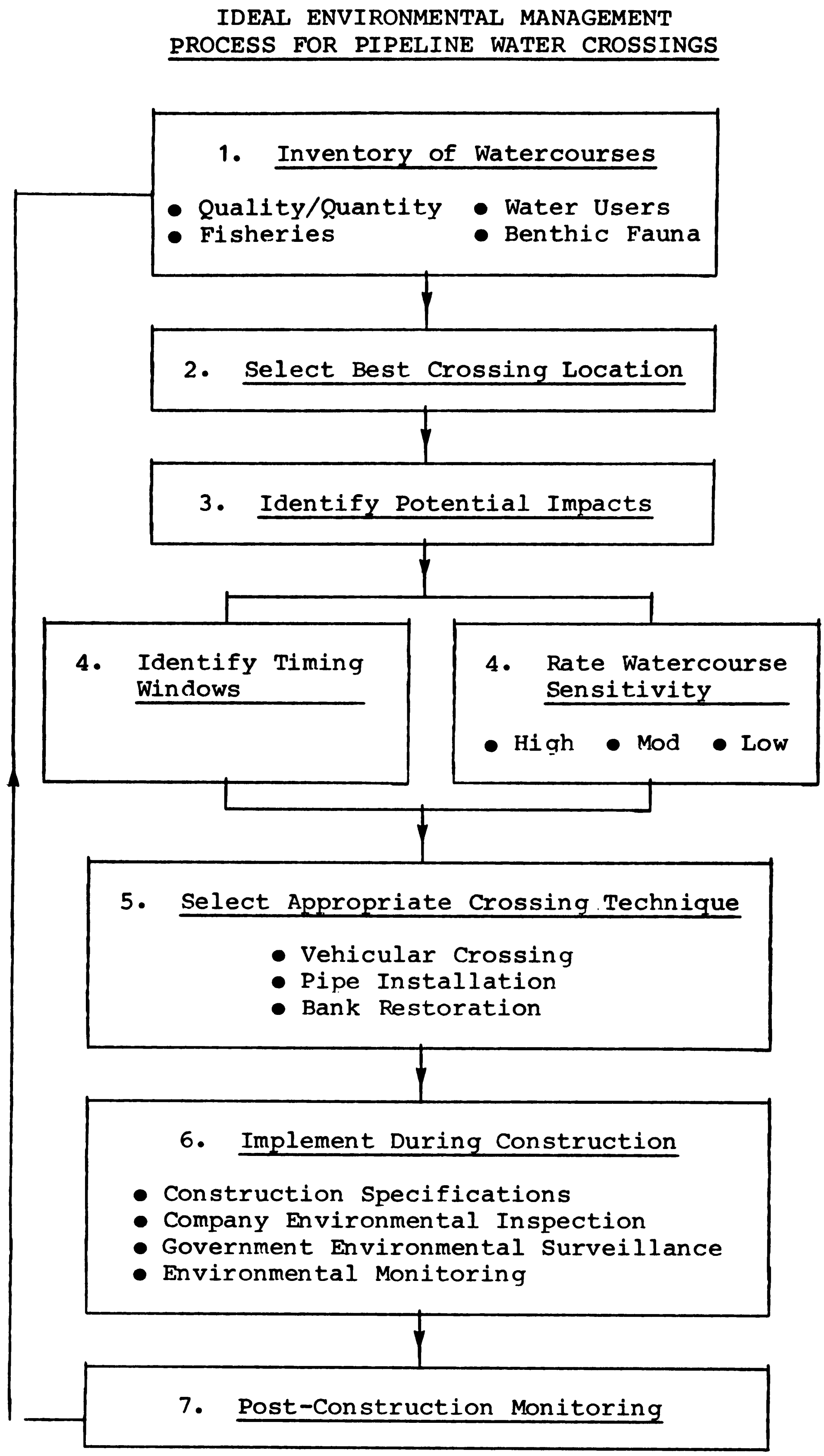

Figure 1. Ideal environmental management process for pipeline water crossings.

TABLE 1

EVALUATION OF VEHICULAR CROSSING METHODS

METHOD	DESCRIPTION AND USE	SEDIMENT LOADING POTENTIAL	ADVANTAGES	DISADVANTAGES	CONSTRUCTION FACTORS		EVALUATION			
					Relative Cost	Applicability	Recommended Application for Watercourse Sensitivity			Comments and Improvements
							Low	Mod.	High	
1. Fording	Driving equipment across streambed. Most commonly used	High unless gravel bed, then low.	- Fast. Usually facilitates construction. - Inexpensive.	- Repeated trips may cause excessive sedimentation from disturbance of bed and rutting of approach slopes. - Use by rubber-tread vehicles may be limited, particularily if water level rises.	Low	Shallow watercourse with solid bottoms, low banks	Yes	No (If gravel Yes)	No (If gravel Yes)	Minimizing number of trips and gravelling streambed and approach slopes can reduce sediment loading. Use washed gravel. Rip rap banks to avoid erosion.
2. Swamp Mats	Logs or ties cabled together to form a platform similar to a raft. Used occasionally.	Low - Mod.	- can use local materials - moderately fast and easy to construct - portable - minimizes disruption to banks	- Grading for setting in may destroy banks - Deteriorate and break up over time - Susceptible to washout and blocking flow	Low	Watercourses <20' wide, 2' deep, solid bottom, low banks	No	Yes	Yes	Minimizing number of trips and ramping with washed gravel (not fill) can extend life. Ensure swamp mat large enough to accommodate all vehicles.
3. Culvert (flume)	Direct flow through culvert(s) laid in streambed perpendicular to pipeline. Build ramp over top. Used occasionally.	Low	- Minimal sediment - maintains flow - minimizes timing constraints	- requires special materials - Susceptible to washout - heavy traffic can crush - Potential problems with icing up in winter or blocking fish migration if improperly installed.	Low to Mod.	Limited to flows <100 cfs or depths greater than culvert	No	No	Yes	Set up culvert with sand-bags (not fill). Construct ramp with washed gravel (not fill).
4. Ice Bridge	Drive equipment across ice stengthened by ploughing snow and flooding. Used extensively on northern projects	Low	- Minimal sediment - Use local materials	- slow and susceptible to winter thaw - potential safety hazard	Mod. to High	Northern winter construction. Ice thickness of >15 inches	No	No	Yes	Prepare contingency plan for winter thaw. Use logs to reinforce ice bridge rather than fill. Prepare approach to avoid erosion.
5. Temporary Bridge	Install a temporary bridge (eg. Bailey Bridge, pre-fab) Used occasionally	None - Low	- Minimal sediment - Resistent to washout - portable	- requires special materials - Moderately slow - grading for setting in may disturb banks	High	Spanable watercourses	No	Yes	Yes	Minimize grading of banks. Span bridge from bank to bank.
6. Existing Bridge	Use existing bridge off right-of-way. Commonly used on larger rivers where road access is good	None	- no sediment	- requires considerably more travel for vehicles and potentially complicates construction process	Depends on distance	Large watercourses. Existing bridge nearby	No	Yes	Yes	

TABLE 2

EVALUATION OF PIPE INSTALLATION METHODS - WET CROSSINGS

METHOD	DESCRIPTION AND USE	SEDIMENT LOADING POTENTIAL	ADVANTAGES	DISADVANTAGES	CONSTRUCTION FACTORS		EVALUATION			
					Relative Cost	Applicability	Recommended Application for Watercourse Sensitivity			Comments and Improvements
							Low	Mod.	High	
1. Wheel Ditch	Ditch through watercourse with ditching wheel. Used commonly on smaller watercourses in western Canada.	High	- Fast and facilitates construction.	- Maximum sediment - Potential problems with: • R/W grading destroying banks; • spoil pile blocking flow; • trench sloughing in if open too long	Low	low-banks, flat terrain	Yes	No	No	Not a recommended technique but could be acceptable in low sensitivity watercourse with low flow, and low banks. Not practical if rocky substrate.
2. Hoe Ditch	Ditch through watercourse with backhoe. Most commonly used.	High (Max. values of 6074 mg/l S.S. conc. 30,200 kg/hr T.S. load recorded at crossing in 1979.	- Fast and facilitates construction	- Maximum sediment	Low	Shallow watercourses with diggable substrate, solid bottom, gentle or moderate current	Yes	No	No	With gravel substrate sedimentation minimized. Delay excavation as long as possible. Retain hard plugs at banks as long as possible. Don't wade in stream if reach of hoe permits. If backfill unsuitable, cover surface of ditch with gravel.
3. Hoe Ditch with downstream sedimentation control	As above but install downstream sediment control devices, eg. sand bag dams, straw bales, filter fabric. Used occasionally.	Moderate to High	- Minimizes movement of sediment	- Moderate - Maximum sediment - Requires wide ROW and excessive terrain and downstream disturbance - settled sediment difficult to remove and usually washed downstream - Susceptible to washout - backs water up trench causing sloughing of trench - potential barrier to fish	Mod.	Shallow watercourse (max. 5') moderate current	No	Yes	No	Generally not a recommended technique because marginal gains in reducing sediment are offset by disadvantages and cost. Additional research and development of sediment control devices required. In certain situations this technique can be very effective. However before construction commences details on location of sediment traps, settling ponds must be determined. Determine when traps should be removed.
4. Dragline/clam	Excavate trench with dragline or clam working from either bank (possibly yoyo fashion) Used occasionally on marshy crossing or larger crossings where backhoes cannot reach	Moderate to High	- Equipment does not wade in watercourse	- Slow and susceptible to trench sloughing	Mod.	Watercourses with fine textured substrate or where backhoe can't reach	Yes	Yes	No*	*Not recommended but no other method may be practical due to applicability factor.
5. Blasting	Blast trench with explosives. Common wherever bedrock occurs	Low to High	- None	- Potential for direct mortality to fish through shock waves - potential barrier to fish	High	Can be done under most conditions	Yes	No*	No*	*Not recommended but no other method may be practical due to applicability factor. If blasting required consider diversion to blast in dry streambed Schedule blasting to aim for appropriate "windows", use lower or delayed charges, bubble curtains.

TABLE 3

EVALUATION OF PIPE INSTALLATION METHODS - DRY CROSSINGS

METHOD	DESCRIPTION AND USE	SEDIMENT LOADING POTENTIAL	ADVANTAGES	DISADVANTAGES	CONSTRUCTION FACTORS: Relative Cost	CONSTRUCTION FACTORS: Applicability	EVALUATION: Recommended Application for Watercourse Sensitivity: Low	Mod.	High	EVALUATION: Comments and Improvements
1. Dam upstream	Block flow upstream and cross in dry downstream. Once used extensively on smaller watercourses.	Low (Possibly higher when dam broken)	- Fast and facilitates construction. - Minimal sedimentation from trenching - No trench sloughing	- Upstream flooding and susceptible to washout - Direct mortality of fish in dried up channel downstream - Blocks fish migration - Loss of water supply to downstream users - Problems of dam removal	Low		No	No	No	Not a recommended technique under any circumstances.
2. Dam Upstream and Pump Around	As above but pump flow across ROW. Dam downstream end. Used occasionally.	Low	- Minimal sediment	- Susceptible to washout - Blocks fish migration - Dries up short reach of streambed	Mod.	Smaller watercourses	Yes	Yes	Yes	Set up dams with sand bags (not fill). Ensure that pumps are sufficiently large to accomodate flow. Protect hoses.
3. Fluming	As above but direct flow through culvert(s) laid in streambed perpendicular to pipeline Dam downsteam end. Pump out water. Recently coming into common use. N.B. This is the same as #3 on Table 1 except flume is extended to lie over trench.	Low	- Minimal sediment	- Moderately slow and susceptible to washout - Dries up short reach of streambed - Potential barrier to fish migration - Potential icing problems in winter - Flume pipe can be crushed or become blocked	Mod.	Limited by amount of flow capable of being directed through flume pipe while permitting trenching and laying in underneath. Maximum is 3 or 4 flume pipes & 100 cfs. Limited by depth of flume height. Requires solid bottom.	No	Yes	Yes	A good technique but sometimes used when not appropriate because is is widely held to be a panacea. Works best on smaller watercourses (1-2 cfs). Set up dams with sand bags (not fill) and place inlet and outlet at correct levels. Ensure flume pipe(s) is long enough to prevent undercutting of dams. Better to use steel pipe.
4. Upstream Diversion	Install pipe up to watercourse. Install upstream dam directing flow elsewhere. Dam downstream side and pump out channel. Install pipe (ditch with hoe or explosives) Redivert when complete. Occassionally used where multiple channels associated with braided streams preclude other methods.	Moderate	None	- Slow and susceptible to washout - Dries up long reach of streambed - direct fish mortality - Requires large ROW and terrain disturbance	High		No*	No*	No*	*Not recommended because of disadvantages and cost. If no other method is practical, see below. Set up dams (and dykes) with sand bags or other acceptable materials (not fill). Carry out as quickly as possible. Consider capturing fish and releasing downstream before pumping channel dry.

(cont'd)

TABLE 3 (Continued)

EVALUATION OF PIPE INSTALLATION METHODS - DRY CROSSINGS

METHOD	DESCRIPTION AND USE	SEDIMENT LOADING POTENTIAL	ADVANTAGES	DISADVANTAGES	CONSTRUCTION FACTORS		EVALUATION			
					Relative Cost	Applicability	Recommended Application for Watercourse Sensitivity			Comments and Improvements
							Low	Mod.	High	
5. Instream Diversion	Install coffer dam halfway across watercourse and pump area dry. Install pipe (ditch with hoe or explosives). Remove dam and repeat process on other side. Used occasionally.	Moderate	None	- Slow and susceptible to washout - Dries up long reach of streambed - direct fish mortality - Requires large ROW and terrain disturbances	High		No*	No*	No*	*Not recommended because of disadvantages and cost. If no other method is practical, see below. Set up coffer dam with sand bags or other acceptable materials (not fill) Carry out as quickly as possible.
6. Slip boring (horizontal drilling)	Bore underneath watercourse. Occasionally used. More common for irrigation ditches, road and railway crossings particularly large diameter pipe (> 12").	None - Low	- Minimal sediment - No disturbance of streambed - Fast under some circumstances - Maintains normal stream flow	- Slow under some circumstances - Requires large ROW and excessive disturbances and deep pit for set up. - Water disposal problem	Mod. to High	Limited by soil material and by high water table. Best in fine-textured soil (silt/clay) and low water table. Unfeasible in rocky or gravelly soils.	No	No	Yes	An excellent technique under the correct circumstances. Cost may not be prohibitive if a boring crew is already assigned to project for roads. Dewater bore pit over vegetated area or through straw bales to remove fine sediment.
7. Punching	Push punch rod under watercourse then pull pipe back through. Use as in #6 but with small diameter pipe (< 12").	None - Low	- Minimal sediment - Fast under normal conditions - No disturbance of streambed	- Difficult with till or rubble substrate - Requires bell hole which may require grading - Seepage of water in to bell hole	Mod.	Same as #6	No	No	Yes	Same as #6.
8. Aerial Crossing	Install pipeline over watercourse by building free span suspension bridge, piers, or using existing bridge. Occasionally used.	None - Low	- Minimal sediment and disturbance of streambed, floodplain, or valley slopes - Maintains normal stream flow - Avoids blasting if bedrock present	- Greater security risk to exposed pipe	Very High	Specialized situations where excessively steep valley, wide floodplain or other geotechnical and hydrological conditions warrant it.	No	No	Yes	Avoid footings in watercourse if possible.

sedimentation. The use of an existing bridge off right-of-way is very effective but increases transportation costs considerably.

Figure 2. Classification of watercourse sensitivity.*

High Sensitivity**

1. Downstream water users with treatment facilities incapable of handling increased sediment loading.
2. High quality fishery with active spawning beds or nursery habitats.
3. Cold water fishery (e.g., salmonids).
4. Construction coincides with major fish migration.
5. Rare or endangered species present at crossing.

Moderate Sensitivity**

1. Susceptible downstream water users within potential zone of increased sediment loading.
2. Medium quality fishery or nursery habitats well downstream, or with no known active spawning beds or nursery habitats.
3. Warm water fishery.
4. Construction timing coincides with minor fish migration.
5. Rare or endangered species not present or located well downstream.

Low Sensitivity

1. Watercourse with none of the above criteria.

*A watercourse is defined as any flowing water body at time of construction.
**One or more of the criteria being present.

Pipe Installation Techniques. Pipe installations can be classified as either wet or dry crossings. Generally, with a wet crossing, the trench is excavated through flowing water. With a dry crossing, a trench may or may not be excavated. If a trench is required, excavation normally occurs in the dry stream only after water flow has been controlled. Aerial crossings and bored crossings do not require a trench. Tables 2 and 3 describe and evaluate the various crossing techniques.

In using these tables, it is important to note that engineering (geotechnical, hydrological, design) and cost factors should be taken into consideration before the appropriate method is chosen. For example, the presence of bedrock may require blasting within the watercourse. In these instances, the environmental manager can only recommend the optimal time for construction and outline special protective measures such as low velocity charges or bubble curtains to reduce impact of blasting. Likewise, the crossing should not be planned in isolation from terrestrial environmental concerns. Otherwise, a few fish may be saved at the expense of extensive terrain disturbance.

The crossing technique should be kept simple and carried out as quickly as possible. The crossing should be preplanned so that all necessary materials such as flume pipe or sand bags are on site when required. The contractor should have the pipe welded up and ready for lowering in once trench is complete. In some cases, a knowledgeable environmental inspector should be on site to supervise the crossing (see Mutrie and Dorney, 1981). Actual field conditions such as unexpected presence of bedrock or greater flows may necessitate a change of plans.

Wet Crossing Methods

The normal wet crossing can potentially yield extremely high sediment loadings downstream (>1000 mg/l suspended solids) over the short-term (See Table 2). Such crossings are not recommended in watercourses of moderate to high sensitivity.

A controlled wet crossing is one where provisions are made to trap sediments downstream behind filters, check dams, and settling ponds. While these controls may be partially effective in fulfilling this purpose, the construction of such facilities may actually cause as high a level of disturbance as the crossing itself. Comprehensive in-stream sediment control is likely to result in further terrain disturbance, and even the reduction in sediment concentrations may not be sufficient to preclude ecological damage (Revill Associates, 1979). For moderate or high sensitivity watercourses it is best to minimize sedimentation at the source rather than allow it to move downstream and attempt to remove it. For low sensitivity watercourses, high sediment loadings are acceptable.

Dry Crossing Methods

Dry crossing methods are described and evaluated in Table 3. When trenching a dry crossing, methods of controlling water flow include diversions, coffer dams, and flumes. Aerial and bored crossings do not require either a trench or control of flow.

Dry crossings can yield less sediment than wet crossings but are more expensive and time consuming. They are only recommended for watercourses of moderate to high sensitivity. Fluming can potentially reduce sedimentation, but its use is limited by watercourse morphology, hydrology, and the time of year. Boring, one of the most expensive crossing methods, is also probably the most effective for reducing sedimentation. However, its use is limited by cost and substrate composition, steep approaches, and other engineering considerations.

CONCLUSION

Wise environmental management requires identification of environmental sensitivities of watercourses and matching these to a construction technique of corresponding sensitivity. Blanket application of one crossing technique will result in environmental damage in some cases and environmental overkill in others. When planning and implementing a water crossing, cooperation between environmental managers, pipeline companies, and contractors will yield greater net returns in environmental quality than the more traditional and less productive adversary approach.

Finally, the lack of credible data available on the sediment levels actually generated by different crossing techniques and the impacts on aquatic ecosystems indicates the need for further research. For example, plowing-in and directional drilling are two techniques not yet used in Canada but reported in use in the United States.

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VALUATION OF WETLANDS

Douglas L. Smith[1]

ABSTRACT.--A methodology for assessing wetland functional values has been developed by FHWA providing State highway agencies and anyone else with a means of assessing the value of a specific wetland for all of the principal functions it might provide. It provides a method of assessing the potential impact of a project on a wetland and a means of determining the type of mitigative strategies which might be the most cost effective. Most importantly, however, it provides a means of thoroughly documenting the decisions which are made, showing exactly what was considered and how it was considered. Copies of the manual will be available in June, 1983, from the Federal Highway Administration, HRS-42, Washington, D.C. 20590.

INTRODUCTION

The Federal Highway Administration (FHWA) and the State highway agencies must comply with a number of laws and regulations pertaining to the protection of wetlands. Executive Order 11990 (1) requires Federal agencies to minimize the destruction, loss, or degredation of wetlands, and to preserve and enhance natural and beneficial values of wetlands in carrying out their responsibilities.

As part of the implementation of these mandates FHWA has developed policy for "Mitigation of Privately Owned Wetlands" (2). This policy allows for certain mitigative procedures and makes available Federal-aid highway funds for the protection of wetlands through the purchase of private wetlands to replace wetlands impacted by highway construction.

A significant question which arose in the development of this policy was, how much replacement or mitigation would be allowable? The Policy (2) provides that the extent of Federal participation in mitigative measures should be directly related to the importance of the impacted wetland and the significance of the impact. However, because no acceptable method was available for adequately determining the functional values being lost or replaced, the policy allows a maximum of one to one replacement based upon acreage.

As a result, while highway agencies support the intent of the regulations protecting wetlands, occasionally conflicts develop over the value of a

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wetland, or the costs involved in protecting or mitigating losses to the wetland. The State highway and regulatory agencies need a reliable method for assessing wetland values in order to protect valuable wetlands while providing safe, efficient transportation at a reasonable cost.

FHWA contracted with the Center for Natural Areas, South Gardner, Maine, to develop a procedure to evaluate individual wetlands and wetland functions. It is anticipated that the methodology will be available in June of 1983 as a two volume manual. The methodology will provide a way of evaluating individual wetlands to determine (1) their value based upon their ability to perform specific functions, (2) the possible impact of a highway (or any other type of development) on these functions, and (3) the cost effectiveness of different mitigative strategies.

With such a tool, State highway agencies can evaluate individual wetlands. They can determine the values of a wetland, make decisions concerning the amount of disturbance the wetland might be able to tolerate, and the type of mitigation that can best restore its functional values.

The methodology utilizes the U.S. Fish and Wildlife Services's (FWS) wetland classification (3) and considers most of the many functions a wetland may perform. The functions considered are ground water recharge, ground water discharge, flood storage, shoreline protection (erosion control), sediment trapping, nutrient retention and removal, food chain support, fish habitat, wildlife habita, active recreation, and passive recreation and heritage value. The methodology is also designed to be applicable for all wetland types found in the lower 48 states.

The methodology specifically avoids assignment of monetary values to wetlands or wetland functions. The current state-of-knowledge on wetlands is not adequate to support this type of valuation approach. Instead, procedures are provided for ranking wetlands high, medium, or low according to their ability to perform each of the above functions. Determinations are made of the wetlands overall functional value, and the possible impacts to the wetland.

The first volume of the methodology will be a detailed critical review of the literature concerning wetland functions. Volume one will also contain support data beneficial to conducting the assessment, and "case studies" which illustrate the use of the assessment procedure. Volume two will be the assessment procedure.

Relationship to Other Procedures

In developing the methodology, approximately 30 other procedures were reviewed. The Federal Highway Administration did not only want to add one more procedure to the list, but wanted to build upon what had already been accomplished. None of the procedures reviewed could be used by all of the highway agencies. We needed a methodology applicable for all types of wetlands, and under as many situations as possible. Also, the methodology had to be easy to use.

Most important, however, was that the methodology be as technically sound as possible which was essential, so that it would be acceptable to everyone involved in making decisions affecting a wetlands. Representatives from the Environmental Protection Agency and the FWS participated in the selection of a contractor and reviewing the methodology as it developed. The methodology is also being reviewed by other Federal and State agencies.

Use of the Methodology

At first glance, the methodology appears very time consuming and inhibiting. In fact, it is not. It is similar in operation to a taxonomic key or decision-tree process. It can provide estimates of wetland functional values based upon detailed investigations, brief site visits, or simply an office review of topographic maps and other basic references. The level of effort will determine the reliability of the results. However, with only an office level evaluation, meaningful results can be obtained.

The methodology is composed of three separate procedures whose application depends upon the user's objective. Figure 1 illustrates the use of the methodology for conducting a wetlands assessment.

Procedure I is a "Threshold Analysis" which is used to determine if an individual wetland is of high, medium, or low importance for specific functions. It ia also used to determine if a replacement wetland or other type of mitigation will acceptably perform the same functions.

Procedure II is a "Comparative Analysis" which will provide greater sensitivity in ranking wetlands. This procedure will allow the user to make a finer distinction between two wetlands when the initial analysis indicates they are of equal functional value. Like Procedure I it requires data on the wetlant, highway design, and highway routing.

Procedure III, "Mitigation Cost Analysis," is used to make decisions concerning the cost effectiveness of various mitigative alternatives. In addition to technical data, Procedure III requires information on the projected costs of the alternative mitigative features.

The first step in determining the value of a specific wetland (Procedure I) is to develop a data or information base for the wetland (Figure 2). This is accomplished by utilizing three forms: A, Functional Opportunity and Effectiveness; B, Functional Significance; and C, Impact Evaluation.

Form A is used to determine a wetland's functional opportunity and effectiveness. This is a wetland's ability and effectiveness in performing a particular function or service. Form B looks at the significance of the function. How much is the particular function valued? This is partly reflected by its scarcity. Form C focuses on the actual impact of the highway on the wetland. It deals with information such as location, design, erosion potential, and the types of biological communities which may be impacted.

These forms have a series of yes/no questions grouped according to the data required. A wetland evaluation can be made using any of three data types: office data, cursory field visits, and detailed field data. It is possible to conduct an evaluation without completing all sections.

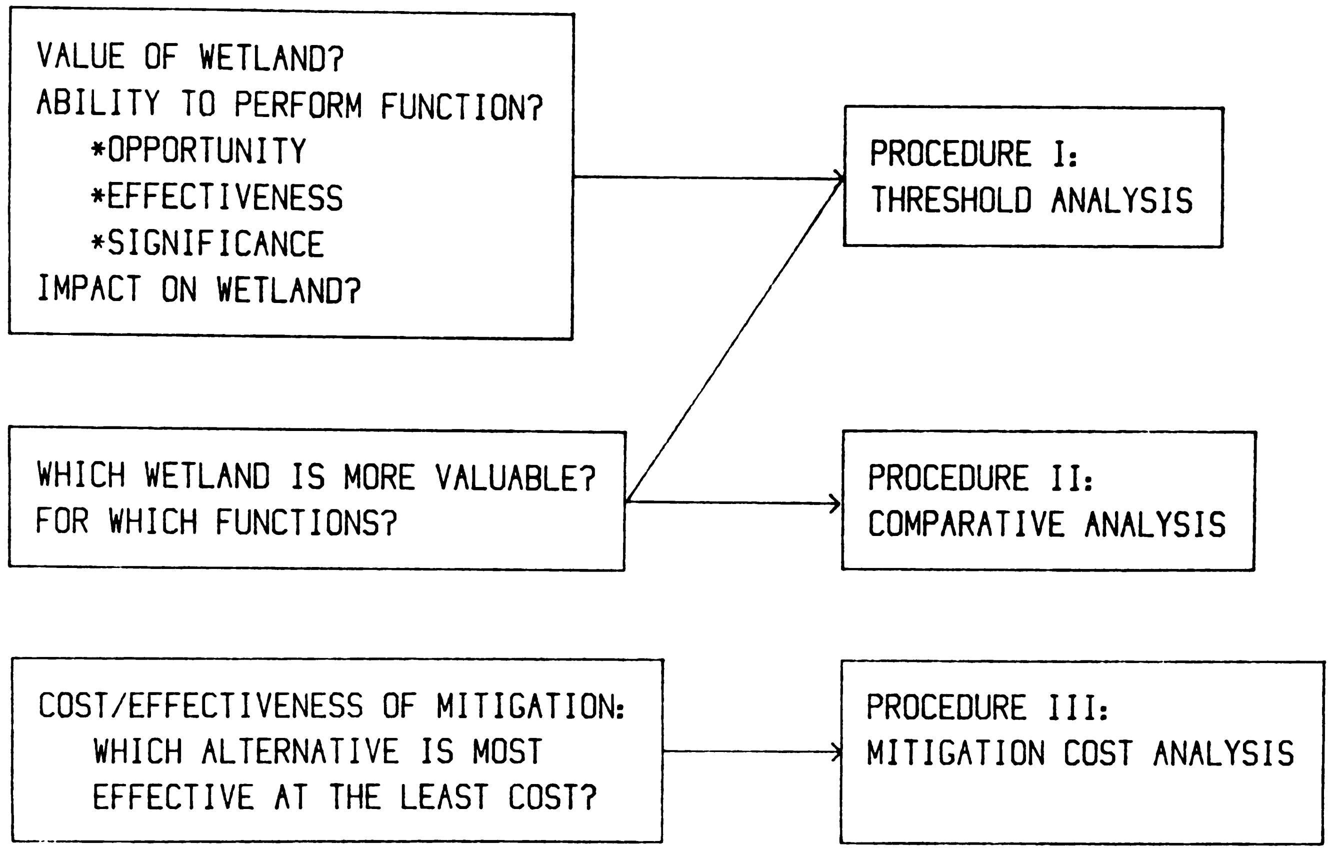

Figure 1: Selection of Procedures

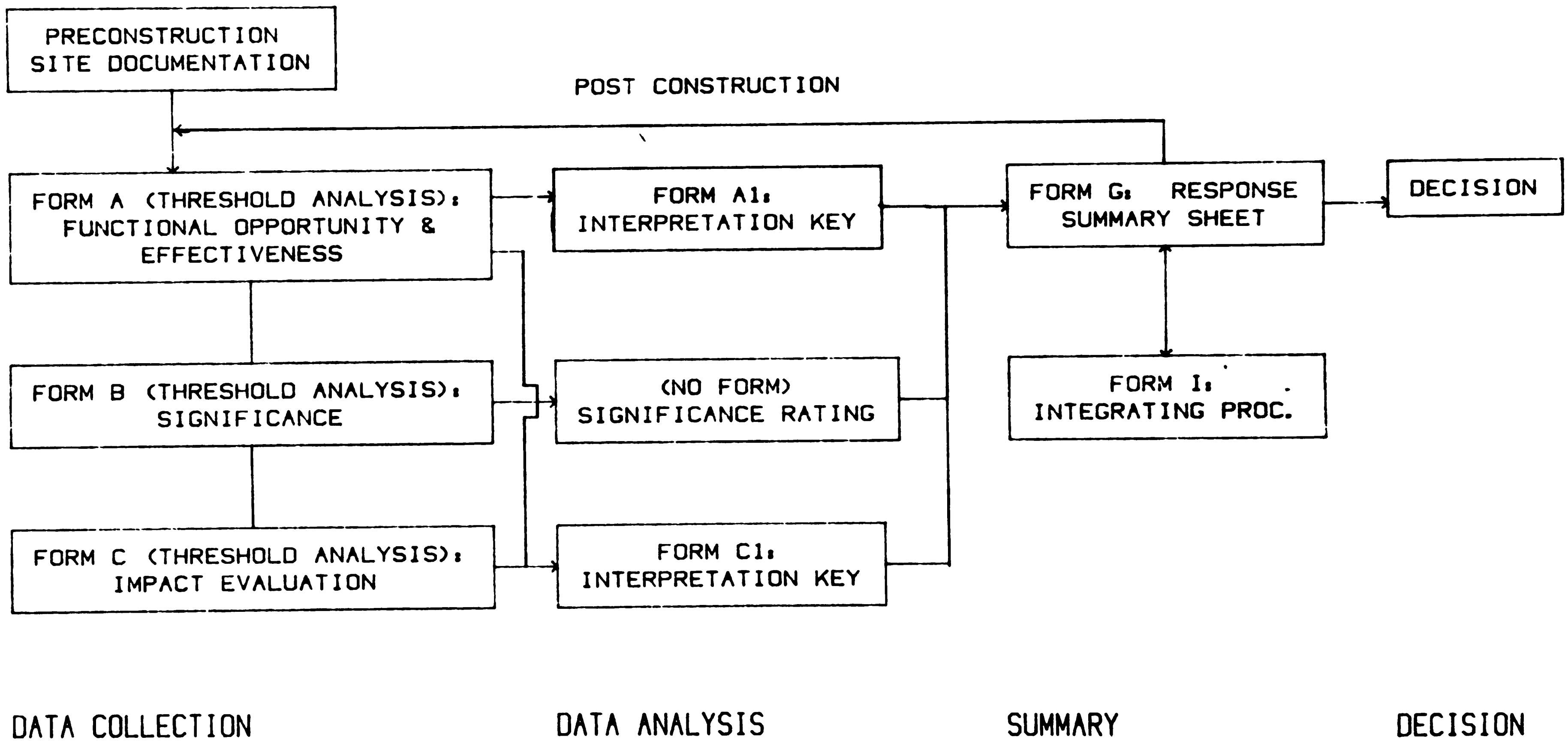

Figure 2: Steps in conducting "Threshold Analysis", Procedure I

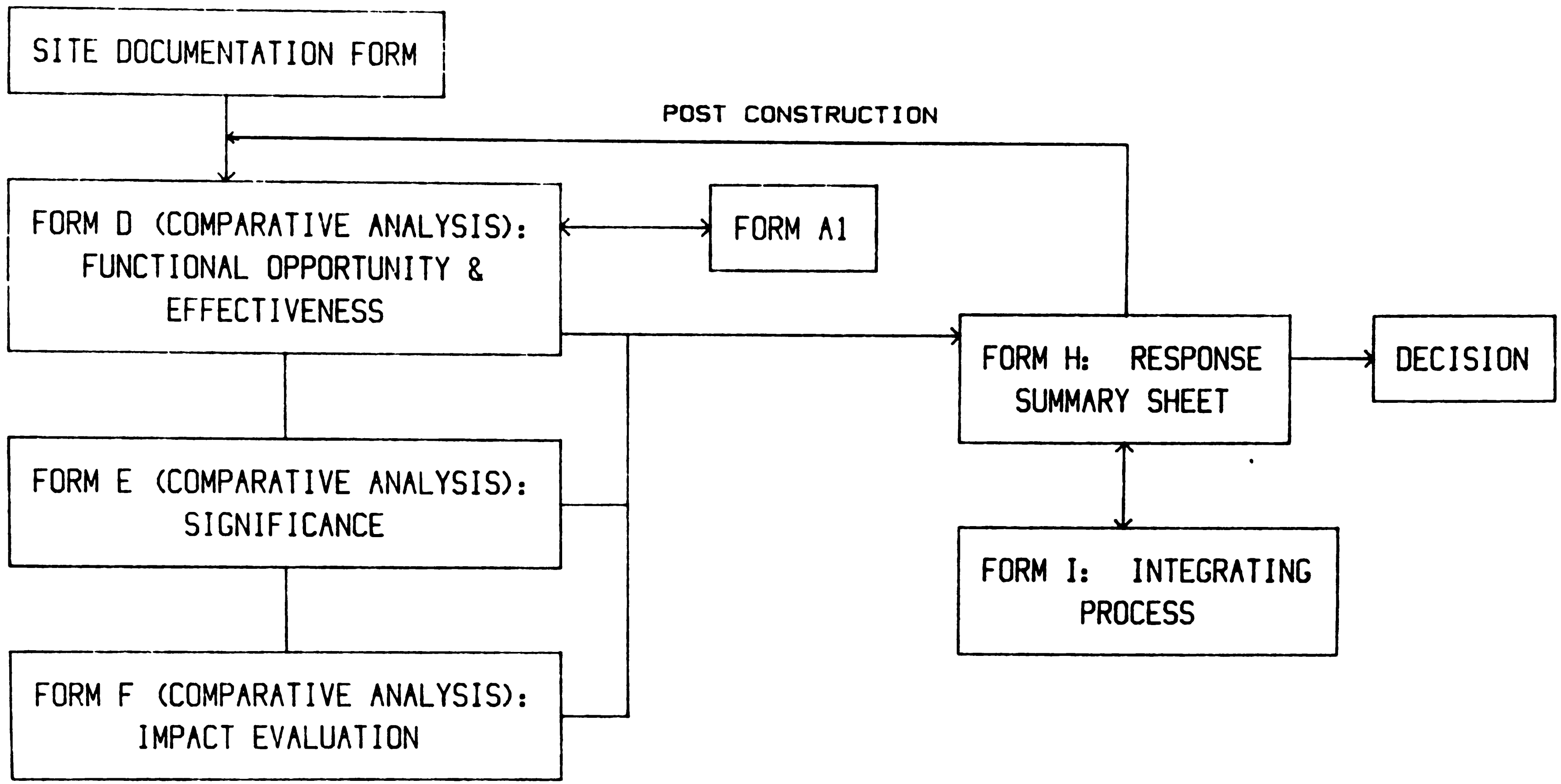

Figure 3: Steps in conducting "Comparative Analysis". Procedure II

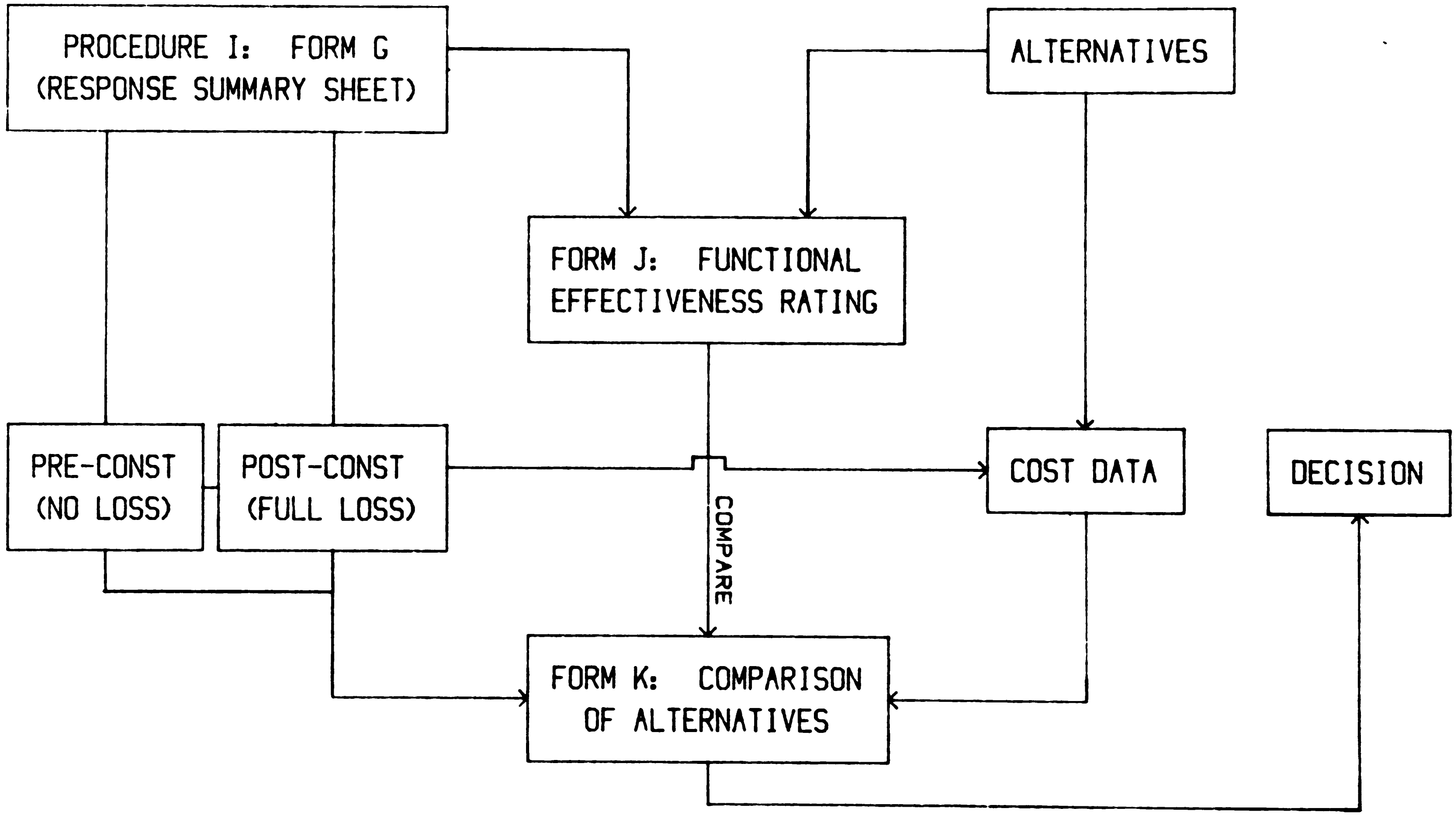

Figure 4: Steps in conducting "Mitigation Cost Analysis", Procedure III

After answering the questions, the information is analyzed utilizing two interpretation keys and the results are recorded on a summarization sheet. With this procedure, the user is carried step by step through a decision process.

Procedure II (Figure 3) also begins with three forms on "Functional Opportunity and Effectiveness," "Functional Significance," and "Impact Evaluation." The questions are derived from Forms A, B, and C. In this procedure wetlands are compared against each other (e.g., which has the largest basin). The answers are integrated and recorded, and again the user is carried step by step through the analysis.

Like the other two procedures, Procedure III (Figure 4) has its own set of forms for comparing the cost effectiveness of mitigation. To conduct the "Mitigation Cost Analysis" it is necessary to first complete Procedure I, "Threshold Analysis." Information on the pre and post construction values are recorded as "no-loss" and "maximum loss," respectively. Information on the effectiveness of mitigative alternatives and their costs are recorded and compared. The procedure allows an orderly comparison of all of the benefits gained and costs. A decision can be made to strike a balance between costs and functional gain.

By going through the above analyses, the user will be able to determine whether a particular wetland performs a certain function or service, how well it does so, if a project will impact the performance of that function, or if mitigation will be effective. Any wetland analysis may use all or part of this methodology. This is determined by the objectives of the analysis. Most importantly, the methodology documents any decisions that are made and shows the criteria used to make the decision.

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WILDLIFE MANAGEMENT

Kent Schreiber, Session Chairman

RAPTOR UTILIZATION OF POWER LINE RIGHTS-OF-WAY IN NEW HAMPSHIRE

James E. Denoncour[1] and David P. Olson[2]

ABSTRACT.--The purpose of this study is to determine which species of raptors utilize power line rights-of-way (ROWs) in New Hampshire and what their activities are. The red-tailed hawk (Buteo jamaicensis) and the American kestrel (Falco sparverius), both open land species, utilized the wide transmission ROW exclusively. Broad-winged hawks (Buteo platypterus), the most abundant species in the state, and other forest raptors were absent from the transmission line study area. ROWs serve as permanent openings in the forest environment. Utilization by open land raptors appears to increase with line width and proximity to other open habitat. Power line ROWs are used as hunting, nesting, and perching areas, and migrating corridors for young red-tails prior to the autumn southward migration. Transmission line structures were used as nesting platforms. This activity has increased over time and has spread out from earlier nest sites indicated learned behavior. American kestrel avoidance reactions to the helicopter caused an underestimate of ROW use by this species.

INTRODUCTION

Most studies of power line management have dealt with vegetative control and general interaction of wildlife with these chemically controlled, relatively stable vegetative communities. Most raptor studies on power line rights-of-way (ROWs) have been in the western United States, where they concentrated on raptor electrocution and raptor-induced power outages (Miller et al. 1975, Nelson and Nelson 1976).

The power line ROW has been studied as an edge habitat in a forested environment in New Hampshire (Cavanagh et al. 1976). The width of power lines as they relate to bird populations was anlayzed by Anderson et al. (1977). The cleared ROW functions as a permanent opening in a forested ecosystem and as such is a unique vegetative community making substantial contributions to the overall diversity of an area. Its character and quality for wildlife habitat result from a combination of vegetation,

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species composition, clumping of vegetation, juxtaposition to other upland and lowland communities, distance to disturbance factors, and line width.

Eighty-six percent of New Hampshire is forested (Kingsley 1976). This percent of forest cover has remained stable over the last 25 years even though 27% of the agricultural land since the 1950s has gone out of production and the state has experienced a tremendous increase in personal home and other types of development (Coppelman et al. 1978). Loss of open habitat to development and natural succession impacts open land species. The approximately 22,000 acres of New Hampshire's power line ROWs contribute a major portion of permanently open habitat and therefore play an important role in the distribution of species such as the red-tailed hawk and the American kestrel.

This paper outlines basic raptor utilization of a power line ROW in a forested environment and makes general management recommendations.

METHODS

Description of Study Area

The ROW selected for this study was the 15 Mile Falls/Tewksbury Line consisting of the A-201 and B-202 lines. The line was constructed in 1929 and is managed by the New England Power Company. It is a 230 kV transmission line with steel towers and ROW clearing limits of 350 feet. The line runs from the Comerford Substation located in Grafton County, Monroe, New Hampshire, to a substation in Middlesex County, Tewksbury, Massachusetts. The line bisects the southern two-thirds of New Hampshire in a northwest to southeast direction, cutting through all major forest types in the state (Fig. 1). Along the course of the line, all types of land use are encountered, from major urban development around Manchester, New Hampshire, to agricultural and remote forest land. Topography is gently rolling in the south to very rugged in the more northerly sections. The line vegetation has been managed with herbicides for several decades and is a relatively stable grass, sedge, fern, forb, and shrub mixture with few tree species.

Raptor Observation Procedures

A Bell piston-driven helicopter was used to make observations of ROW use by raptors. Eleven flights made from June 1976 to June 1977 were part of the routine line patrol and were scheduled to accommodate raptor phenology. Five flights began at the Tewksbury Substation at the southern terminus of the line and went north to the Comerford station. On June 28, 1976, the authors returned south of the study line in an attempt to eliminate the bias of viewing the same portions of the line at the same time of day. Ten flights were made on New England Power lines; one additional flight was made on a Public Service Company of New Hampshire line. For each observation on all flights, the following data were recorded: time, pole number, species of raptor, male or female kestrel, juvenile or adult red-tail, adjacent forest type, and whether the distance was more or less than one-quarter mile to other cleared land.

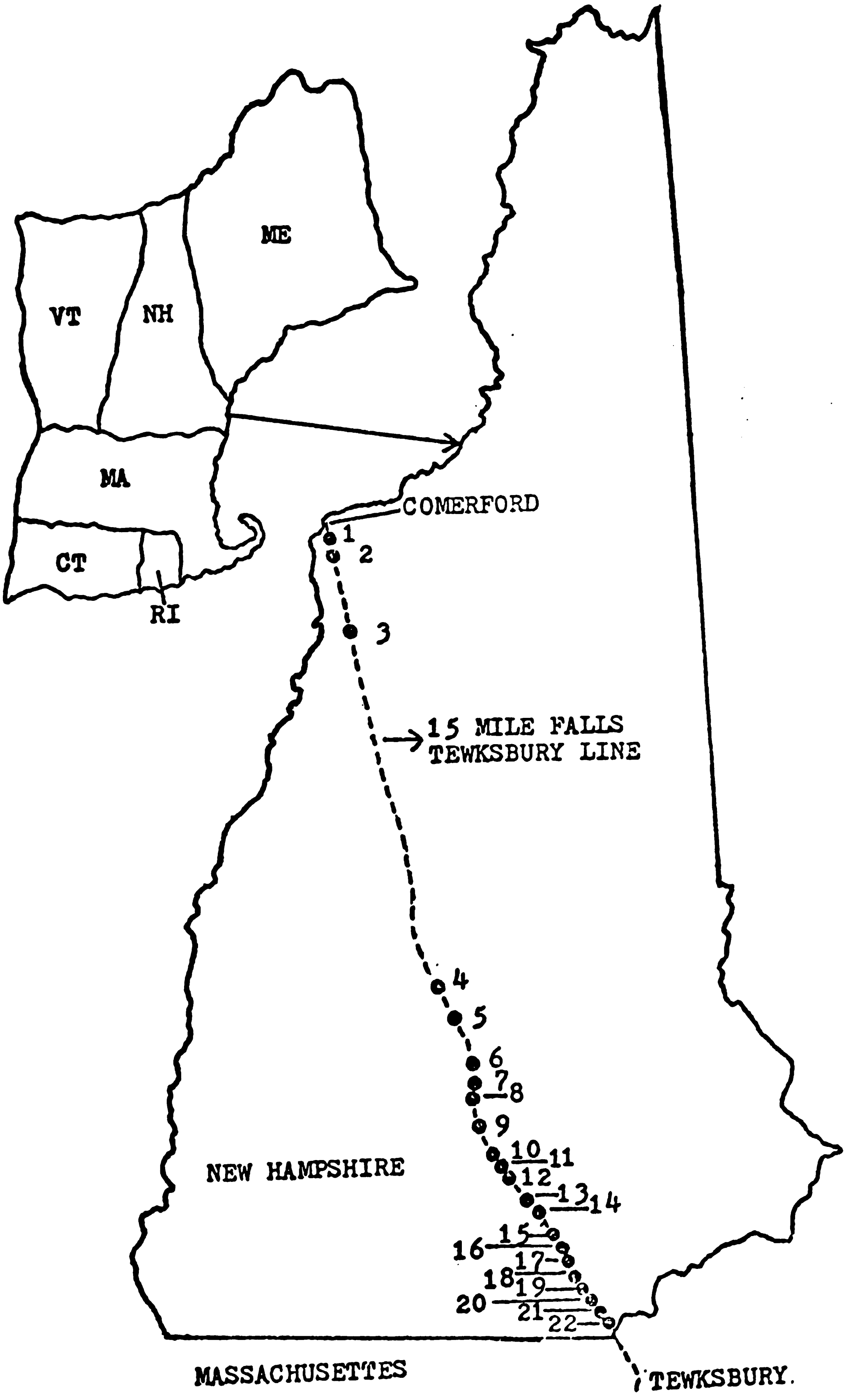

Figure 1. Location of the study line in New Hampshire and the activity centers 1-22.

Areas of high use were determined by sighting hawks on three or more of the six flights and all nest sites. Areas of little or no use were also selected. Twenty-two sites on the Falls/Tewksburg Line were selected for analysis and are called "activity centers" throughout this paper (Fig. 1). Four of these sites were red-tailed hawk nesting sites; five sites showed no activity; and other sites favored either red-tails or kestrels, or were used by both. Areas of no activity were selected near areas of activity to attempt to define differences in habitat desirability. The paucity of raptor sightings on the ROW in the north central part of the line ruled out this area for selection of high-use or no-use sites. The combination of dense forest cover and lack of cleared land, other than on the ROW, appears to exclude open land species of raptors. Additional observations of raptor activity were made during extensive amounts of field time while mapping line vegetation and measuring habitat parameters.

Vegetative Management

Vegetative cover maps of the study area were made for each of the 22 activity centers. For consistency, the pole number from the B-202 line was used for all sites. Plots began in the middle of the ROW adjacent to the pole number identifying the site and were 20 feet wide, running one-quarter mile in each direction down the center line. Vegetation was mapped by communities of grass/sedge, fern, forbs, or shrubs, and by height categories to further sensitize the analysis of the line's vegetative structure. A diagonal grid was used on each 20 ft by 20 ft section of the line vegetation map after Baxter and Wolfe (1972). The method was weighted so that when a vegetative type line or height difference was crossed, a point was given, but an extra point was added if a height and type change occurred simultaneously. This measure was used to estimate edge, interspersion, and overall diversity.

Vegetation adjacent to the ROW was analyzed from aerial photos. The center of the vegetative plots was used as an interpretation center point for the photo analysis. The vegetation was measured by the categories: tree cover, shrubs, fern/forb, and pasture, and grass or cropland. The latter three are treated as a single type and were measured for a radius of one-half mile and one mile from the activity center. Each activity center was then ranked by the percent occurrence in each category. Other parameters measured and ranked included the most water, the most edge (Fried 1975), and the distance to disturbance factors, such as roads, buildings, or industrial sites. The disturbance factors were used to rank the magnitude of possible human interference with raptor activity. The ranked vegetative parameters were compared to a ranked distribution of raptor usage by Rank Correlation Tests (Sokal and Rohlf 1973) (Table 1).

RESULTS

Raptor Observations

During six flights 182 raptors were seen perched, nesting, or soaring within the clearing limits of the study line. Red-tailed hawks and American kestrels were the two primary species observed. Their need for the open habitat apparently makes the larger power lines important to them

Table 1. Ranking of 17 site variables for red-tailed haw usage and American destrel usage for 22 locations on a transmission line ROW in New Hampshire.

		Vegetation Adjacent to ROW						ROW Vegetation										Dist.[a] Index
		1/2-Mile Radius			1-Mile Radius													
Site No.	Pole No.	Tree Cover	Shrub Cover	Grass Past.	Tree Cover	Shrub Cover	Grass Past.	Most Div.[b]	Most R-T[c] Use	Most K[d] Use	Most Grass Sedge	Most Fern Forb	Most Grass Fern Forb	Most Trees	Most Shrub	Most Water	Most Edge	
1	44	2	15	2	2	19	20	11	19	17	4	13	6.5	15	18	17	8	21.5
2	63	7.5	21	8	4	21	14	2	15	17	2	22	12	14	7	17	1	9
3	130	5.5	19	13	9	21	10.5	20	9	4.5	1	19	2	21	20	9	14	21.5
4	585	18	1.5	17	5	17.5	17.5	13	9	4.5	8	20	17	12	5	3	16	17
5	626	15	4.5	4	20	2	3.5	10	15	9	17	6	12	16	6	7	5	9
6	694	20.5	5	16	14	1	19	4	15	1	6	15	8.5	7	12	8	2	18
7	719	13	9.5	14.5	17.5	11	5	19	15	17	5	10	5	19	13	17	18	15
8	755	11	17	2	14	6	9	8	15	2	11	1	1	20	19	17	4	13
9	765	19	3	10.5	6	15	17.5	17	15	17	9	5	3	17	21	17	6	9
10	811	16.5	6	9.5	10	6	14	22	9	17	22	4	17	22	17	1	22	13
11	830	3	17	18.5	8	15	10.5	15	15	9	13	11	17	11	4	5	17	16
12	843	20.5	1.5	14.5	17.5	3	12	12	6.5	17	20	2	6.5	18	14	17	11	4
13	870	22	4	1	22	6	1	18	15	9	3	18	10	8	10	6	19	4
14	887	16.5	9.5	3	21	6	2	17	6.5	17	15	3	4	3	16	10	16	2
15	943	5.5	11.5	21	1	21	22	5	3	3	7	12	8.5	6	11	17	13	19.5
16	953	1	21	21	3	15	21	1	4.5	9	19	17	21	5	1	17	13	19.5
17	961	14	7	5	11	4	14	3	15	9	18	9	19	5	1	17	3	19.5
18	985	4	14	10.5	12	9	8	9	1	17	12	8	12	2	9	17	6	13
19	1001	9	17	6	14	11	6.5	16	15	17	14	16	20	1	8	4	11	1
20	1017	7.5	21	7	7	10	14	14	2	6	10	14	14	10	15	17	21	6
21	1041	11	13	9.5	14	11	6.5	21	15	17	21	21	22	9	22	2	20	9
22	1062	11	8	11.5	9	17.5	3.5	6	4	9	16	7	15	13	2	17	12	4

[a] Lowest numerical value indicates highest disturbance potential.
[b] Diversity value calculated from Baxter Wolfe 1972
[c] Red-tailed hawk
[d] American kestrel

while other raptors in New Hampshire are forestland and edge species. The number of observations for the six flights on the 15 Mile Falls/Tewksbury Line by species were

Date	Red-tailed hawk	American kestrel
6/28/76	16	11
6/29/76	9	10
8/3/76	26	59
2/14/77	4	0
4/11/77	17	5
6/29/77	15	10
	87	92

There were 72 observations of raptors in the 22 activity centers chosen for analysis of raptor usage (Table 2).

Few species of raptors other than red-tailed hawks and kestrels were found on the ROWs. One broad-winged hawk was observed soaring over a 100-foot ROW. Since birds outside of the ROW clearing limits were not counted, broad-wings--the most abundant raptor in the study area, but a forest dwelling species--were seldom recorded. The edge of the ROW is undoubtedly an important hunting area for this species, but the broad-wing's habit of perching under the canopy of trees and waiting for prey would make it very difficult to observe them from the air. A pair of broad-wings was observed hunting the edge of a 150-foot power line while making ground observations. They perched just inside the edge of the opening and waited for periods of from 5 to 20 minutes. They would then change stations, sometimes quickly flying across the power line to the other edge. A barred owl (Strix varia) was observed perched along the edge of a 100-foot ROW in February 1977. There was a heavy snow storm at the time, so the bird was hunting in mid-afternoon; this was the only owl seen during the study. Owls undoubtedly utilize the edge of the ROW as a hunting area during the night.

There was some separation of American kestrel and red-tailed hawk activity centers. Kestrels predominated in the northern portions of the line where small diary farms provided additional open habitat. The small pastures and open areas are not large and are probably not extensive enough to provide prime red-tailed habitat with the ROW. The higher frequency of red-tail use on the southern end of the line seemed to be influenced by the abundance of other open lands, the high visibility of the power pole perch sites, which were normally higher than the surrounding forest canopy, and the isolation of these perches from human activities.

American Kestrel

Kestrels were the most abundant raptor during this study, but this fact could be misleading, since 59 sightings were on one flight in August 1976. This was due to observations of family groups hunting and perching along the power line. In midsummer, when the young fledge, there are abundant grasshopper and small rodent populations in the ROW. Also, hayfields near the brood rearing areas were mowed for hay. This increased

Table 2. Raptors observed during aerial surveys at selected activity centers on the 15 Mile Falls-Tewksbury line from June 1976 through June 1977.

Site No.	Pole No.	6/28/76 R-T	6/28/76 K	6/29/76 R-T	6/29/76 K	3/3/76 R-T	3/3/76 K	2/14/77 R-T	2/14/77 K	4/11/77 R-T	4/11/77 K	6/19/77 R-T	6/19/77 K
1	44	-	-	-	-	1	-	-	-	-	-	-	-
2	63	-	-	-	2	1	-	-	-	-	-	-	-
3	130	-	-	-	-	1	3	-	-	-	-	1	-
4	585	-	-	1	-	1	1	-	-	-	-	1	-
5	626	-	-	-	-	-	1	-	-	-	1	-	-
6	694	-	1	-	-	-	5	-	-	-	1	-	-
7	719	-	-	-	1	-	2	-	-	-	-	-	-
8	755	-	1	-	2	-	3	-	-	-	-	-	-
9	765	-	-	-	-	-	1	-	-	1	-	-	-
10	811[c]	-	-	-	-	-	1	-	-	1	-	-	-
11	830	-	-	-	-	-	-	-	-	-	-	-	-
12	843	-	-	-	-	1	1	-	-	1	-	1	-
13	870	-	-	-	-	-	-	-	-	-	-	-	-
14	887	1	-	-	-	1	1	-	-	-	-	1	-
15	943	-	1	1	-	2	4	-	-	1	-	-	-
16	953[c]	-	-	1	-	-	1	-	-	1	-	-	-
17	961[c]	-	-	-	-	-	1	-	-	-	-	-	-
18	985[c]	1	-	-	-	2	-	-	-	1	-	2	-
19	1001	-	-	-	-	-	-	-	-	-	-	-	-
20	1017	2	-	-	-	2	-	-	-	2	-	-	-
21	1041	-	-	-	-	-	-	-	-	-	-	-	-
22	1082	1	-	1	-	-	1	1	-	1	-	1	-
Species Total		5	3	4	5	12	25	1	0	8	1	7	1
Total Raptors		8		9		37		1		9		8	

[a]Red-tailed hawk

[b]American kestrel

[c]Structures with nests

local disturbance and disruption of food availability could cause the small falcons to utilize the power line as late summer habitat. Many stoops by kestrels were witnessed during field work, and insect catches made up the majority of successful attempts.

Kestrels had a very low tolerance for the helicopter, and most were spotted in the beginnings of their escape maneuver, which usually consisted of diving from a structure or ground wire and twisting to the left or right from the path of the helicopter. Observing kestrels from the helicopter was difficult due to their brown and gray back coloration. During vegetative sampling on the ground, kestrels occurred in abundance over time in several areas, but were never detected on the aerial survey. On the ground, a greater amount of time is spent in an area, thereby increasing the chance of making an observation. We believe that kestrel numbers are consistently underestimated when counted from a piston-driven helicopter.

The data revealed no close association with the variables tested in the adjacent vegetation or in the line vegetation that could be used to predict kestrel use (Table 1). Kestrels were rarely seen more than one-half mile from hayfields, pastures, croplands, or farms. The authors believe that kestrels occur where there is other cleared land adjacent to the ROW and that the line itself is not sufficient to support kestrels. But this is not supported by the data. The large number of kestrels counted on the August 1976 flight and the difficulty in counting kestrels from the helicopter may have masked a more significant relationship with habitat variables.

Red-tailed Hawks

Red-tailed hawks were the most abundant raptor on the power line on a year-wide basis. Red-tails nest, hunt, and spend abundant time resting within the confines of the ROW under study. Observations on smaller lines, 75-100 ft wide, revealed only hunting activity by red-tails. There are many mammalian prey species on the ROW (Cavanagh et al. 1976). But, the availability of this prey on a transmission line with herbicide induced "climax" vegetation is doubtful. The rank nature of the vegetation and the extensive areas of shrubs and ferns greatly limit the area in which a red-tail might be successful in detecting and capturing prey. When hunting transmission lines, the red-tails usually sat along the edges on low tree branches where some of the larger mammals they prefer may venture into the open. Much of the remainder of the transmission line is probably not prime hunting habitat for red-tailed hawks.

Nesting by red-tailed hawks on power line structures has been documented in the West (Gilmer and Wiehe 1977), where transmission line towers are often the only platforms available or are so much higher and more numerous than the scattered trees in these arid areas that they are highly preferred sites. With the exception of ospreys, little or no mention of raptor nesting on power line structures has been documented in the Northeast. The steel towers of the study line are well suited to red-tailed hawk nesting. Although there is no apparent shortage of nesting trees in heavily wooded New Hampshire, sites out in the open with good visibility are uncommon. Dutch elm disease (*Ceratocystis ulmi*) has claimed many of the solitary American elms (Ulmus americana) that grew in farm fields and along their edges. The quest for firewood has removed many other hardwoods along edges and in open areas that are easily reached by vehicle.

The 1976 census flights revealed four nests on the study line. The next spring, a fifth nest was found. It seems reasonable to assume that young reared in the transmission line structure could be imprinted to this situation and may select a power line structure when they become sexually mature. Thus red-tailed hawks may have only recently learned to nest on transmission line structures, and utilizing this newly acquired behavior, they may be spreading out along the ROW. A Public Service Company of New Hampshire transmission line connecting to the 15 Mile Falls/Tewksbury study line had eight nests on it in the summer of 1980; none were present in 1976 or 1977. This line connects to the study line near where most of the nesting activity was recorded in 1976-77. On the newly used line the red-tails are utilizing wooden structures. This seems to reinforce the belief that this behavior is learned and that this activity will increase in the future.

Vegetation around nest sites was analyzed, but no parameters could be identified that correlated with preferred sites. One factor at each nest site which could not be measured or ranked was the esthetic and panoramic view. This may be the deciding factor when a pair of red-tails has an almost unlimited number of poles from which to select. This penchant of red-tails for a commanding view in nest-site selection was also recognized in Western studies (Fitzner 1980).

Red-tailed hawk response to the helicopter was basically one of indifference. Occasionally, a bird would flush from a structure at the authors' approach, but generally, the birds would watch them go by and pay little attention. There may be some conditioning involved since line surveys are flown every six weeks (White and Sherrod 1973). Nesting birds which were incubating or brooding remained on the nest. A red-tail would occasionally bluff-attack the helicopter, especially around nest sites. The bird would approach from the front or side with its legs outstretched and its talons spread, avoiding collision at the last moment. Evasive action on the pilot's part was not practical due to the low level of the survey flight.

The vegetative criteria examined revealed no critical habitat correlation between line vegetation or vegetation parameters adjacent to the ROW and red-tailed hawk use (Table 1). That open lands other than the ROW are necessary seems apparent by the lack of red-tailed hawk use in the isolated north central portions of the study line where there are few farms. The most red-tailed hawk usage occurred on the southern half and the northern tip of the 15 Mile Falls/Tewksbury transmission line. There is more open agricultural land adjacent to the power line in the southern half of the line and at the northern end in the Connecticut River valley farming areas. Therefore, there is more edge habitat, a condition desired by red-tails (Luttich et al. 1971).

DISCUSSION

The ROW as a Permanent Opening

There is ample documentation of ROWs providing edge and important vegetative communities within forested environments. More than 40 years ago, Lay (1938) recognized the significance of forest openings to avifauna. Larson (1967) reviewed 119 references on this subject for his critical review of the value of this community. Many state and federal agencies as well as individuals have recognized the importance of this community to wildlife. Openings in the forest ecosystem also contribute important ecological and social values, such as recreation, esthetics, and water yield. The State of Wisconsin places emphasis on openings and forest edges for white-tailed deer (*Odocoileus virginianus*) (McCaffery and Creed 1969). The USDA Forest Service in Region 9 has a goal of maintaining 5 to 10% of their upland land base in a permanently open community in many forests. The belief that maintaining this community does more for total diversity than any other presently conceived management practice has been substantiated by a Wildlife Habitat Association Data Base (USDA 1981) recently developed on the Chippewa National Forest in northcentral Minnesota. The Data Base reveals that 50% of the vertebrate species inhabiting forests in that region utilize permanent openings during some part of their life cycle. Power line ROWs are being considered a valuable part of these permanent openings. Consideration of this community type's contribution to overall diversity cannot be overstressed.

Raptors and ROWs in a Forested Ecosystem

Another dimension to be considered in the relationship of raptors to power lines in forested areas is ROW width. Only the wider lines, in excess of 200 feet, will probably have red-tailed hawks nesting on them. Anderson and others (1977) who studied power lines in eastern Tennessee did not find red-tailed hawks on lines less than 300 feet (91.5 m) wide. They also observed, as in this study, broad-winged hawk use on a power line 100 feet (30.5 m). Power lines of 100 feet and less in width are probably hunted by both forest raptors and open land species. Lines larger than 100 feet present two distinct edge zones to be utilized by forest raptors. The middle sections of these lines and their edges are hunted by the open-land species. It is this wider ROW that begins to take on the character of a grassland community. These larger lines displace forest species and have less value as edge, but do allow for the extension and increase of the red-tailed hawk population and possibly the American kestrel in New Hampshire's densely forested environment.

Only the August 1976 flight revealed large numbers of immature red-tails using the central and north end of the line. This may be explained by the large attractions of open line to this species which provided the young with a contiguous migrating corridor on which many birds may move before beginning their southward migration. During this flight, there were many more brown-tailed (juveniles) birds present on the line than were produced on it, and it is reasonable to assume that the line serves as a collector for the young birds recently moved from adjacent natal areas.

Kestrels, as mentioned earlier, used the line extensively after their broods had fledged. It may be possible to have increased breeding of this species on the ROW area if boxes are installed. There may also have been some northward migration of recently fledged young of this species along the corridor similar to the red-tailed hawk populations.

It seems evident that power lines can provide valuable raptor habitat. The lines themselves, however, do not appear to be sufficient to attract raptors without other associated open land nearby. A 350-foot line such as the authors' study line might have substantially supported red-tailed hawks--if the vegetation on the line was less dense and tangled. The present herbicide-tailored climax community makes capturing prey very difficult except in grass/forb areas and along the edges. Use of selective herbicides or other management techniques, such as prescribed burning to favor grasses and thin out other undesirable vegetation, could be used toward this end.

Although the power lines have many positive aspects for raptors, there are also some negative ones. Conflicts with other users might make encouraging raptor use of power lines undesirable. The red-tail nest on Pole Number 953 failed in 1977, probably due to high levels of trail bike use on the access road. What was presumed to be the same pair was later seen at this nest site with three young, and they vocalized and went through normal defense actions of the nest site. Apparently, they had successfully re-nested somewhere off the line. Target shooting, or plinking, is also a favorite activity along these lines, as the high maintenance costs suffered by utility companies for damaged insulators and other utility pole components will attest. It could be expected that some people will shoot at these highly visible and accessible hawks. There may be potential for collisions with conductors and support wires which would cause some mortality to hawks, but no incidents were witnessed during survey flights or field work, and no dead birds were found in the field.

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MITIGATING THE INCIDENCE OF BIRD COLLISIONS WITH TRANSMISSION LINES

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ABSTRACT.--Studies sponsored by the Bonneville Power Administration (BPA) have documented the extent of bird collisions with several high voltage transmission lines. The amount of mortality caused by collisions was not biologically significant for the lines and bird species studied, but could be important where endangered or threatened species or large bird concentrations occur. Birds collided primarily with small diameter overhead groundwires. These wires were removed from three lines to assess the effect on collision rates. Groundwire removal appeared to reduce collisions by about one-half. This is comparable to reductions attributed to marking of groundwires reported in other studies. Because removal of groundwires is not practical in many cases, further development and testing of the effectiveness of various marking techniques is needed.

INTRODUCTION

Over the past few years there has been increased interest by the public, resource agencies, and electrical power utilities in the potential flight hazard electrical transmission lines present to migratory birds. Since 1976 the Bonneville Power Administration (BPA), a Federal power-marketing agency maintaining over 12,000 miles of transmission lines, has sponsored investigations to determine the impact of lines on birds in flight (Lee 1978, Meyer 1978, James and Haak 1979, James 1980, Willdan Associates 1981, Beaulaurier 1981). These studies have documented the extent of bird collision mortality with portions of 230-kV and 500-kV transmission lines crossing waterfowl flyways in Oregon and Washington. Primary data collection consisted of observations of bird flights and systematic searches for dead birds and feather remains in the vicinity of the lines.

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To date, the amount of avian mortality from collision with the lines studied has not been biologically significant. This finding is consistent with published reviews of collision mortality (e.g., Stout and Cornwell 1976, Banks 1979). However, because a potential exists for line collision mortality to become significant under certain conditions, it is desirable to have mitigation measures available. In this paper mitigation is defined as reduction or elimination of bird collision mortality.

Objectives of this paper are to (1) report results of recent studies involving bird collisions with transmission lines, (2) report on studies done to assess the effectiveness of removing overhead groundwires in reducing bird collisions, and (3) review the literature on marking of groundwires and conductors as mitigation measures.

RECENT BIRD COLLISION STUDIES

Two studies between 1977 and 1979 focused on locating areas within the BPA transmission line network, where collision mortality would likely be greatest. Ten sites were monitored. Factors influencing collision mortality were identified to develop a better understanding of the problem. Meyer (1978) and James and Haak (1979) studied three sites with small but measurable amounts of collision mortality: Lower Crab Creek and Saddle Mountain Lake in central Washington, and Bybee Lake in northwest Oregon (Fig. 1). At seven other sites levels of collision mortality were not detectable apparently because of small flight intensities.

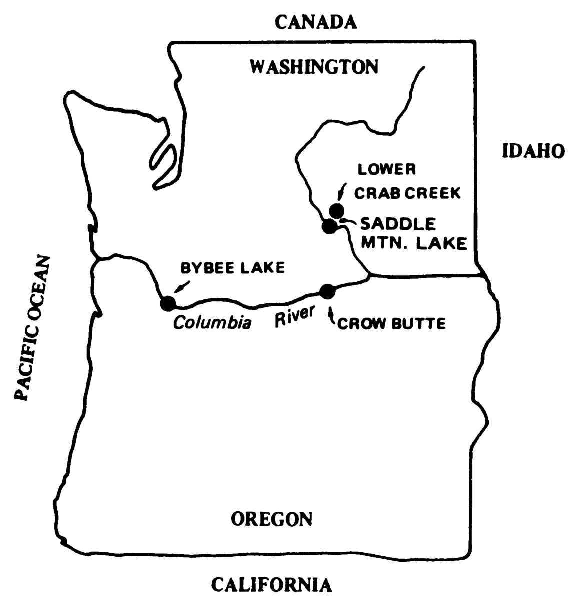

Figure 1. Locations of study areas.

The two sites studied in Washington involved 500-kV lines and a 230 kV line was studied in Oregon. Ducks, geese, gulls, starlings, and blackbirds were the predominant species observed flying near the lines. For both studies a total of 36 bird collisions were observed and 101 dead birds or feather remains were found. Estimated collision mortality, assuming all collisions were fatal, for each site was less than 200 waterfowl per wintering season. Estimates of total collisions were based on dead birds and feather spots found within 164 ft (50 m) of each line, plus bias estimates for birds missed during searches, birds removed by scavengers, birds which collided with the line and flew out of the study area, and birds which fell in unsearchable habitat. The number of dead birds found varied among sites and between years. However, the resulting collision rates were of similar magnitude when related to corresponding flight intensities (Table 1).

Table 1. Comparison of daily duck flight intensities and corresponding collision rates among five BPA-sponsored studies.

Author/Site	Avg. No. Flights/ Day (24 hours) (At or below groundwire height)	Collision Rate (%)[a]
Meyer 1978[b]		
Lower Crab Creek	248	0.34
Bybee Lake	54	1.61
James and Haak 1979[b]		
Lower Crab Creek	150	0.65
Bybee Lake	190	0.68
Saddle Mtn. Lake	250	0.51
Beaulaurier 1981		
Lower Crab Creek	67	0.28
Bybee Lake-GW Removed	64	0.58
Bybee Lake-GW Intact	12	1.03
James 1980		
Crow Butte Slough	2070	0.12[c]
Columbia River	3730	0.57[c]
Willdan Associates 1981		
Crow Butte Slough	102	0.31
Columbia River	368	0.01[d]

[a]Total estimated collisions based on dead bird counts during study period divided by total flights approaching below groundwire during study period multiplied by 100.

[b]Seven other sites were observed during these studies, but flight intensities and number of dead birds found were too low for collision rates to be calculated.

[c]These rates were calculated from Lower Crab Creek data and were used to make preconstruction predictions of collision rates for a 500-kV line at Crow Butte Slough and the Columbia River.

[d]Based on observed collisions. All other collision rates are based on dead bird studies.

Collisions were observed under a variety of environmental conditions, including clear weather. Apparently fog and darkness were not major collision factors because of reduced flight intensities during these periods.

Flight altitude was one key element associated with collisions. Birds approaching at or below line heigh were most vulnerable to collision. Most birds flew over the line rather than cross through or beneath it. A second key element associated with collisions was the presence of overhead groundwires. About 80% of observed collisions were with groundwires (.39-.62 inch (1.0-1.6 cm) diameter), which are much less conspicuous than single 1.3 inch (3.3 cm) diameter or bundled conductors (12 inches (30 cm) diameter bundle on 500 kV lines).

A U.S. Fish and Wildlife Service study in North Dakota (Faanes 1981) monitored seven "worst case" sites for bird collisions. A total of 242 dead birds were found, and 48 collisions observed. Of the observed collisions 81% were with overhead ground wires. Collision rates (observed collisions/observed flights) we interpreted from data in Faanes (1981) ranged from 0.1 to 0.34% of birds crossing the line at all heights, which are similar to rates calculated in BPA sponsored studies. European studies have indicated that collision mortality can be high for certain lines and bird species. Comparison with American studies is difficult due to differences in methodology, primarily a lack of flight intensity information in the European work.

BPA MITIGATION STUDIES

Because studies by Meyer (1978) and James and Haak (1979) had shown that approximately 80% of observed bird collisions were with overhead groundwires (OHGW), a study was initiated in September 1980 in which short sections of groundwire were removed from the 500-kV single circuit transmission line at Lower Crab Creek, Washington, and the 230-kV double circuit line at Bybee Lake, Oregon. At Bybee Lake, the overhead groundwire on an adjacent span served as a control. Collision rates were estimated and compared with preremoval rates. An estimated 65 collisions occurred at both sites based on dead bird studies. No collisions were observed. Flight intensity for waterfowl was approximately one-third of preremoval levels. Table 2 summarized the results of the groundwire removal study. Groundwire removal appeared to reduce collision rates to an average of about one-half of preremoval rates (range -35 to -69%).

In 1979 a study was initiated to test whether the collision potential of a new line could be predicted prior to construction and to evaluate mitigation measures. The Columbia River crossing of the Ashe-Slatt 500-kV line, within the Umatilla National Wildlife Refuge was the site selected (Fig. 2). Prior to construction, baseline data on flight intensities and flight patterns were gathered during the fall and winter of 1979-1980 (James 1980).

During the preconstruction study two major flight paths across the line route were identified: the slough and the main river channel. Most low altitude bird flights originated from habitat adjacent to the line route. Birds usually crossed the line route as they left the refuge each day on feeding flights to nearby agricultural land. Flight intensities were much

Table 2. Collision rates (%) before and after overhead groundwire (OHGW) removal.

Site/Group	Collision Rate[a]		
	With OHGW	Without OHGW	% Change
Lower Crab Creek			
Total Ducks	0.52[b]	0.28	-46
Bybee Lake			
Total Ducks	0.89[b]	0.58	-35
Total Ducks[c]	1.03	0.60	-42
Gulls	0.016[d]	0.005	-69
		Average % Change	-48

[a]Total estimated collisions based on dead bird counts during study period divided by total flights below groundwire during study period, multipled by 100.

[b]Mean for Meyer (1978) plus James and Haak (1979).

[c] Beaulaurier (1981) only, spans with and without groundwire.

[d]James and Haak (1979) only, not calculated in Meyer (1978).

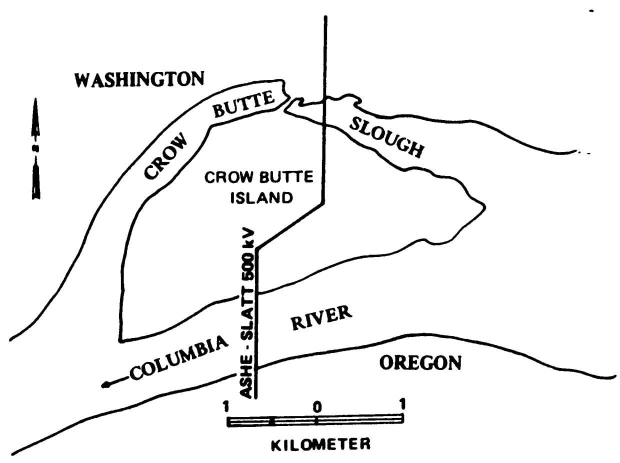

Figure 2 - Ashe - Slatt 500 kV line crossing site at Crow Butte Island in the Columbia River.

greater than those observed in previous studies. Collision rates (no. collisions÷no. flights) for ducks, calculated for Lower Crab Creek by James and Haak (1979), were applied to average flight intensities at Crow Butte to estimate the collision potential of the line. Up to 3,600 duck collisions per season were predicted, assuming 1979-80 data were representative of average flight patterns in the area.

A 500 kV double circuit line was built the following spring and post-construction data collection was initiated in the fall of 1980 (Willdan Associates 1981). Spans across the slough north of Crow Butte Island were designed without an overhead groundwire as mitigation for bird collisions. The river crossing contained a groundwire with 26 orange airway marker balls (24 inches (61 cm) in diameter) spaced approximately 150 ft (46 m) apart. High intensity strobe lights were installed on the river crossing towers as additional aircraft warning devices.

The span on the Oregon shore is unusual in that it drops at a steep angle from a 475-foot (145 m) tower to a 180-foot (55 m) tower. On half the span (portion nearest the 475-foot (145 m) tower) the overhead groundwire is marked with airway marker balls spaced at approximately 300 ft (100 m) intervals.

The first year of the post-construction study at Crow Butte (Willdan Associates 1981) documented collision rates of 0.31% for the slough crossing and 0.01% for the river crossing. Flight intensities were much less than during the preconstruction study. The estimated numbers of duck collisions for the season were 45 for the slough, 8 for the river, and up to 523 for the Oregon shore. No collision percentage was derived for the Oregon shore due to insuffiicent flight data. The reason for the high number of collisions is unclear at this time. However, it is under further study.

A rate of 0.12% had been predicted for the slough crossing, based on a 0.57% collision rate derived from a line of similar configuration at Lower Crab Creek. An 80% reduction in collisions was anticipated because no groundwire was present on the line (i.e., 0.57-(0.57)(0.8) = 0.12). Groundwire removal did appear to reduce the collision rate from 0.57% (line with overhead groundwire), but the reduction was not as great as the predicted 0.12% (line without overhead groundwire). The collision rate documented at the Columbia River crossing was 0.01%, compared to a predicted rate of 0.57. This large difference may have been attributable to the presence of airway marker balls and flashing strobe lights on this crossing.

MITIGATION MEASURES

Various authors have tested or suggested the following measures for mitigating bird collisions: (1) route planning (Thompson 1978, Miller 1978), (2) underground cable (Heijnis 1976, Thompson 1978, Glystorff 1979, Dames and Moore 1981), (3) modifying tower and line structure (Renssen et al. 1975, Miller 1978), (4) marking groundwire to increase visibility (Scott et al. 1972, Renssen et al. 1975, Heijnis 1976, Glystorff 1979, Meyer and Lee 1981, and (5) groundwire removal (Meyer and Lee 1981).

The first three methods are most applicable when a line is being planned. These methods are aimed at avoiding high risk areas or building lines which would minimize bird collisions. Although use of underground cable would eliminate collision potential, costs for undergrounding can range up to 30 times higher than for overhead transmission lines. The last two methods are important in planning, but are also useful in modifying existing lines known to have a significant number of bird collisions. The potential for collisions with each transmission line is unique and is dependent upon such variables as habitat, relation of the line to migratory flyways and feeding flight patterns, migratory and resident bird species, and structural characteristics of the line. Therefore, mitigation for a particular line would best be accomplished by selecting one or more of the above measures, based on site-specific information.

Groundwire or conductor marking studies have shown that some types of line marking appear to reduce bird collisions (Table 3). Each of the studies in Table 3 compared either number or rate of birds killed on marked and unmarked lines, but corresponding flight intensities were not documented. For studies in which collision casualties were given, marking reduced collisions by an average of 45%. This is similar to the 48% reduction estimated during the groundwire removal study. It appears that these two mitigation methods may be equally effective. Groundwire marking with airway marker balls and strobe lights on the towers at Crow Butte, generally appeared to be more effective in reducing collisions than groundwire removal or other reported marking methods. Some of the marking techniques in Table 3 may have been unsuccessful in those cases because most collisions occurred at night when markers were not visible. Heijnis (1980) concluded that a reflective or fluorescent marker reduced collisions while two other non-fluorescent markers had no effect. The predominant flight activity (diurnal vs. nocturnal) should be considered when designing a marker for a particular site.

Mitigation measures are available that can reduce collision mortality, and are feasible for use on existing and proposed transmission lines. However, the effectiveness of most of these measures has received only limited testing. Mitigation will probably be applied only in cases where actual or potential collision losses are significant biologically or socially and warrant the expense (i.e., significance of mortality versus economic, land use, and engineering trade-offs).

Of the mitigation measures discussed, removal and marking of the overhead groundwires appear most feasible. Although removal of overhead groundwires seemed to reduce the incidence of bird collisions with transmission lines, the reduction was not as large as expected. The studies of the two BPA 500-kV lines without groundwires show that birds do collide with the large conductor bundles. It is not know, however, whether the collisions occurred during day or night. No collisions with conductors were observed during the groundwire removal studies; however, this may have been a function of the low flight intensities observed. Most waterfowl typically fly above the groundwire when crossing a transmission line, at a distance of about 25 ft (8 m) from the conductors. With no groundwires, birds appear to cross a line at lower altitudes nearer the conductors. This lower altitude could increase the incidence of collisions with conductors.

Table 3. Results of studies marking groundwire or conductors.

Study	Marker Type	Size	Collisions Reduced	Comments
Scott et al. 1972	Black tapes on groundwire	1.5 cm long	Yes	3 cases cited
	Luminous orange bands on groundwire	5 cm wide	No	Position of line with respect to power station was the most important association with the number of birds killed
	Strips on groundwire	5 cm wide	No	
Renssen et al. 1975	White ribbons on groundwire	No size given	Yes	-28%* *Compared to unmarked line
	Black ribbons on groundwire		Yes	-48%*
	Black and white ribbons on groundwire		Yes	-52%*
	Orange spacers between subconductors		Yes	-60%*
	Orange marker balls		No	
Heijnis 1976	Black and white plastic strips on groundwire	30 cm long 1.3 cm wide	Yes	
1980	Plastic strips	50 cm long	No	
	Plastic spirals	11 cm wide	No	
	Raptor silhouettes	100 cm long	Yes	Silhouettes were visible in poor light while the other methods were not.
Kaiser and McKelvey 1978	Fishing Floats	No size given	Yes	After marking the loss of swans was almost eliminated.
Rigby 1978	Orange marker balls	No size	Yes	No deaths of sandhill cranes recorded after markers were installed.
Glystorff 1979	Yellow plastic streamers on conductors	50 cm wide 10 cm wide	Yes	-37%*
Totals	Collisions reduced		12	
	Collisions not reduced		5	
	Total number of studies		17	

*Average percent reduction -45% compared to unmarked line.

The use of marking devices on groundwires appears to be about as effective in reducing collisions as groundwire removal. Depending on the type and extent of marking, birds may perceive a marked line as a more substantial obstacle, and may begin increasing their flight altitude at greater distances from the line than when a line is not marked. When crossing a marked line, fewer birds would be near the groundwire or conductors. In the postconstruction study of Crow Butte Island, the collision rate for the marked river crossing span was around 30 times smaller than for the slough where the groundwire was removed. It is not clear whether the reduction was related primarily to the presence of the air-way marker balls on the groundwire and/or the high intensity strobe lights on the towers. It is possible that extensive marking to mitigate for waterfowl collisions may be so effective that birds tend to avoid using habitat near the marked line.

A number of problems were identified that made it difficult to assess the effectiveness of collision mitigation measures. For example, collisions with most transmission lines are rare events, so data available at any one particular site may be so small that statistical treatment of data is questionable. Also, it is not clear what factors most influence the degree of collisions with a particular line. We believe that a primary factor is low altitude flight intensity near a line. Without some idea of flight magnitude, it is difficult or impossible to assess the effectiveness of mitigation. A decrease in the number of dead birds found near a line may mean mitigation was effective, but if significantly fewer birds were flying across the line a reduction in collisions would probably result anyway. Therefore, it is essential that flight numbers be measured and reported in any experiment in order to evaluate collision mitigation.

Although both groundwire removal and marking of groundwires can mitigate collisions, to date a definite need for mitigation has seldom arisen. It appears that in most cases, the number of collisions of common bird species with transmission lines is too small to warrant mitigation.

One of the few known cases in the United States where an obvious need exists for mitigating or compensating for transmission line collision mortality is a unique situation near Billings, Montana. Two years after a 230-kV line was constructed across a dry basin, the area filled with water for 2 to 3 miles (3-5 km) surrounding the line. Large numbers of waterfowl were attracked to the lake. During one 6-month period an estimated 2,530 birds died from striking the line (Malcolm, personal communication 1981). The collision mortality has also aggrevated bird losses due to botulism. Birds killed by striking the line have provided a substrate for the botulism bacteria, which may cause outbreaks to occur earlier and to last longer than if this substrate did not exist. For this situation groundwire removal is not appropriate due to the proximity of the site to a substation. Recommendations under study by an interagency committee include compensation for losses and regular clean up of carcasses near the line (Thompson, personal communication). This committee did not believe groundwire marking would be cost-effective in reducing collision mortality.

The use of groundwire removal and marking as mitigation measures require consideration of both electrical and structural effects on transmission lines. Groundwires provide protection against lightning strikes on conductors. The most serious consequence of groundwire removal is a possible significant reduction in line reliability. In addition, structural modifications of towers are usually required. Line marking could be used when groundwire removal is not feasible due to line reliability considerations. Size, shape, weight, and spacing of markers are important characteristics affecting the loading, wind resistance, and ice build-up potential of a line. Line markers should be designed to minimize structural hazards and maximize visibility to birds.

CONCLUSIONS

Studies sponsored by the Bonneville Power Administration found that bird collision mortality was measurable at 5 of 12 transmission line sections studied but was not a biologically significant cause of avian mortality. Birds were most susceptible to collisions with overhead groundwires. Groundwire removal reduced bird collisions to about one-half of preremoval levels. Thus, this technique appears to be a feasible mitigation measure for future use on existing and proposed transmission lines. Other studies indicate some types of groundwire marking also reduce bird collisions. Mitigation measures require further study to better evaluate effectiveness. Determining when and how to apply these measures requires good communication and planning on the part of biologists and utility engineers.

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EFFECTS OF POWER-LINE CORRIDORS ON THE DENSITY AND DIVERSITY OF BIRD COMMUNITIES IN FORESTED AREAS

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ABSTRACT.--Breeding bird populations were estimated by the territory-mapping method in two plots totaling more than 143 ac (58 ha) in East Tennessee. Each plot contained a power-line corridor along one edge, and the remainder was oak-hickory forest. Bird species number and diversity were greater in the forests ($P<0.001$) while differences in bird density and biomass were not significant ($P>0.10$). The number of species endemic to the forests was two to three times that in the corridors ($P<0.001$). Conversion of forest to power-line corridor increased total species number, density, and diversity on each previously entirely forested plot, and apparently did not result in the loss of any forest bird species.

INTRODUCTION

The clearing of forests for power lines can affect forest birds not only by loss of forest habitat but also by the fragmentation of otherwise continuous forests. Effects of forest fragmentation on birds, especially long distance migrants of forest interiors, have recently been addressed by Robbins (1979) and Whitcomb et al. (1981). Although power-line corridors are mentioned as one of many factors causing forest fragmentation, there is little literature on effects specific to power lines as opposed to effects of clearing for agriculture, residential areas, etc.

The purpose of this study is to determine the effects of power-line corridors on breeding bird communities in relatively undisturbed forests. Bird density and diversity based on territory mapping are presented for over 143 ac (58 ha) of two power-line corridors and their adjacent, relatively undisturbed hardwood forest stands in East Tennessee. Previous studies of bird abundance along power-line corridors reported on frequencies of observations rather than density (Anderson et al., 1977; Geibert, 1980), did not distinguish between migrating and breeding birds (Anderson et al., 1977), or were conducted in areas already highly disturbed by previous forest clearing (Anderson, 1979; Geibert, 1980). Latin names of birds follow the American Ornithologists' Union "Check-list of North American Birds" (1957, fifth ed.) and the thirty-second and thirty-third supplements (Auk, 90:411-419 and Auk, 93:875-879). Censusing terminology follows that of the International Bird Census Committee (1970).

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STUDY AREAS

One study area is located on the Department of Energy Reservation at Oak Ridge and the other is at Haw Ridge at the east end of the Reservation. Each study plot was rectangular, covered the entire width of the power-line corridor, extended into forest on only one side of the corridor, and was surrounded by additional upland forest (except on the corridor). Each corridor was bounded by upland oak-hickory, pine-hardwood, and pine forest. The vegetation on the corridors was cut with a tractor-mounted large rotary blade (brush hog) usually once every four years. Cutting was conducted up to the forest edge. Right-of-way widths were 260 ft (79 m) and 350 ft (107 m).

The Reservation study plot was 1138 ft X 2625 ft (347 m x 800 m) and contained 15.5 ac (6.3 ha) of a corridor 260 ft (79 m) wide and 53 ac (21.4 ha) of adjacent hardwood forest. The plot extended 879 ft (268 m) into the forest. One-third of the corridor was cleared for construction prior to 1965, sprayed with herbicide, and then allowed to revegetate naturally. This portion of the corridor was characterized by blackberry (*Rubus* spp.), goldenrod (*Solidago* spp.), broomsedge (*Andropogon virginicus*), and various species of saplings. The other two-thirds were cleared in 1969, fertilized, and planted with fescue (*Festuca* spp.). The fescue still dominated where it was planted but was being invaded by blackberry, sumac (*Rhus typhina*), and various species of saplings. The forest was typical second growth oak-hickory forest dominated by several species of oaks. Roughly 60 years ago the forest was apparently selectively logged, and about an eighth of the plot was a cleared pasture, judging from aerial photos taken in 1935.

The Haw Ridge plot in 1980 was 1050 ft X 3110 ft (320 m X 948 m) and contained 25 ac (10.1 ha) of a corridor 350 ft (107 m) wide and 50 ac (20.2 ha) of adjacent oak-hickory forest. The plot extended 700 ft (213 m) into the forest. In 1981, the forest portion of the plot was increased in size to 114 ac (46.3 ha) and extended 1600 ft (488 m) into the forest. On 1935 aerial photos the entire plot appeared to consist of medium- to old-aged forest that had been subjected to light selective logging. At that time the forest (and also the Reservation forest) was probably dominated by American chestnut (*Castanea dentata*), which is now absent from the plot as a mature tree. The corridor was cleared for construction about 1964 and allowed to revegetate naturally. Vegetation was similar to the naturally revegetated portion of the Reservation corridor.

METHODS

Breeding bird populations were censused by the territory mapping technique (International Bird Census Committee, 1970; Robbins, 1978; Svensson, 1978). The Reservation corridor was visited 3 times in 1975, 7 times in 1976, 4 times in 1978, and 10 times in 1980. In 1975, 1976, and 1978, birds were mapped twice during each visit (once when walking in one direction and again when returning). The Reservation forest was visited 4 times in 1975, 13 times in 1977, and 12 times in 1979. The four visits in 1975 provided a less accurate estimate of bird density than visits in other years, but the results are included for comparison. The Haw Ridge corridor was visited 6 times in 1980 (birds mapped 12 times) and 8 times in 1981 (also mapped 8 times). The forest was visited 13 times in 1980 and 11 times in 1981. The vast majority of registrations involved songs and calls rather than sightings. The occurrence of contemporary registrations played a major role in delineation of territories.

Surveys on each plot were on different days, generally between 0600 and 0900 EDT, and between May 10 and June 15. The long open corridors enhanced census efficiency (Svennson, 1978) and territory delineation by allowing detection and accurate mapping of singing males at long distances (often up to 500 ft (150 m)). Thus, the lower number of surveys in corridors was probably as effective as the higher number of surveys in forests. Densities were calculated using only the estimated fractions of territories within the study plots. Bird species diversity (H') was calculated with the Shannon-Wiener index ($-\Sigma p_i \ln p$). This index has two components, species richness, which depends on the number of species observed (S), and equitability, which depends on the equality of the densities of the various species (Tramer, 1969). Equitability was calculated using

$$J' = H'/H'_{max}, \text{ where } H'_{max} = \ln S$$

(Tramer, 1969). Weights of birds were used to calculate community biomass. The weights were obtained from Baldwin and Kendeigh (1938), Norris and Johnston (1958), and from museum specimens at the University of Georgia. Data were transformed to natural logarithms and differences between corridor and forest bird communities were tested using analysis of variance.

RESULTS

Comparison of Corridor and Forest

Species number and diversity of the bird communities were significantly greater ($P<0.001$) in the forests than in the power-line corridors (excluding 1975 forest data because, as a result of the small number of visits, visiting species could not be distinguished from territorial ones) (Table 1). The greater size of the forested portions of the plots compared to the corridor portions accounted for a negligible fraction of the higher number of species recorded in the forest. The average species number for strips of the forested portions comparable in size to the corridors were 22.6, compared to an average of 24 for the entire forested portion of each plot. Also, increasing the area of corridor censused would not appreciably increase the observed species number in corridors; Kroodsma (1982) censused birds on a total of 150 ac (60 ha) of corridors of various widths and did not record territorial males of any species other than those reported in the present paper.

In contrast to species number, bird densities indicated a trend toward being higher in the power-line corridors except during the first breeding season following brushhogging. Overall, there was no significant difference ($P>0.5$), possibly because sample size (number of plot-years) may not have been large enough to detect a difference. Mean bird biomass per unit area was greater in the forests in spite of the lower forest bird densities, which resulted from the greater average size of the forest birds. Again, however, the difference was not statistically significant ($P>0.10$). The number of species with territories restricted to either forest or corridor (endemic species, Table 1) was two to three times greater in the forest than in the corridor ($P < 0.001$). The smaller difference in the Haw Ridge plot resulted from several occurrences unusual on other power-line corridors on the Oak Ridge Reservation (Kroodsma, 1982)--(i.e., a pair of Kentucky warblers in a young forest in an unusually deep ravine traversing the corridor, a pair of Carolina wrens with territory in the corridor, and song sparrows in two patches of willows (Salix spp.) on the corridor. Of the total number of species occurring in the forests, the endemic fraction was greater (81% average) than that in the corridors (60% average). Thus, most forest species were absent from the parcel converted to power-line corridor. Certain species that occurred regularly in the forests may have been absent or much less abundant in the absence of the corridors (gnatcatcher, summer tanager, cardinal, towhee, see Tables 3 and 4).

In each year birds on the Reservation corridor were observed considerably more often in the naturally vegetated, brushy portion than in the portion with planted fescue (310 vs 125 observations over 1975, 1976, and 1978). This indicates that brushy corridors support greater bird densities than corridors of planted grasses. Density on the Haw Ridge corridor was higher than that on the Reservation corridor, probably because it consisted entirely of naturally revegetated, brushy areas. Bird densities on the Reservation corridor (and on other corridors, Kroodsma, 1982) increased significantly with the growth of vegetation over the three years following brushhogging. Average densities of birds during future brushhogging cycles on the Reservation corridor should continue to increase as brushy vegetation invades the areas of planted fescue.

Average bird density over the years and plots was 145 pairs/100 ac (40 ha) in the forests and 182 pairs/100 ac in the corridors. The average in the corridors would likely have been about 200 pairs/100 ac if the fourth breeding season after brushhogging had been included (Kroodsma, 1982) and if the higher-density Haw Ridge community had been sampled in additional years. Bird density and diversity in the forests may increase as the forests grow older (Shugart et al., 1978).

Comparison of Forest and Corridor/Forest

Changes in the bird community resulting from the clearing of forest for the power lines can be postulated based on knowledge of birds currently breeding in more extensive unbroken forests. Several changes on each plot (forest plus corridor) were apparent. First, the species number increased by an amount equal to the number of species endemic to the corridor. The increase averaged 30% for the four cases presented (Table 2). This increase was independent of the stage of the cutting cycle because cutting did not eliminate corridor species but only reduced their density. This percent increase would be lower if forest species were eliminated from the plots due to clearing for the corridor. Apparently none was eliminated; all species that could be expected to be found regularly in Reservation forests (Dahlman et al., 1977) were present. In addition, extending the Haw Ridge plot deeper into the forest in 1981 did not result in the observation of any additional species.

Table 1. Bird species number, density, and diversity in two power-line corridors and their adjacent forests in East Tennessee.[a]

	Reservation Plot						Haw Ridge Plot				
	Forest			Corridor			Forest			Corridor	
	1975	1977	1979	1975	1976	1978	1980	1980	1981	1980	1981
Species number	27	23	25	9	9	9	10	25	23	12	10
Density (pairs/40 ha)	136	148	126	143	182	92	216	170	144	230	226
Diversity	2.88	2.82	2.84	2.05	2.03	2.14	2.09	2.92	2.63	2.31	1.96
Equitability	0.87	0.90	0.88	0.93	0.92	0.97	0.91	0.91	0.84	0.93	0.85
Endemic species[b]	23	19	21	5	5	5	6	18	21	9	8
Visiting species[c]	0	11	7	6	4	3	5	11	15	9	8
Biomass (g/40 ha)	4256	4923	3977	2374	2725	1476	3941	4991	4176	4590	4346

[a]The numbers of breeding seasons following brushhogging on the power-line corridors were: for the Reservation plot, 2 in 1975, 3 in 1976, 1 in 1978, and 3 in 1980; and for the Haw Ridge plot, 2 in 1980 and 3 in 1981.

[b]Endemic species had territories located in either the forest or the corridor, not both.

[c]Visiting species were nonterritorial (nonbreeding) or rarely seen species observed in the plot, but not included in calculations of density, diversity, species number, or endemic species.

[d]Not enough counts were made to distinguish between visitors and territorial birds; see Methods.

Table 2. Bird species number, density (pairs/100 ac (40 ha)) and diver sity in the corridor/forest system.[a]

	Reservation plot		Haw Ridge plot	
	1977 forest 1978 corridor	1977 forest 1980 corridor	1980 forest 1980 corridor	1981 forest 1981 corridor
Species number	28	29	34	31
Density	141	168	190	159
Diversity	3.12	3.17	3.26	3.00
Equitability	0.94	0.94	0.92	0.87

[a]The data are the forest and corridor data combined.

Table 3. Weight and density (pairs/100 ac (40 ha)) of birds in oak-hickory forest plots at the Oak Ridge Reservation in East Tennessee.[a]

Species	Weight (g)	Reservation plot[a] 1975	1977	1979	Haw Ridge[a] 1980	1981
Cooper's hawk (*Accipiter cooperii*)			P			P
Red-tailed hawk (*Buteo jamaicensis*)			P	P	P	P
Bobwhite (*Colinus virginianus*)	171.6			V	V	
American woodcock (*Philohela minor*)				V	V	
Yellow-billed cuckoo (*Coccyzus americanus*)	51.6	23.3	7.9	4.7	8.5	6.7
Barred owl (*Strix varia*)						P
Whip-poor-will (*Caprimulgus vociferus*)	60.0	P	4.7	4.7		
Ruby-throated hummingbird (*Archilochus colubris*)	2.6		V	V	V	2.0
Yellow-shafted flicker (*Colaptes auratus*)	126.4			1.9	1.5	V
Pileated woodpecker (*Dryocopus pileatus*)	237.7	0.5	0.5	0.5	0.5	0.5
Red-bellied woodpecker (*Melanerpes carolinus*)	72.4	2.3	9.3	5.6	8.1	7.9
Hairy woodpecker (*Picoides pubescens*)	56.7	2.8	4.2	3.7	4.3	3.5
Downy woodpecker (*Picoides pubescens*)	27.3	3.3	1.9	3.7	8.6	5.4
Crested flycatcher (*Myiarchus crinitus*)	35.7	3.7	5.6	0.5		V
Eastern phoebe (*Sayornis phoebe*)	15.0			1.9		
Acadian flycatcher (*Empidonax virescens*)	13.0	3.3	7.0	3.7	4.3	2.6
Eastern wood pewee (*Contopus virens*)	15.0		V	1.9	V	V
Blue jay (*Cyanocitta cristata*)	89.3	3.7	5.6	3.7	4.0	3.7
Common crow (*Corvus brachyrhynchos*)	430		V	V	V	0.5
Carolina chickadee (*Parus carolinensis*)	9.2	7.5	7.5	4.2	11.1	11.9
Tufted titmouse (*Parus bicolor*)	20.2	3.3	9.3	5.1	11.7	7.2
White-breasted nuthatch (*Sitta carolinensis*)	19.1	4.2	8.4	7.5	6.8	6.0

Table 3. Continued.

Species	Weight (g)	Reservation plot[a] 1975	1977	1979	Haw Ridge[a] 1980	1981
Carolina wren (*Thryothorus ludovicianus*)	18.3	5.1	1.9	V	4.8	V
Catbird (*Dumetella carolinensis*)			V			
Wood thrush (*Hylocichla mustelina*)	44.5	10.3	16.3	15.3	10.1	6.2
Eastern bluebird (*Sialia sialis*)	31.2				0.6	V
Blue-gray gnatcatcher (*Polioptila caerulea*)	6.2	0.9	1.9	0.9	16.9	10.7
Cedar waxwing (*Bombycilla cedrorum*)					V	V
Yellow-throated vireo (*Vireo flavifrons*)	17.5	1.9	V		4.9	V
Red-eyed vireo (*Vireo olivaceous*)	17.9	14.9	25.3	20.5	25.4	41.3
Black-and-white warbler (*Mniotilta varia*)	12.4	3.7	V		5.9	2.6
Worm-eating warbler (*Helmitheros vermivorus*)	13.4	0.9	V			1.3
Yellow-throated warbler (*Dendroica dominica*)					V	V
Pine warbler (*Dendroica pinus*)	12.9	4.2	V	3.7		
Ovenbird (*Seiurus aurocapillus*)	18.9	14.9	8.4	9.1	3.9	5.4
Louisiana waterthrush (*Seiurus motacilla*)	20.9	0.5			1.5	0.9
Kentucky warbler (*Oporornis formosus*)	14.2	5.6	2.8	1.9	1.8	0.9
Hooded warbler (*Wilsonia citrina*)	11.6	3.7	6.1	4.7		V
Common grackle (*Quiscalus quiscula*)					V	V
Brown-headed cowbird (*Molothrus ater*)			V	V	V	V
Scarlet tanager (*Piranga olivacea*)	31.8	6.1	9.3	13.8	10.4	8.0
Summer tanager (*Piranga rubra*)	31.8		1.9	0.9	3.6	3.0
Cardinal (*Cardinalis cardinalis*)	41.4	3.3	2.3	1.4	9.1	5.5
Rufous-sided towhee (*Pipilo erythrophthalmus*)	45.4	1.9			1.6	V
TOTAL		136	148	126	170	144

[a]A blank space indicates none present; P = present, but no estimate made, counted as a visitor; V visitor.

Table 4. Weight and density (pairs/100 ac (40 ha)) of birds in two power-line corridor plots at the Oak Ridge Reservation in east Tennessee.[a]

Species	Weight (g)	Reservation plot[a]				Haw Ridge[a]	
		1975	1977	1979	1980	1980	1981
Red-tailed hawk (*Buteo jamaicensis*)		P	P	P	P	P	P
Bobwhite (*Colinus virginianus*)	171.6			V			
American woodcock (*Philohela minor*)						V	V
Mourning dove (*Zenaida macroura*)						V	V
Yellow-billed cuckoo (*Coccyzus americanus*)	51.6				V		
Ruby-throated hummingbird (*Archilochus colubris*)	2.6	V				V	
Yellow-shafted flicker (*Colaptes auratus*)	126.4					V	
Blue jay (*Cyanocitta cristata*)	89.3					V	
Carolina chickadee (*Parus carolinensis*)	9.2		V		V	V	V
Carolina wren (*Thryothorus ludovicianus*)	18.3	V				4.1	1.0
Catbird (*Dumetella carolinensis*)			V		V		
Eastern bluebird (*Sialia sialis*)	31.2	V				V	V
Blue-gray gnatcatcher (*Polioptila caerulea*)	6.2	1.2	1.2	2.3	8.6		V
White-eyed vireo (*Vireo griseus*)	12.8				5.8	4.1	1.0
Prairie warbler (*Dendroica discolor*)	9.4	23.1	51.9	15.9	46.1	30.4	30.2
Kentucky warbler (*Oporornis formosus*)	14.2					3.1	V
Yellowthroat (*Geothlypis trichas*)	9.9	23.1	25.4	18.0	23.1	24.6	37.6
Yellow-breasted chat (*Icteria virens*)	24.0	34.6	23.1	17.3	34.6	35.7	41.5
Hooded warbler (*Wilsonia citrina*)	11.6	V					
Summer tanager (*Piranga rubra*)	31.8	2.3	2.3	1.7	5.8	3.4	4.3
Cardinal (*Cardinalis cardinalis*)	41.4	1.2	3.5	2.3	11.5	6.8	7.9

Table 4. Continued.

Species	Weight (g)	Reservation plot[a] 1975	1977	1979	1980	Haw Ridge[a] 1980	1981
Indigo bunting (*Passerina cyanea*)	14.5	28.8	40.3	20.2	40.3	30.4	29.7
American goldfinch (*Spinus tristis*)	12.5	P	P	P		P	P
Rufous-sided towhee (*Pipilo erythrophthalmus*)	45.4	5.7	5.7	2.9	17.3	29.9	26.1
Field sparrow (*Spizella pusilla*)	12.6	23.1	28.8	11.5	23.1	51.3	46.3
Song sparrow (*Melospiza melodia*)	21.6				V	6.2	
TOTAL		143	182	92	216	230	226

[a]A blank space indicates none present; P = present, but no estimate made, counted as a visitor; V visitor.

Second, the density of birds in the plots increased over that in the previously solid forest (Table 1) and was higher in all years of the cutting cycle except the first. Third, the biomass per unit area was slightly lower in all years of the cutting cycle. Because the percent changes in density and biomass depend on the ratio of corridor acreage to forest acreage, these would be meaningless figures and are not given here.

Finally, the diversity of birds on the plots increased, and was higher in all years of the cutting cycle. The increase in the equitability component of the diversity index resulted from the fact that most shrubland bird species added to the plots were relatively abundant. (Tables 1, 2, 3, and 4).

DISCUSSION

Recently, several authors have addressed the effects of forest size and fragmentation on the abundance of forest interior bird species (Robbins, 1979; Galli et al., 1976; Whitcomb, 1977; Whitcomb et al., 1981). The problem is that several species have apparently become much less abundant or have disappeared completely from previously extensive forest tracts that have been fragmented by clearing for housing developments, roads, transmission lines, etc. (Robbins, 1979). In this study, the clearing of power-line corridors within forested plots resulted in the addition of several abundant shrubland-bird species and an increase in species diversity without an apparent loss of any forest-bird species. However, it is not known for certain what species existed in Reservation forests prior to construction of the transmission lines, or what their densities were. The lack of a loss of forest species is indicated by the occurrence of the same bird species in the forests adjacent to the transmission lines as in other extensive forests on the Reservation.

The forest interior species most frequently mentioned (Robbins 1979) as having declined or disappeared in certain areas include (in order of decreasing forest size needed to maintain viable populations): ovenbird, worm-eating warbler, black-and-white warbler, red-shouldered hawk (Buteo lineatus), wood thrush, yellow-throated vireo, red-eyed vireo, prothonotary warbler (Protonotaria citrea), parula warbler (Parula americana), Louisiana waterthrush, scarlet tanager, summer tanager, and others. The species that were present on this study's plots in relatively high, more or less "normal" densities were the ovenbird, wood thrush, red-eyed vireo, scarlet tanager, and summer tanager. The ovenbird, however, appeared to be significantly less dense in portions of the plots near the corridors. The summer tanagers showed a preference for the forest-corridor edge over the forest interior. Species with relatively low densities were worm-eating warbler, black-and-white warbler, yellow-throated vireo, and Louisiana waterthrush. These species, however, typically exhibit low densities in forests on the Reservation. The red-shouldered hawk, prothonotary warbler, and parula warbler were absent from the plots. Because these species are generally absent in upland forests on the Reservation, their absence may have been independent of the transmission lines.

The lack of observed impacts on forest birds may have been a function of a few factors. First, the plots were portions of fairly extensive forests. Thus, there was little forest fragmentation. In addition, the power-line corridors are fairly narrow and would not seem to significantly isolate forest tracts. Second, the overall disturbance level on the corridors is relatively low. Vehicular traffic includes a tractor for cutting of vegetation only once every four years, and at Haw Ridge, occasional offroad vehicles and motorcycles. There are no homes in the area, and people use the area infrequently.

The lack of obvious impacts on forest interior birds should not be interpreted to mean that the selection of transmission-line routes should not consider avoiding forest fragmentation. With the current trend toward greater forest clearing, further fragmentation should be avoided whenever feasible alternatives are available.

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EFFECTS OF ROADS ON BREEDING BIRDS

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ABSTRACT.--Some effects of roads and adjacent right-of-way (ROW) habitat on the distribution of breeding bird populations were studied nationwide. During 1978 and 1979 a standardized breeding bird survey was conducted in relation to interstate highways and county roads. Road-associated bird mortality also was measured. Several field and edge species were attracted to the ROW. Brewer's and red-winged blackbirds, indigo buntings, field sparrows, house sparrows, cardinals, and song sparrows made use of the ROW habitat and edge created along roads. The blue jay, wood thrush, horned lark, chestnut-backed chickadee, Nashville warbler, hermit warbler, savannah sparrow, and lark sparrow were negatively affected by roads. Many woodland species made up a substantial portion of the total number of birds recorded along interstate highways but did not show up at all in the mortality survey. The most abundant species recorded in the mortality survey were also the most abundant in habitat near the highway.

INTRODUCTION

Two of the most direct effects of roads on birds and other wildlife are loss or modification of habitat and road-associated wildlife mortality. Published numbers of wild animals killed on highways are generally quite large and appear alarming; however, available data indicate that such mortality does not seriously harm wildlife populations (Leedy and Adams 1982).

Direct loss of wildlife habitat occurs during road construction when pavement replaces vegetation. In addition to this direct loss, some habitat, particularly that within the right-of-way (ROW), will be modified and new habitat types developed. For a typical interstate highway, habitat lost or modified will be on the order of 60 ac/mi (15 ha/km). In the present study, significant findings are summarized on the effects of roads on the distribution of breeding bird populations from a nationwide study designed to determine the effects of roads on the distribution and abundance of a wide variety of wildlife species.

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METHODS

Location of Study Areas and Sample Design

The study was conducted in the southern Piedmont of Virginia, North Carolina, and South Carolina (Southeast); the midwest Tillplain of Illinois (Midwest); and the valley region of Oregon between the Cascade and Coastal ranges, including a portion of northern California (Northwest). Sample sites were systematically distributed in relation to interstate highways and county roads. Bird censuses were conducted on strip transects consisting of six 262 X 262 ft (80 X 80 m) plots extending from the road edge to 1312 ft (400 m) from the road. One thousand three hundred and twenty transects were distributed along the two road types.

Habitat Description

Sample plots were cover-mapped before conducting bird censuses as described by Adams and Geis (1981). A quantitative vegetation survey also was conducted which provided information on the vegetational structure and plant species composition of study plots. The survey provided a means of determining the similarity of plots within a habitat type at the various distances from road. Thus, only those plots within a habitat type that were similar with respect to vegetation structure and plant species composition were used for comparisons.

Bird Census

The bird census was conducted during late May through June, began 15 minutes before local sunrise and continued for approximately 4½ hours. An observer slowly walked through the center of each plot and counted all birds seen or heard out to 131 ft (40 m) on either side of the center line. Birds were recorded by plot or habitat type within a plot. Exactly 5 minutes were spent in each plot. Scientific names in the text are according to the American Ornithologists' Union (1957, 1973, 1976).

Bird Mortality on Roads

The survey was conducted during the month of June. One-mile (1.6-km) sections of road were searched on foot by an observer, and all dead birds observed were recorded to species, when possible. No time limit was placed on the observer for this survey, who was free to move laterally to cover specific spots beside the highway or to make positive identifications. On the interstate sites, each side of both lanes was surveyed.

Data Analysis

Data were analyzed by habitat type, and where appropriate, by combined habitat types for each road type within each geographical area. Comparisons were made of species composition at three distances from road within a habitat type. Data from plots 1 and 2 (adjacent to road), 3 and 4 (262-787 ft (80-240 m) from road), and 5 and 6 (787-1312 ft (240-400 m) from road) were combined to yield the three comparisons (referred to as plots 2, 4, and 6 in the Discussion). Homogeneity of the bird community in relation to distance from road then was tested with chi-square. Where a significant chi-square statistic resulted, the individual species contributing the most to this statistic were removed from the data set and the procedure was repeated. This routine continued until no signfiicant chi-square was obtained. Species removed from the analysis were tested individually with chi-square. The assumption in this case was that individuals would be uniformly distributed in relation to roads if no road effect was present. The expected value in each instance was weighted by the sample size (number of plots) which varied slightly among the three distances from road. Thus, the test gave us a means of comparing bird density in relation to distance from road without requiring the assumptions of normality and equality of variances. Statistical significance in the paper is $\underline{P} \leq 0.01$.

RESULTS AND DISCUSSION

Southeast

Bird community structure and density were studied primarily in upland hardwood, bottomland hardwood, and loblolly pine habitat types. Few species were responsible for significant differences in species composition in relation to roads. In upland hardwood along interstates the wood thrush (*Hylocichla mustelina*) was significantly more abundant away from the road than near the highway. Distribution of the species in relation to county roads was uniform. The acadian flycatcher (*Empidonax virescens*), Louisiana waterthrush (*Seiurus motacilla*), and cardinal (*Cardinalis cardinalis*) were responsible for observed differences in species composition in bottomland hardwoods adjacent to interstates. Variability associated with the flycatcher and waterthrush was unrelated to the highway and most probably was due to specific wetland features of the habitat. The cardinal showed some preference for roadside plots and was favorably influenced by the ROW edge habitat.

Nine of the most abundant species in the Southeast were analyzed separately area-wide. Blue jay (*Cyanocitta cristata*) and wood thrush densities were negatively affected by roads, and the indigo bunting (*Passerina cyanea*) and field sparrow (*Spizella pusilla*) were positively affected (Table 1). The Carolina chickadee (*Parus carolinensis*), tufted titmouse (*Parus bicolor*), red-eyed vireo (*Vireo olivaceus*), eastern meadowlark (*Sturnella magna*), and cardinal were unaffected by roads.

For a strictly woodland species like the wood thrush we would expect somewhat fewer observations in plots immediately adjacent to the road because these plots contained ROW habitat that almost exclusively was maintained in an herbaceous or shrubby state. This type of habitat made up from less than 1 to about 2% of plots immediately adjacent to county roads and generally from 15 to 20% of those plots immediately adjacent to interstate highways. Thus, a 15 to 20% reduction in the abundance of a woodland species in plots immediately adjacent to interstates would be expected. Wood thrush abundance over the entire Southeast study area showed a 55% reduction in these plots. In a subsequent North Carolina study, breeding wood thrush were abundant in wide 443-469 ft (135-143 m) wooded interstate highway median strips, but only 1 bird was recorded during 23 replicate counts each on 7 narrow 141-194 ft (43-59 m) wooded median strips. We are confident that the species was not nesting in the narrow medians. One

Table 1. Numbers of four abundant breeding bird species, and (number of sample plots) in relation to roads in the Southeast study area, 1978-79.

Species	Road Type	Plot 2	Plot 4	Plot 6
Blue jay	Interstate	22(420)	40(424)	59(416)
	County	14(281)	25(329)	50(358)
Wood thrush	Interstate	35(406)	65(405)	63(393)
	County	18(296)	19(347)	23(381)
Indigo bunting	Interstate	83(461)	21(465)	30(455)
	County	42(401)	33(425)	36(424)
Field sparrow	Interstate	49(425)	24(425)	27(409)
	County	38(390)	37(406)	35(395)

might speculate that there may not be adequate "interior" woods in these narrow linear strips of habitat for the species. Ferris et al. (1977) recorded 9 species of forest birds in wooded median habitat (about 98 ft (30 m) wide) of I-95 in northern Maine during the breeding season. The wood thrush was not represented although it was recorded outside the median strip. Allen (1934) postulated that the species may dislike bright sunlight perhaps because its eyes are so large that too much sunlight makes the bird uncomfortable. On the other hand, the species may be disturbed by highway traffic. The blue jay avoided both interstates and county roads. The species showed a similar trend for interstates in Illinois. Ferris (1979) found blue jays to be negatively influenced by Interstate 95 in northern Maine.

The indigo bunting and field sparrow were positively affected by interstates and are recognized edge species (Pettingill 1970, and others). Both were significantly more abundant immediately adjacent to the highway than they were at farther distances. No difference was detected in the density of either species in relation to county roads, perhaps reflecting the effect of the much smaller ROW habitat there.

Among the five species not affected by roads, the eastern meadowlark and cardinal were very near our accepted 0.01 level of significance. Meadowlark density was slightly higher ($0.01 < \underline{P} < 0.025$) near both road types than away from these roads. This grassland species may be benefited by the grassy ROW habitat. The cardinal also showed some preference ($0.01 < \underline{P} < 0.025$) for edge habitat created along interstate highways but not for that along county roads. This observation may result from the greater amount of edge habitat associated with interstate highways where ROWs generally averaged about 49-66 ft (15-20 m) compared with edge habitat associated with county roads where ROWs averaged less than 16 ft (5 m).

Midwest

Breeding bird species composition and density were studied primarily on agricultural lands (predominantly corn and soybean fields) and upland hardwood forest. The horned lark (Eremophila alpestris), house sparrow (Passer domesticus), and red-winged blackbird (Agelaius phoeniceus) were responsible for differences observed in species composition in relation to distance from both road types through agricultural areas (Tables 2 and 3).

Table 2. Numbers of breeding horned larks and house sparrows, and (number of sample plots) in relation to roads in the Midwest study area, 1978.

Species	Road Type	Plot 2	Plot 4	Plot 6
Horned lark	Interstate	3(177)	9(170)	26(171)
	County	2(185)	21(182)	5(180)
House sparrow	Interstate	26(203)	0(208)	1(211)
	County	26(213)	0(212)	7(214)

Table 3. Numbers of breeding Brewer's and red-winged blackbirds, and (number of sample plots) in relation to roads in three geographical areas of the United States, 1978-79.

Species	Geographical Area	Road Type	Plot 2	Plot 4	Plot 6
Red-winged blackbird	Southeast	Interstate	40(150)	4(144)	1(167)
		County	34(208)	27(195)	23(177)
	Midwest	Interstate	94(177)	23(170)	21(171)
		County	85(185)	53(182)	34(180)
Brewer's blackbird	Northwest Oregon	Interstate	118(247)	32(250)	8(271)
		County	80(254)	14(270)	3(273)
	California	Interstate	60(69)	29(63)	22(61)
		County	6(54)	13(50)	3(46)

The lark and blackbird made up 64-68% of the bird community in agricultural habitat along interstates and 60-87% along county roads. Red-wings were significantly more abundant in plots immediately adjacent to both interstates and county roads than they were in more distance plots. Clark and Karr (1979) reported this relationship while working on an earlier phase of the present study. They believed that interstate ROW provided vegetation for red-wing nest supports that were not present along county roads. Small pieces of marsh habitat are present in drainage ditches along interstates, which may be attractive to the species. High fences and wires of various kinds also appear to be attractive guard perches (i.e., singing sites) for the territorial males. Horned larks preferred open habitat away from interstate highways, but there was no significant trend in relation to county roads. Clark and Karr (1979) reported similar findings for breeding horned larks.

The house sparrow was more abundant in plots adjacent to both interstates and county roads than in more distant plots. The species was not very abundant in either of the other two study areas; however, the trend was the same for the Southeast and Oregon. House sparrow nests were observed on structural supports beneath bridges and on large metal highway signs which may have some effect on distribution of the species.

Northwest

Bird populations were studied primarily in ryegrass fields and Douglas-fir forests in Oregon. In Douglas-fir habitat the chestnut-backed chickadee (*Parus rufescens*), Nashville warbler (*Vermivora ruficapilla*), hermit warbler (*Dendroica occidentalis*), and Oregon junco (*Junco hyemalis oreganus*) added significantly to the chi-square statistic and these species were analyzed individually (Table 4). The hermit warbler was more abundant away from both road types, and the Nashville warbler was more abundant away from the interstate. Chestnut-backed chickadee distribution was suggestive of greater abundance away from the interstate ($0.05 < P < 0.10$) and its distribution in relation to county roads was more distinct ($P < 0.005$). Oregon juncos were not significantly affected by roads although slightly more were observed adjacent to interstates than more distant from the highway.

Table 4. Numbers of three abundant breeding bird species and (number of sample plots) in Douglas-fir forest habitat in relation to roads in the Oregon study area, 1978.

Species	Road Type	Plot 2	Plot 4	Plot 6
Chestnut-backed chickadee	Interstate	6(56)	13(64)	21(72)
	County	1(57)	9(61)	18(75)
Nashville warbler	Interstate	3(56)	10(64)	20(72)
	County	10(57)	6(61)	6(75)
Hermit warbler	Interstate	3(56)	8(64)	19(72)
	County	6(57)	6(61)	30(75)

The most abundant species in ryegrass fields were Brewer's blackbird (*Euphagus cyanocephalus*) and savannah sparrow (*Passerculus sandwichensis*). The two species, along with the song sparrow (*Melospiza melodia*), were analyzed separately. Savannah sparrows were more abundant away from the interstate than near the highway, but the species was uniformly distributed in relation to county roads (Table 5). The song sparrow (recognized as an edge species) was more abundant in plots adjacent to the interstate than in plots more distant from the highway (Table 5).

Table 5. Numbers of savannah and song sparrows, and (number of sample plots) in relation to roads in the Northwest, Oregon study area, 1978.

Species	Road Type	Plot 2	Plot 4	Plot 6
Savannah sparrow	Interstate	37(197)	81(163)	85(163)
	County	58(114)	65(120)	53(118)
Song sparrow	Interstate	24(208)	9(194)	6(198)
	County	14(135)	3(132)	9(123)

Brewer's blackbird was more abundant adjacent to both the interstate and county roads than away from either road type, showing the same relation that the red-wing did in the Midwest study area (Table 3). Field observations showed that Brewer's blackbirds were feeding on insects killed by road traffic, particularly along interstates where the insects tended to be "windrowed" in the ROW habitat. In California, the species showed the same relation to the highway (Table 3).

Bird Mortality on Roads

In the Southeast study area, many woodland species--Carolina chickadee, tufted titmouse, wood thrush, red-eyed vireo, and woodland warblers--made up a substantial portion (24%) of the total number of birds recorded along interstate highways but did not show up at all in the road mortality survey. Either these species were not flying across roads frequently or they were flying across these highways high enough to avoid collisions with motor vehicles. Apparently, once the breeding season was initiated there was little movement across the highway system as territories were established and being defended, and birds were busy around the nest site. Three of the 16 species recorded in the road mortality survey made up 50% of the bird mortality. These species were the eastern meadowlark, indigo bunting, and field sparrow. The bunting and sparrow were found in greater abundance adjacent to the highway and the meadowlark approached our 0.01 level of significance, with more birds recorded in roadside plots than in more distant plots. Thus, 50% of the interstate bird mortality was incurred by 3 species making up 5.5% of the total bird count recorded in plots adjacent to interstate highways.

A similar pattern emerged from the Oregon data. Many woodland species--western wood pewee (*Contopus sordidulus*), black-capped chickadee (*Parus atricapillus*), chestnut-backed chickadee, Swainson's thrush (*Catharus astulatus*), woodland vireos, hermit warbler, western tanager (*Piranga ludoviciana*), black-headed grosbeak (*Pheucticus melanocephalus*), and evening grosbeak (*Hesperiphona vespertina*)--made up 17% of the total bird count along interstate highways but did not show up at all in the road mortality survey. Ninety-one percent of the bird mortality on interstates in Oregon consisted of Brewer's blackbirds. The species also contributed more to the total road mortality than did any other species in California. The species was more abundant adjacent to the highway.

Seventeen species were recorded in the road mortality survey in the Midwest with the red-winged blackbird making up 28% of the total kill. The species was more abundant in plots adjacent to interstates than in more distant plots, making up 50% of the bird community in these areas.

Bird mortality on highways apparently does not have a serious effect on the species studied, a belief shared by others who have analyzed highway mortality of various species (see Leedy and Adams 1982). However, under some situations involving mortality of threatened and endangered species, highway traffic may pose serious problems.

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EFFECT OF VEGETATION MANAGEMENT ON BIRD POPULATIONS ALONG ELECTRIC TRANSMISSION RIGHTS-OF-WAY

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ABSTRACT.--There are approximately 80,000 acres (32,000 ha) of vegetation presently being managed by New York State's seven major electric utilities on their electric transmission rights-of-way (ROWs). A variety of vegetation management techniques are used on these ROWs whose effects on songbirds during the breeding season are relatively unrecorded. Bird species diversity (BSD) and density values were determined from transect-strips on ROWs in eastern New York. BSD and density were highest on ROWs where trees received cut-and-stump or basal treatments with herbicides. BSD and density were consistently found to be lower on ROWs brush-mowed the year previous to census taking, and similarly low densities were found years later on ROWs broadcast sprayed with herbicides. The effect of mowing mixed-woody vegetation on ROW bird populations is very short-termed when compared to ROWs aerially treated with herbicides.

The effects of various ROW vegetation management techniques on nesting and foraging guilds were also analyzed. Low and middle foliage feeders were more abundant on ROWS which received cut-and-stump and basal treatments. ROWS with a diverse cover of shrubs and low-growing trees appear to provide the greatest number of nesting sites for most of the 40 species observed. Ground feeders such as the red-tailed hawk, mourning dove, and American robin were common on newly mowed ROWs. The gray catbird, common yellowthroat, and song sparrow were abundant on ROWs with a large percentage of shrub and low-tree cover. Aerial spraying lowered the densities of the low and middle foliage feeders and shrub nesting species. The costs of the commonly used vegetation management techniques are also discussed.

INTRODUCTION

In 1980, the New York State Public Service Commission (NYS PSC) issued a policy statement on electric transmission rights-of-way (ROWs) managed by New York State's seven major electric utilities (NYS PSC, 1980). The principal vegetation management objective endorsed by the PSC is the encouragement of low-growing, relatively stable plant communities that are

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compatible with electric system reliability requirements, aesthetically appealing, beneficial to wildlife and in need of relatively little maintenance over the life of a ROW. Most New York utilities have adopted this objective and use various vegetation management techniques to achieve it on approximately 80,000 acres (32,000 ha) of brushland-covered ROWs. Few studies, however, have investigated the effects which these techniques can have on songbirds, a large part of the wildlife commonly observed on ROWs in the Northeast.

In a recent study, Chasko and Gates (1981) and Lawson and Gates (1981) found higher avian breeding success, more habitat diversity and greater bird species diversity (BSD) in shrubland habitat maintained by "selective" herbicide spraying than on an annually mowed grassland located on a transmission line right-of-way (ROW) in Maryland. Cavanagh et al. (1976) found significantly lower wildlife abundance (mostly birds) on an old clear-cut ROW in New Hampshire which had received five foliage sprayings of 2,4-D and 2,4,5-T when compared to a newly clear-cut and a selectively cut area of ROW.

This paper reports on three years of observations to determine the effects of different ROW vegetation management techniques on songbirds which utilize ROWs with adjacent forest cover during the breeding season. Non-selective management techniques investigated include brush-mowing and aerial broadcast applications of herbicides, while species selective techniques examined include stem-foliar, basal, and stump spraying of undesirable plants. These techniques represent the spectrum of vegetation management techniques commonly used in New York on electric transmission ROWs.

METHODS

Sections of 11 ROWs ranging in size from 3.3 to 18.0 acres (1.3 to 7.2 ha) with adjacent forest cover in eastern New York were selected for this study. Some sites were chosen to examine pre- and post-treatment effects, while others were chosen to examine post-treatment effects on ROW bird population composition of different vegetation management programs.

Transect-strips were used to take a census of birds during the breeding season (Emlen, 1977). The edges of the transect-strips were located where tree heights abruptly changed between managed areas and adjoining forest vegetation. Bird species and numbers heard or seen were recorded during the censuses which were conducted between 0530 and 0930 EDT from late May to mid-june in 1979, 1980, and 1981. Most censuses were replicated four times.

Bird abundance was expressed as a density in numbers per 100 acres (40 ha). Duncan's multiple range test was performed at an alpha level equal to 0.05 to determine which total mean densities were statistically different. Bird species diversity (BSD) was calculated from the mean density value of each species recorded on the individual transect-strips (Shannon and Weaver, 1964).

RESULTS

Vegetation Cover

During the first breeding and vegetation growing season after brush-mowing, the Catskill, Freehold, and Plass Road rights-of-way had a sparse cover of root and stump sprouting trees and shrubs, a moderate cover of herbs, grasses, and ferns, and a moderate cover of woody debris (Table 1). At the time of the second breeding season, the Catskill right-of-way had a 70% cover of 3-6' (1-2 m) shrub and tree sprouts. The Plass Road right-of-way received a stem-foliage application prior to the second breeding season which caused herbs, ferns, and grasses to dominate the right-of-way (60%) instead of tree and shrub sprouts.

Aerial-broadcast treated rights-of-way (Table 1) were usually dominated by herbaceous cover and a low percent of shrubs (5-25%). Some of the rights-of-way (i.e., Pikes Hill) which were examined five years after the last aerial treatment had a moderate cover of white ash (*Fraxinus americana*).

Vegetation cover on cut-and-stump and basally treated rights-of-way varied considerably due in part to herbicide effectiveness, past treatments, and age. The highest percent shrub cover of all was found on the Pleasant Valley right-of-way which received two basal treatments in a four-year period. However, the Kent right-of-way which has a similar treatment history, is much lower in shrub cover due to a greater percentage of tree cover which formerly dominated it. The influence of right-of-way age and past treatment history on vegetation can be seen on the adjacent New Alps and Old Alps rights-of-way. The Old Alps had three foliar applications between 1953 and 1967 and one aerial application of herbicides in 1968. The right-of-way was widened on one side between 1975 and 1977 by selectively removing and stump-treating undesirable trees to create the New Alps. Both rights-of-way were stump treated in 1978 and 1979. The Old Alps is dominated by herbaceous cover, while the New Alps is dominated by a mixture of shrubs and tall- and low-growing trees.

Bird Abundance and Species Diversity

Bird species diversity (BSD) and abundance were highest on rights-of-way where selective vegetation management techniques (i.e., basal, cut-and-stump) were used (Table 2). BSD and abundance were generally lower on rights-of-way which were recently brush-mowed or aerially broadcast sprayed with herbicides (Table 3). Bird abundance on three rights-of-way which were brush-mowed the year prior to censusing was not significantly different from bird abundance on those broadcast-sprayed with herbicides one to four years prior to census taking. The density of birds observed on recently mowed rights-of-way and those one- to four-year-old broadcast sprayed was significantly lower when compared to most selectively managed rights-of-way.

The Catskill and Plass Road rights-of-way were brush-mowed in 1978 and a census taken each subsequent breeding season. Bird abundance has increased each year on both rights-of-way with the greatest increase occurring in the second breeding season (Table 3), which coincides with greatest yearly increase in vegetative cover (Table 1). The Plass Road

Table 1. Percent ground cover of study sites.

	Litter/ Open	Herbaceous	Low-Tree/ Shrub	Tall-Tree
Mowed				
Catskill - 1979	60	30	5	5
Catskill - 1980	20	10	45	30
Catskill - 1981	10	20	30	55
Freehold	40	55	0	5
Plass Road - 1979	30	60	10	0
Plass Road - 1980	15	90	0	0
Plass Road - 1981	0	90	10	0
Aerial Broadcast				
Pikes Hill - 1979	0	55	15	50
Pikes Hill - 1980	15	70	5	15
Pikes Hill - 1981	0	95	10	5
Ravena - 1979	0	75	20	5
Ravena - 1980	0	70	25	5
Ravena - 1981	0	65	35	5
Nassau - 1979	5	35	20	50
Cut-and Stump				
New Alps - 1980	10	25	40	60
New Alps - 1981	10	20	40	70
Old Alps - 1980	0	75	20	20
Old Alps - 1981	0	70	25	25
Reynolds - 1979	15	60	20	5
Reynolds - 1980	5	65	25	10
Reynolds - 1981	0	65	25	15
Nassau - 1980	25	60	25	5
Nassau - 1981	5	55	40	20
Cut-and-Stump/Basal				
Pleasant Valley - 1979	5	15	65	25
Pleasant Valley - 1980	5	15	65	15
Pleasant Valley - 1981	5	15	70	15
Kent - 1980	15	55	25	5
Kent - 1981	15	55	25	5

Table 2. Breeding bird composition of selectively treated rights-of-way (average no. individuals per 40 ha (100 acres)).

Site	New Alps		Old Alps		Reynolds			Nassau		Pleasant Valley			Kent	
Census Year	1980	1981	1980	1981	1979	1980	1981	1980	1981	1979	1980	1981	1980	1981
Treatment[1/]	C&S		C&S		C&S			C&S		B/C&S	B/C&S		B/C&S	
Treatment Year	1978-79		1978-79		1978-79			1979		1976	1979		1979	
Foraging Guild[2/]														
Ground														
Rufous-sided Towhee (G, ST)[3/]	5	27	-	-	6	-	3	5	16	-	-	5	4	9
Brown-headed Cowbird (ST)	-	-	-	-	11	6	3	5	11	-	11	32	4	2
American Robin (LT)	-	-	-	-	-	-	-	-	-	41	-	-	4	4
Red-tailed Hawk (LT)	-	-	-	-	2	3	3	-	-	-	-	-	-	-
Wood Thrush (LT)	-	-	-	-	-	-	-	-	-	-	11	-	-	-
Common Flicker (CT)	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Brown Thrasher (G, ST)	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Veery (ST)	-	-	-	-	-	-	3	-	-	-	-	-	-	-
Guild Density	5	27	-	-	19	9	12	10	27	41	22	37	12	21
Low Foliage														
Song Sparrow (G, ST)	24	24	25	28	39	28	40	5	21	104	73	37	11	20
Common Yellowthroat (W, ST)	43	43	25	3	16	22	20	42	21	41	-	21	18	18
Chestnut-sided Warbler (ST)	62	53	10	3	8	17	17	-	16	21	11	26	-	7
Gray Catbird (ST)	-	15	-	-	21	14	6	5	37	83	42	47	-	12
Field Sparrow (G, ST)	-	19	10	18	13	3	9	11	37	-	-	5	18	22
American Goldfinch (ST)	5	15	-	-	2	-	3	-	-	21	-	26	-	-
Yellow Warbler (ST)	-	-	-	-	7	6	6	-	-	-	11	5	11	5
House Wren (CT)	14	-	6	-	6	-	3	-	-	-	-	-	-	-
Northern Cardinal (ST)	-	-	-	-	-	-	-	-	-	-	21	5	-	-
Red-winged Blackbird (W)	-	-	-	-	6	12	-	-	-	-	-	-	-	-
Ruby-throated Hummingbird (ST)	-	4	-	-	-	-	-	-	-	-	-	-	-	-
Mockingbird (ST)	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Guild Density	148	173	76	52	118	102	104	63	132	270	158	172	58	88
Middle Foliage														
Indigo Bunting (ST)	28	19	-	5	2	-	-	11	16	-	-	32	-	-
Blue-winged Warbler (G)	-	4	-	-	4	3	-	-	-	21	11	37	11	9
Black-capped Chickadee (CT)	-	4	-	-	-	-	9	-	-	-	-	16	4	-
Cedar Waxwing (ST)	28	-	-	-	-	-	-	-	-	-	-	-	-	-
Rose-breasted Grosbeak (LT)	-	-	-	-	-	-	3	-	-	-	-	-	-	-
Black-billed Cuckoo (ST)	-	-	-	-	3	-	-	-	-	-	-	-	-	-
Nashville Warbler (G)	-	-	3	-	-	-	-	-	-	-	-	-	-	-
Northern Oriole (LT)	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Guild Density	56	27	3	5	9	6	12	11	16	21	11	85	15	9
High Foliage														
Blue Jay (LT)	-	-	-	-	-	-	-	-	-	-	-	11	-	-
Scarlet Tanager (LT)	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Guild Density	5	-	-	-	-	-	-	-	-	-	-	11	-	-
Aerial														
Eastern Kingbird (LT)	-	-	-	-	2	-	9	-	-	-	-	-	4	5
Prairie Warbler (ST)	-	-	-	-	-	-	-	-	-	-	11	5	4	7
Eastern Bluebird (CT)	-	-	-	-	9	-	-	-	-	-	-	-	-	-
American Redstart (LT)	-	-	-	-	-	-	-	-	-	41	-	-	-	-
Guild Density	-	-	-	-	11	-	9	-	-	41	11	5	8	12
Total Density	214	227	79	57	155	117	137	84	175	373	202	310	93	130
Diversity (H')	1.99	2.13	1.57	1.23	2.48	2.10	2.26	1.55	1.99	1.90	1.88	2.46	2.20	2.46
Total No. Species	9	11	6	5	17	11	16	6	8	8	9	15	11	15
Plot Size (ha)	2.1		3.2		7.2			1.9			1.9		5.7	
No. Strip-Transects	4	5	4	5	4	2	2	4	4	1	2	4	2	4

1/ C&S - Cut and Stump, B - Basal
2/ Foraging guilds after Willson 1974
3/ Nesting Guilds: LT - Large Tree, ST - Shrub, Small Tree, G - Ground, W - Wetland, CT - Tree Cavity (after U. S. Fish and Wildlife Service 1979)

Table 3. Breeding bird composition of aerially sprayed and mowed rights-of-way (average no. individuals per 40 ha (100 acres)).

Site	Nassau	Ravena			Pikes Hill			Catskill			Plass Road			Freehold
Census Year	1979	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979
Treatment[1]	AB		AB		AB	AB			M		M	SF		M
Treatment Year	1974		1977		1974	1979			1978		1978	1979		1978
Foraging Guild[2]														
Ground														
Rufous-sided Towhee (G, ST)[3]	7	3	6	-	9	2	9	3	7	13	-	-	-	16
Brown-headed Cowbird (ST)	-	-	-	-	-	7	2	3	15	15	-	14	20	-
American Robin (LT)	-	-	-	-	-	2	-	6	-	-	-	27	-	-
Common Flicker (CT)	-	-	3	-	3	-	-	3	5	-	-	-	-	-
Mourning Dove (LT)	-	-	-	-	-	-	-	6	2	-	-	41	-	-
Red-tailed Hawk (LT)	7	-	-	-	-	-	-	9	-	-	-	-	-	16
Guild Density	14	3	9	-	12	11	11	30	29	28	-	82	20	32
Low Foliage														
Common Yellowthroat (W, ST)	35	3	12	6	40	23	7	3	31	42	-	-	7	-
Song Sparrow (G, ST)	7	-	6	-	21	2	18	-	13	2	-	-	47	-
Field Sparrow (G, ST)	21	9	-	3	15	9	-	6	2	7	-	-	-	-
Gray Catbird (ST)	7	3	-	-	-	2	14	-	-	7	-	-	-	-
Chestnut-sided Warbler (ST)	14	-	-	-	6	-	2	-	9	31	-	-	-	-
Chipping Sparrow (ST, LT)	-	-	-	-	-	-	-	-	-	-	-	-	-	16
White-throated Sparrow (ST)	-	-	-	-	-	-	-	-	2	-	-	-	-	-
American Goldfinch (ST)	-	-	9	-	-	-	-	-	2	-	-	-	-	-
Mourning Warbler (G)	-	-	-	-	3	-	-	-	-	-	-	-	-	-
Ruby-throated Hummingbird (ST)	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Guild Density	84	15	27	9	85	36	41	9	61	89	-	-	54	16
Middle Foliage														
Indigo Bunting (ST)	7	9	6	9	3	2	-	-	9	7	-	-	-	-
Blue-winged Warbler (G)	-	-	-	-	-	-	2	-	-	2	-	-	14	2
Black-capped Chickadee (CT)	-	-	6	-	-	2	-	-	-	-	-	-	-	-
Rose-breasted Grosbeak (LT)	-	-	-	-	-	-	-	-	-	-	-	-	7	-
Yellow-breasted Chat (ST)	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Guild Density	7	9	12	9	3	4	2	-	9	11	-	-	21	-
High Foliage														
Blue Jay (LT)	-	-	-	-	-	5	-	-	-	-	-	-	-	-
Blue-gray Gnatcatcher (LT)	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Guild Density	-	-	-	-	-	5	-	-	2	-	-	-	-	-
Aerial														
Prairie Warbler (ST)	-	6	-	-	-	-	-	-	-	-	-	-	-	-
Guild Density	-	6	-	-	-	-	-	-	-	-	-	-	-	-
Total Density	105	33	48	18	100	56	61	39	101	128	0	82	95	48
Diversity (H')	1.86	1.05	1.87	1.01	1.68	1.63	1.45	1.31	2.14	1.86	0.00	1.01	1.34	1.10
Total No. Species	8	6	7	3	8	10	8	8	13	10	0	3	5	3
Plot Size (ha)	1.9		3.4			4.5			4.7			1.5		1.3
No. Strip-Transects	3	4	4	4	3	4	4	3	4	4	1	2	4	2

1/ AB - Aerial Broadcast, M - Mowed, SF - Stem-Foliage
2/ Foraging guilds after Willson 1974
3/ Nesting Guilds - LT - Large Tree, CT - Tree Cavity, ST - Shrub, Small Tree, G - Ground, W - Wetland (after U. S. Fish and Wildlife Service 1979)

right-of-way was treated with a stem-foliage herbicide application before a census in 1979 and since then, BSD and bird abundance has been somewhat lower than at the Catskill right-of-way which was stem-foliar treated after three breeding seasons. Bird abundance in the second and third census years since mowing has been significantly higher than the first census year at both sites.

Although BSD and bird abundance are low on recently mowed rights-of-way, consistently low bird abundance and BSD were recorded several years after the ROW had received an aerial broadcast application of herbicides. Bird abundance was significantly higher on several rights-of-way (e.g., Pleasant Valley, New Alps) recently treated with basal and/or stump-applied herbicides when compared to rights-of-way (e.g., Nassau and Pikes Hill-1979, Ravena-1981) which were aerially sprayed four and five years prior to a census. Bird abundance has ranged between 7 and 43 birds per hectare, and BSD has ranged between 1.01 and 1.86 for aerially sprayed rights-of-way, while bird abundance and BSD has ranged between 23 and 151 and between 1.01 and 2.48, respectively, for ROWs selectively treated with herbicides.

Foraging Guilds

Bird species recorded on the rights-of-way were listed in Tables 2 and 3 according to their foraging guild (stratum used most often for gathering food). As expected, the guild associated with low level foliage contained the largest number of species and was highest in density, especially of those species most frequently observed in this study [i.e., common yellow-throat (Geothylpis trichas), song sparrow (Melospiza georgiana), field sparrow (Spizella passerina), gray catbird (Dummatella carolinensis), and chestnut-sided warbler (Dendroica pensylvanica)]. The ground and middle foliage guilds contained similar numbers of species and were similar in density. However, considerably more middle foliage feeders were present on selectively maintained rights-of-way than on those which were mowed or aerially treated with herbicides. High foliage and aerial feeders were uncommon on most rights-of-way sites.

Although only one or two low foliage species were present on rights-of-way mowed in the fall previous to census taking, species from the middle and high foliage and aerial guids were entirely absent. Ground feeders present at these sites included the American robin (Turdus migratorius), mourning dove (Zenaidura macroura), common flicker (Colaptes auratus), and rufous-sided towhee (Pipilo erythrophthalmus). The brown-headed cowbird (Molothrus ater) and red-tailed hawk (Buteo jamaicensis), which obtain their food from the ground, were also observed, mostly perched on static wires and support structures (cowbirds) or on support structures only (hawk).

One of the most dramatic shifts in foraging guilds during the three-year census period occurred at the Catskill right-of-way. By the time of the second censusing following mowing, numerous root and stump sprouts from staghorn sumac (Rhus typhina), red maple (Acer rubrum), and red oak (Quercus rubra) covered 75% of the area and raised the woody plant layer one to two meters above the right-of-way floor. This resurge in vegetation produced habitat for low foliage gleaners such as the common yellow-throat, chestnut-sided warbler and song sparrow. Low foliage guild density has increased in each of the three subsequent years since mowing, while the density and number of ground feeding species has decreased (Table 3).

Species with the highest densities on aerially sprayed rights-of-way belong to the low foliage guild (e.g., common yellowthroat, song sparrow, and field sparrow). It is also evident that the majority of birds observed on selectively treated rights-of-way are members of the low foliage guild (Table 2). The low foliage guide for selectively treated rights-of-way contained 35% of all species observed and, generally, contained more than 60% of all individuals observed. The indigo bunting (Passerina cyanea) and blue-winged warbler (Vermivora pinus) were frequently observed middle foliage feeders on selectively maintained rights-of-way.

Nesting Guilds

Of the 40 species observed in this study, 21 (52.5%) nest in shrubs or small trees, 12 (30%) nest in large trees, 7 (17.5%) are ground nesters, 4 (10%) nest in tree cavities, and 2 (5%) nest in wetlands (Tables 2 and 3). A total of 24 species (60%) nest on the ground or in small trees and shrubs which can be found on the various rights-of-way. It is unlikely that large tree and tree cavity nesters could find suitable nesting habitat on most rights-of-way. Large tree and cavity nesters were never very abundant and, presumably, most are occasional visitors to the right-of-way from adjacent forests or forage there to a certain extent. Nests, however, of American robins were found on rights-of-way in tree saplings and low-growing trees, and red-tailed hawks were observed nesting in steel-lattice structures.

Species belonging to the shrub and small tree nesting guild were the most abundant and commonly observed birds, especially on stump or basally treated rights-of-way. A similar number of species from this guild were found on aerially sprayed sites, but densities were significantly lower there. Very few species of any nesting guild were found on recently mowed rights-of-way. A substantial increase in shrub and small tree nesters (from 4 to 10) was observed between the first and second censuses at the mowed Catskill right-of-way.

DISCUSSION

Right-of-way vegetation maintenance methods, designed to remove target plants and alter vegetation composition, will affect songbirds which depend on the vegetation for foraging and nesting habitat. Habitat variables such as tree spacing, number of shrubs, foliage height diversity, and percent vegetation cover in vertical layers have been used to explain habitat differentiation and diversity differences for breeding songbirds on rights-of-way (McCuskey, 1978; Geibert, 1979; Lawson and Gates, 1981).

Of all the rights-of-way examined, those recently mowed (less than one-year-old) or aerially broadcast sprayed with herbicides contained the lowest number of individuals and species of songbirds. Brush-mowing, obviously, can totally eliminate the above-ground foraging and nesting habitat for most potential right-of-way songbirds. This effect is very short-lived since root- and stump-suckering plants grow quickly--reaching 3 ft (1 m) in height in their first full growing season. Species of the low foliage guild quickly inhabit this vegetation unless herbicides have been applied to most woody vegetation, as was observed at Plass Road. Bird densities increased in each of the three breeding seasons since mowing at the Catskill right-of-way. Similar results have been observed by Stapleton and Kiviat (1979) for songbird usage on a mowed railroad causeway and in breeding bird density by McCuskey (1978) on an electric transmission right-of-way in Virginia.

Aerial broadcast spraying, in contrast to mowing, is used to eliminate undesirable vegetation, and therefore, has a longer-lasting effect on vegetation structure and composition than does periodic brush-mowing. All aerially sprayed ROWs in this study, even those sprayed 12 years previous to censusing, were low in bird abundance and species diversity. Using this method to kill tall-growing trees on right-of-way target areas also eliminates most desirable shrubs. Bramble and Byrnes (1972) have shown that it has taken ten or more years for shrubs to recover their original abundance after broadcast spraying. All of the aerially sprayed rights-of-way in this study had a history of broadcast herbicide applications and were dominated by herbaceous vegetation. Giebert (1979) and Lawson and Gates (1981) have also shown that reducing the structural complexity of the shrub layer will reduce songbird diversity.

Open-habitat species such as the red-tailed hawk and mourning dove might benefit from the broadcast spraying and recent mowing in increased foraging habitat. Bramwell (1980) found an increase in the sighting of raptors which coincided with an increase in rodents, particularly meadow voles (Microtus pennsylvanicus) following ground broadcast and basal applications of herbicides to a Quebec right-of-way dominated by saplings of high density.

Bird abundance and BSD remained relatively high on basal and cut-and-stump treated rights-of-way. While there is some indication of lowered songbird densities and BSD in the year following treatment on the Pleasant Valley and Nassau rights-of-way, the decreases were not as significant as those on recently mowed and aerially sprayed rights-of-way. Longcore (1971) also found small fluctuations in numbers of territorial male songbirds between 1967 and 1971 on a Maryland right-of-way which twice received selective cutting and basal applications of herbicides.

Other authors, after studying various aspects of avian right-of-way ecology, have concluded that selective applications of herbicides would result in greater songbird abundance and BSD than maintenance by frequent mowing or broadcast applications of herbicides (Lawson and Gates, 1981; Ferguson, 1976; Geibert, 1979). Selective spraying leaves much of the right-of-way untreated and thereby allows shrubs and low-growing trees to provide an increased vertical dimension to right-of-way vegetation for new nesting and foraging habitats.

The degree of impact of maintenance techniques on breeding right-of-way songbirds relates to the degree in which vegetation structure and composition upon which they depend is disturbed. The use of selective techniques will not necessarily increase songbird density and diversity. For example, selectively cutting and stump treating a right-of-way site dominated by a mixture of tall-growing trees might cause the composition of the next season's breeding bird population to resemble that of a mowed right-of-way population. A foliar application of herbicides would, at least, provide a vertical stratum of dead vegetation of use to bark foragers or to territorial males as singing perches. However, where compatible vegetation does occur, techniques should be selected which favor the development of a mature shrub layer and scattered low-growing trees, if one desires to enhance songbird diversity and abundance.

Currently, the major electric utilities in upstate New York minimize the use of relatively nonselective techniques. In a recent two-year period (1979-80), the two largest upstate utilities (Niagara Mohawk Power Corporation and New York State Electric & Gas Corporation) treated about 19,500 acres (7,900 ha). Only 8% was aerially broadcast sprayed and 2%, mowed. Selective cutting, basal, and cut-and-stump treatments accounted for nearly 60% of the treated ROW acreage with the remainder being stem-foliar.

Very selective techniques are, however, more costly than nonselective techniques if compared as single, one-time treatments. The range in average costs per acre (per ha) for techniques used by New York utilities in 1980 was as follows: cut-and-stump (drop and lop disposal $225-271 ($91-110); basal $85-291 ($34-118); stem-foliar, $89-287 ($36-116); aerial $190 ($77); and brush-mowing $165 ($67). Costs for more selective techniques would be higher if applied to high density sites. For example, for the same sites on one right-of-way, a New York utility estimated costs to be $300 ($120) for aerial, $450 ($180) for selective foliar, and $590 ($240) for cut-and-stump treatment. Using 1977 cost figures, Spangler (1979) predicted long-term maintenance costs for West Penn Power Company's rights-of-way. Ground foliar application of herbicides followed by basal applications over a 40-year period were comparable to repeated aerial application costs and must less costly than repeated mowing.

New York's Public Service Commission has recently endorsed selective applications of herbicides on electric transmission rights-of-way based on appropriate vegetation and environmental inventories. New York utilities have also been required to develop sustained, long-range, right-of-way management plans (NYS PSC, 1980). Most utilities have developed strategies which increasingly use more selective methods and promote woody shrub-low tree communities which should favor breeding songbirds across the entire transmission ROW system of the State.

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SPECIAL CONSIDERATION FOR IMPLANTING TWO 735 kV LINES IN THE HILL HEAD DEER YARD; NEAR MONTREAL

Pierre Lamothe[1] and Pierre Dupuy[2,3]

ABSTRACT.--Prior to construction of two 735 kV lines from the James Bay LG-2 Powerhouse to the Montreal area, a study was conducted to determine winter utilization by deer within the central portion of the Hill Head deer yard and to evaluate the loss of food and cover that would result from the implantation of the 500 ft (150 m) right-of-way (ROW) through the deer yard. Mitigating measures were identified and implemented in the clearing and construction of the transmission line in order to minimize the barrier effect and to provide cover for deer to cross the right-of-way.

Clearing the forest at tower structure sites was done in winter in order to provide extra food for deer. Observations on deer distribution within the yard were continued throughout the forest clearing operation in the right-of-way. Both lines were constructed from late spring to early fall to minimize the effect on the deer population.

The study continued in the winter 1980-1981, one year after the lines were under tension, to monitor the use by deer of the forest screens left as a mitigation measure and to determine the winter utilization in the right-of-way and in the yard portion on both sides of it.

INTRODUCTION

The energy produced by the James Bay hydroelectric project in northern Quebec is carried to southern urban areas in three different corridors. The western corridor links the LG-2 powerhouse near the La Grande River in

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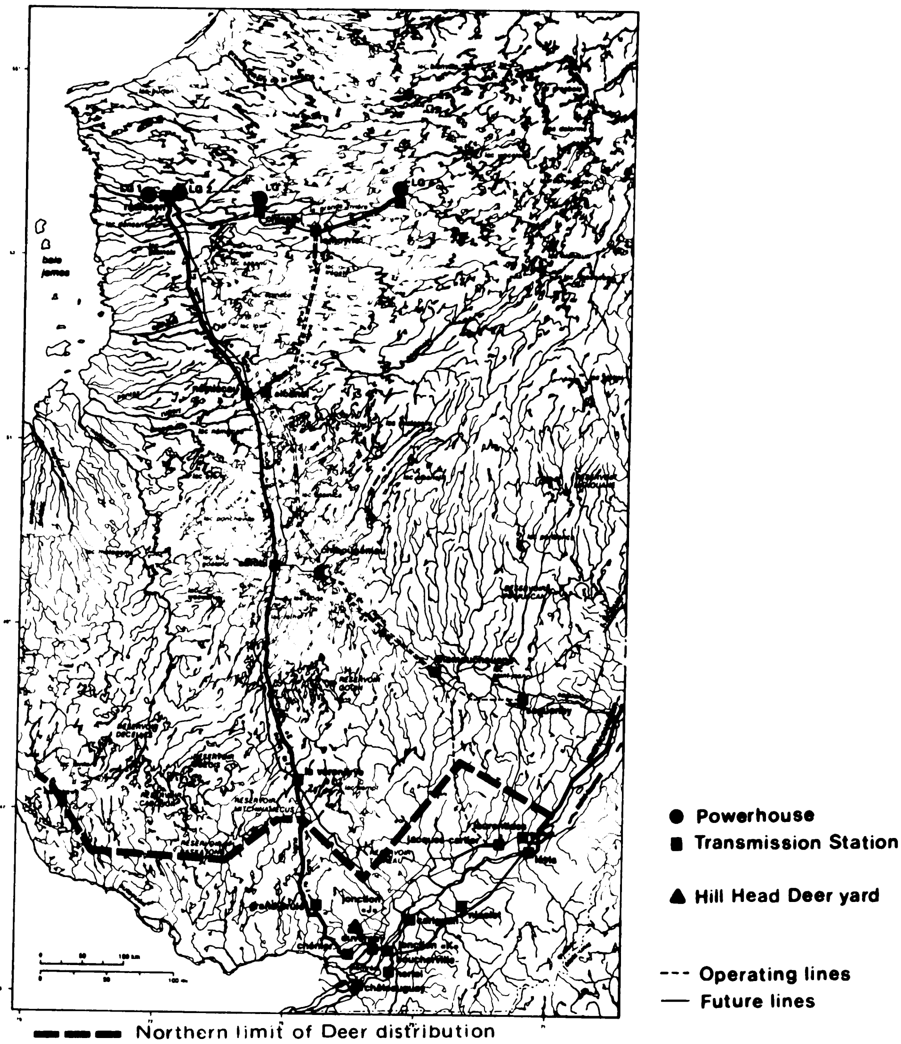
northern Québec to the Chénier substation located at the western fringe of the Montreal metropolitan area. Two 735 kV transmission lines on guyed V-shaped towers are located side by side in a 500 ft (150 m) wide corridor. The southern 60 miles (100 km) of the route are in the northernmost limit of the distribution of white-tailed deer (Odocoileus virginianus) in Quebec (Fig. 1).

FIGURE 1 : The James Bay Transmission network, & the Hill Head Deer yard location.



When Hydro-Québec began its studies to determine the routes for transmission lines, deer yards were included in the list of areas to be avoided because these yards constitute critical habitat for white-tailed deer management in Quebec. This paper discusses the problems associated with the construction of transmission lines through the Hill Head deer yard. In the planning stage when different routes were considered for the corridor, it was found difficult to avoid this yard, owing to the existence of a large airport zone and urban areas on each side. In the immediate region of the yard, a municipal resolution opposing the passage of a transmission line corridor through the municipality and the planning of a park to the south forced Hydro-Québec to select a route passing through the east-central part of the yard.

It was expected that a 500 ft (150 m) corridor running through a deer yard would act as a barrier and eventually separate the yard, resulting in altered utilization on either side of the corridor and a reduction in the vegetation and food supply in the ROW. Hydro-Quêbec therefore formulated special mitigating and protective measures.

This paper provides a general picture of the various mitigating measures implemented during construction of two parallel 735 kV transmission lines in the Hill Head deer yard and evaluates the effectiveness of some of these measures in relation to the expected impact.

Study Area

The Hill Head deer yard is located some 30 mi (50 km) northwest of Montreal, Quebec (45° 41N, 74°13' W), and extends over 10 mi (15 km) along a slightly undulating plateau that has a generally southern exposure and is bounded by sloping ground. In 1976 and 1977, the surface area of the yard ranged between 15 and 24 km^2, depending on weather and deer populations. In 1977, the population was estimated to be 325 ± 50 deer (Potvin 1979) but is expanding. During the winter of 1976, the forest cover appeared as a mosaic composed of 40% conifers, 24% mixed, 14% deciduous, and 22% open grounds which were mainly old fields or pasture (Potvin 1979). The main tree species were sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), white pine (*Pinus strobus*), hemlock (*Tsuga canadensis*), balsam fir (*Abies balsamea*), white cedar (*Thuja occidentalis*), poplar (*Populus spp.*), and birch (*Betula spp.*)

In normal winter, the snowfall is about 100 in (250 cm). The accumulation of more than 20 in (50 cm) lasts less than 50 days (Potvin 1979). The average temperatures in December, January, and February are respectively -6.7°C, 9.4°C and 8.9°C (Powe 1969). Deer normally occupy the yard from December 15 to April 15 (Potvin 1979).

Mitigating Measures

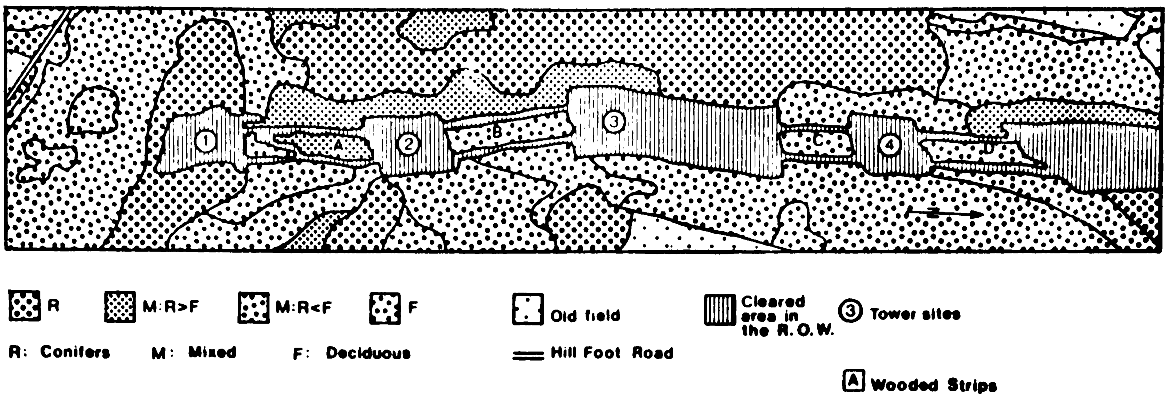
The surveys carried out in 1978 determined the deer utilization pattern in the corridor proposed for the transmission lines. The results of the surveys and the general characteristics of yards were taken into consideration to determine the mitigation measures to be implemented. These measures included (1) increasing tower height up to 60 ft (20 m) to preserve strips of forest vegetation in the corridor, (2) clearing during the winter and piling of the slash in such a way that deer could use it as additional browse. Winter clearing also reduced the disturbance to the soil and promoted better regeneration, (3) burn the remaining slash in the spring in order to reduce obstacles to subsequent movements by deer, and (4) build the two lines in the summer and fall when the yard was not occupied.

The application of the first measure resulted in a corridor consisting of cleared sections alternating with strips of forest vegetation (Fig. 2). The cleared areas, required for implanting the towers measured approximately 90 m X 130 m, while clearing of 150 m X 260 m was required for angle towers. The length of the wooded strips varied from 100 m to 250 m. The cleared areas were linked by two centerlines varying in width from 6 to 13 m.

METHODS

Four types of surveys were conducted to determine habitat utilization pattern by deer.

FIGURE 2 :Oblique view * of the study area



* From an assembly of photographs taken at low altitude from an helicopter. On Feb. 14, 1981.

In the first instance, individual deer and tracks were located in most of the yard during seven surveys carried out by helicopter in the winter of 1978, 1979, and 1981.

The second surveys were conducted on the ground in winter in order to ascertain the specific utilization of the corridor and the area immediately adjacent. On each occasion deer tracks were noted along three sets of transects: one set was in the corridor, another on both edges, and a third set was located 100 ft (30 m) into the adjacent forest on either side.

A third type of survey determined pellet groups in the spring of 1978 and 1981 in sampling areas scattered uniformly along the corridor. A fourth survey consisted in counting stems and twigs used or available as browse. These estimates were done in the same sampling areas as those for pellet group counts using methods similar to those proposed by Potvin (1978). In 1981, the same type of inventory was carried out and the sampling areas were selected according to the new characteristics of the study area created by the ROW. Figure 3 shows the location of the sampling area in 1981. During land-clearing in February 1979, we estimated the browse of the slash pile by deer.

RESULTS

Deer Surveys

Results indicated that the eastern sector, the ROW, and the western sector were used by the deer before, during, and after construction of the line (Table 1). The barrier effect, if present, was not severe. Most of the deer were observed at the top of the slope at the southern edge of the yard. Very few were seen in the northern part of the yard.

FIGURE 3 : Sampling zones

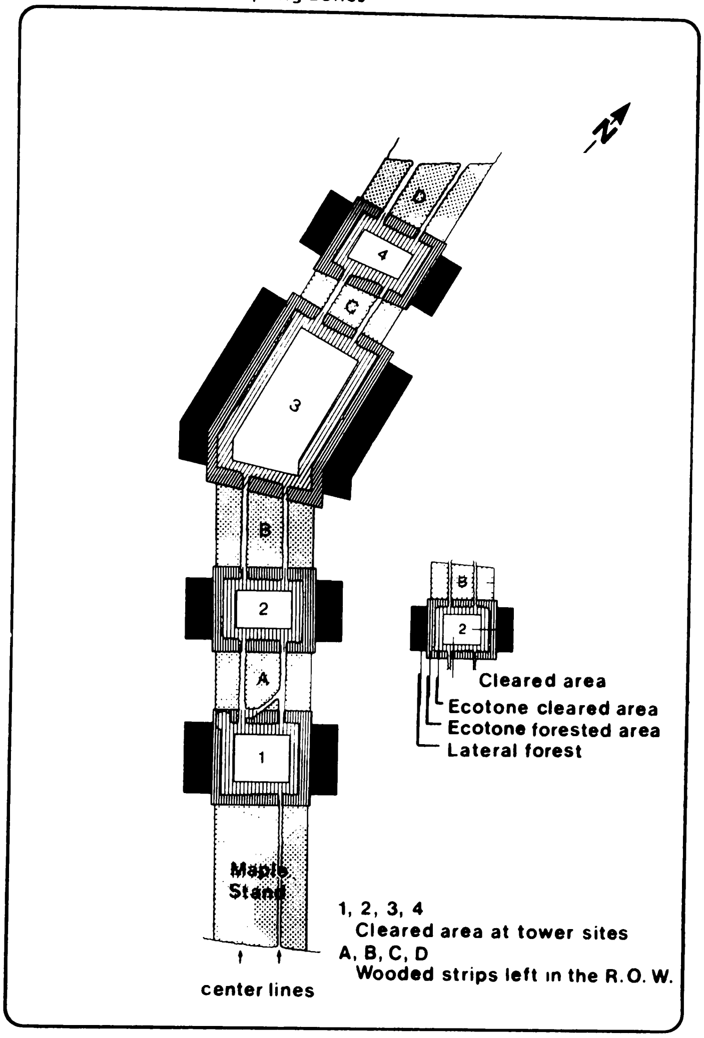


TABLE I : Deer observed during aerial surveys.

PERIOD	DATE	NUMBER OF DEER West sector	R.O.W.	East sector
Before clearing	03/25/78	6	1	8
	04/15/78	6	0	0
	01/20/79	4	4	6
During clearing	02/17/79	33	4	24
	03/28/79	19	0	3
After clearing	02/14/81	24	1	8
	03/09/81	6	0	6

Track Surveys

Nearly all the tracks and trails were found south of the angle towers before the clearing operation. During the period of confinement when snow on the ground is more than 50 cm, deer concentrated their activities on the top edge of the slope where exposition and shelter provided better protection. After construction of the two lines, surveys of tracks and trails (Fig. 4) showed that deer continued to be active at site 3 (south of the angle towers). Deer displayed some reluctance to cross the ROW in cleared areas, except for site 2 where a high density of tracks was observed at the edge of the cleared area. However, deer preferred wooded strips A and B to cross the ROW. With regard to the ROW as a whole, deer were more active along the lateral edges than in the forest alongside or in the cleared areas. Similarly, trails were mainly located parallel to and outside the ROW.

TABLE 2 : Comparison of mean density of pellets / 80m² between areas.

	SITE 1		SITE 2		SITE 3		SITE 4		CLEARED AREAS	
F & Fe	8.1-5.9	N.S.	2.2-2.4	N.S.	2.8-1.1	$P < 0.005$	2.1-1.1	N.S	3.5-2.4	N.S.
F & Ce	8.1-3.2	$P < 0.025$	2.2-0.5	$P < 0.005$	2.8-0 3	$P < 0.001$	2.1-0.1	$P < 0.001$	3.5-1.0	$P < 0.001$
F & C	8.1-1.1	$P < 0.001$	2.2-1.5	N.S.	2.8-0.2	$P < 0.001$	2.1-0.0	$P < 0.001$	3.5-0.6	$P < 0.001$
Fe & Ce	5.9-3.2	N.S.	2.4-0.5	N.S	1.1-0.3	N.S.	1.1-0.1	N.S.	2.4-1.0	$P < 0.025$
Fe & C	5.9-1.1	$P < 0.005$	2.4-1.5	N.S.	1.1-0.2	$P < 0.025$	1.1-0.0	N.S.	2.4-0.6	$P < 0.005$
Ce & C	3.2-1.1	N.S.	0.5-1.5	N.S.	0.3-0.2	N.S.	0.1-0.0	N.S.	1.0-0.6	N.S.

Strips A & B + Lateral forest at site 2 & 3	4.5	2.6	$P < 0.005$
Strips C & D + Lateral forest at site 3 + 4 :	2.7	0.7	$P < 0.005$

Sampling zone. F : Lateral forest Fe : Forest ecotone

Ce : Cleared area ecotone C : Cleared area

Student test

Pellet Counts

The distribution and abundance of pellets in the ROW before clearing showed a density of 875 pellets/ha for the pine-hemlock association at site 1, compared with 210 for the maple stand south of this site, 91 in the mixed stands around site 2 and site 3, and virtually none at site 4.

Two years after the clearing, results indicated that on the whole there was little change in deer utilization in the yard. However, within the study area, the utilization of habitats at the edge of the ROW was modified. The different pellet densities are presented in Table 2.

FIGURE 4 : Track density along transects in sampling units.

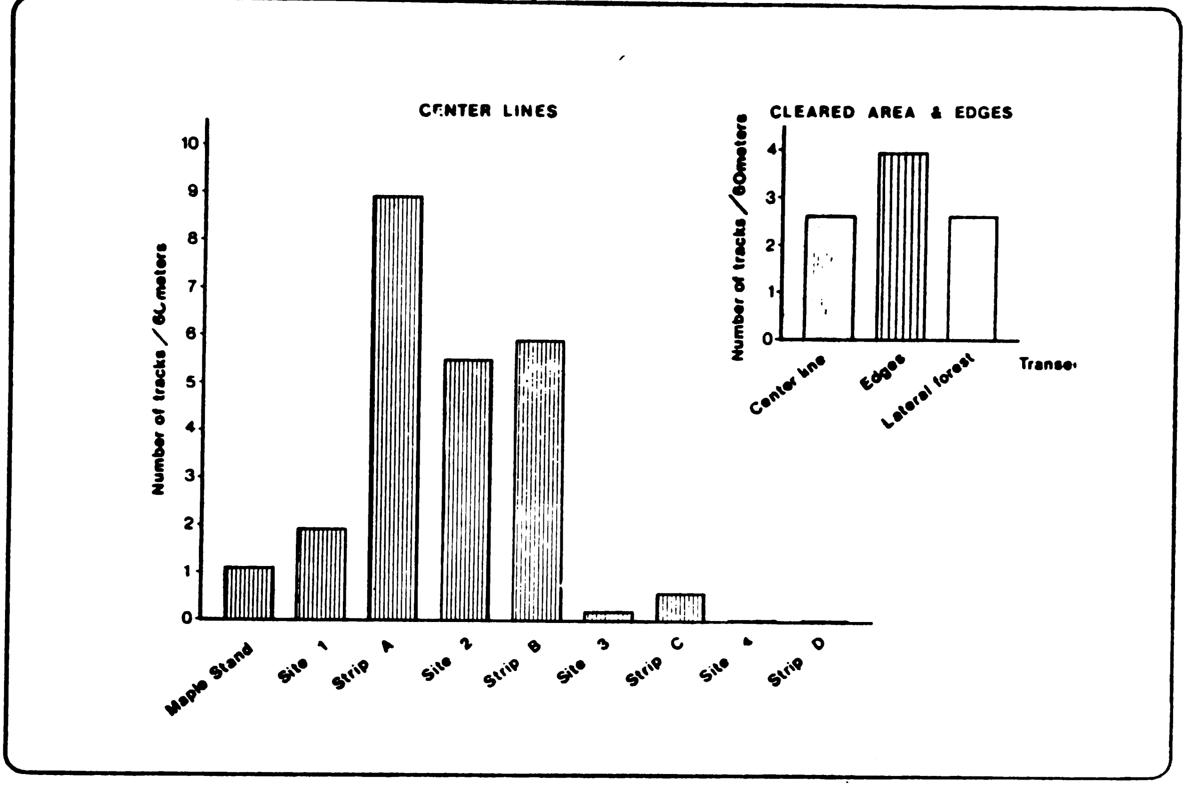


TABLE 3 · Characteristics of food available & used by white - tailed deer in each sampling units

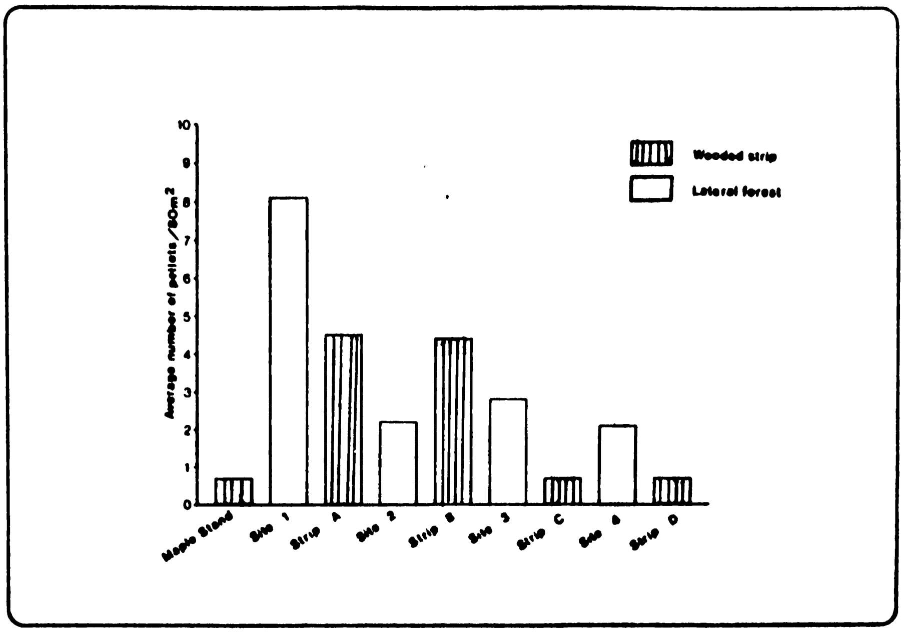
	LATERAL FOREST							CLEARED AREAS			
	Maple stand	Pine-Hemlocks stand Site 1	Mixed forest Site 2	Mixed forest A & B	Mixed forest Site 3	Birch stand Site 4	Birch stand C & D	Site 1	Site 2	Site 3	Site 4
Number of stems / ha	18,800	3,600	3,800	7,100	9,500	6,300	7,400	6,600	8,200	4,700	5,000
% browsed	19.3	71.1	36.8	56.7	16.7	9.5	8.7	54.4	44.6	9.4	6.2
Number of twigs / ha	115,700	52,200	144,700	94,400	113,000	150,100	130,000	8,800	47,000	55,400	26,800
% browsed	10.5	20.4	3.0	25.7	8.2	2.9	1.1	47.6	34.6	4.2	7.7

(1) Including conifers.

(2) Including ecotone-forested units.

(3) Including ecotone-cleared area units.

FIGURE 5 : Pellet density in the wooded strips & lateral forest



The cleared areas were used very little in comparison to the adjacent forest ($P < 0.001$). Utilization by deer was most intense in these lateral forests, decreased in intensity in the forest ecotones, decreased again in the cleared ecotones, and was least intense in the cleared areas. Site 2 is an exception to this pattern inasmuch as the cleared corridor ecotone is significantly ($P<0.005$) less utilized than the others. (Table 2).

Figure 5 shows that the lateral woods at site 1 were preferred to other sites. Wooded strips A and B are used for crossing the ROW and that wooded strips C and D are seldom used by deer.

Regeneration in Cleared Areas

In 1981, two years after the clearing operations, the vegetation in the cleared areas was at the shrub stage. Sprouts and suckers were between 3 and 6 ft (1 and 2 m) high. An increase in the number of stems per hectare was noted in sites 1, 2 and 3, whereas there was a slight decrease at site 4. The number of stems per hectare increased from 3800 to 6600 at site 1, from 4100 to 8200 at site 2, and from 3300 to 4700 at site 3. In contrast, the number at site 4 dropped from 6000 to 5000. The number of twigs per hectare at site 4 dropped from 52,700 to 26,800, whereas at site 1, this number increased from 41,600 to 58,800; from 38,200 to 47,000 at site 2; and from 39,200 to 55,400 at site 3. However, we noted a reduction in the quality of the browse in the cleared areas. The maples and red oak (*Quercus rubra*) which are preferred by deer have been replaced by intolerant species such as aspen (*Populus tremuloides*), birch, and cherry trees, which are not as useful to deer.

Feeding in Cleared Areas

Table 3 shows the utilization of food available in and around the ROW. Regardless of species browsed, sites 1 and 2 provided more stems and twigs than the lateral forest. The difference ranged from 1.4 to 2.6 for stems and from 2.5 to 3.6 for twigs. At sites 3 and 4, we noted 2 to 4 times less stems and twigs in the cleared areas than in the lateral forest. The available browse was used at a higher rate in wooded strips A and B than in the lateral forest at sites 2 and 3. The vegetation in wooded strips C and D are of the same type as those in the lateral forest at site 4. Both strips C and D showed low deer utilization. The lateral forest around site 1 is considered separately, in view of the fact that deer used it heavily, even before the line was built.

Utilization of Slash Piles

Slash was heaped into 27 irregular piles accessible to deer for feeding. Deer took advantage of this supplemental food source immediately, but they used it selectively. During the first few days, deer browsed on more than 75% of the available twigs of sugar maple, red maple, red oak, and white cedar, compared with 50 to 75% of the twigs of linden (*Tilia americana*), aspen, and wild red cherry (*Prunus pensylvanica*).

DISCUSSION

Studies have shown that during the winter, deer are less active in a conventional 100 ft (30 m) wide ROW running through another deer yard than in the adjacent woodland. Moreover, deer seemed to be hesitant about crossing a completely cleared ROW (Doucet et al. 1981).

The study showed that deer prefer to cross the ROW in the wooded strips spared by the original clearing operation rather than to use the cleared areas. The utilization of these strips depended on the quality of the protective cover in them. Willey and Marion (1980) showed that the preservation and maintenance of screens of vegetation in a ROW proved to be an effective way facilitating the crossing of a ROW by deer in winter. The most traveled wooded strips in the Hill Head yard contained a high proportion of conifers. This result agrees with previous studies (Ozoga 1968; Stephenson 1972; Huot 1973) which showed that in winter, deer clearly prefer mixed and coniferous forest stands. The tracks and trails observed alongside the ROW suggest that deer move through the lateral forests rather than cross the cleared areas. In fact, cleared areas seemed to impede deer movement. This type of behavior was also observed by Doucet et al. (1981) in a conventionally cleared ROW.

Deer utilization of ROW can be related to the amount of food available therein (Goodwin 1975; Cavanaugh et al. 1976, Eaton and Gates 1981). Forest management through the creation of clearings in deer yards with a low production of stems and twigs usually gives a maximum production of deer browse two years after the operation. Production is even higher five years after a second clearing operation (Potvin and Huot 1979). In cleared areas of the ROW under study, more food was available two years after the clearing operation than before. However, the observed regeneration did not attain the optimum value of 10,000 to 15,000 stems per hectare, as suggested by Potvin (1972) for deer habitats in Quebec.

The utilization of the new vegetation in the cleared areas seemed related to the existence and quality of shelter in the lateral forests. Browsing was heavier at sites 1, 2 and 4 than in the lateral forests. The lighter browsing observed at site 3 could be attributed to the larger size of the cleared area and the disturbance of the site during the construction of the angle towers.

Deer started to feed at the slash piles immediately after they were completed. The animals did not seem to be bothered by the presence of men and equipment. They made extensive use of this additional food source, and the slash piles constituted centers of attraction. However, it is difficult to assess the trade-off between the standing browse removed and the food made available in the slash piles.

CONCLUSION

Raising towers and taking advantage of the topography enabled 300 to 800 ft (100 to 150 m) wooded strips to be preserved intact. These wooded strips facilitated the crossing of the ROW by deer. The most traveled strips were those providing shelter mainly in the form of large conifers. The level at which these strips were used also depended on the quality of the habitats on either side.

Regenerating vegetation in the cleared areas of the ROW provided a food source quantitatively greater than that observed in the adjacent forest. The browse was more utilized in three of the four sites than in the adjacent forests.

The Hill Head deer yard is part of a network of green spaces along this energy corridor, where special maintenance measures will be applied. Maintenance of the vegetation in the cleared areas will be done by mechanical means when the vegetation will threaten the structures. Raising the tower will result in longer periods between maintenance work on the vegetation in the cleared areas. Winter maintenance would, in addition, provide extra food for deer.

In conclusion, the steps taken by Hydro-Quebec have helped to minimize appreciably the impact resulting from the implantation of two 735 kV transmission lines through the Hill Head deer yard.

ACKNOWLEDGMENT

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CHANGES IN ANIMAL ACTIVITY IMMEDIATELY FOLLOWING THE EXPERIMENTAL CLEARING OF A FORESTED RIGHT-OF-WAY

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ABSTRACT.--The sand transect technique was used to study the influence of habitat manipulation on the activity of a terrestrial animal community in the Laurentians, Quebec, from 1972 to 1974. During the first year (1972), part of the study was conducted in a 1 acre (0.4 ha) enclosure. To simulate the development of a right-of-way, two 66 ft (20 m) wide strips totalling 3000 m were clear-cut and the slash was removed. Animal activity after the clear-cut was compared to that preceding the cut. Two 246 ft (75 m) linear transects measured the activity within the clear-cut right-of-way, while circular transects adjacent to the right-of-way and a linear transect 656 ft (200 m) away were used as controls. A total of 14 taxa were studied. The clear-cut and debris removal contributed to a decrease in activity for birds and small mammals while invertebrates, toads and snakes showed an increase in activity after the cut.

INTRODUCTION

Animal activity in the wild reflects species mobility and capability of macro and micro habitat utilization in time and space. Consequently, locomotor activity is a good criterion to determine the response of a resident animal community to habitat manipulation. This paper was part of a more encompassing study (Doucet 1975) on the effects of physical factors on animal activity. Several studies concerning the effects of rights-of-way (ROW) on animals have concentrated on already established ROWs (Bramwell and Bider 1981; Doucet et al. 1981; Gates and Dixon 1981; Ladino and Gates 1981; Schreiber et al. 1976).

The objectives of this experiment were to determine the short-term effects on animal activity of the vegetation removal resulting from the original clearing for the establishment of a ROW. Data are presented for 14 animal taxa for the period 1972-74.

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Study Area

The field work was done at the Lac Carre Ecological Station (46°09'N, 74°29'W), an area of the mid-Laurentians series, about 68 mi (110 km) northwest of Montreal, Quebec. Bider (1968) and Wishart and Bider (1976) have described the vegetation. The experimental and control sites were predominantly flat, sandy plateaus with no free water available in the form of puddles or streams.

Two types of habitats were represented in the study area: (1) an old field, last pastured in 1953, hayed in 1955 and planted with balsam fir (*Abies balsamea*) planting stock (7.8-16 in (20-40 cm) in height) in 1962, and (2) an adjacent stand of mixed forest. The old field was in an advanced state of succession and young willows (*Salix spp.*), trembling aspens (*Populus tremuloides*), and wild red cherries (*Prunus pensylvanica*) were common. The woods section contained a mixture of large poplars, maples (*Acer spp.*), cherries, and balsam firs.

Tall herbs in the field consisted mainly of goldenrods (*Solidago spp.*). Few trees except poplars and willows were higher than 10 ft (3 m) in the old field. The high hazelnut (*Corylus cornuta*) coverage in the woods may have contributed a good food source for species such as chipmunk (*Tamias striatus*) at certain periods and thus contributed to higher activity. In the woods, the arborescent vegetation was mainly deciduous and maples, trembling aspens, and balsam firs were often more than 33 ft (10 m) in height.

The Animal Community

Bider (1968) listed all the member species of the community under study. In this project, some species were grouped for convenience or because tracks were difficult to differentiate. Aves included all bird activity except ruffed grouse (*Bonasa umbellus*) and woodcock (*Philohela minor*), but the majority of tracks were made by passerines. Zapodidae included meadow jumping mouse (*Zapus hudsonius*) and woodland jumping mouse (*Napaeozapus insignis*). The Colubridae data included tracks from four genera: *Thamnophis*, *Storeria*, *Opheodrys*, and *Diadophis*. However, the majority of tracks recorded were those of the garter snake (*T. sirtalis*). Although tracks of frogs (*Rana spp.*), striped skunk (*Mephitis mephitis*), woodchuck (*Marmota monax*), weasel (*Mustela spp.*), porcupine (*Erithizon dorsatum*), domestic cat (*Felis catus*), and mole (*Condylura cristata*) were recorded occasionally, activity was too low to justify analysis. The largest track recorded (7 in (18 cm)) was that of a black bear (*Ursus americanus*).

METHODS

Technique and Treatment

The activity was recorded by the sand transect technique (Bider 1968). The transects were read at least five times during a 24-hour period and total daily activity was recorded before, during, and after the clear-cut. All the animal activity reported in this paper represents total activity for a 24-hour period. For noctural species this represented a period extending from noon to noon, and from midnight to midnight for diurnal species.

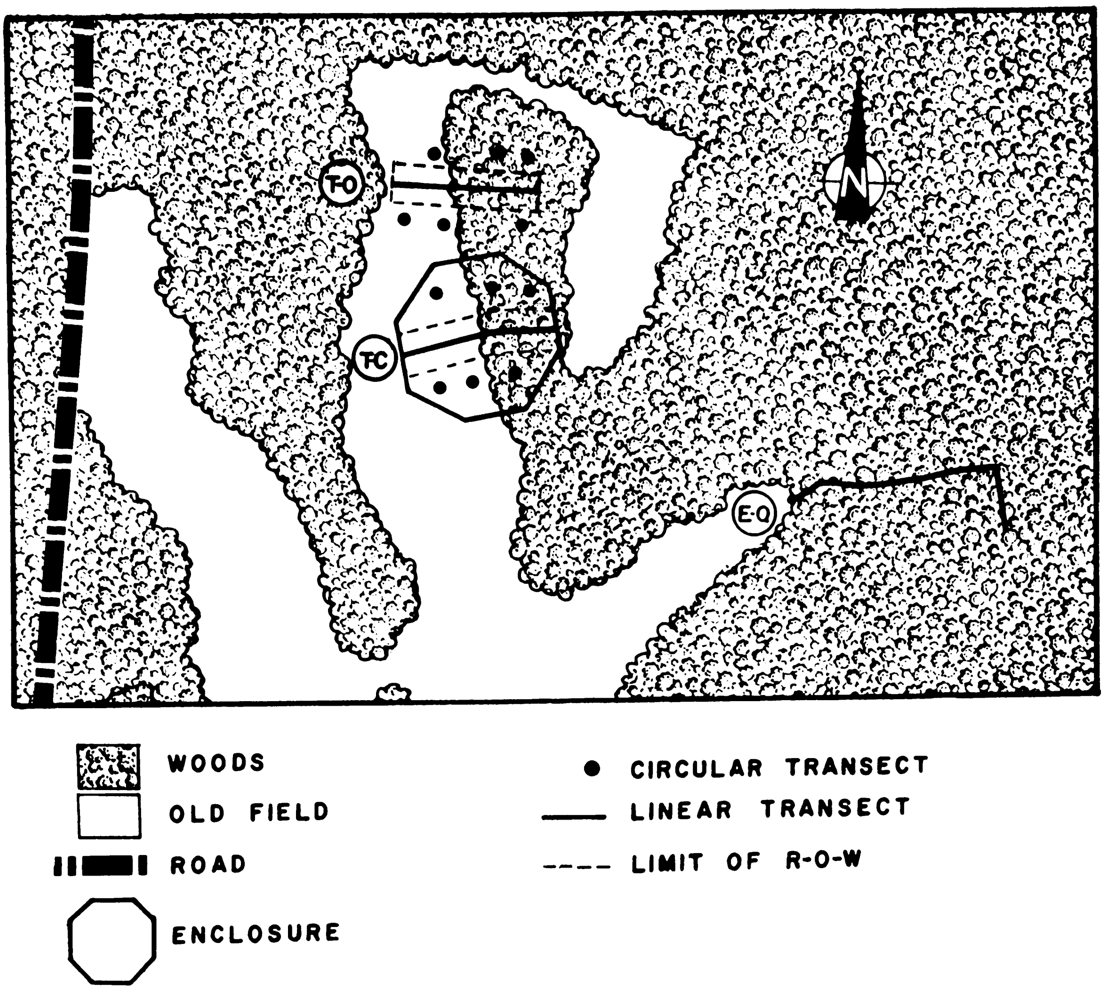

Figure 1. Study area and transect locations.

In late August 1972, two identical clear-cuts simulating rights-of-way were made at the treatment transects (T-0, T-C; Fig. 1). Trees and shrubs were removed from the two treatment areas, each measuring 246 X 66 ft (75 m X 20 m), and all the slash and debris were hauled far enough not to influence the experiment. A total of 10 days were required to complete these two clear-cuts. The short-term effects on animal activity and those recorded for the next two years following the original clearing of the experimental ROWs were studied according to the following experimental designs.

Short-Term Effects - 1972

Two simultaneous experiments were conducted to determine the changes in activity immediately following the clear-cut. In the first experiment, the treatment transect was a 246 ft (75 m) long linear transect (transect T-0), half of which was located in the old field and half in the forest. The activity at the control area was recorded on six circular transects totaling 394 ft (120 m) in length. These circular transects were located approximately 66 ft (20 m) away from, and on either side of transect T-0; three in the old field and three in the forest (Fig. 1). The daily activity was recorded on all these transects before, during, and after the clear-cut. The activity of transect T-0 (treatment) was compared to that of the pooled six adjacent circular transects.

In the second experiment, the transect layout and lengths were identical to that detailed above. The linear treatment transect (trasect T-C) of the second experiment was located 70 m from transect T-0 (Fig. 1). The activity at transect T-C (treatment) was compared to the pooled activity recorded on the six adjacent circular transects.

The major difference between these two experiments is the fact that the second experiment was entirely conducted within a 1 acre (0.4 ha) octagonal enclosure. The community within the enclosure was a collection of natural animal populations contained by a wall which would stop or minimize immigration and emigration. The wall, which was erected around transect T-C, was 8 ft (2.4 m) high and 771 ft (235 m) long. The structure consisted of a wooden frame, covered with polyethylene. The width of polyethylene allowed an overhang at the top and a buried strip at the bottom of the wall. The plastic sheet itself was applied on the inside face of the wall and this smooth surface kept animals from climbing. On the outside, the overhang created a pocket which discouraged climbing animals. The plasticized sheet extended about 16 in (40 cm) below the ground at the base of the frame. All vegetation, debris and other cover were removed 1 m on each side of the wall. It was assumed that if those areas were made least attractive, activity would be reduced, and thus the movement of animals in and out of the enclosure would be minimized. The enclosed segment of the community was not submitted to the action of larger terrestrial predators such as raccoons, skunks, cats, red fox (*Vulpes vulpes*), and weasels. Most birds and flying insects had no difficulty crossing this barrier. The wall was in place in 1972 but was not erected in 1973 or 1974.

Effects in Subsequent Years: 1973 and 1974

The following experimental design was used to determine changes in activity during the two summers following the clear-cut of the two experimental rights-of-way. In this experiment, the 246 ft (75 m) long T-0 transect was the treatment transect which was cleared in August 1972. The control transect (transect E-Q) was a 492 ft (150 m) long transect located in forested habitat approximately 656 ft (200 m) from the treatment area (Fig. 1). The pre clear-cut activity at both T-0 and E-Q transects for an 8 day period in 1972 (5 August - 12 August) was compared to the activity for an 8 day period in 1973 (24 August - 31 August) and in 1974 (24 July - 31 July).

Analysis

The following procedure was used for all data analysis. Pre-cut activity at treatment and control transects was compared to post-cut activity at the same transects by means of a 2 X 2 contingency table. Chi-square tests (two tailed, 1 df; Siegel 1956) were performed in all cases except when a cell of the contingency table had less than five observations. In these cases Fisher exact probability tests were used. This procedure enabled the researchers to determine the short-term effects of vegetation removal on activity and to determine if there was a time lag in the response of some animal taxa to the clear-cut.

RESULTS

Short-Term Effects 1972

When pre and post clear-cut activity at the T-0 transect was compared to the pooled activity at the six adjacent transects, the response of the community intensified with time (Table 1). Change in activity with time at the T-C transect area was less noticeable because of the absence of Procyon and Lepus and perhaps lower populations of small nocturnal mammals (Table 2).

Table 1. Comparison of activity before and after the clear-cut at transect T-0 (treatment) and at adjacent circular transects (control) in 1972.

Taxon	2 days pre cut vs 2 days post cut	6 days pre cut vs 6 days post cut	16 days pre cut vs 16 days post cut
Aves	$p < 0.001$	$p < 0.001$	$p < 0.001$
Colubridae	-	-	-
Bufo	n.s. (1) (2)	$p < 0.05$(1)	$p < 0.01$(1)
Tamiasciurus	n.s.	$p < 0.05$	$p < 0.001$
Tamias	n.s. (2)	$p < 0.05$	$p < 0.05$
Procyon		n.s. (F)	n.s.
Lepus	n.s.	n.s.	n.s.
Sorex	$p < 0.05$	$p < 0.001$	$p < 0.001$
Peromyscus	-	n.s. (F)	n.s. (F)
Blarina	p 0.001	$p < 0.001$	$p < 0.001$
Zapodidae	n.s.	n.s.	$p < 0.001$
Microtine	n.s. (F)	n.s. (2)	$p < 0.001$

Note: n.s.: Not significant.
(F): Fisher exact probability test.
- : Insufficient data for testing.
(1): Higher activity after the clear-cut.
(2): Marginal significance.

Two days after the clear-cut, Aves, Sorex, and Blarina showed significantly lower activity at transect T-0 (Table 1). Tamias were less active in the clear-cut area but the significance level was marginal. Only Bufo showed increased activity during the 2 days following the clear-cut, but the level of significance was marginal.

The analysis of 6-day pre and post-cut samples showed that Aves, Tamiasciurus, Tamias, Sorex, and Blarina were significantly less active at transect T-0 after the clear-cut (Table 1). Microtine activity was noticeably lower but significance was marginal. Bufo was the only species to be significantly more active in the clear-cut area ($p < 0.05$, Table 1).

Aves, Tamiasciurus, Tamias, Sorex, Blarina, Zapodidae, and Microtines showed a significant decrease in activity at transect T-0 during the 16-day period following the clear-cut. After 16 days, Bufo remained the only species significantly more active in the clear-cut area at transect T-0 (Table 1).

Table 2. Comparison of activity before and after the clear-cut at transect T-C (treatment) and at adjacent circular transects (control) in 1972.

Taxon	2 days pre cut vs 2 days post cut	6 days pre cut vs 6 days post cut	16 days pre cut vs 16 days post cut
Aves	$p < 0.001$	$p < 0.001$	$p < 0.001$
Colubridae	-	-	-
Bufo	n.s.	$p < 0.001$(1)	$p < 0.001$(1)
Tamiasciurus	n.s.	n.s.	n.s.
Tamias	$p < 0.001$	$p < 0.001$	$p < 0.001$
Sorex	-	-	-
Peromyscus	-	-	-
Blarina	-	-	-
Zapodidae	n.s.	n.s.	-
Microtine	n.s.	$p < 0.001$	$p < 0.001$
Glaucomys	n.s.	n.s.	$p < 0.001$

Note: n.s.: Not significant
(F): Fisher exact probability test
- : Insufficient data for testing
(1): Higher activity after the clear-cut

At the enclosed T-C transect, Bufo were significantly more active in the clear-cut area 6 days after the cut and the response persisted throughout the 16-day sample (Table 2). Aves and Tamias showed significantly lower activity two days after the clear-cut and maintained their response throughout the analysis. Microtines were significantly less active in the clear-cut area during the six-day sample. Since northern flying squirrels (Glaucomys sabrinus) are arboreal and sufficient data were available, an analysis was done for Glaucomys response to the clear-cut. No significant response was observed during the 2 and 6-day samples; however Glaucomys were significantly less active ($p < 0.001$) in the clear-cut area at transect T-C during the 16-day sample (Table 2).

Effects Over Successive Years - 1973 and 1974

Most species or groups of animals showed a significant response in the experimental clear-cut in at least one of the two years (1973, 1974) during which activity was monitored (Table 3). Five taxa (Aves, T. striatus, Sorex spp., B. brevicauda, Zapodidae) demonstrated a significant decrease in activity in the treated area for both 1973 and 1974, while two taxa (snakes, invertebrates) showed a significant increase in activity for both years. Toads and raccoons were significantly more active in the treated area in 1974 only, while L. americanus was significantly more active in the treated area in 1974 only. Finally, T. hudsonicus and Microtines showed a significant decrease in activity at the clear-cut in 1973 only. Deer mouse activity at the clear-cut was very low throughout the study and precludes strong conclusions (Table 3).

Table 3. Animal activity at the control (E-Q) and treatment (T-O) transects before (1972) and during successive years after the clear-cut.

Taxon	1972		1973			1974		
	E-Q	T-O	E-Q	T-O		E-Q	T-O	
Aves	1029	2384	1087	1132	p<0.001	812	1369	p<0.001
Colubridae	20	1(1)	6	13	p<0.001(2)	1(1)	6	p<0.001(2)
Bufo	283	21	173	91	p<0.001(2)	184	10	n.s.
Tamiasciurus	173	434	47	2(1)	p<0.001	1(1)	2(1)	n.s.
Tamias	5	87	90	148	p<0.001	247	133	p<0.001
Procyon	18	1(1)	27	17	p<0.01(2)	18	3(1)	n.s.
Lepus	52	41	44	22	n.s.	13	78	p<0.01(2)
Sorex	138	200	490	241	p<0.001	324	140	p<0.001
Peromyscus	96	2(1)	89	0(1)	n.s.	47	2(1)	n.s.
Blarina	32	146	22	10	p<0.001	33	25	p<0.001
Zapodidae	647	433	978	208	p<0.001	1042	133	p<0.001
Microtine	237	82	234	17	p<0.001	250	89	n.s.
Invertebrates	4121	2848	1173	1432	p<0.001(2)	1930	2281	p<0.001(2)

Note: n.s.: not significant
(1): Fisher exact probability test
(2): higher activity after the cut

DISCUSSION

In both experiments where circular transects were used as non-treatment areas, a differentiation can be made as to the time required for the various groups to respond to the clear-cut. No species which showed a significant decrease in activity 2 days after the clear-cut re-established its original pattern of activity during the rest of the 1972 tracking season. As samples increased in length (16 days), the response to the clear-cut intensified, with more species significantly less active in the clear-cut area than at the adjacent circular transects. The only species which showed significant increase in activity soon (6 days) after the clear-cut was Bufo. This response seemed to indicate that the removal of the vegetation was consequential for Bufo and led to increased activity. Bramwell and Bider (1981) recorded higher toad activity following defoliation by means of herbicides. It was thought that arboreal species would be most disturbed by the clear-cut. The significantly reduced Glaucomys activity after the clear-cut was attributed to removal of several large trees. Birds were forest species and responded quickly, Tamias showed reduced activity, but Glaucomys was slow to show reduced activity. The faster response of birds and Tamias was attributed to their great mobility to leave an area where a basic resource was lacking.

The clear-cut removed enough elements of the habitat to cause most species to reduce their utilization of the area and they failed to re-establish their pre-cut activity pattern in 1972. Some individuals probably moved to adjacent areas. On a short-term basis, the clear-cut probably removed most of the cover, a great portion of the food supply for omnivores and granivores, and created different microclimatic conditions which contributed to the response in activity immediately following the clear-cut.

Data for 1973 and 1974 pointed to a community already adjusting to the habitat changes. Most small mammals and birds maintained a reduced activity level in the treated area. However, invertebrates and two insectivores (Bufo, snakes) showed increases in activity. The significant increase in Procyon activity in 1973 may be the results of the increase in Bufo activity since a reduced Procyon activity level in 1974 matched a reduced Bufo activity level for that same year. Bracher (1981) observed a disruption of the predator-prey activity patterns following insecticide applications. Finally, the significant increase in Lepus activity in 1974 may be due to an increase in food availability during the second growing season. Keith and Surrendi (1971) observed that snowshoe hares were restricted to a moderately burned corner of their burn study area. As the vegetation progressed during the summer, the hares re-invaded the more severely burned areas. They attributed the response to scarcity of cover and food in the area.

The effects of clear-cutting on wildlife have created a great deal of controversy (Pengelly 1972; Resler 1972). Bird populations seem to benefit from the new vegetation following logging or burning (Hagar 1960; Lawrence 1966). These studies were conducted after the vegetation had at least one partial growing season. Hagar (1960) observed temporary declines in total overall numbers of birds immediately after logging, but within a year after cutting former numbers were regained, although species composition was markedly different. Small mammal populations usually show a marked decline after clear-cuts or burns (Cook 1959; Krull 1970; Lawrence 1966; Lovejoy 1973; Sims and Buckner 1973). There are two exceptions: (1) Peromyscus is usually the first invader after burns or clear-cuts (Ahlgren 1966; Tevis 1956); and (2) Oregon voles (Microtus oregoni) thrive in clear-cuts (Gashwiler 1972), showing preference for the newly formed grassland habitat.

Clear-cuts resulting from logging operations and burns are quite different from clear-cut and debris removal in the Lac Carre study. Logging operations produce large amounts of debris while burns are uneven and often leave several large trees standing. The clear-cut in this study removed both of these features. The change in activity of Aves indicated a possible response to cover, food removal and destruction of the habitat stratification. The response to the clear-cut in the Lac Carre study was attributed to scarcity of macro- and micro-cover, associated with limited food supply and elimination of the vertical dimension of the habitat. Hammer (1969) stated that wind can influence small mammal activity. Air displacement may have increased in the clear-cut and this factor possibly contributed to cause the decrease in activity.

The experimental clear-cut represented a rapid change of habitat for resident animals. It was expected that the clearing of an experimental ROW would produce, on a short-term basis, an increase in activity of species which favor prairie or open field habitat. On the other hand, forest species were expected to show a decrease in activity following the clear-cut. Two species of forest mammals (deer mouse and red squirrel) showed practically no activity in the treated area in the 1973 and 1974 samples. In the case of red squirrel, this represented a drastic decrease in activity. However, P. maniculatus was not very active in the experimental area prior to the clear-cut. Small mammals such as Tamiasciurus, Tamias, Sorex, Blarina and Zapodidae can be considered forest species and they all demonstrated significant reduction in activity in the treated area in 1973 and only Tamiasciurus failed to maintain this pattern in 1974. Microtines showed a significant decrease in activity at the clear-cut in 1973 which was attributed to reduced red-backed vole (Clethrionomys gapperi) activity. The increase in microtine activity observed in 1974 was probably due to an increase in M. pennsylvanicus activity, a field species. The tracks of those two microtines could not be segregated consistently.

Invertebrates showed significant increases in activity in the treated area in subsequent years (1973-1974); however, it is possible that species composition and abundance were different. Snakes and toads also showed increased activity at the treated area in subsequent years and these responses could possibly be associated with the changes in invertebrate activity.

The Lac Carre study showed that some members of the animal community were very quick to respond to the clear-cut simulating that of a ROW while other species took several days to change their activity patterns. The response of some species to the cut changed during the two summers following the vegetation removal. Results indicate that some animal taxa benefited from the right-of-way clearing while others were negatively affected. The proportional species representation in the animal community was disturbed and competition and predator-prey relationships appeared disrupted. It can be concluded that single species approach in habitat manipulation programs can be quite unreliable and that animal activity remains one of the most suitable approaches to examine the response of an animal community to habitat manipulation.

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ACTIVITY OF WHITE-TAILED DEER ALONG AN INTERSTATE HIGHWAY RIGHT-OF-WAY

Kenneth R. Dixon[1], George A. Feldhamer[1], J. Edward Gates[1] and Dan M. Harman

ABSTRACT.--Activity of white-tailed deer along a 23 mi (36.8 km) section of Interstate 84 in northeastern Pennsylvania was studied using radio-telementry. Home ranges were calculated using the harmonic mean of the areal distribution of activity loci. Preferential orientation and direction of movement related to the highway right-of-way were tested using vector analysis. Results of these analyses are compared with data from studies of white-tailed deer activity in unrestricted habitats.

INTRODUCTION

Accidents involving white-tailed deer and vehicles on interstate highways are a major concern in wildlife management. The purpose of this study is to determine the spatial pattern of activity along a fenced highway right-of-way (ROW) and compare it with the activity pattern of deer away from the highway to determine if fenced ROW affects deer movements.

STUDY AREA

The study area is located in the Lords Valley area of Pike County, Pennsylvania along Interstate 84. A deer fence 10 ft (3 m) high runs along the ROW for a distance of 14 mi (22.4 km). The area is predominately forested and in fairly rugged terrain in the Pocono Mountains.

METHODS

Deer were captured by darting using the tranquilizing drug, succinylcholine chloride.

Telemetry

Deer were fitted with expandable collars attached with 350 g radio transmitters. Frequencies between 150.850 and 151.450 MHz with channels 30 kHz wide were used.

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Location bearings were obtained using standard triangulation techniques. Bearings were taken simultaneously from highway mileage markers. A vehicle-mounted 8-element antenna 13.8 ft (4.2 m) long was used at one station while a hand-held, 4-element yagi antenna was used at a second station.

Home Ranges and Orientation

Home ranges and centers of activity were calculated using the method of Dixon and Chapman (1980). This method is based on the harmonic mean of an areal distribution of activity loci. With this method, the calculated center of activity is located at the point of greatest activity and the isopleths of activity are directly related to the frequency of occurrence of each deer within its home range.

As a deer moves within its home range, the points at the beginning and end of a movement define a vector or angle of orientation. In a sequence of movements, the angle and distance of the resultant vector describe a "preferred" direction of movement or orientation of the deer in response to a stimulus such as the highway ROW. Resultant vectors are compared for movements of deer along and away from the ROW.

Directional data that indicate a preferred direction of movement will show a circular normal or von Mises distribution (Batchelet 1965). If deer move within their home range in a random pattern, the modal vector should have a length and direction close to zero. However, the study was directed at determining whether the deer move in a direction determined by the highway ROW, not in a single preferred direction. In other words, if a ROW ran east to west, a deer near the ROW moving at an angle of 0° was considered the same as if it moved at an angle of 180°. The following statistical tests ($p = .05$) were made for each deer:

1. A test for randomness (The null hypothesis is that there is no preferred direction).

2. A test for position of the modal vector (The null hypothesis is that the angle of the modal vector is the same as the angle of the highway ROW.

Following tests made for each deer, tests were also made between deer found near the highway ROW and those found at a distance from the ROW. Tests made between these deer groups were

1. A test to determine if the preferred direction was the same for each group of deer within the ROW and off the ROW.

2. A test to determine whether the modal vectors of the deer groups on the ROW were the same as for the deer groups off the ROW.

RESULTS AND DISCUSSION

Single Sample Tests

Deer in both the ROW ($n = 6$) and off the ROW ($n = 3$) groups showed preferential directions of movement. The fact that all deer showed nonrandom movement is significant, but the reason for this directional movement is not known. All of the nonROW group had modal vectors significantly different from the angle of the ROW. (The ROW changes direction slightly; however, each modal vector was compared with the section of ROW closest to the deer's home range.)

Multi-Sample Tests

The group off the ROW showed significant differences in the angle of the modal vector. This result was not unexpected because there was no obvious stimulus to cause an orientation of movement. However, significant differences also were found in the preferred directions in the ROW groups. The nonalignment of the home ranges in this group probably results from intraspecific behavioral factors that outweight any stimulus from the ROW. On the average, however, deer in the ROW group did show a greater "preference" for movement in the direction of the highway ROW (Fig. 1). The mean modal vector of the ROW deer group was 127° compared with the ROW angle of 155°. The mean modal vector of the nonROW group was 80°.

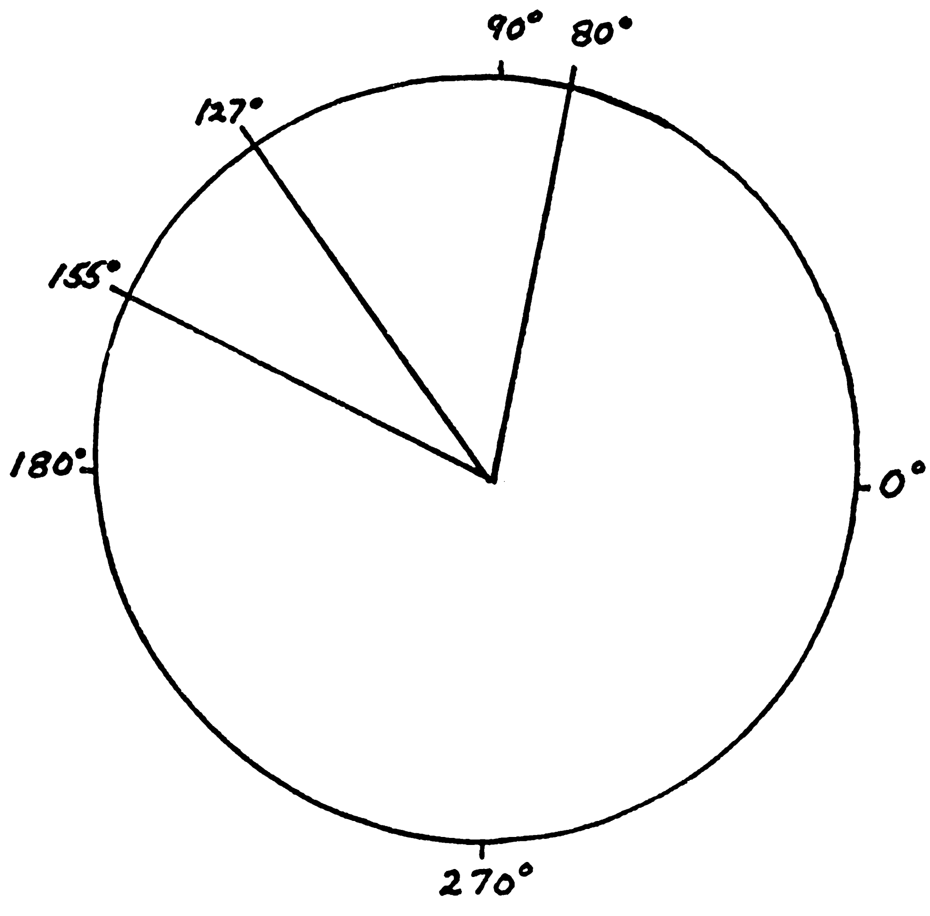

Figure 1. Mean preferred direction of movement of white-tailed deer. (a = deer near highway right-of-way, and b = deer away from highway right-of-way).

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DETERMINING THE EFFECTS OF RIGHTS-OF-WAY ON ANIMAL MOVEMENT BEHAVIOR

Kenneth R. Dixon[1]

ABSTRACT.--The use of cricular statistics can improve our understanding of the effects of rights-of-way (ROWs) on animal movement behavior. Statistical methods reviewed in this paper are designed to answer such questions as (1) do animals on or near ROWs have a preferred direction of movement? (2) if yes, is the direction of movement the same as or different from the direction of the ROW? and (3) is there a difference between the directional behavior of animals found on or near a ROW and those found some distance from the ROW?

INTRODUCTION

A number of studies have addressed the question of the effect of ROWs on animal movement behavior. Getz et al. (1978) found that interstate roadsides act as dispersal routes for small mammals. On the other hand, Oxley et al. (1974) and Schreiber and Graves (1977) found that ROWs could act as possible barriers to the movement of small mammals. Few studies have used circular statistics to test the effects of ROWs on animal movement behavior. The purpose of this paper is to review some of the statistical methods for analyzing these data. Such methods may improve our ability to determine the impact of ROWs on animal movements.

METHODS

A preferred direction is indicated when an animal moves in either one of two opposite directions.

These axial data can be tested if the sample distribution is a bimodal distribution which has two equal and opposite modes. These axial data with angles between 0° and 360° must be reduced modulo 180° by doubling each angle.

The mean direction of movement is measured by the polar coordinates of the mean vector: the mean vector length of the sample, r_2, and the mean angle of the sample, $\bar{\phi}$. The mean vector can be determined by its rectangular components.

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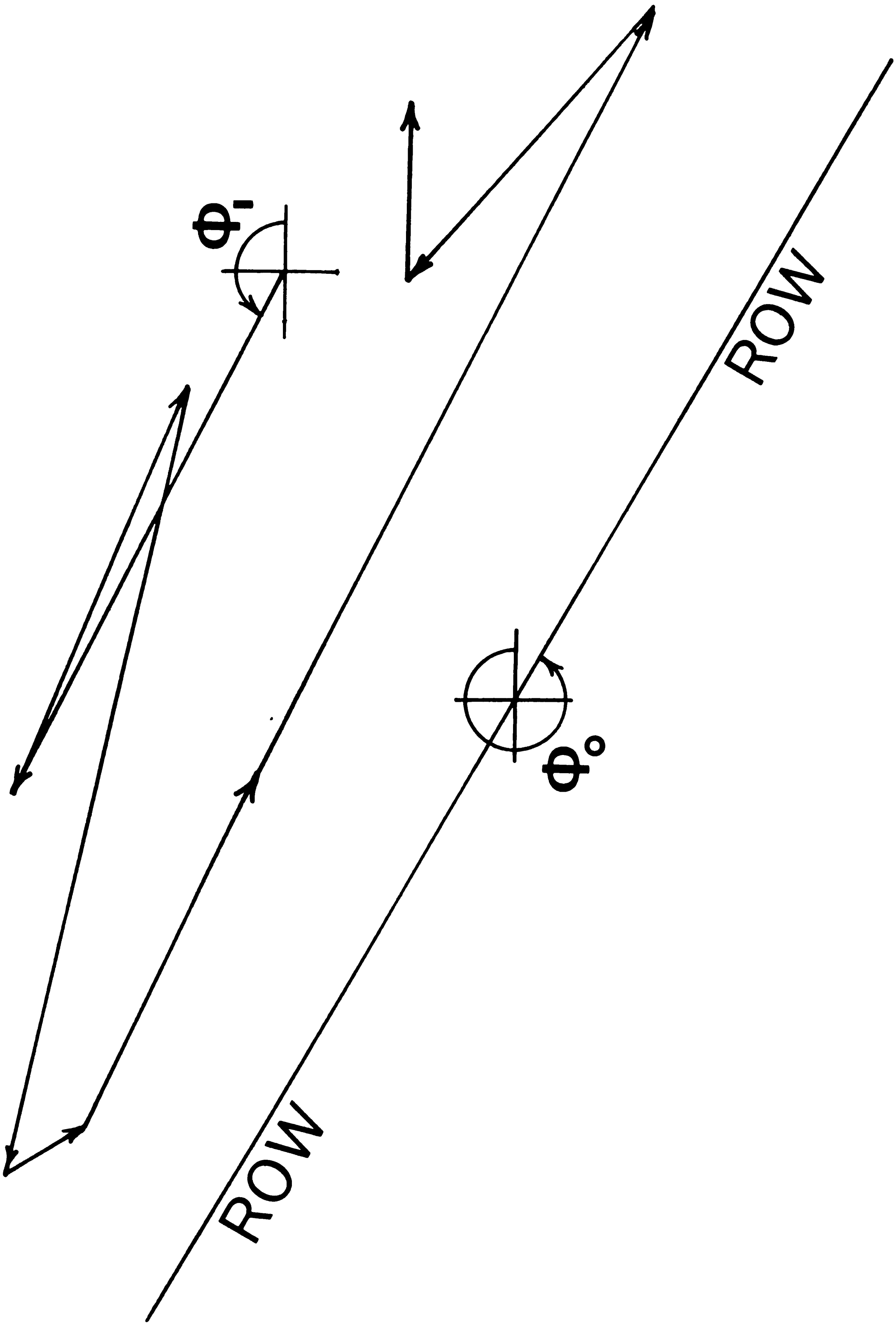

Figure 1. Example of eight directional movements of an animal along a right-of-way (ROW). The first observed angle is ϕ_1 = 311.6° and the angle of the ROW, ϕ_0, is 330.0°.

Let ϕ_i be one of the n observed angles (doubled). Then

$$\bar{x} = \frac{\Sigma \cos \phi_i}{n} \qquad (1)$$

$$\bar{y} = \frac{\Sigma \sin \phi_i}{n} \qquad (2)$$

Now

$$r^2 = \sqrt{\bar{x}^2 + \bar{y}^2} \qquad (3)$$

and

$$\bar{\phi}_2 = \begin{cases} \arctan(\bar{y}/\bar{x}) & \text{if } \bar{x} > 0 \\ 180° + \arctan(\bar{y}/\bar{x}) & \text{if } \bar{x} < 0 \end{cases} \qquad (4)$$

To obtain the angle of the undirected axis of the original sample, we have to cancel the effect of doubling. Therefore

$$\bar{\phi}_1 = \bar{\phi}_2/2 \qquad (5)$$

A measure of dispersion equivalent to the standard deviation in linear statistics is the mean angular deviation, S_1 which is a function of r_2:

$$S_2 = \frac{180^o}{\pi} \sqrt{-2 \ln r} \qquad (6)$$

Again, correcting for doubling of the angles leads to

$$S_1 = S_2/2 \qquad (7)$$

EXAMPLE 1. Figure 1 shows the directional movements of an animal along a ROW. The measured angles (using Cartesian coordinates) are given in Table 1 along with the double angles and their sines and cosines.

Table 1. Observed angles of movement, ϕ_i, of a single animal, the doubled angles, and their sines and cosines.

ϕ_1	2ϕ (mod 360°)	$\cos 2\phi$	$\sin 2\phi$
155.8	311.6	0.6639	-0.7478
338.2	316.4	0.7242	-0.6896
166.0	332.0	0.8824	-0.4695
303.7	247.4	-0.3843	-0.9232
337.4	214.8	0.7046	-0.7096
332.9	305.8	0.5850	-0.8111
138.0	276.0	0.1045	-0.9945
0.0	0.0	1.0000	0.0000
Total		4.2803	-5.3453

The rectangular components from eqs 1 and 2 are:

$$\bar{x}_2 = \frac{4.2803}{8} = 0.5350$$

$$\bar{y}_2 = \frac{-3.3453}{8} = -0.6682$$

The mean vector length, r_2, and mean angle ϕ_2 from eqs 3 and 4 are:

$$r_2 = \sqrt{(0.5350)^2 + (0.6682)^2} = 0.8560$$

$$\bar{\phi}_2 = \text{arc tan } (-0.6682/0.5350) = -51.3^\circ = 308.7^\circ$$

The mean axis of direction, ϕ_1, is (eq 5):

$$\bar{\phi}_1 = \frac{-51.3^\circ}{2} = -25.6^\circ = 334.3^\circ$$

The angular deviation, S_2 is (eq 6):

$$S_2 = \frac{180}{\pi} \sqrt{-2 \ln 0.8560} = 32.0^\circ$$

and canceling the effect of doubling (eq 7) gives:

$$S_1 = \frac{32.0^\circ}{2} = 16.0^\circ$$

Statistical Test for Directedness

From a sample of movement data, it may not be intuitively obvious whether the animal has, in fact, shown a "preferred" direction of movement. The length of the mean vector, r , can be used to test for directedness, using the Rayleigh test, i.e., whether the sample differs significantly from randomness. If r exceeds the critical level, P, for a given sample size, n, and significance level, a, the null hypothesis of randomness is rejected. Tables of critical values can be found in Mardia (1972), Zar (1974) and Batschelet (1981).

EXAMPLE 2. In Example 1 we found the mean vector length for the data in Table 1 was $r_2 = 0.8560$. The critical value for sample size $n = 8$ is $P<.001$. Therefore we can reject the null hypothesis of randomness and conclude the animal has a preferred direction.

If our hypothesis is that the ROW determines the preferred direction of movement, we can use this information to increase the power of our test of randomness. Such a test is the V test which tests whether the angles of the directions of movement, ϕ_1, ϕ_2, ..., ϕ_n are determined by the angle of the ROW, ϕ_0. A measure of the influence of ϕ_0 on the observed angles ϕ_i is the projection v of the mean vector onto the direction of the ROW, so that

$$v = r_2 \cos (\bar{\phi}_2 - \phi_0) \qquad (8)$$

where v and ϕ_2 are defined as before and ϕ_0 has been doubled. Our test statistic then is

$$u = v\sqrt{2n} \qquad (9)$$

As with the Rayleigh test, if u exceeds the critical value u (α), the null hypothesis of randomness is rejected. Tables of critical values are available in Batschelet (1981) and Zar (1974). It should be pointed out that the V test is only a test of randomness and not a test of direction.

EXAMPLE 3. In figure 1 we measured the ROW angle ϕ_0 = 330.0°. Doubling ϕ_0 modulo 360° gives an angle of 300.0°. The mean angle of the sample calculated in Example 1 was $\bar{\phi}_2$ = 308.7 and the mean vector length was r_2 = 0.8560. Therefore from equations 8 and 9

$$v = 0.8560 \cos (308.7 - 330.0) = 0.7975, \text{ and}$$

$$u = 0.7975 \quad \sqrt{2(5)} \quad = \quad 2.52$$

Table I of Batschelet (1981) gives a critical value of P<.005, which confirms the result achieved with the Rayleigh test.

If one is interested in testing whether the mean direction of a sample differs significantly from the ROW direction, ϕ_0, a confidence interval for the mean angle, θ_1 is required. The confidence interval is determined first by calculating the angle of deviation, δ. The confidence interval then is $\phi \pm \delta$. Charts for obtaining δ at α = 0.05 and 0.01 can be found in Mardia (1972) and Batschelet (1981). If ϕ_0 falls within the confidence interval, we conclude that there is no evidence that the population mean angle differs from ϕ_0.

EXAMPLE 4. Using the random mean vector length,

$$r_2 = 0.8560$$

and the sample mean angle, rounded

$$\bar{\phi} = 334$$

from Example 1, we obtain for $\alpha = 0.05$

$$\delta = 27^{o}$$

Hence, the confidence limits are 334 ± 27° or $303° < \theta_1 < 1°$. Therefore, the mean angle of the population cannot be distinguished from the ROW angle.

Second Order Statistics

In order to make inferences about the behavior of animals that might be affected by a ROW, it is necessary to obtain random samples of angular values from several individual animals. The sample mean angles then can be compared among individuals. For example, we might be interested in determining whether there is a significant difference in the mean direction of movement between animals found along a ROW and a control group some distance from the ROW. Such a test requires the further assumption that one animal's movement has no effect on another animal's movement; i.e., they are independent.

Suppose we have two groups of animals: one group found along a ROW and a second group of control animals studied some distance from the ROW. We would be interested in testing whether the two groups show a difference in their movements relative to the direction of the ROW.

Assume that we have independent samples yielding n and m sample mean angles, $\bar{\phi}_1, \bar{\phi}_2, \ldots, \bar{\phi}_n, \bar{\psi}_1, \bar{\psi}_2, \ldots \bar{\psi}_m$ from two groups of animals. By considering the angular distance between the mean angles and the ROW angle ϕ_0, we can compare the relative effect of the ROW on the two groups. A non-parametric test suggested by Walraff (1979) for this purpose is the Wilcoxon-Mann-Whitney test (Batschelet 1981). First we rank the absolute values of the angular distances between the mean angles and the ROW angle for both groups combined. Let S_1 and S_2 be the rank sums of the two groups. Then

$$U_1 = S_1 - \frac{n\ (n + 1)}{2} \quad , \quad U_2 = S_2 - \frac{m\ (m + 1)}{2} \qquad (11)$$

and the test statistic is $U = U_1$ or $U = U_2$ whichever is smaller. Critical values of the test statistics U can be found in most non-parametric statistics texts (e.g., Siegel 1956).

EXAMPLE 5. Let $\bar{\phi}_j$ be the mean angles of animals found along a ROW (experimentals) and $\bar{\psi}_k$ the mean angles of those found at a distance from the ROW (controls) in Table 2.

Table 2. Mean angles, angle distances and ranks of a sample of control ψ_k versus experimental $(\bar{\phi}_i)$ animals with a ROW angle of ϕ_0 = 330°.

Experimentals			Controls		
ϕ_i	$\lvert\bar{\phi}_i, \phi_0\rvert$	Rank	$\bar{\psi}_k$	$\lvert\psi_k, \phi\rvert$	Rank
334°	4°	3	270°	60°	13
327°	3°	2	292°	38°	10
318°	12°	5	37°	67°	14
332°	2°	1	340°	10°	4
357°	27°	8	304°	26°	7
10°	40°	11	212°	118°	15
295°	35°	9	285°	45°	12
			310°	20°	6
Totals		39			81

The rank sums are S_1 = 39 for the experimental animals and S_2 = 81 for the controls. From eq 11:

$$U_1 = 39 - \frac{7}{2}(8) = 11, \qquad U_2 = 81 - \frac{8}{2}(9) = 45$$

Using the smaller value, we obtain U = 11. From a table of probabilities of the Wilcoxon-Mann-Whitney test for n_1 = 7 and n_2 = 8 the probability of $U \leq 11$ is P = .027. Therefore we reject H_0 and conclude that the angular distance between the ROW angle and the observed mean angle of the experimentals is less than that of the controls.

SUMMARY

Methods for statistically testing the impact of ROWs on animal movement behavior are reviewed. Each method assumes that an animal's directional movements are independent. The validity of this assumption depends upon the sampling frequency. (Telemetry can provide continuous locational data, whereas live trapping data will be discrete.) However, we may be interested in independent discrete point-to-point distances rather than dependent continuous movements. Second-order statistics also require the assumption of independence between animal's movements. Whether the assumption holds depends on the species and the sociability of the individuals at the time of the study. The use of circular statistics such as those reviewed in this paper should enable researchers to gain improved understanding of the relationship of ROWs to animal movement behavior.

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COMPARATIVE USE OF TRANSMISSION LINE CORRIDORS AND PARALLEL STUDY CORRIDORS BY MULE DEER IN THE SIERRA NEVADA MOUNTAINS OF CENTRAL CALIFORNIA

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ABSTRACT.--Mule deer (Odocoileus hemionus) fecal pellet groups were counted and cleared from 191 circular plots 6 ft (1.8 m) in diameter, 66 ft (20 m) apart directly under 200 kV transmission lines, and from 176 similarly sized and spaced plots along transects parallel to the lines 164 ft (50 m) away from the edge of the right-of-way (ROW). Vegetation types in the plots were characterized as bare ground (roads), grass, grass with scattered brush or trees, and dense brush. The distribution of these vegetation types did not differ significantly in plots within and outside ROWs. For the combined data from all transects, there were 2.05 ± 0.43 (± 95% confidence interval) pellet groups per plot under the lines, and 2.11 ± 0.41 pellet groups per plot outside the ROWs, with no significant differences in pellet deposition among transects. There were also no significant differences between plots inside and outside ROWs when transect pairs were compared or when data were segregated by vegetation type. There were significant differences, however, between plots in different vegetation types, irrespective of the presence of the transmission lines.

INTRODUCTION

This study is based on the premise that if the suitability of habitat for deer is influenced by transmission line ROWs, then indicators of deer use should have values within an ROW different from values in parallel undisturbed alignments. The indicator of use chosen was the number of fecal pellet groups found in systematically placed sample plots.

Study Area

Electric transmission lines from hydroelectric power plants cross the low elevation (2000-4000 ft (160-1524 m) above sea level) winter range of mule deer at many locations on the western slope of the Sierra Nevada mountains in central California. The ROWs are frequently more open with lower, less mature brush than in the surrounding areas. While the less mature brush provide enhanced winter browse for deer, the comparative

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openness provides less visual and thermal protection (cover), and could be a deterrent along with the presence of energized transmission lines to use of the corridor for feeding or to movement across the corridors.

The transmission lines that were the object of this study are the Big Creek 3-Mammoth Pool 220 kV line running through Kinsman Flat in Madera County, California, and the Big Creek 8-Big Creek 2 and Big Creek 8-Big Creek 3 220 kV lines running side by side in the same ROW through Chawanakee Flat in Fresno County, California. The ROWs were approximately 115 ft (35 m) wide for the single 220 kV line and twice that for the double 220 kV lines.

METHODS

Study plots consisted of circles 6 ft (1.8 m) in diameter centered on permanent stakes placed at 66 ft (20 m) intervals in transects running either directly under the transmission lines, or parallel to the lines and 164 ft (50 m) outside the edge of the ROW. Three transect pairs 3,4; 5,6; and 9,10 each had 50 plots inside the ROW and 50 plots outside. Snow prevented completion of transects 7,8 limiting them to 41 plots inside and 26 plots outside. Two additional unpaired transects (1,2), each with 50 plots, were established away from existing alignments. Figure 1 shows the locations and elevations of the lines and the transects. All transects were at elevations between 2800-4000 ft (853-1524 m) above sea level, in characteristic mule deer winter range.

The data reported here consist of the numbers of fecal pellet groups cleared from circular plots at the time the plots were established. "New" (green inside) and "old" (brown inside) pellets were distinguished from one another during data collection. Most of the pellets were "old," and data for both groups were combined for this analysis.

Pellet group counts are used routinely by the California Department of Fish and Game in the same protocol described here, and are one of the oldest and most thoroughly discussed means of taking a census of deer. The general method was described by Bennett et al. (1940) and it has been reviewed and commented on several times since (Rasmussen and Doman 1943; Dasmann and Taber 1955; Eberhardt and Van Ellen 1956; Neff 1968). Most of the discussion has centered on the ability of pellet plot counts to serve as indices of absolute population size. When used for that purpose, time of year, rate of pellet decay, type of food being eaten, and observer bias related to differences in ease of finding pellets in different substrates must be taken into account. When used solely to compare use inside and outside of corridors which are vegetationally indistinguishable from the surroundings, none of these considerations apply, and any method which provides a clear record of deer presence is suitable. Pellet groups provide a clear indication of deer presence and nicely integrate presence over the life of the pellets giving a larger sample size than might be expected from visual observation, integrated over a much longer time period than would be expected from monitoring tracks. Although the probability of observers missing pellet groups may differ among vegetation types, a reasonable amount of care can reduce the probability nearly to zero in any vegetation type.

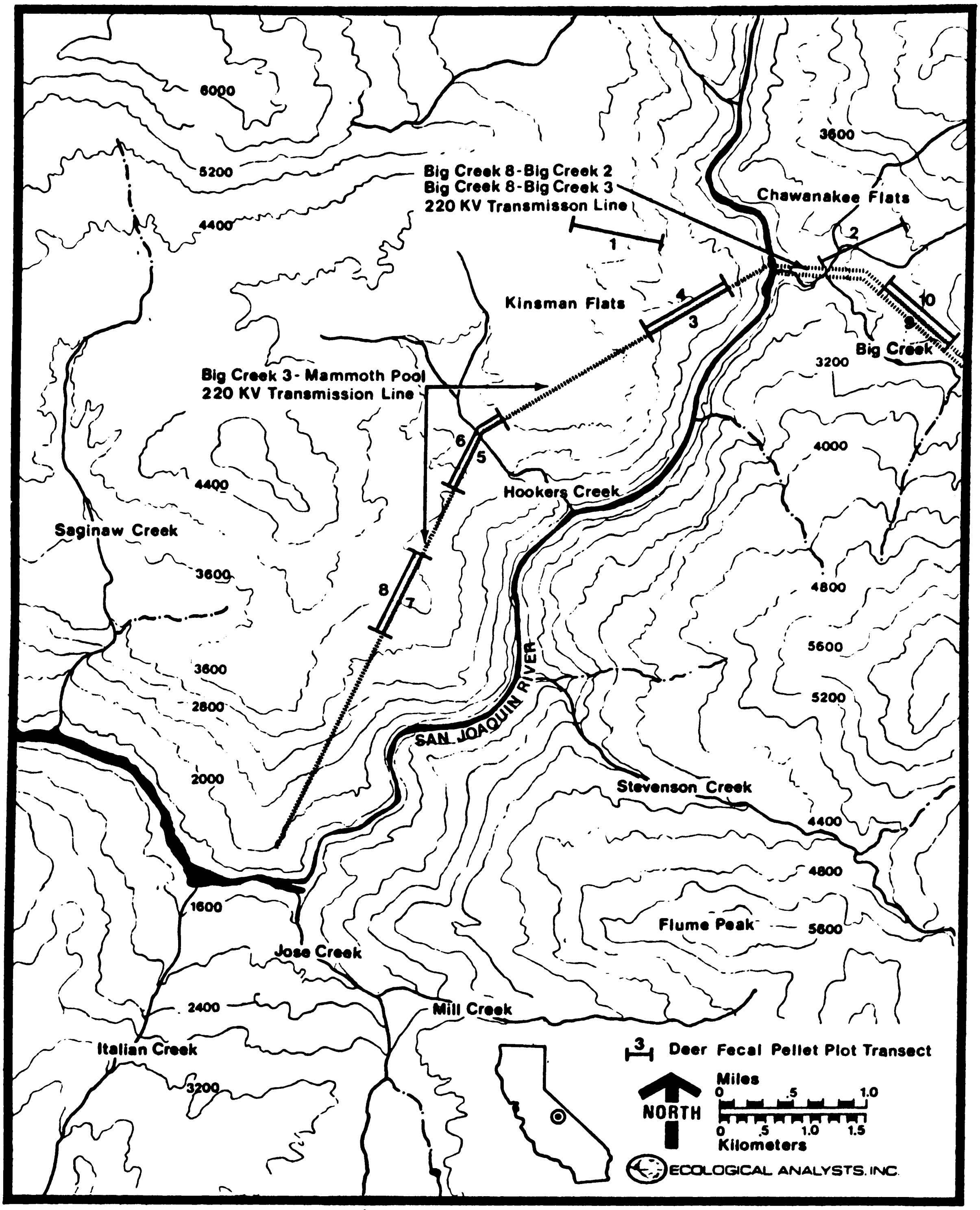

Figure 1. Locations of deer fecal pellet plot transects.

The principal vegetation in all areas is a chaparral shrub community consisting mostly of manzanita (Arctostaphylos spp.), Ceanothus spp., and poison oak (Rhus diversiloba) with scattered live oaks (Quercus spp.) and digger pine (Pinus sabiniana) in some areas. The shrub vegetation is naturally sufficiently low so that it provides little hazard to transmission lines, and except at the tower sites and within the dirt access roads serving the lines, the vegetation within corridors does not appear much different from that on the surrounding hillsides. The principal exception is that at towers there are frequently larger grassy areas than outside the corridors.

At each sampling site the vegetation was characterized as (1) bare disturbed ground . . . most frequently dirt roads, (2) open grassland without brush, (3) grass with scattered clumps of brush or trees, and (4) dense brush.

RESULTS

The distribution of vegetation types within and outside of the ROWs is generally similar (Figure 2), although inside there are more plots of grass and of bare ground (roads) than outside.

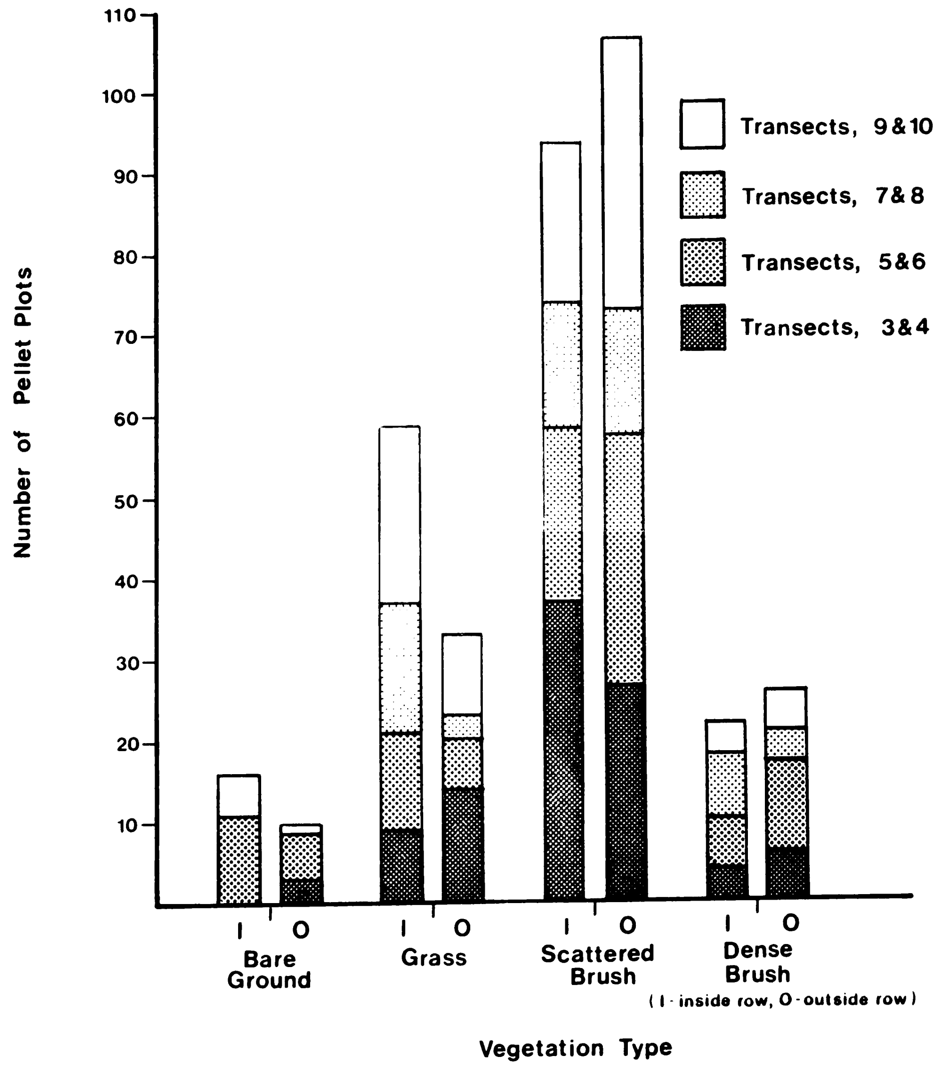

Figure 2. Distribution of vegetation types in plots among transects.

Figure 3 shows the numbers of fecal pellets found per sample plot for all 10 transects. The 95% confidence intervals of all inside-outside pairs overlap, and t-tests between pairs show no significant differences in numbers of pellets per plot inside and outside the ROWs. Transects 1 and 2 are not included in further analyses because they are not paired with transects in existings ROWs.

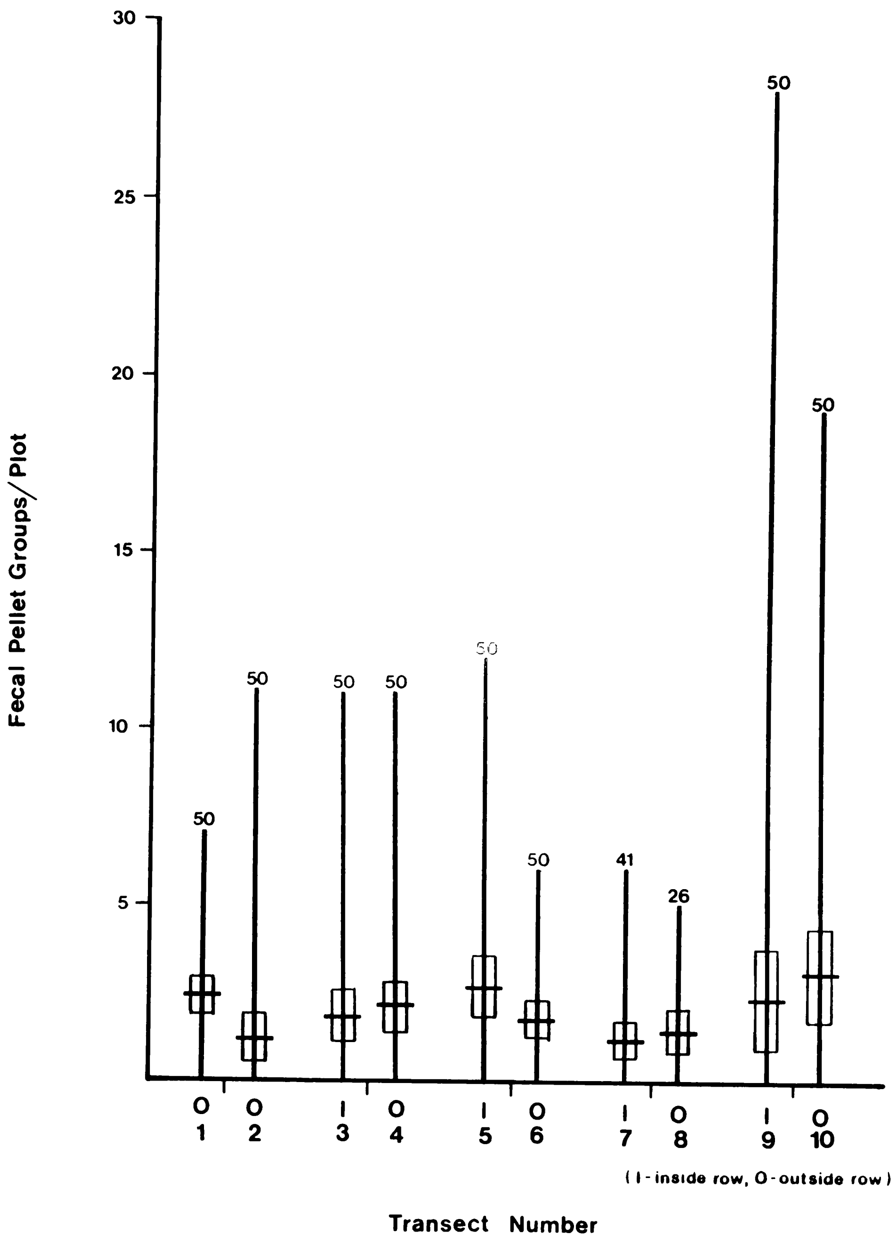

Figure 3. Numbers of fecal pellets found in plots in all transects. Center lines show range, boxes indicate 95% confidence interval, cross bars indicate mean. Number of plots on each transect is shown at the top of the range line. Transects 1 and 2 were not together and are well away from existing ROWs.

When all data inside ROWs are combined and compared with all data outside ROWs there are clearly no differences attributable to the ROWs whether or not data are stratified by vegetation type (Figure 4).

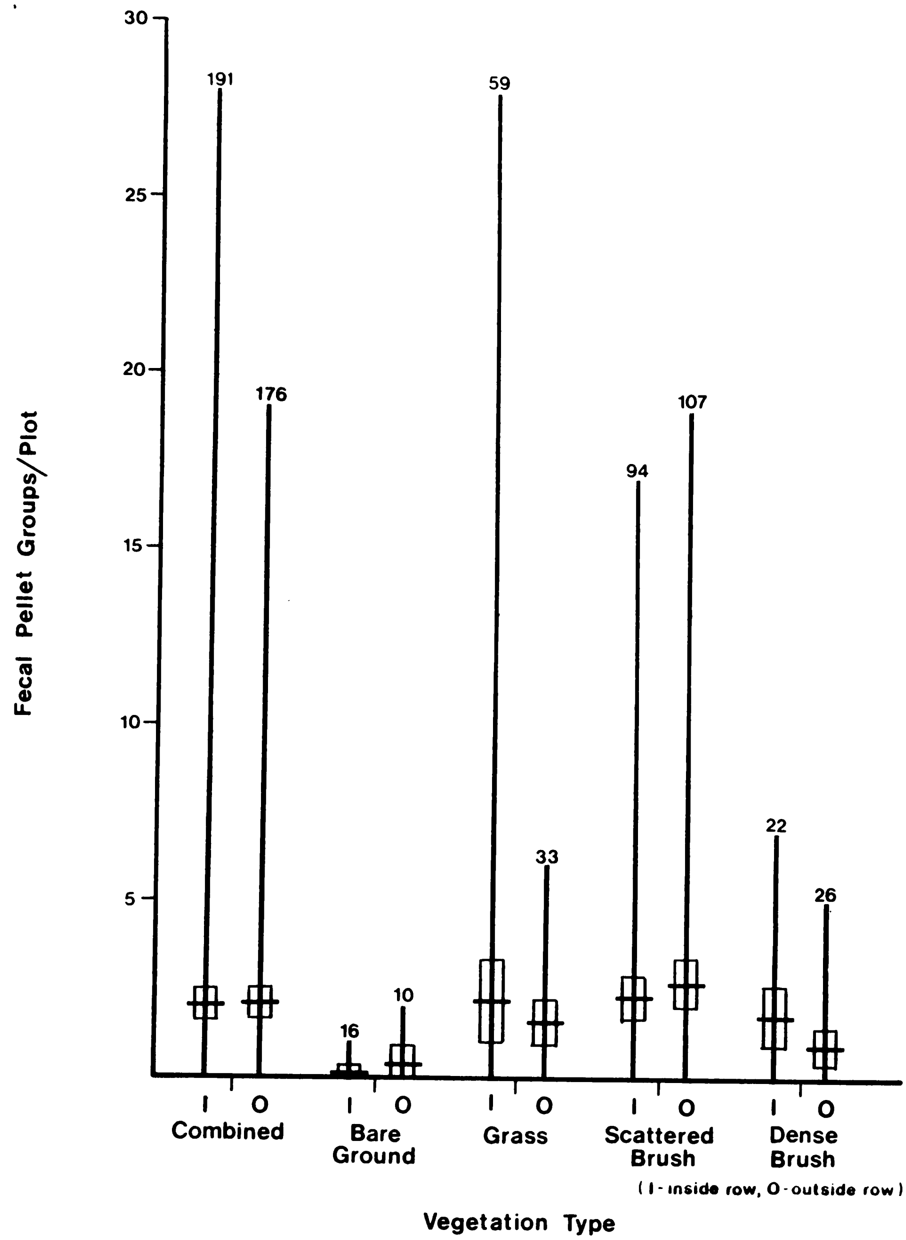

Figure 4. Numbers of fecal pellets found in plots in Transects 3-10 segregated by vegetation type. Symbols and notation are the same as Figure 3.

The possibility of differences between plots inside and outside ROWs for individual transect pairs with the plots stratified by vegetation type was also tested (Table 1). The tests were made only for grass, scattered brush, and dense brush because of the uneven distribution of plots of bare ground. In only one instance out of the 12 pairs tested was there a significant difference in numbers of pellet groups per plot between plots inside and outside of ROWs.

Table 1. Comparison of numbers of pellet groups/plot in paired transects stratified by vegetation type.

Transect	n	X	df/t
Vegetation Type: Grass			
Inside 3	9	0.44 ± 0.77	21
Outside 4	14	1.00 ± 0.67	-1.16 ns
Inside 5	12	3.17 ± 2.11	16
Outside 6	6	2.67 ± 2.16	0.33 ns
Inside 7	17	1.12 ± 0.85	18
Outside 8	3	2.00 ± 2.48	-0.88 ns
Inside 9	21	3.29 ± 3.05	29
Outside 10	10	1.70 ± 1.69	0.72 ns
Vegetation Type: Scattered Brush			
Inside 3	37	2.05 ± 0.75	62
Outside 4	27	2.89 ± 1.19	-1.27 ns
Inside 5	21	3.29 ± 1.55	47
Outside 6	28	1.93 ± 0.74	1.77 ns
Inside 7	16	1.25 ± 0.90	32
Outside 8	18	1.56 ± 0.75	-0.83 ns
Vegetation Type: Dense Brush			
Inside 3	4	0.75 ± 1.52	8
Outside 4	6	1.50 ± 2.18	-0.67 ns
Inside 5	6	4.00 ± 2.20	15
Outside 6	11	1.09 ± 0.63	3.99**
Inside 7	8	1.00 ± 0.89	10
Outside 8	4	0.25 ± 1.80	1.31 ns
Inside 9	4	1.00 ± 1.84	7
Outside 10	5	0.40 ± 0.68	1.04 ns

**Significant at the 99% level.

Finally, to explore the possibility that vegetation type rather than presence or absence of the transmission corridor was the determinant of numbers of pellets per plot, an analysis of variance was done on the data by vegetation type. Data from inside ROWs was combined and analyzed separately from data outside corridors. The results (Table 2) show that there were significant differences in numbers of pellets/plot between plots in the various vegetation types irrespective of the presence of the transmission lines.

Table 2. Analysis of variance (ANOVA) of fecal pellets/plot by vegetation type for transects 3-10. Plots inside corridors were combined as were plots outside corridors. The F statistic shows a significant (P = .05) difference among vegetation types.

	SS	df	MS	F
Treatments	185.49	7	26.50	2.58*
Error	3685.21	359	10.27	
TOTAL	3870.71	366		

DISCUSSION

The question asked in this study is the site-specific one: do transmission lines and ROWs in this open chaparral habitat alter use by deer? It was asked because additional transmission lines are being contemplated and because deer populations are declining. Although the vegetation inside the ROWs appears somewhat more open with fewer trees, less dense brush, and mostly grass at transmission towers, by our simple vegetation classification the two areas turned out to be statistically indistinguishable. The shrubs and trees are generally scattered enough that deer would not need to seek out roads as thoroughfares. This leaves only the presence of towers, the sometimes noisy energized line, and the lack of visual cover to influence deer movement.

The results of this study show no difference in pellet deposition attributable to the presence of the transmission lines. This result is similar to that of Goodwin (1975) who monitored animal activity under a 500 kV line in northern Idaho. We interpret it to mean that deer are indifferent to the presence of the line under these circumstances.

The results also show that there are differences in pellet deposition based on vegetation type, with the most pellets deposited in plots of scattered brush and the fewest on bare ground. This may be reflective of habitat preference by the deer, but alternatively may be attributable to the fact that pellet groups last longer in some settings than others (Low, unpublished data, abstracted in Neff 1968, page 609).

ACKNOWLEDGEMENTS

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A COMPARISON OF RIGHT-OF-WAY MAINTENANCE TREATMENTS AND USE BY WILDLIFE

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ABSTRACT.--A comparison was made of deer, cottontail rabbit, and nongame bird usage of two power line rights-of-way (ROW) which were maintained by two different techniques. One ROW had a history of maintenance by broadcast spraying of herbicides, the other ROW was a demonstration ROW maintained by multiple techniques. In 1980 and 1981, the demonstration area had approximately 3 times the usage by deer and rabbits as the sprayed ROW. Nongame bird usage also showed an increased usage of the demonstration ROW over that of the sprayed ROW.

INTRODUCTION

Wildlife management on rights-of-way (ROW) lands is gaining widespread emphasis (Lancia and McConnell 1976). Because the land available for wildlife habitat is steadily shrinking while the demands on wildlife for recreational use are constantly accelerating, wildlife management programs are gaining increasing consideration. For this reason the Biological Services Program, U.S. Fish and Wildlife Service, has developed a technical assistance Manual for Management of Transmission Line Rights-of-way for Fish and Wildlife and has provided funding for the establishment of a pilot demonstration ROW. This paper reports on the use by white-tailed deer (*Odocoileus virginianus*), cottontail rabbits (*Sylvilagus floridanus*), and nongame birds on a segment of the demonstration ROW as compared to a segment of a ROW maintained by herbicides.

Most of the literature on ROW management deals with the effect of brush control on vegetation. Few studies actually document wildlife use and are carried on long enough to assess adequately the effects of various management techniques on individual wildlife species.

Cavanagh et al. (1976) compared wildlife usage on a ROW managed by clearcutting methods to that on an experimental, selectively cut ROW. The selectively cut ROW showed greater wildlife utilization in their study. Mayer (1976) evaluated wildlife use of electric transmission line ROW for major game mammals in Georgia, West Virginia, and New Hampshire. His

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study revealed that desirable plant community development on ROW was comparable or in some cases superior to that on adjacent old fields. Foster (1956) found that wildlife utilized ROW strips in Michigan more than adjacent woodlands.

Cliburn (1967) used rabbit pellet group counts as an index of utilization to compare prescribe burned ROW plots to unburned plots in three physiographic regions in Mississippi. His study showed that rabbits used burned ROW more than ROW maintained by herbicides.

Study Sites

Two study sites were selected for the purpose of comparing ROW utilization by selected wildlife species. Study site selection was based upon ROW vegetation and previous management practices.

The first study site will be referred to as the demonstration area and was located along a 161 KV transmission line established in 1965 and belonged to the Tennessee Valley Authority. This ROW is located within the upper coastal plain soils province in northeastern Winston County, Mississippi. The study area averages 100 feet (30.4 meters) in width and is approximately 4,300 feet (1,311 meters) in length. The ROW vegetation had been maintained since 1965 by mowing with rear-mounted bush hog type mowers on a two to three year cycle.

In 1977 a demonstration/study was established on the ROW. For this study, four maintenance techniques were used to achieve a diversity of vegetative communities and reduce maintenance costs. These techniques consisted of winter burning, spring burning, spring mowing, and selective basal spraying. In 1979 funding was received from the United States Fish and Wildlife Service and the treatments were amended. Three techniques were used: winter burning, summer mowing, and selective foliar herbicide application. The treatments selected were based entirely on the topography of the area, with the selected basal herbicide being used on the steepest slopes, mowing on the more gentle slopes, and burning on the flatter areas.

The soils are typically acid (pH 4.5 to 5.5) and are low in organic matter (0.5 to 2.5%). Nitrogen, phosphorus, potassium, and sulfur are also deficient in these soils (Vanderford 1975). Topography of the demonstration area ranged from level to hilly with slopes ranging from 0% to 18%.

The second study area was located within the interior flatwoods soils province in Oktibbeha County, Mississippi. The topsoils of this area typically range from 6-15 inches (15-38 cm) in depth and are composed of acid silt loams or loamy sands. These soils are very similar to those in the first study area and should develop similar vegetative communities with similar maintenance practices. Range potential of the two study areas for white-tailed deer and cottontail rabbits is also very similar. The topography ranges from nearly level to gently sloping uplands. The herbaceous vegetation on this ROW has been extensively studied by Huntley et al. (1981) and an analysis of that vegetation will be presented at this symposium. Fifty-four vegetative community types were recognized in 1977 with legumes constituting over 7.7 percent of the ground cover of the burned segment.

This ROW in the second study area has a past maintenance history of blanket herbicide application and mowing with bush hog mowers which has encouraged the development of a different type of vegetative composition (Carvell, 1976). The second study area lacks many of the native legumes and forbs that are considered by Arner et al. (1976), Stoddard (1936), Hurst and Stringer (1975) to be essential for the production of upland game and nongame birds. The vegetation on the second study site consists mainly of extensive stands of mixed grasses, primarily broomsedge (*Andropogon* spp.) mixed with bracken fern (*Pteridium* sp.), and incidental woody species.

METHODS AND MATERIALS

A comparison was made of usage by white-tailed deer, cottontail rabbits, and nongame songbirds between the multiple technique management demonstration area and the ROW maintained by broadcast herbicides. Usage of the two study areas by deer and rabbits was determined by pellet group counts in 20 randomly tossed one meter diameter hoops. Each area was sampled annually in late winter to give each treated area equal intensity of sampling. Hendrickson (1939) stated that most wildlife technicians generally agree the distribution of pellet groups is a good indication of rabbit utilization.

ROW usage by nongame songbirds was determined by walking the center line of each of the two ROW study areas on three consecutive mornings in mid-May of 1979 and 1980. All birds seen or heard were recorded from one-half hour before sunrise to three hours past sunrise. Inventories were conducted simultaneously on both study sites to prevent accumulated errors. Mist nets were also strategically located throughout the study area to increase the intensity of sampling. A similar technique was used by Meyers and Provost (1979) to measure bird population responses to a forest-grassland and shrub ecotone on a Georgia ROW.

RESULTS AND DISCUSSION

The two right-of-way study areas were compared for cottontail rabbit and white-tailed deer utilization during 1980 and 1981 (Table 1). It appears that the multiple technique management strategy is effective in that both rabbits and deer responded to differences in plant composition. In both 1980 and 1981, the demonstration study area had approximately three times the use by rabbits and three times the use by deer as the blanket herbicide study area. The 1980 and 1981 sample data for deer and for rabbit were combined and subjected to a log likelihood ratio test (G-test). These tests showed significantly more (P 0.05) utilization of the multiple use ROW than the herbicide treated ROW by deer and rabbits. These results support earlier findings on these plots of Cliburn (1967) that there was 10.26 times more use by cottontail rabbits on the burned plots than on herbicide plots.

Nongame songbird species also showed a favorable response to the diversity of plant communities that the multiple technique management plan yielded (Table 2). There was more usage by songbirds on the demonstration study area than on the ROW maintained by blanket herbicide. There were 58 species of birds seen, heard, or captured in mist nets on the

Table 1. Comparison of the number of deer and rabbit pellet groups found from random hoop tosses on a demonstration right-of-way (Multiple Maintenance) and a similar right-of-way maintained by blanket herbicide application.

Note: Figure gives actual percentage of hoop tosses that contained pellet groups.

	ROW Maintained by Blanket Herbicide		ROW Maintained by Multiple Techniques	
	1980	1981	1980	1981
Rabbit	25%	25%	75%	70%
Deer	10%	10%	35%	30%

demonstration area in May, 1980 and 43 species documented in May, 1981 as compared to 30 species identified on the blanket herbicide study area.

MANAGEMENT IMPLICATIONS

The results of the study indicated that the segment of ROW under multiple management techniques was used by more songbirds, cottontail rabbits, and white-tailed deer than a segment of ROW which was maintained by herbicides and mowing. It is our opinion that the diversity of plants, especially legumes and herbs which was brought about by multiple management techniques, as compared to the grass complex brought about by blanket spraying and mowing techniques, were responsible for the difference in animal usage noted on the two ROWs.

Single maintenance techniques especially blanket herbicide applications have been shown to produce browse and some fruit for deer and rabbits, as well as nesting cover for upland game birds. However, it does not provide the essential low herbaceous cover, particularly legumes, needed for feeding by upland game birds. Everett et al. (1979) found that 9 out of 18 wild turkey hens went to nest directly on a ROW which was dominated by shrubs. However, immediately after the eggs had hatched, the hens and young left the ROW and went to openings containing low legume grass cover where insects could be easily captured. In areas where quail and turkey are of major importance, herbaceous plant communities interspersed with shrub dominated areas, are of extreme importance.

A major objective of ROW management should be directed toward the development and maintenance of diverse plant communities. Multiple technique management yields a more diverse stable habitat that is utilized by an increased abundance and diversity of wildlife and can result in an improved public image of the utility companies.

Table 2. A comparison of bird species observed on the two study areas in May, 1981.

Bird species observed on the ROW demonstration area maintained by multiple techniques.	Bird species observed on the study area maintained by herbicides.
1. American Robin	1. Black and White Warbler
2. Barred Owl	2. Blue-gray Gnatcatcher
3. Belted Kingfisher	3. Blue Jay
4. Black and White Warbler	4. Brown-headed Cowbird
5. Black Vulture	5. Brown Thrasher
6. Blue Jay	6. Bobwhite Quail
7. Blue-winged Teal	7. Cardinal
8. Brown-headed Cowbird	8. Carolina Chickadee
9. Brown Thrasher	9. Carolina Wren
10. Bobwhite Quail	10. Common Crow
11. Cardinal	11. Common Flicker
12. Carolina Chickadee	12. Common Yellowthroat
13. Carolina Wren	13. Downy Woodpecker
14. Common Crow	14. Eastern Phoebe
15. Common Grackle	15. Gray Catbird
16. Common Yellowthroat	16. Great Crested Flycatcher
17. Downy Woodpecker	17. Hairy Woodpecker
18. Eastern Kingbird	18. Indigo Bunting
19. Eastern Phoebe	19. Kentucky Warbler
20. Eastern Wood Peewee	20. Mourning Dove
21. Gray Catbird	21. Pileated Woodpecker
22. Great Crested Flycatcher	22. Prairie Warbler
23. Green Heron	23. Red-bellied Woodpecker
24. Hairy Woodpecker	24. Red-shouldered Hawk
25. Indigo Bunting	25. Rufus-sided Towhee
26. Kentucky Warbler	26. Summer Tanager
27. Mockingbird	27. Tufted Titmouse
28. Mourning Dove	28. White-eyed Vireo
29. Prairie Warbler	29. Yellow-breasted Chat
30. Prothonatary Warbler	30. Yellow-billed Cuckoo
31. Red-headed Woodpecker	
32. Red-shouldered Hawk	
33. Red-winged Blackbird	
34. Rough-winged Swallow	
35. Rufus-sided Towhee	
36. Summer Tanager	
37. Tufted Titmouse	
38. White-eyed Vireo	
39. White-throated Sparrow	
40. Wood Duck	
41. Yellow-billed Cuckoo	
42. Yellow-breasted Chat	

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WILDLIFE USE OF IRRIGATION CANAL RIGHTS-OF-WAY IN THE PRAIRIE POTHOLE REGION OF NORTH DAKOTA

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ABSTRACT.--Representative sample areas of a grass-seeded 12,306 acre (4,980 ha) irrigation canal right-of-way were studied from 1977 to 1980 to determine wildlife use. Numbers of species and individuals of birds encountered on roadside Breeding Bird Surveys were consistently higher on the canal right-of-way compared to the control area from 1977 to 1979. Dove call-count surveys in 1979 indicated a significantly higher number of mourning doves (*Zenaida macroura*) on the control route compared to the canal route. Tracks of 9 species of mammalian predators were identified on the canal route scent post survey compared to 5 species on the control route in 1979. Approximately 4 times more small mammals were trapped on the canal right-of-way than on adjacent agricultural lands in both 1978 and 1979. During 1979 winter aerial surveys, 6.3 white-tailed deer (*Odocoileus virginianus*) were observed per 16 mi (10 km) on the canal compared to 0.4 deer per 16 mi (10 km) on the control. Duck pairs were more numerous on the canal route than on the control route in 2 of 3 years surveyed and duck broods were more numerous on the canal route in all 3 years surveyed. In 1979, 8 species of ducks initiated 83 nests per km on the right-of-way upland, with an average nest success of 50%. It is estimated that the canal upland right-of-way can potentially produce 12 times the number of successful duck nests that it did before acquisition and management. Management recommendations include periodic rejuvenation treatment of the grassland on the canal at 5- and 10-year intervals to maintain its optimum vigor.

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INTRODUCTION

Large parcels of publicly owned rights-of-way associated with the nation's roads, highways, railroads, utility lines, pipelines, and irrigation canals are potentially valuable wildlife habitat (Oetting and Cassel 1971). Within the North-Central states several studies have indicated a high use of rights-of-way by nesting birds. While waterfowl nesting has been documented on interstate highway rights-of-way (Oetting and Cassell 1971) and on railroad rights-of-way (Page and Cassel 1971), no detailed studies of wildlife use of irrigation canal rights-of-way have been published. From 1977 to 1980 Bureau of Reclamation biologists conducted wildlife surveys on the McClusky Canal right-of-way to determine its value as wildlife habitat.

McClusky Canal, extending through central North Dakota, is the principal waterway for the initial stage of the Garrison Diversion Unit. As originally authorized, the Garrison Diversion unit, a multipurpose water development project, would contain 298 mi (480.4 km) of canal with 18,750 acres (7,590 ha) of canal right-of-way. Managed for wildlife, these right-of-way areas could offset some of the unavoidable habitat losses caused by a water development project. Based on the wildlife data collected, recommendations are made for the preservation and improvement of the existing wildlife habitat on canal rights-of-way.

Study Area

The western three-fourths of the canal lies within the wheatgrass-needlegrass zone of the Missouri Coteau. The eastern one-fourth of the canal lies in the wheatgrass-bluestem-needlegrass zone of the Drift Prairie. The most important wildlife habitats in the canal area are the prairie wetlands (potholes) and the native grasslands. Mean annual precipitation is 22 inches (55.8 cm) and the average July temperature is 71°F (21.8°C) (U.S. Department of Commerce 1979).

The canal right-of-way width varies from 358'-2,260' (109 m to 689 m). Of the 12,306 ac (4,980 ha) acquired for right-of-way, 48% was previously cropland, 42% was heavily-grazed pasture, and about 10% was wetland basins. When in operation, land use on the canal right-of-way will be 8% water, 4% road, 86% idle grassland, and 2% trees. The McClusky canal is 73.6 mi (118.4 km) long and required little excavation for a reach of 14.9 mi (24 km) where it passes through a chain of lakes which serves as a natural channel. The canal will have a water depth of 17.4' (5.3 m), bottom width of 25' (7.62 m) and water surface width of 95' (29 m), making it the largest mand-made water conveyance facility in North Dakota. The canal was not in operation while these studies were conducted, but it held ground water with depths ranging from less than 3.3-10' (1 m to 3 m).

Present Right-of-Way Management Practices

The initial wildlife management practices on the canal right-of-way were to establish and maintain vegetation that provides wildlife habitat. Plant species which have been seeded include little bluestem (*Andropogon scoparius*), green needlegrass (*Stipa viridula*), sideoats grama (*Bouteloua curtipendula*), western wheatgrass (*Agropyron smithii*), slender wheatgrass

(A. trachycaulum), tall wheatgrass (A. elongatum), intermediate wheatgrass (A. intermedium), sweet clover (Melilotus spp.), and alfalfa (Medicago sativa). Top soiling and reseeding of the canal right-of-way began in 1971, and were completed in 1980. Trees and shrubs were planted for aesthetic value and to provide shelter and food for wildlife. Noxious weeds are being controlled by mowing, cultivation, and herbicide application on the canal right-of-way. Insecticides may be used to control infestations of grasshoppers and other insects. The effects on vegetation, wildife, adjacent agricultural lands, and aquatic habitat are considered in selecting the method of management for an individual parcel of right-of-way. Agricultural uses include haying of selected portions of the right-of-way (not to exceed 10% of the right-of-way) under drought disaster conditions when the Governor of North Dakota requests Federal lands be opened for haying. Areas to be hayed are selected by the Bureau of Reclamation in consultation with the Fish and Wildlife Service and the State of North Dakota to meet agricultural needs, while attempting to recognize best wildlife management techniques.

METHODS

A 25 mi (40.2 km) canal survey route (34% of total canal) was established for wildlife surveys. To permit comparisons of wildlife use along the canal to wildlife use in adjacent agricultural areas, a second 25 mi (40.2 km) route was established on gravel county roads south of the canal for use as a control. Land uses and water areas adjacent to the two routes are not significantly different (x^2=2.44, 3df, p .05). Two breeding duck pair counts (Hammond 1969) were conducted annually in early and late May and 3 duck brood counts (Hammond 1970) were conducted annually in June, July, and August on the two 25 mi (40.2 km) routes. Birds were surveyed on the two routes four times annually using the U.S. Fish and Wildlife Service Cooperative Breeding Bird Survey Technique (U.S. Department of the Interior 1975). Surveys were conducted in winter, spring, summer, and fall.

Mourning doves (Zenaida macroura) were censused 7 June 1979 on a 20 mi (32 km) canal route and on a 20 mi (32 km) control route using the standard U.S. Fish and Wildlife Service call-count technique (described on Form 3-159, 1973, available from Office of Migratory Bird Management, Laurel, Maryland.)

An aerial survey for deer was conducted along the entire 73 mi (118.4 km) McClusky Canal and on a parallel 84 mi (135.2 km) control route in March 1979. A spotlight survey for deer and mammalian predators was conducted in August 1979 on 38 mi (61 km) of the canal right-of-way and on a 24 mi (38.6 km) control route parallel to the right-of-way.

A snap-trap, line transect technique similar to that used by Golley, et al. (1965) was used to sample small mammal populations in 4 canal right-of-way plant communities and on 4 control plots in agricultural lands typical of the canal land before development. Vegetation density (Robel, et al., 1970) was measured along all small mammal transects to permit comparison of vegetation density to small mammal populations.

Mammalian predator scent post survey procedures outlined by Linhart and Knowlton (1975) and modified for use on smaller study areas as described by Roughton (1979) were used in 1979. Surveys were conducted during the second week of September. Twelve survey lines were established on the canal right-of-way and 12 lines along the control route.

Five sample areas totaling 767 ac (308 ha), or 6% of the 12,300 ac (4,980 ha) canal right-of-way, were searched to determine densities of ground nesting birds. Three areas were adjacent to the canal channel and 2 areas were adjacent to the canal lakes. These areas were selected because their vegetative cover, water areas, and adjacent land use are representative of the McClusky Canal right-of-way (x^2=2.44, 3df, $p<.05$). The 5 sample areas were searched for bird nests 4 times annually at approximately 2-week intervals between May and July. Nests were located using a technique that flushes the hen off the nest without disturbing the eggs (Higgins, et al., 1977). Nests were revisited after the calculated hatching dates and success determined. Permanent vegetation transects established in 1978 were surveyed within each of the 5 nest search areas using a modification of the technique described by Cain and Castro (1959). Plant species and vegetation density measurements (Robel, et al., 1970) were also recorded at each observed nest site.

RESULTS AND DISCUSSION

Deer Surveys

The winter aerial survey resulted in a total of 75 white-tailed deer (*Odocoileus virginianus*), (6.3 per 10 km) observed along the canal compared to 6 deer (0.4 per 10 km) along the control route. The late summer spotlight survey resulted in a total of 13 deer (2.1 per 10 km) observed along the canal compared to 4 deer (1.0 per 10 km) along the control route. Sixty-five of the deer (87%) observed along the canal route during the winter survey were on the canal right-of-way. In winter the banks of the canal were one of the few areas where grasses were still available as food and cover for deer and other wildlife. The agricultural land outside the canal right-of-way, including the control route, had very little vegetation above the snow cover with the exception of limited areas of unmowed wetland vegetation and planted shelter belts.

Small Mammal Surveys

In 1979 a total of 127 small mammals of 5 species were trapped during 1,126 trap nights (112.8 per 1,000 trap nights) on the McClusky Canal right-of-way. In comparison, only 30 small mammals of 4 species were trapped during 1,140 trap nights (16.3 per 1,000 trap nights) on the control transects in agricultural areas. All canal mammal trapping transects had higher average vegetation densities than did the control transects. Highest numbers (216.4 per 1,000 trap nights) of small mammals were found on the idle smooth brome grass (*Bromus inermis*) canal transect which also had the highest vegetation density reading (6.5 dm) of all plots. The lowest number (10.1 per 1,000 trap nights) of small mammals was trapped on the control transect on bare soil. Voles (*Microtus spp.*) were the dominant species on the canal while deer mice (*Peromyscus spp.*) were the most frequently captured species on the agricultural transects.

Approximately 4 times more small mammals were trapped on the canal right-of-way than on adjacent agricultural lands in both 1978 and 1979. From the standpoint of prey base availability, these data would indicate that the canal right-of-way could potentially support higher numbers of raptors and mammalian predators than adjacent agricultural areas. These relatively high rodent populations found on the canal right-of-way could prove beneficial to the canal revegetation program by increasing the recycling rate of soil nutrients and preventing an excessive buildup of litter (Chew 1978). However, rodent population levels of the canal should continue to be monitored to determine if unusually high numbers might adversely affect cropland adjacent to the canal or canal bank stability.

Mammalian Predator Surveys

Tracks of 9 species were identified on the canal route scent post survey compared to 5 species on the control route. A higher number of red fox (*Vulpes vulpes*) recorded on the control routes compared to the canal routes was statistically significant based on the scent station results (x^2=0.802, p<.05). Both the scent post and the spotlight surveys show no significant difference in the occurrence of striped skunks (*Mephitis mephitis*) between the canal and the control routes (scent post survey x^2=1.207, p<.05); spotlight survey x^2=2.701, p<.05).

Roadside Bird Surveys

A total of 9,929 birds of 85 species were recorded on the McClusky Canal right-of-way, and 3,629 birds of 76 species were recorded on the control route during four quarterly surveys in 1979. Numbers of species and numbers of individual birds were consistently higher on the canal route than on the control route over a 3-year period (1977-1979) during the breeding season surveys (a complete species list is available from the authors).

The differences in total numbers and species composition of birds on the canal right-of-way compared to the control route appear to be closely related to the habitat available. The canal channel held water even when natural wetlands in the area were dry. Birds associated with wetland habitats were much more numerous along the canal route compared to the control route. This was especially evident in 1977, a drought year, in which 127 waterfowl of 5 species were recorded on the canal versus only 6 waterfowl of 2 species on the control. The higher number of upland species and individuals recorded on the canal route compared to the control route is probably most related to the undisturbed grass cover provided along the right-of-way in contrast to the sparse vegetation along the control route where cropping, haying, and grazing limit the amount of wildlife cover available.

Dove Surveys

Seventy-one mourning doves were recorded on the control route compared to 45 doves recorded on the canal route. The mean number of doves per km on the control was significantly greater than the mean of the canal (t=2.35, p<.05). The significantly higher numbers of doves on the control route compared to the canal route may be related to the somewhat greater percent of trees and farmsteads along the control route (4.6%) compared to the canal route (1.4%). Considerable ground nesting by doves occurs in the Plains States; however, shelterbelts planted in this area have increased nesting habitat for doves (Keeler 1977). Although portions of shelterbelts along the canal alignment were removed during construction, 46,000 trees and shrubs have been planted on the canal right-of-way. Repeating these surveys after these plantings become established would determine the response of dove populations to this new habitat.

Duck Pair and Brood Surveys

Duck pairs were recorded in higher numbers on the canal route compared to the control route in 1978 (7/km vs. 2/km) and 1980 (13/km vs. 6/km). In 1979, a wet year, an equal number of pairs were recorded on both routes (7 pairs per km). Duck broods were recorded in higher numbers on the canal route compared to the control route in all 3 years surveyed, averaging 1.5 per km on the canal vs. 0.4 broods per km on the control. It should be noted that the canal right-of-way was regularly used by breeding ducks in the study areas with a high density of adjacent natural wetlands, but was only minimally used in study areas with few nearby wetlands. Also, the amount and quality of pair and brood habitat in the canal channel may be reduced by future operational water levels and velocity. This decrease in duck use could result from excessive water depth, low rates of nutrient recycling, competition for invertebrates by minnows, and the scarcity of vegetated, shallow-water feeding areas caused by steep, rocky shorelines (Swanson and Nelson 1970).

Nest Survey

In 1979, the five study areas yielded an overall ground nest density of 97 nests per km of which duck nest density totaled 83 nests per km . Duck nest densities in 1979 were 1.2 times greater than in 1978 and 7 times greater than in 1977. The increase in density of duck nests found on the canal right-of-way from 1977 to 1979 was positively correlated with the increase in the number of ponds holding water found on the statewide survey conducted by the State Game and Fish Department during the same time period. Other factors that could be involved in the increase in nest densities from 1977 to 1979 include greater vegetation densities, population recruitment with the homing of young to natal areas, and the return of successful hens.

Observed nesting success was 45% for all bird species and 50% for ducks on the canal right-of-way in 1979. The fate of 250 of the 256 duck nests was determined. Fifty percent hatched, 43% were destroyed, and 7% were abandoned. Of the 109 duck nests destroyed, mammalian predators accounted for 94%, vehicles for 2%, and unknown causes for 4%. Nesting success was lower on the plots along the channel (34%) than on the wider plots along the canal lakes (58%). Successful duck nests had a higher average vegetation density than destroyed nests, except for the common pintail (*Anas acuta*) and northern shoveler (*A. clypeata*).

The three plant species recorded most frequently on vegetation transects in the nest search area in 1979 were green needlegrass (27%), smooth brome grass (17%), and western wheatgrass (16%). The three plant species occurring most frequently at duck nest sites in 1979 were smooth brome, sweet clover, and wheatgrasses. The upland nesting cover provided by the idle grasses on the right-of-way in conjunction with the natural wetland basins adjacent to the canal right-of-way are the primary attraction to nesting waterfowl. Griffith (1948) states that lack of nesting cover is the usual factor limiting duck nesting. Cultivation and heavy grazing around potholes restricts duck nesting to limited areas (Dwyer 1970).

Figure 1 compares successful duck nest densities on the McClusky Canal to densities and success found by other investigators in the Prairie Pothole Region. It demonstrates that the canal has higher successful nest densities than do cropland or pastureland. Based on the previous use of the land now occupied by the canal right-of-way (48% cropland, 42% pasture, and 10% wetland), it can be estimated from other studies in similar habitats that the cropland potentially produced only 0.6 successful nests per km (Higgins 1977) and the pasture potentially produced only 5.9 successful nests per km (Kirsch 1969). The canal right-of-way is now 86% idle grassland and produced an average of 40.2 successful nests per km in 1979. These data show that canal right-of-way land can potentially produce 12 times more successful duck nests than it did when it was cultivated and grazed before acquisition and has the potential for even higher densitics if managed properly. Figure 1 also illustrates that the canal right-of-way nest densities are still below what has been attained on idle grasslands along other rights-of-way in North Dakota (Page and Cassel 1971; Oetting and Cassel 1971).

RECOMMENDED FUTURE MANAGEMENT PRACTICES

The future operation of the canal should not appreciably affect use of the upland right-of-way by nesting ducks provided the adjacent natural wetlands are not drained, and the upland vegetation on the canal is maintained. During this 4-year study, disturbance caused by canal construction and repairs, weed control, and wildlife investigations has been a regular occurrence on the study areas, but did not appear to discourage duck nesting provided the nesting vegetation was not disturbed.

Duebbert, et al. (1981) concluded that seeded grassland generally produces more ducks and other game species within the first 2 to 8 years after it is established or rejuvenated. Seeded grasslands must be periodically rejuvenated to maintain their optimum vigor. This is due to a nitrogen deficiency causing a condition commonly described as "sod-bound" (Canode 1965). Methods used to rejuvenate seeded grasslands can be natural, chemical, or mechanical. Establishment and maintenance of grasslands in the prairie pothole region are discussed in detail in Duebbert, et al. (1981). Future management in the form of early spring mowing, controlled burning, fertilizers, mechanical scarification or reseeding on alternating plots at 5- to 10-year intervals may be necessary to maintain high quality wildlife habitat on the canal right-of-way.

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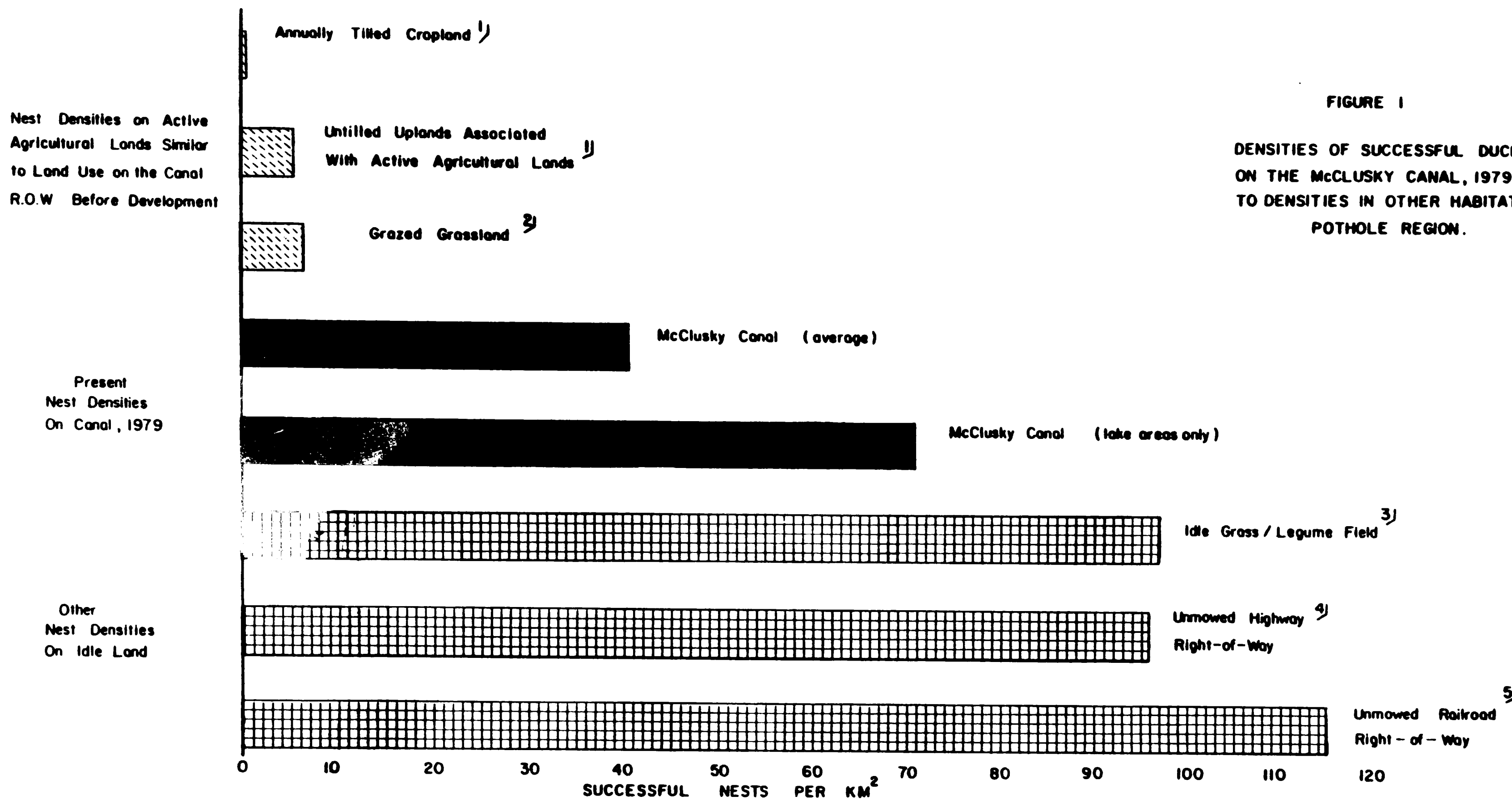
FIGURE I

DENSITIES OF SUCCESSFUL DUCK NESTS ON THE McCLUSKY CANAL, 1979 COMPARED TO DENSITIES IN OTHER HABITATS OF THE POTHOLE REGION.



1) Higgins, K.F. 1977.

2) Kirsch, L.M. 1969

3) Duebbert, H.F. 1969

4) Oetting, R.B. and J.F. Cassel 1971.

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IMPACTS OF THE GRANITE REEF AQUEDUCT ON DESERT UNGULATES

Paul R. Krausman[1] and John J. Hervert[1]

ABSTRACT.--The Central Arizona Project (CAP) is being constructed to deliver Colorado River water from Parker, Arizona to Tucson. The Granite Reef Aqueduct (GRA) is part of the CAP and extends from Parker Dam to the start of the Tucson Aqueduct, 25 mi (40 km) northeast of Phoenix. The GRA is a barrier to desert ungulates. We began an intensive study in 1979 to determine the effects the canal will have on desert mule deer (*Odocoileus hemionus crooki*) and mountain sheep (*Ovis canadensis mexicana*). Mountain sheep inhabit ranges along 56 mi (90 km) of the GRA. Sheep have not entered the canal but inhabit areas within 0.6 mi (1 km) of the GRA. Desert mule deer inhabit 120 mi (193 km) along the canal and more frequently associate with it according to telemetry data, visual observations, and track plot data. From February 1979 to December 1981, eight dead deer were found in the canal and 23 were observed in or on the canal. A minimum of eight deer crossed the canal; three crossed on a regular basis.

INTRODUCTION

Habitat alteration from man-created barriers such as highways (Muller 1967, Reed and Woodard 1981), pipelines (Klein 1971, Child 1974), and canals (Campbell 1981) are a serious threat to wildlife. Barriers cut off migratory routes (Klein 1971, Child 1974, Reed et al. 1975) and eliminate habitat important to species survival. Barriers become even more damaging when animals attempt to cross them and die by being hit by vehicles, drowning, or being electrocuted. When barriers are constructed it is important they be designed so impacts on wildlife resources are minimal.

The Bureau of Reclamation (BR) is constructing the Granite Reef Aqueduct (GRA) as part of the Central Arizona Project (CAP) to convey Colorado River water to the central Arizona service area. The GRA extends from Parker Dam, Yuma County to the start of the Tucson Aqueduct 25 mi (40 km) northeast of Phoenix, Maricopa County, Arizona. The concrete-lined canal is 182 mi (293 km) long, creating a barrier 19 ft (5.7 m) deep with a base width of 24 ft (7.3 m). The top width of the canal is 80 ft (24.4 m) along most of the route.

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Approximately 56 mi (90 km) of the GRA goes by the Harquahala-Little Harquahala-Granite Wash Mountain complex (Fig. 1) which provides habitat for mountain sheep (Ovis canadensis mexicana). Up to 120 mi (193 km) of the canal is in desert mule deer (Odocoileus hemionus crooki) habitat. Water is the major limiting factor in the desert ecosystem traversed by the GRA. Large mammals are more or less bound to available water sources during dry weather. Because water is limited, mule deer populations are sparse and localized around water. Population estimates of deer along the canal are as low as 1 deer per 2-4 mi^2 (5-10 km^2) (United States Department of the Interior 1974:44).

Mountain sheep are limited to the Granite Wash, Harquahala, Little Harquahala, and Big Horn Mountains (Fig. 1) along the open GRA. Occasionally, sheep inhabit the Belmont Mountains (Fig. 1). The Harquahala Mountains provide habitat for approximately 50 sheep; a minimum of 10 sheep are in the Granite Wash range and at least 20 sheep occupy the Little Harquahala Mountains. Several sheep inhabit the Big Horn Mountains.

Native ungulate drownings can be expected when water is introduced to the environment in an open canal, as has occurred at the Welton-Mohawk Canal in southwestern Arizona. When water was first placed in this canal, sheep occasionally wandered from their normal range and drowned while trying to drink from the canal (Furlow 1969, United States Department of the Interior 1974:83). Deer drownings, which are quite frequent in the Welton-Mohawk canal, have reduced this deer herd in the area by 90% (Furlow 1969, United States Department of the Interior 1974:83). Deer loss in canals has been documented from the Ainsworth Canal in Nebraska where an average of 50 deer were lost annually between 1965-1969 (Menzel 1967) and southeast of Farmington, New Mexico where approximately 7-8 deer entered an open canal in 1978 and five drowned (Bolders and Bailey 1979). Up to 5 deer per year are also drowned in the Caochella Canal, California (Dave Bush, BR pers. comm.), and deer drownings are a problem in other canals throughout the western United States (MacGreger 1965, Hinkle 1966).

A major concern is how the GRA will influence native ungulates along the CAP. Water added to a water limited habitat in an open canal may alter the behavior and movements of deer and sheep and result in high mortality rates. Although water will not be placed in the GRA until after 1985, the canal collects rainwater which attracts deer and sheep. This paper examines the seasonal effect of the GRA on mountain sheep and desert mule deer based on data collected from January 1979 to December 1981.

METHODS

Between November 1979 and March 1981, 17 mountain sheep and 22 desert mule deer were fitted with radio collars. The Harquahala-Little Harquahala-Granite Wash Mountain complex was selected to study sheep and the Belmont Mountains for deer because of the availability of animals and the close proximity of the canal to their habitats. Marked animals were located weekly from a Cessna 172 or 182 and from ground triangulation.

Ungulate use of the canal was recorded whenever it was observed during routine field activities. Canal construction workers also reported incidences of sheep or deer in or near the canal.

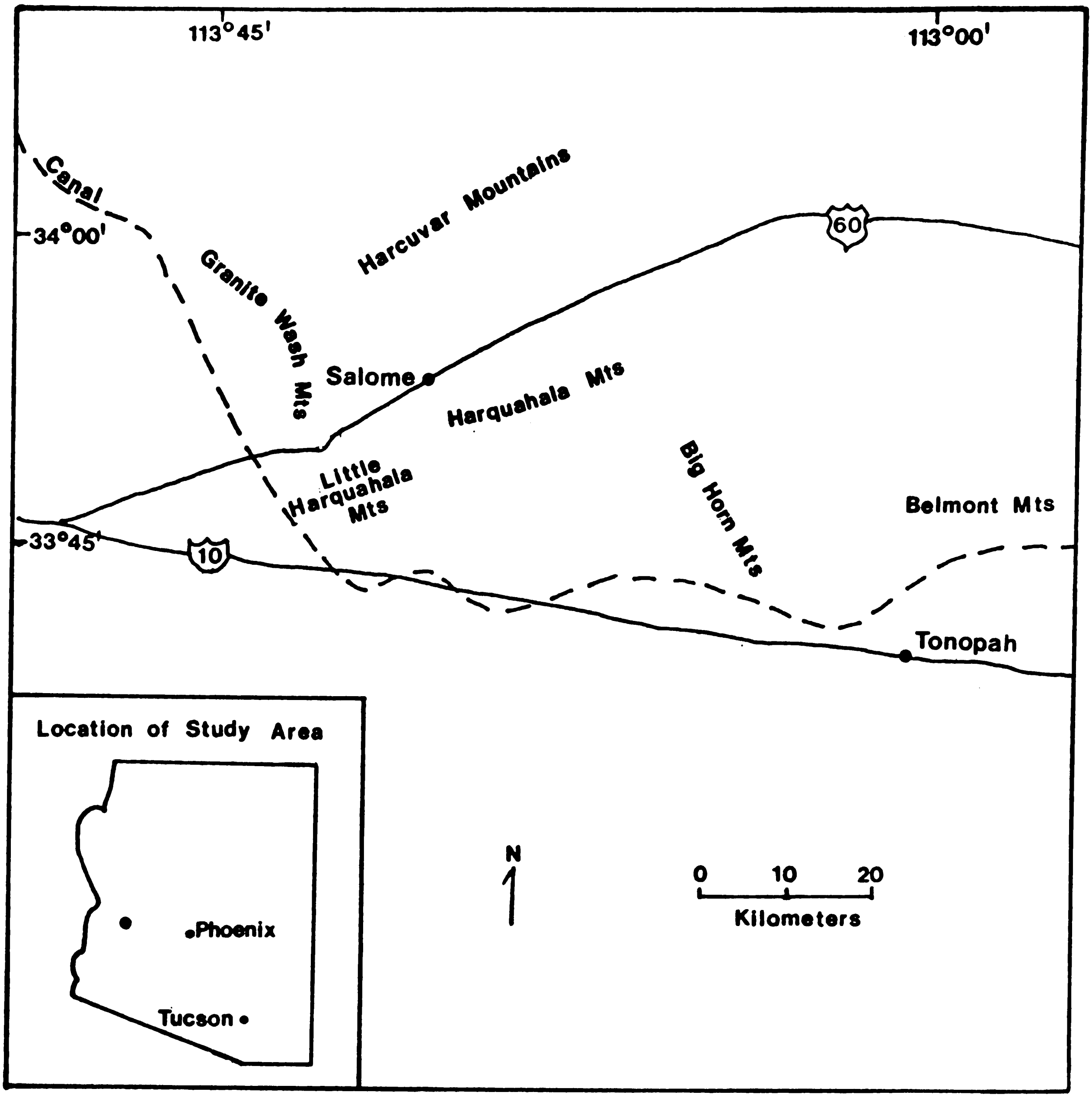

Figure 1. Location of the Granite Reef Aqueduct in western Arizona.

Overshoots ranging from 33-79 ft (10-24 m) wide were made during canal construction to allow water runoff from the desert and surrounding mountain ranges to be continuous in major washes. We created a 10-13 ft (3-4 m) strip of dirt to provide easy access over the canal for vertebrates. At the bottom and top of eight dirt strips, track plots 3 ft (1 m) wide were cleared and read 49 times from 1 January 1981 to 30 September 1981. Winter rains washed the dirt strips away in October. Coyote (*Canis latrans*), lagomorph, fox (*Vulpes* spp.), domestic dog, and deer tracks were recorded to obtain frequency of animal use.

RESULTS

Movements Across the Canal

Deer. Eight of the 22 collared deer crossed the dry canal; three crossed on a regular basis. A yearling male crossed the canal three times in April and May 1980 and approached an agricultural field on the south side of the canal. His radio failed in May 1980. Two females made regular trips between the Belmont Mountains and the agricultural fields directly south between March and June 1980. Four other deer crossed the canal at infrequent intervals.

An adult male in the Little Harquahala Mountains had a home range which crossed the canal route, and he crossed Interstate 10 at least three times in the summer of 1981. The home ranges of 4 collared male mule deer selected from along the CAP average 30 mi^2 (78 km^2) with a mean maximum distance across ranges of 12 mi (19 km). The habitat used by mule deer is large and is related to water availability. In southwest Texas desert mule deer ranges were much smaller but water was common throughout the range (Dickerson 1978).

Mountain Sheep. During the construction of the canal, workers observed sheep along the Little Harquahala Mountains, located 0.6-1.2 mi (1-2 km) from the canal, and Burnt Mountain, located at the east end of the Big Horn Mountains (Fig. 1). During our surveys, we noted only one sheep within 0.6 mi (1 km) of the GRA. An adult female traveled from the Big Horn Mountains to the Belmonts 7 mi (11 km) and resided on several rock outcrops adjacent to the GRA. Although sheep sightings or movements along the canal have been limited, the distances they have traveled are extraordinary. Adult males have ranges in excess of 39 mi^2 (100 km^2) and have traveled 19 mi (30 km) which places the GRA within the accessible area of the mountain sheep. The Little Harquahala population has the easiest access to the canal.

Observations

In 1978, construction workers observed one deer in the canal. No mortalities were recorded; deer had not become trapped in the canal. From February 1979 to 9 December 1981, 23 deer were observed in or on the canal: 11 adult females, 4 adult males, 2 yearling females, 1 yearling male, and 5 fawns.

Two adult females, an adult male, and one yearling male were found in the bottom of the canal, unable to escape. Three of these animals were chased an average of 4 mi (6 km) until they exited the canal. During the summer, temperatures in the canal were in excess of 129°F (54°C) and deer in the canal were chased out to prevent them from dying of exposure.

Only two deer, an adult female and male, in the bottom of the canal, ran out when first observed. Two adult females and one yearling female trapped in the canal were captured after being chased for 2-4 mi (3-6 km). Upon capture, the deer were carried into available shade and provided with water. But they died from shock and exposure. Four other deer died after being trapped in the canal. An adult male was found dead and two male fawns and an adult female drowned. The fawns had entered the canal after late summer rains when the canal had over 75 in (35 cm) of water in it and were unable to escape. The adult female drowned after jumping a fence which surrounded an overshoot filled with water.

Three deer that were trapped in the canal were captured by hand and fitted with radio collars. An adult female and an adult male died shortly after capture. The male was seen in the canal on 6 October and captured the following day. He died on 11 October 1980. The female was captured on 20 April 1980 and released from the canal, but was found dead in the canal on 14 May 1980 in the general area where she was captured.

In July 1981, two female fawns were observed walking along the edge of the canal. Three adult females were observed along the canal's edge in August 1981; one was feeding, one crossed the canal on a dirt plug, and the third walked to the west on the canal's south side. She walked along the canal access road, periodically approached the canal, and turned back to the road. This locomotion pattern indicated that she was trying to cross the canal for a distance of 0.5 mi (0.8 km) until she was out of sight.

On 9 December 1981 an adult female and a fawn were observed on the north side of the canal. When alerted they turned and walked away from the aqueduct.

The majority, 19 of 23 deer associating with the canal, were observed during the warm period of the year when temperatures were high and available free standing water was limited. Some animals tried to obtain access to the opposite side of the canal and many used the canal as a water source.

Track Plots

Deer tracks were recorded on 4 of the 8 track plots established over the canal. The frequency of coyote, lagomorph, fox, and domestic dog crossing track plots is recorded in Table 1. Coyote and lagomorph tracks were more common, followed by fox and dog. Most deer tracks were counted during time periods of high temperatures and limited free standing water.

DISCUSSION

Desert mule deer came into contact with the GRA more often than mountain sheep. When water is put in the canal, more use by sheep can be expected. Preliminary results from this study indicate that most of the deer interactions with the canal occur during the warmer months when the canal holds free-standing rainwater: 9 of 11 incidences of deer tracks were recorded in summer months, 6 of 9 mortalities occurred in warm months, and 11 of 16 observations of live deer in and around the canal occurred in summer.

Table 1. Incidence of coyote, lagomorph, fox, dog, and deer tracks in 8 track plots read from January-September 1981 along the GRA. (Numbers in parenthesis is the number of times the plots were read).

Species	Number of plots with tracks							
Coyote	7	6	6	6	5	5	7	8
Lagomorph	3	2	7	7	5	7	7	7
Fox	3	4	3	2	0	1	0	2
Dog	2	2	0	0	0	2	2	2
Deer	2	0	0	0	3	1	3	2
Month	Jan	Feb	Apr	May	Jun	Jul	Aug	Sep
N	(6)	(3)	(4)	(4)	(2)	(8)	(11)	(11)
$\overline{X}$ Temp °C	8	11	15	20	26	30	28	25

We are currently evaluating whether it is necessary for deer and sheep to use habitat on both sides of the canal. The majority of deer and sheep habitat occurs north of the canal. If access to the south side is not critical, the canal may be fenced. However, if critical habitat components exist on both sides of the canal, crossings are necessary. Areas of concentrated deer use are being evaluated. Various crossing structures will be tested along GRA areas frequently visited by deer. Our goal is to keep ungulates out of the water-filled canal rather than concentrating on ways to help them exit the canal if they fall in.

ACKNOWLEDGEMENTS

We acknowledge the technical assistance of Rick Ockenfels, Rick Seegmiller, and MaryEllen Chilelli of the Wildlife Ecology Division, School of Renewable Natural Resources, University of Arizona. This study was funded by the Bureau of Reclamation and the U.S. Fish and Wildlife Service.

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A METHOD FOR EVALUATING THE EFFECTIVENESS OF A DEER PROTECTION SYSTEM ON A CONCRETE-LINED CANAL (WITH COMMENTS ON THE PLANNING OF THESE SYSTEMS

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ABSTRACT.--Methods and preliminary results of a study to determine the effectiveness of deer protection facilities associated with a concrete-lined canal in California are presented. Successful canal crossings by deer were monitored using electric counters activated by pressure switches. Track count surveys were used in an effort to interpret counter data. Regression analysis resulted in a model of reasonably high precision for use in estimating deer use of canal crossings and escapes. Important considerations in the planning of deer protection systems for canals is discussed.

INTRODUCTION

Deer losses occur in canals used for transporting water for hydroelectric power and irrigation systems throughout the west (Gubser, 1960). In some cases, the number of deer losses has been significant. But even where deer losses are few, they may give rise to public and agency concern for wildlife protection.

Gubser (1960), Latham and Verzuh (1971), and Seaman (1977) provide reviews of documented deer losses and descriptions of deer protection facilities currently in use. The overall effectiveness of these facilities, however, does not appear to have been adequately tested.

Pacific Gas and Electric Company (PGandE) is working with the California Department of Fish and Game (CDF&G) to minimize deer losses in Company-owned canals. A study is in progress on the Hamilton Branch Canal to determine the overall effectiveness of its existing deer protection facilities. The study is directed at quantifying and comparing the number of unsuccessful crossings of the canal (deer losses) with the number of successful crossings. This paper presents the methodology employed in that study and discusses considerations in effective deer protection planning.

STUDY AREA

The Hamilton Branch Canal carries water about 3.6 miles (5.8 km) from the Hamilton Branch of the North Fork Feather River to a point above the

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Hamilton Branch Power House on the east shore of Lake Almanor in Northern California (Figure 1). The canal lies along the lower slope of Little Dyer Mountain at an elevation of about 5000 feet (1524 m). The major vegetation habitat type adjacent to the canal right-of-way (ROW) is second growth sierran mixed conifer forest (Cheatham and Haller, 1975).

The canal transects a migration corridor of the Tehama deer herd. This migratory population of columbian black-tailed deer (Odocoileus hemionus columbianus) is one of the largest recognized herds in California. Figure 1 shows the general pattern of deer migration in the study area and surrounding vicinity.

The canal was constructed in 1921 and acquired by PGandE in 1945. Deer protection facilities consisting of crossings and in-channel deer escapes have been in use on the canal since the mid-1960's. To date, thirteen crossings have been constructed along approximately 3 miles (4.8 km) of the canal for use by wildlife. The crossings, made of redwood planks and beams, are approximately 6 feet wide (1.8 m). Shallow side boards allow the crossings to be covered with a layer of soil. In addition, five deer escapes have been constructed.

The deer escapes are of two types, a step-out escape with log boom and flasher cable (Fig. 2), and a ramp-out escape with flasher cable or rail barrier (Fig. 3). The step-out escapes have a recess of gunite on both sides of the canal. The recess acts as a step during low water periods (water depth 1 to 2 ft, .31 to .61 m), allowing the deer to climb or jump from the canal. During high water periods (water depth 4 to 5 ft, 1.22 to 1.53 m), the steps provide shallow still water bays through which deer may escape to dry land. The floating log boom, positioned diagonally across the canal, helps direct deer into the escape. The flasher cable provides a downstream visual barrier, and further helps direct deer into the escape. The angle of the log boom and flasher cable is changed to direct deer out of the canal on either the uphill or downhill side. This is done twice each year, just ahead of the spring and fall migrations.

The two ramp-out escapes utilize a gently sloping concrete ramp which extends from dry land to the bottom of the canal. One escape is equipped with a flasher cable as described above. The other incorporates a series of six steel pipes running parallel to each other through the water column, and diagonally across the canal. The pipe rails are about 10 inches (25.4 cm) apart, and will deflect deer, including young fawns, directly onto the escape ramp.

METHODS

Deer traffic across the canal was monitored in two ways. Remote monitoring, using battery powered counters provided a continuous record of activity. Track count surveys were used to determine a model for the prediction of deer crossings based upon counter readings.

Track Count Surveys

Track count surveys, similar to those discussed in the annual progress reports of the Interstate Deer Herd Committee (IDHC 1947, and 1951), were

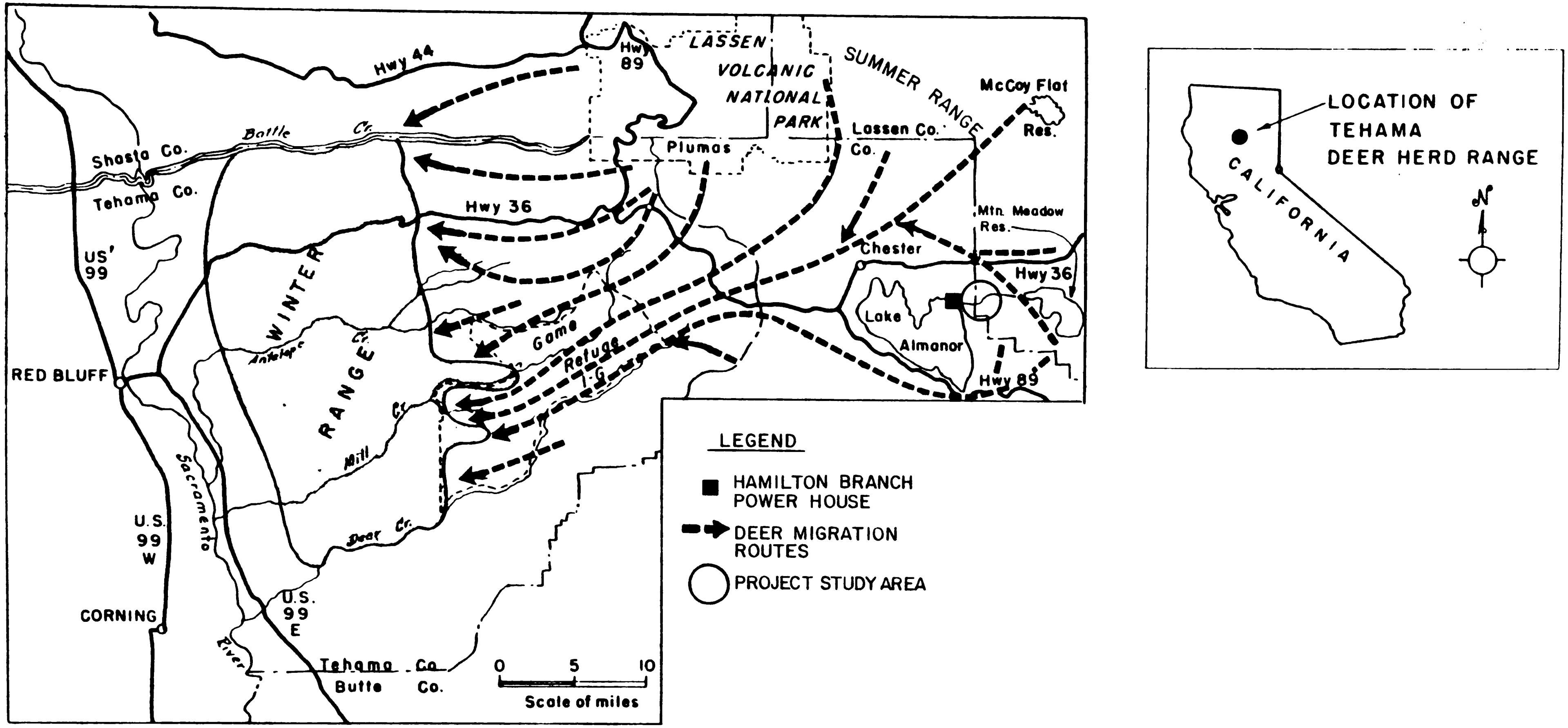

FIGURE I. Map showing study area in relation to the summer and winter deer ranges of the Tehama deer herd (modified from Leach and Hiehle, 1957).

Figure 2. Step-out design deer escape, with log boom and flasher cable.

Figure 3. Ramp-out design deer escape, with pipe-rail barrier.

conducted on 12 deer crossings over 38 days in the spring, summer, and fall of 1981. The crossings were divided into tracking segments 4 feet (1.2 m) in length. The length of the tracking segment was determined by measuring the distance between deer tracks in the study area, and by a review of literature (IDHC 1947, 1951; Rue 1978). The average number of tracks per segment was determined for both uphill and downhill traffic at each crossing. This number, divided by four, provided an estimate of the number of deer crossing the canal during a tracking period. During each of the three seasons of field study each crossing was examined daily, then raked in preparation for the following day's count. During the fall period, when storm activity caused a rapid downhill movement, crossings were examined three to four times per day.

Remote Monitoring

Small electro-mechanical four digit counters, powered from a 12-volt DC battery and actuated by pressure switch mats, comprised the basic remote monitoring system. The switch mats, like those used in intruder alarm systems (Tapeswitch, Inc., New York), measured 3 feet x 2 feet (.91 m x .61 m), and were made of heavy 1/2-inch (1.27 cm) rubber. Two switch mats were located side-by-side near the center of each crossing, covering a total surface area of 12 square feet (1.22 m^2). The mats were covered lightly with soil. Each counter, with battery, was mounted in a cast aluminum box and buried in a shallow, wood-lined pit near the crossing (Figure 4). Similarly, a single switch mat and counter was installed at each escape. The switch mats were sensitive to pressure in the range of 5 to 10 pounds (2.27 to 4.54 kg).

The remote monitoring system was installed following the spring migration in mid-June, 1981. Summer and fall data were analyzed using linear regression to evaluate the relationship between the number of counter hits and the number of deer judged to have crossed at each station based upon track counts. In constructing the data sets, certain of the paired observations were deleted. These included (1) observations influenced by human traffic, (2) observations consisting of zero deer crossings and zero counter hits, and (3) incomplete observations (i.e., one value missing).

Wet Crossings

Some deer are reluctant to use the crossings and attempt to cross the canal by jumping into the water. Evidence of these wet crossings was sought daily during each field season. Evidence consisted of (1) drip trails crossing the canal road, (2) splash marks on the canal wall, (3) deer hair on the canal wall, (4) hoof scratch marks in the moss covering the canal bottom, and (5) deep impact hoof marks in the soil at the base of the canal wall. Evidence of deer exiting the canal through one of the deer escapes usually consists of hits recorded by the electric counter and tracks and drip trails leading from the escape bay.

Of those animals entering the canal, some were unsuccessful in escaping. To determine the number of deer losses, carcass searches were conducted daily from 27 April to 30 November 1981. Carcass searches consisted of an examination of all canal structures where floating carcasses were likely

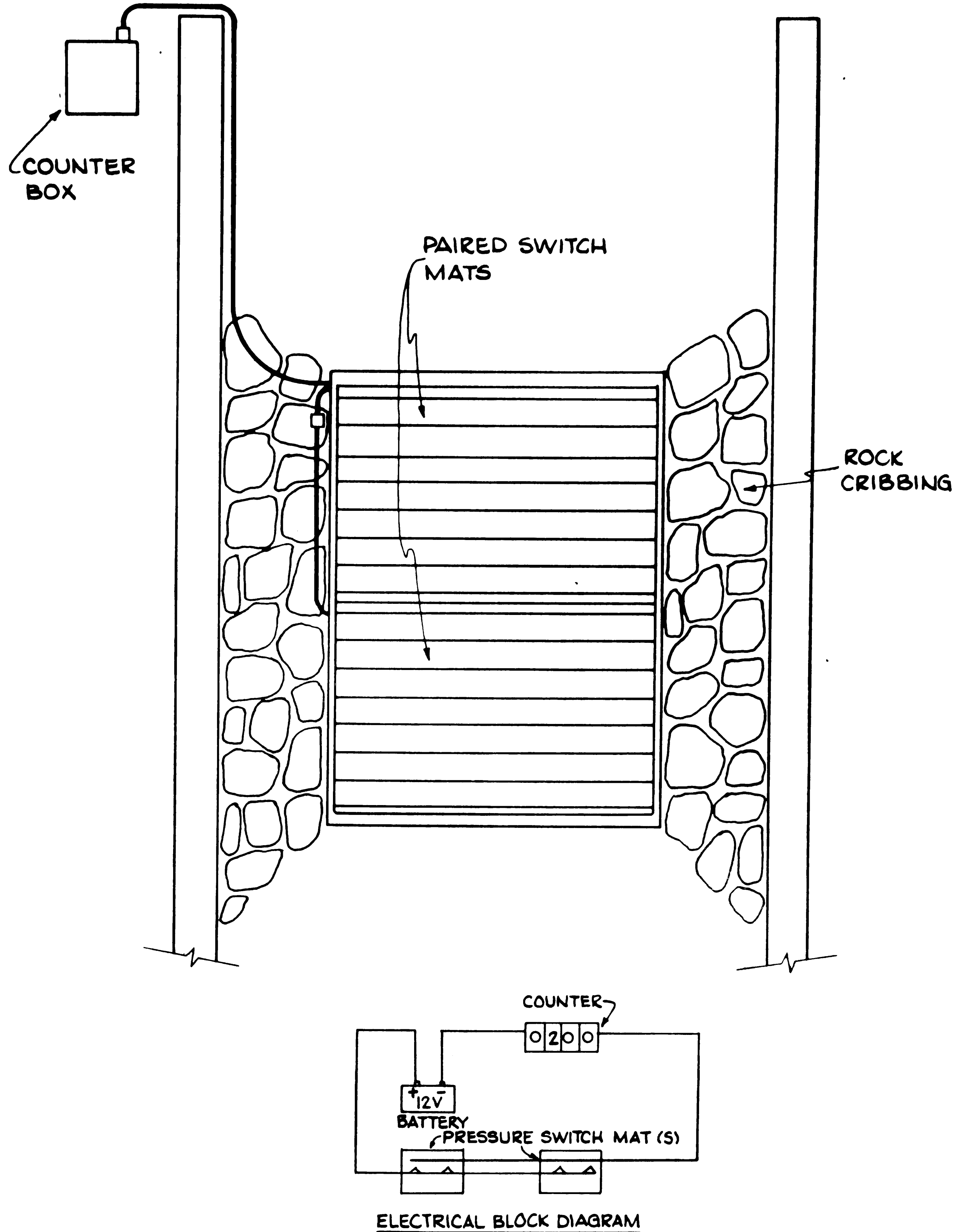

Figure 4. Deer crossing showing position of switch mats and counter box. Rock cribbing was used to direct traffic over the mats. Block diagram illustrates functional relationships.

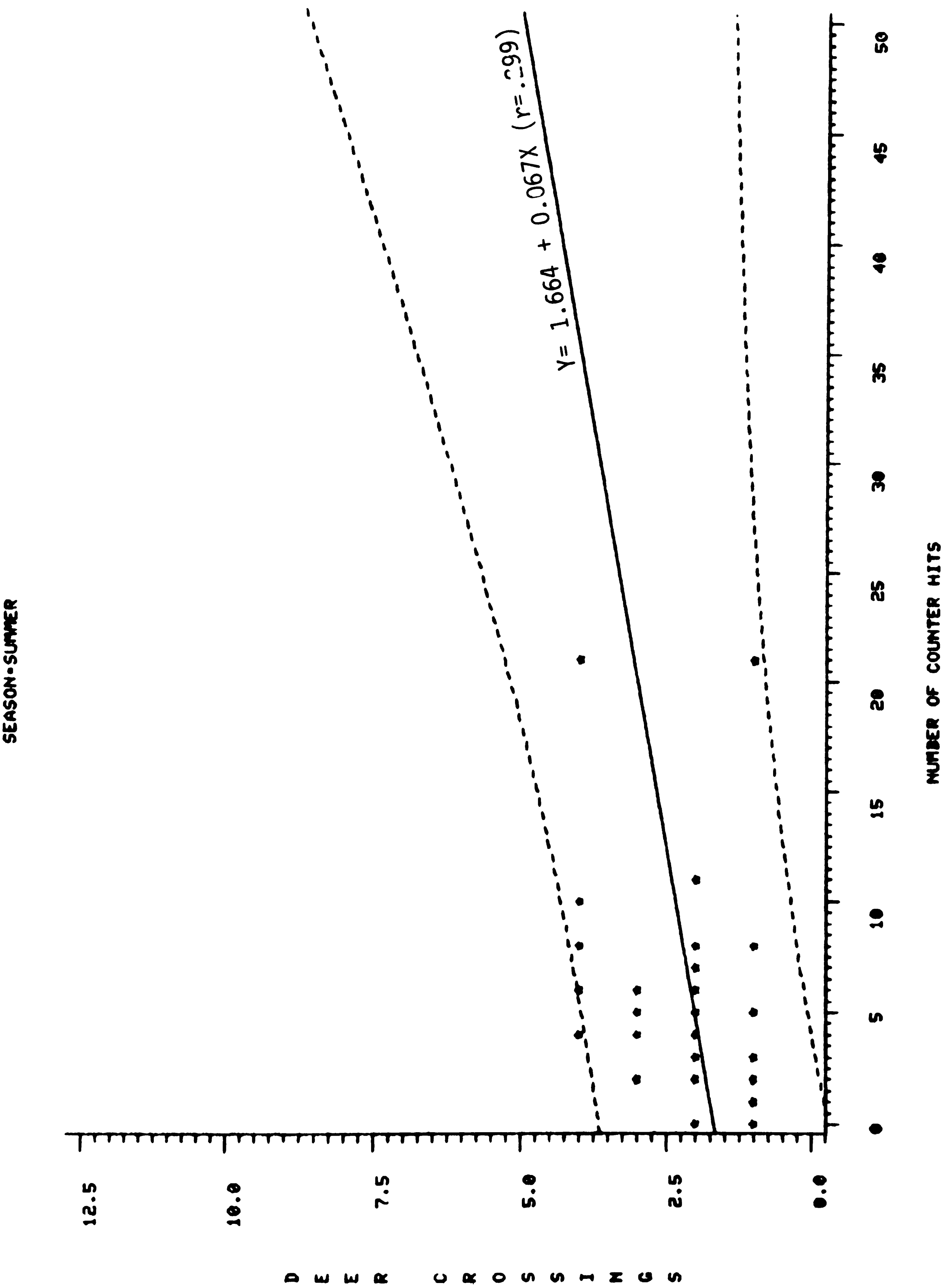

Figure 5. The relationship between number of counter hits and the number of deer crossing the canal as determined by track counts (summer data). Confidence intervals are at 95% level.

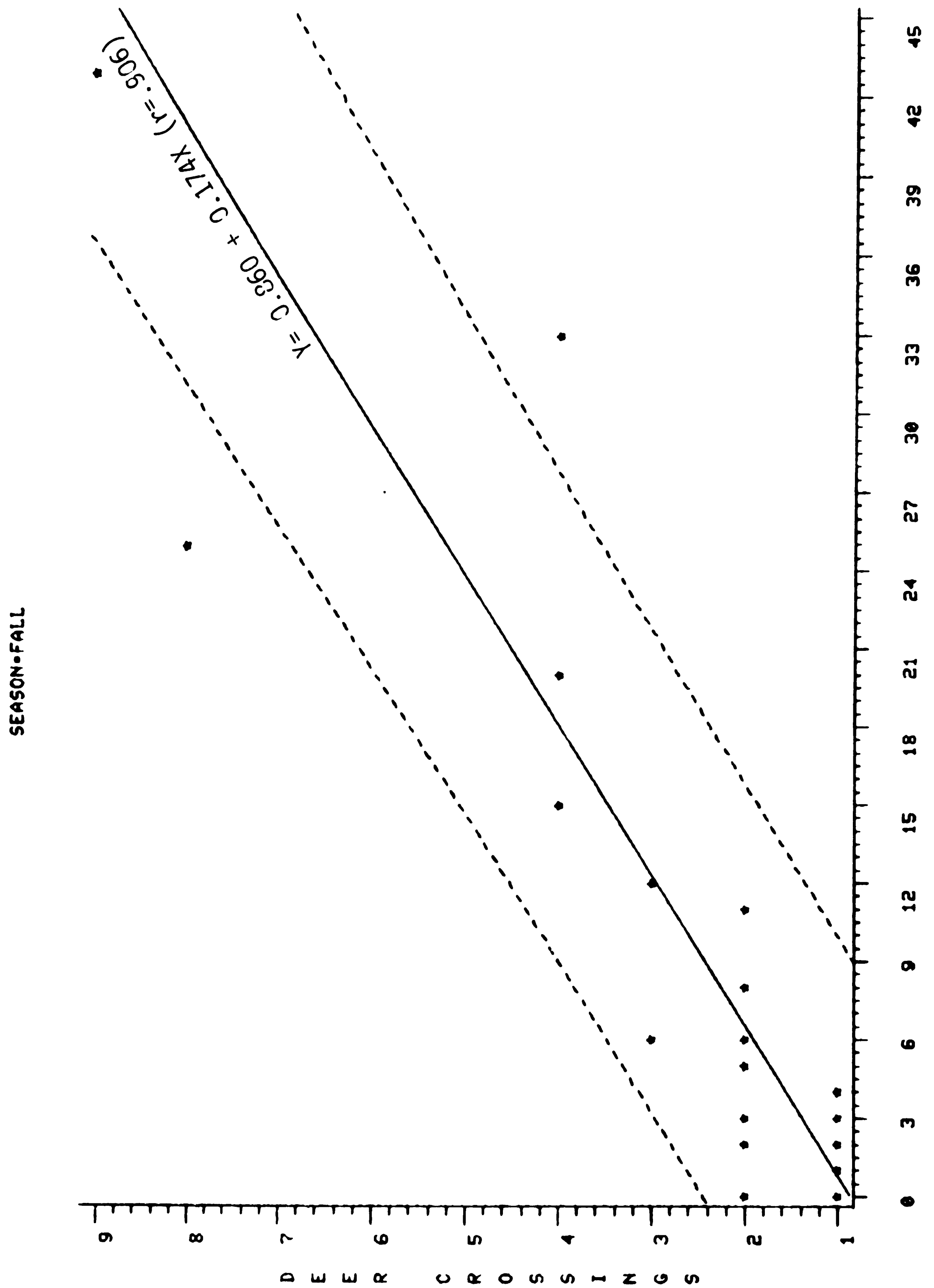

Figure 6. The relationship between number of counter hits and the number of deer crossing the canal as determined by track counts (fall data). Confidence intervals are at 95% level.

to become trapped. These included the trash racks, sand traps, and the pipe-rail barrier at deer escape number one.

RESULTS

Regression analysis of the summer data revealed a poor overall correlation between number of counter hits and deer crossings ($r=0.19$, $p<0.10$). It is possible that remote cameras located at two of the crossings and activated by the pressure switch mats were audible to deer and affected their behavior while on those crossings, causing some to retreat after reaching the mats. Review of the 8 mm movie film tended to support this assumption. Eliminating from the data set all paired observations from these two stations, however, did not result in a significant improvement in the correlation ($r=0.30$, $p<0.10$). The regression line with 95% confidence interval for the predicted values is presented in Figure 5.

Further examination of the data showed that for the most part, fewer hits were being recorded by the counters than would have been expected based upon the track count data. To determine why this occurred, we directed our attention to the design of the switch mats. Running internally the length of each mat are eight tape switches about 3/4 inch (1.9 cm) in width. Each switch is separated from the next by 2-1/2 inches (6.4 cm). The maximum diameter of an adult black-tail deer hoof is about 1-3/4 inches (4.5 cm) (Taber and Dasmann 1958). Because the mats were installed with the tape switches aligned parallel to the crossing, it was possible for deer to step between the switches while crossing the canal. In addition, where the two mats joined in the center of the crossing, a zone 3 inches (7.6 cm) wide and 3 feet (.9 m) long and lacking a tape switch, was created. Tracks landing in this null zone would not be recorded by the counters. Prior to the fall sampling period, the mats were turned 90° with the tape switches running perpendicular to the crossings. The single mat located at each deer escape was not changed.

The linear model, fitted to the fall data, yielded a substantially improved association between counter hits and deer crossings ($r=0.84$, $p<0.0001$). Omitting the data from the two camera stations discussed above further improved this correlation ($r=0.91$, $p<0.0001$). The regression line with 95% confidence interval for the predicted values is presented in Figure 6. The standard error for the intercept and slope coefficients are 0.153 and 0.013 respectively.

DISCUSSION

Determining the number of deer making successful use of deer protection facilities under natural conditions is a good way of evaluating the overall effectiveness of a deer protection system. Obtaining this information through reliance on techniques such as track count surveys and direct observation requires extensive time in the field. Mechanical counters have, in the past, been used for measuring deer activity (Ozoga and Gysel, 1965). We believe the method presented here may represent the first application of this method for the purpose of estimating numbers of deer from counter data. A high level of precision is apparent in the linear model. However, the accuracy of the method can be determined only through controlled experimentation.

Documented efforts to reduce deer losses on PGandE project canals date back to the late 1920s (Bryant, 1929). As stated earlier, many different types of deer protection systems are used today, but no single plan of deer protection can be successfully applied to all canals. The design, operation, and environment of the canal are important considerations in planning an effective system, and result in the need for prescribed protection. A comparison of two canals in the PGandE system, the Tiger Creek Canal (Amador County) and the Hamilton Branch Canal (Plumas and Lassen Counties), aptly illustrates this point.

About 17 miles (27.4 km) of the Tiger Creek conduit consists of a 7-foot high (2.1 m) concrete, bench flume canal. Water velocity in the canal varies little, at 9 to 10 feet per second (3.1 mps). Flow generally ranges from 550 to 620 cfs (15.4 to 17.4 cms). The canal lies in the canyon of the North Fork Mokelumne River where it transects a migration corridor of the Salt Springs deer herd. Some deer activity is present along the lower portion of the canal throughout the year.

In the early 1970s, deer losses in the canal were from 15 to 30 animals per year. In cooperation with CDF&G, live deer tests were conducted to determine the adequacy of existing escape structures. Deer escapes in use at the time of the tests were those described by Seaman (1977). Tests showed that the normally high flows and low water temperatures made it difficult for deer to effectively use the escapes. Therefore, deer-proof fencing was erected along the entire length of the canal. The fencing was nearly complete by 1980. In 1981, the last year for which complete deer loss data are available, losses had dropped to eight. All losses were adult animals.

The Hamilton Branch Canal (3.6 miles (5.8 km) long) consists of concrete bench flume, 4 to 7 feet high (1.2 to 2.1 m), and concrete lined ditch about 7 feet (2.1 m) deep. The water velocity in the canal varies from 4 to 8 feet per second (1.2 to 2.4 mps). Flow varies greatly. Maximum flows of slightly more than 200 cfs (5.60 cms) occur in winter and early spring due to storm activity and run-off. June flows are also generally high. Low flow conditions prevail from July through October of a typical year.

The canal lies roughly parallel to the Hamilton Branch of the North Fork Feather River, where it transects a migration corridor of the Tehama deer herd. Deer are present in the vicinity of the canal between the months of April and December only, with low deer densities occurring during the summer months.

Deer losses on the Hamilton Branch Canal over the past 14 years have averaged 13 deer per year. In 1979, live deer tests were conducted in cooperation with the CDF&G to determine the effectiveness of the existing deer escapes. The escapes (Figures 2 and 3) were functionally similar to those tested on the Tiger Creek Canal. The test, which was conducted under near maximum flow conditions, used young adult male deer. All test animals successfully exited the canal at one or more of the escapes. All deer lost in the canal in 1981 were necropsied and found to be fawns based on tooth eruption (McLean, 1936; Taber and Dasmann, 1958).

Planning Effective Deer Protection

Clearly, differences in design and operation of canals and their protection facilities are factors affecting deer losses. There is an obvious relationship between the number of unsuccessful crossings of a canal by deer and the overall effectiveness of the protection system used. Where unsuccessful crossings represent a very low percentage of the total attempted crossings, the overall effectiveness of the protection system should be judged as high. Determining the lower limit of effective protection, however, must involve biological, economic, and political considerations.

Important biological considerations should include (1) recent population trends and current status of the local deer herd (i.e., expanding, stable or declining); (2) the age and sex composition of the deer lost; (3) the seasonal nature of the losses and total number of deer lost annually; and (4) whether the elimination of these losses is likely to result in a measurable change in the composition or size of the local deer population.

Economic considerations include, but may not be limited to, system construction and maintenance costs and changes in the operational efficiency of the canal caused by structural modifications, change in flow, or limited access for routine and emergency canal maintenance.

Political considerations consist of public concern for wildlife protection and compliance with state and federal law.

Further study of the relative effectiveness of alternative deer protection systems is greatly needed. Providing adequate deer protection on existing canals at a reasonable cost, without jeopardizing their safe and efficient operation, is a challenge that can only be met through careful research and planning.

ACKNOWLEDGMENT

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EXTRA HIGH VOLTAGE HEALTH AND SAFETY

Gus Tillman, Session Chairman

ENVIRONMENTAL IMPACT CONSIDERATIONS FOR FUTURE A. C. TRANSMISSION LINES OF 1000-kV AND ABOVE

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ABSTRACT.--Transmission lines of 500 kV and 765 kV, the largest commercial ac lines, have been in operation in the U.S. since the late 1960's. As demands for electrical power increase, and as new rights-of-way become more difficult to acquire, larger and more efficient transmission lines will be needed in some areas. In the Pacific Northwest, the Bonneville Power Administration is investigating the use of 1100 kV. An 1100 kV line can carry the same amount of power as two 500 kV double circuit lines, with less power loss, and on a narrower right-of-way. Although an 1100 kV line could have less overall environmental impact than that of multiple lower voltage lines, it would be physically larger than existing lines. This contrast in size will increase the visual impact compared to lower voltage lines. With taller towers to increase conductor height, and larger conductor bundles for 1100 kV, corona and field effects can be made comparable to existing lines. Considerable public interest has developed, however, concerning possible biological effects of transmission line electric fields. Many studies are underway, and to date, there is no evidence that electric fields as produced by existing or 1100 kV lines pose any measurable health hazard. However, utilities face the challenging task of determining long-term risks and alleviating concerns about biological effects where these are unfounded. The objectives of this paper are to (1) describe the characteristices of 1100 kV transmission lines, (2) summarize applicable environmental research, and (3) discuss the potential environmental impacts of 1100 kV in relation to lower voltage transmission lines. Although the emphasis is on BPA's 1100 kV program, the information has general applicability for lines of 1000-1500 kV.

INTRODUCTION

The need to supply ever increasing demands for electrical energy has led to a progressive increase in transmission line voltages. By raising voltage and current levels, power carrying capabilities are significantly increased. By the 1950's 345 kV transmission lines were in operation in

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the U.S. The first 500 kV line was energized in 1965 followed by 765 kV in 1969. This voltage range of transmission lines has often been referred to as EHV or Extra-High-Voltage. With the consumption of electric power in the U.S. continuing to grow, higher voltage lines than exist today will be needed. In the western U.S., for example, average annual growth rate in electrical load is projected at around 4% through 1990 (WSCC technical staff 1981).

As early as 1967, Edison Electric Institute and Bonneville Power Administration (BPA) funded research on advancing ac transmission lines into the 1000-1500 kV range, sometimes called UHV or Ultra-High-Voltage. Unlike previous transmission voltage increases, investigations for the new class of lines have also included extensive programs to assess environmental effects. Since 1977, BPA has sponsored studies of plants and animals living near a prototype three phase 1100 kV transmission line in Oregon (Rogers et al. 1981). The American Electric Power Corporation has also conducted environmental studies as part of a research program involving a 1500 kV single phase test line in Indiana (Hodges and Mitchell 1979). Research involving ac transmission lines of 1000 kV and above is also underway in Italy, the Soviet Union, Japan, and Canada (see Electra, No. 73, December 1980). Research to date indicates 1100 kV lines are technically feasible.

Commercial 1100 kV class lines may be needed in the Northwest and other areas of the U.S. by the mid 1990's. However, because of environmental and siting problems encountered by utilities with 500 kV and 765 kV lines, and general unfamiliarity with 1100 kV, considerable public concern and opposition is expected when the first such lines are proposed.

1100 kV TECHNICAL CHARACTERISTICS

Probably the most striking characteristic of 1100 kV is its power-carrying capability. One single circuit ac line of this voltage could carry up to 10,000 MW. Comparative power capabilities of different voltage lines are shown in Table 1. The table also shows the increased efficiency of 1100 kV in terms of power transmission per unit of right-of-way area. We should point out there is considerable variation in right-of-way widths among utilities.

Electrical power is the product of line voltage and current. Transmission line power losses are mostly related to current and resistance of the conductors (I R). Therefore, maintaining reasonable current levels, increasing transmission voltage, and adding more efficient conductor results in significant reductions in power losses. The losses per mile on a 1100 kV line per MW of power transmitted would be about one-fifth as much as for comparable 500 kV lines. A 175 mile long (282 km) 1100 kV line carrying 8000 MW of power would have 150 MW less loss than an equivalent system of standard capacity 500 kV lines. Transmission power losses must be replaced by increasingly expensive generation, so energy conservation is an important attribute of 1100 kV.

BPA estimates that when power transmission requirements exceed about 4000 MW, a 1100 kV line will be more economical than multiple 500 kV lines. The first 1100 kV lines will probably be used to transmit large blocks of power from remote generation sites to distant load centers. In the Northwest, available transmission corridors are severely limited through the Rocky and Cascade Mountain Ranges. Efficient use of rights-of-way by the higher voltage line is a further advantage.

Table 1. Power capability and right-of-way efficiency of 1100 kV transmission in comparison to lower voltage BPA lines.

Line Type	Minimum Right-of-Way width (feet)	Maximum Line Capacity (MW)	No. lines to Carry 10,000 MW	Right-of-Way Efficiency per mile of line (MW/Acre)
230 kV High Capacity, Double Circuit	100	600	16	50
500 kV Standard Single Circuit, "Delta"	105	1,500	7	120
500 kV High Capacity Double Circuit, "Stacked"	125	5,000	2	330
1100 kV Single Circuit, "Delta"	210	10,000	1	400

[a]Right-of-way width for BPA lines varies from the values given here. These minimum widths are intended to show relative comparisons for BPA lines and may not be representative of other utilities.

In essence, 1100 kV transmission lines are an extension of existing technology. For example, the towers used on the BPA prototype are basically larger versions of single circuit 500 kV towers (Figures 1 and 2). The larger size is due to an increase in the conductor to ground clearance for 1100 kV. By using taller towers to elevate conductors, ground level electric field strength beneath 1100 kV lines can be kept comparable to existing lines.

BPA's design criteria for both 500 kV and 1100 kV lines allows for 9 kV/m on the right-of-way and 5 kV/m at the edge. Typically, maximum field strength measured on BPA 500 kV rights-of-way is 6-7 kV/m and 2.5-3.5 kV/m at the edge. In Japan, a double circuit 1100 kV test line utilizes towers over 300 feet tall with underbuilt shield wires, so maximum ground-level electric fields will be around 3 kV/m. In comparison, some existing 765 kV lines in the U.S. produce maximum electric field levels on the right-of-way of around 10-12 kV/m. A unique characteristic

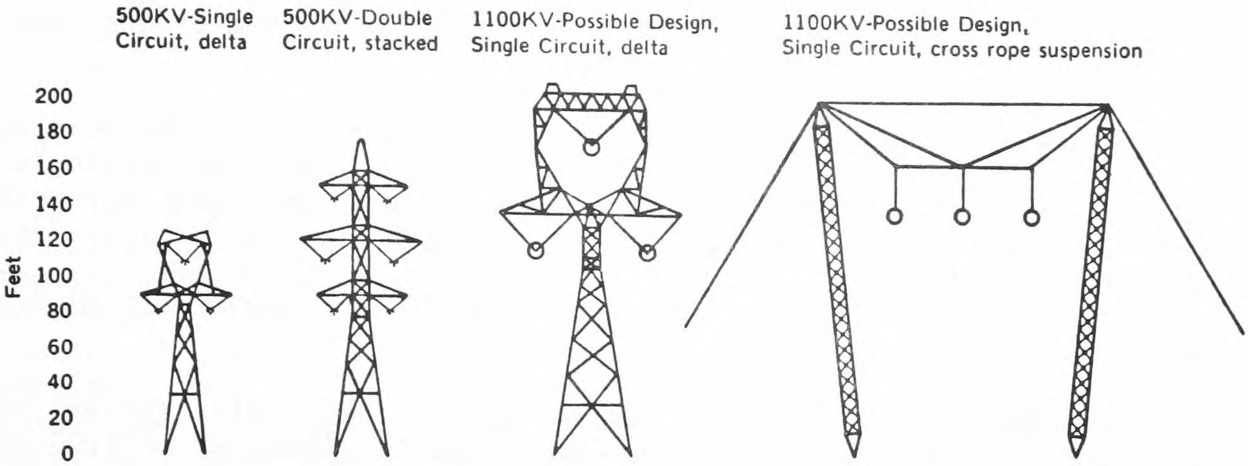

Figure 1 - Latest designs for BPA 500KV transmission line towers and two possible tower designs for future 1100KV lines. The tower height for the 1100KV Delta design is based on the average height of the BPA prototype.

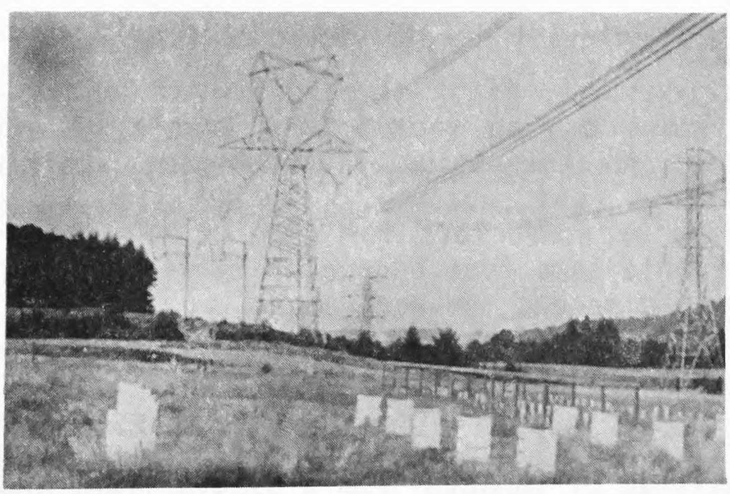

Figure 2 - The BPA 1100-kV prototype transmission line near Lyons, Oregon. A 230-kV double-circuit line is on the right. Honeybee hives under study are in the foreground, and crops are planted in the white tubes behind the hives.

of the next increase in transmission voltage is that unlike previous increases, there may be no corresponding increase in maximum ground level electric field strength on the right-of-way.

There is, however, an aspect of electric fields that should be pointed out. Figure 3 shows electric field strength profiles for two particular designs of 1100 kV and 500 kV lines. Although maximum field strength (i.e., 8-9 kV/m) is about the same, field strength for the 1100 kV line does not diminish horizontally from the line as quickly as does 500 kV. This is because with 1100 kV, conductors are farther apart and higher off the ground.

While the voltage on a conductor produces the electric field, current in the conductor is the source of the magnetic field. Although an 1100 kV line can carry larger current levels than existing lines, resulting magnetic field strength near the ground will not be noticeably increased because of the greater conductor-to-ground clearance. Maximum fields will remain at around 0.5 Gauss which is much smaller than fields produced by many household electrical appliances.

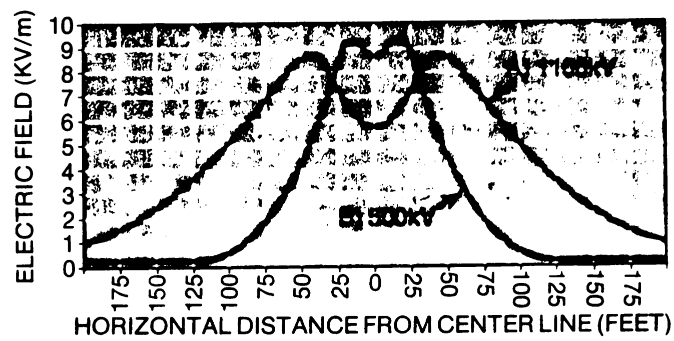

Figure 3. Lateral electric field strength profiles for (A) BPA 1100kV prototype single circuit delta configuration with 75 feet conductor to ground clearance and, (B) BPA 500 kV double circuit stacked configuration with 35 feet conductor clearance.

By using "bundled" conductors, first developed with 345 kV lines, corona effects of 1100 kV lines can be kept within levels of existing lines. Corona produces radio and television interference, audible noise, and small amounts of oxidants (e.g., ozone). The BPA 1100 kV prototype uses 7 or 8, 1.6 inch diameter conductors for each of the three line phases. On BPA 500 kV lines, this same type conductor is used although bundles of only three conductors are needed for each phase.

ENVIRONMENTAL IMPACTS

The impacts of 1100 kV transmission lines should be considered in terms of (1) the type and magnitude of impacts from a single line, and (2) the comparative impact of the total number of lower voltage lines needed to transmit an equivalent amount of power. The sections below emphasize different or unique aspects of 1100 kV. Table 1 shows the number of lines and right-of-way requirements for transmitting a given amount of power.

The direct environmental impact of 1100 kV transmission lines can be considered in terms of construction, maintenance, and operation.

Construction

The 1.3 mile (2 km) long BPA 1100 kV prototype was constructed basically with standard transmission line construction techniques. Major construction activities included surveys, clearing, access road construction, installation of tower footings, tower assembly and erection, stringing and tensioning of conductors, and site restoration. No new kinds of land use or ecological impacts were identified as a result of these activities in constructing and prototype line. However, for a commercial 1100 kV line that may involve a wide variety of vegetation types, topography, and land uses, some environmental considerations may arise that are not typical of existing lines. New or modified construction techniques may also be required to reduce costs of constructing the larger lines.

The magnitude of the impacts from 1100 kV construction will be typically greater than for single lower voltage lines. Towers that may average up to 200-250 feet (61-76 m) high will require large excavations for footings. Also, greater space will be required for assembly and erection of steel lattice towers than typically needed for lower voltage lines. Cranes and other heavy equipment large enough to handle 500 kV double circuit line construction will probably be adequate for most 1100 kV applications.

Massive steel lattice towers and 4 foot (1.2 m) diameter or greater conductor bundles of 8 to 16 subconductors indicate that visual impacts will be a primary environmental consideration for 1100 kV lines. Additionally, compared to existing lines greater numbers of proposed 1100 kV tower locations may have to be submitted to the FAA for a determination on the need for airway marketing.

Tower height could be somewhat reduced by using flat rather than delta configuration towers. However, this may increase right-of-way width and electric field strength. Flat configuration steel lattice towers would still be more massive than existing transmission structures. Cross rope suspension towers (Figure 1) could be used to achieve a more simple, uncluttered appearance, but guy wires needed for this tower type would conflict with some land uses. The use of non-specular (surface dulled) conductors and hardware may find greater application on 1100 kV lines as mitigation for visual impacts.

By placing overhead groundwires and conductors higher in the air, an 1100 kV line could increase the potential for bird collisions. Studies involving BPA 500 kV lines, however, have not detected any significant amount of bird collision mortality. Mitigation measures being developed for 500 kV lines should be applicable to the larger lines (Lee and Clark 1981, Beaulaurier et al. 1982).

Right-of-Way Maintenance

Rights-of-way for 1100 kV lines will pose similar maintenance problems as those for 500 kV and 765 kV lines. However, due to the greater conductor to ground clearance for 1100 kV (i.e., 75 feet vs. 35 feet (23 vs 10 m) more brush and slow-growing tree species may be allowed on the right-of-way. This could change the visual appearance and reduce the contrast between the right-of-way and adjacent forest stands.

As with existing lines, no structures or land uses would be allowed on 1100 kV rights-of-way that might interfere with maintenance or operation of the line. Human activities compatible with 500 kV rights-of-way should also be suitable for 1100 kV. With the greater conductor to ground clearance of the higher voltage line, electrocution risks (e.g., when handling long irrigation pipes) are even further reduced compared to 500 kV.

One difference between 1100 kV and existing lines is that 1100 kV can produce high electric field induction at distances far exceeding flash-over distances (General Electric Co. 1978). Under certain conditions, these fields have caused fires in poles and dead trees near the G.E. test line. To date, however, this effect has not occurred near the BPA 1100 kV prototype. The electric field can induce corona on trees although this effect also occurs if trees grow too close to 500 kV lines. Induced corona damage on live Douglas-fir (<u>Pseudotsuga menziesii</u>) trees has been observed out to about 60 feet (18 m) from conductors of the BPA 1100 kV prototype. Thresholds for these phenomena are fairly well understood and line design and tree clearing criteria can control such effects. Trees growing on the right-of-way of the BPA 1100 kV prototype are under long-term study to see if induced corona damage results in a self-pruning effect which could reduce maintenance requirements.

<u>Operation - Corona and Field Effects</u>

As pointed out above, corona effects and electric and magnetic field maximums on 1100 kV rights-of-way will probably not be greater than for the largest existing lines. Utility experience with 345-765 kV transmission lines over the last 25-30 years has resulted in fairly well defined operating levels for these parameters that minimize environmental effects. Mitigation measures for radio and television interference that are now routine (e.g., Loftness et al. 1981), should also apply to 1100 kV. No increase in mean ozone concentration at conductor height or at ground level was found that could be attributed to corona from the BPA 1100 kV prototype (Stearns and Bracken 1981).

Audible noise levels from 1100 kV lines can be made comparable to the largest lines now in operation. In addition to the noise guidelines of the U.S. Environmental Protection Agency, some states now have noise regulations that encompass transmission lines. Future transmission lines will be required to meet the noise levels now being established. BPA design criteria for audible noise allow an L_{50} of 53 dB(A) at the edge of the right-of-way.

The strength of an electric field is basically a function of line voltage and the distance from the line. When the field strength exceeds about 3 kV/m, large conducting objects near a line begin to have perceptible currents and voltages induced, particularly if they are insulated from ground. The most noticeable effects of the electric field from a 1100 kV line will, therefore, be transient nuisance shocks to persons touching objects or vehicles especially in dry environments. As with existing lines, grounding techniques would greatly reduce the occurrence of shocks.

The National Electrical Safety Code (NESC) specifies 5 mA as the maximum for electric field induced currents from transmission lines. Regardless of the voltage of the line, NESC requirements limit the allowable electric field strength where large conducting objects, e.g., vehicles, might be found on the right-of-way. As shown in Figure 2, areas where field strength exceeds 3 kV/m extend a considerable distance from the line compared to 500 kV. Depending on the width of a 1100 right-of-way, the incidence of nuisance shocks off the right-of-way may be more of a consideration with this voltage line. Several means exist for controlling field strength at the edge of the right-of-way (Gens and Perry 1980). If shield wires or lower voltage lines are used for this purpose, the impacts (e.g., visual) of these structures would add to those of the 1100 kV line. Edge of right-of-way electric field strength could become one of the primary design and environmental considerations for 1100 kV.

Transmission line electric fields can induce weak currents and voltages in people and animals near the lines. Some controversy exists as to the possibility for adverse biological effects from long-term exposure to electric fields. Interest in this subject developed in the early 1970's when reports from the Soviet Union indicated workers in 500 kV substations were adversely affected by electric fields. Substation workers in the U.S. and most other countries, however, have not reported similar problems. Recently, the Soviets have also indicated the expected dangerous effects of electric fields were overestimated (Bourgsdorf 1980).

Extensive research programs throughout the world have investigated the effects of electric fields on plants, animals, and people (e.g., Phillips et al. 1979). For example, studies of 1100-1500 kV test lines indicate that crops grow normally in electric fields of up to 16 kV/m (Hodges and Mitchell 1979). Cattle showed no reluctance to graze and drink beneath a 1100-kV line (Rogers et al. 1980). The only demonstrated harmful effect of transmission line electric fields on animals is poor performance of honeybee hives in commercial colonies in fields above about 2-4 kV/m (Rogers et al. 1980, Lee and Clark 1981). The effects reported only in special studies appear to be related to induced currents in the hives. The effects can be mitigated by placing grounded wire screens over the hives or by moving them out of the maximum field area.

Results of studies with laboratory animals and epidemological studies generally indicate a very low probability for harmful biological effects from electric field strengths and exposure duration as associated with existing or future transmission lines (BSTT 1978). Many of the effects that are reported appear to be related to perception of the electric field or to shocks. A rigorous hazard or risk assessment relating results of these studies to people living near transmission lines has not been done and there are no national standards for electric field levels in the U.S.

Against this background, a growing number of states are establishing field strength standards for transmission lines. The New Jersey Commission on

Radiation Protection set 3 kV/m as an interim guideline for allowable electric field strength at the edge of a transmission line right-of-way. The New York Public Service Commission established 1 kV/m as the maximum edge of right-of-way field strength for 765 kV lines based on experience in New York with 345 kV lines. Oregon allows up to 9 kV/m on the right-of-way.

Although 1100 kV lines will probably not be constructed in the U.S. for another decade, planning and design processes for the first lines are underway. These processes will be strongly influenced by the current interest shown in existing lines, especially the electric field effects issue.

DISCUSSION

It appears the trend toward higher transmission voltages will continue, and that a transmission line of 1100 kV or above may be constructed in the U.S. by the mid-1990's. However, the timing for the new lines will be determined by actual load growths, construction costs, and economics of transmission losses. In the Northwest, utility loads are forecast to grow at a slower rate than in the past (PNUCC 1981). Lines of 1100 kV have the potential for reducing the overall environmental impact required to transmit large blocks of electric power. Even with the expected advantages of higher voltage, utilities proposing these lines will probably face the same routing problems as occur with existing lines.

For 1100 kV, utilities will have to do an even better job of informing the public, other agencies, and regulators about basic technical and environmental aspects. It may be difficult to convince some people that an 1100 kV line can be designed so corona and electric field effects are essentially no different than for 500 kV.

BPA has taken the first steps in an information program for 1100 kV. In addition to the prototype line, BPA operates a visitor center near the line. Basic information on electrical and biological effects of transmission lines are described to school, civic, and professional groups. This effort will intensify when BPA initiates an environmental impact statement process for the Northwest's first commercial 1100 kV line. The EIS, design and construction processes, are expected to take a total of about 10 years for the first 1100 kV line.

Over the long-term, use of 1000-1500 kV lines should mean a reduction in the number of transmission lines needed. However, for the people who learn that one of these large lines is planned to cross their property, the long-term aspect is probably academic. Even with adequate technical information to help them understand these lines, many people will probably perceive them as even greater nuisances than existing lines. Explicit routing criteria and methodology, and expanded and creative mitigation programs, will help utilities gain public acceptance for lines of 1000 kV and above.

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ENVIRONMENTAL IMPACTS OF UNDERGROUNDING HIGH VOLTAGE TRANSMISSION: HEALTH AND SAFETY

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ABSTRACT.--Electric and electromagnetic effects of transmission cables are described quantitatively, together with an indication of the potential impacts to the public health and safety. The three major types of cable systems commercially available, as well as advanced system designs for future applications, are considered at voltage levels from 345 kV to 1100 kV. Both ac and dc cable systems can be designed for minimal impact whenever strict engineering or environmental constraints are appropriate.

INTRODUCTION

The operation of underground cable systems involves electric and electromagnetic (E/M) effects. These phenomena have been the subject of considerable study in recent years. The results of these studies have recently been compiled (U.S. EPA, 1980; IIT, 1979). The Bonneville Power Administration has also sponsored studies and published several documents which address these issues (Lee, 1979; BPA, 1981).

Electric and magnetic fields in the vicinity of underground power cables have been studied previously (Dames & Moore, 1982; BPA, 1981). The results presented here are based on this work. The analysis of electric and magnetic (E/M) effects consists of a quantitative discussion of cable technologies, pertinent system and operating parameters, and estimates of the expected E/M levels. The values obtained are compared with safety standards and common living conditions.

CABLE SYSTEM DESCRIPTION

In recent years, a number of cable systems have been developed which are capable of transmitting power at very high levels. Some systems have increased the current carrying capacity and others have increased their power levels by increasing the voltage. The voltage levels selected for this study are high for the purpose of assessing maximum impacts and for the consideration of cable designs to match existing overhead lines. Lower voltage applications involve equal or less environmental effects.

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The four systems included in this study are (1) Gas-insulated Transmission Line (GITL)--rigid isolated phase bus at 1100 kV, flexible isolated phase cable at 500 kV. The gas insulated systems are designed for alternating current (ac) service, although direct current (dc) has been considered. (2) High Pressure Oil-Filled Cable (HPOF)--a three-phase pipe-type system at 765 kV ac, and a two-pole direct current (dc) system at ±600 kV. (3) Self-Contained Oil-Filled Cable (SCOF)--an isolated phase ac system operating at 765 kV and a dc system at ±600 kV. (4) Superconducting Power Transmission Line (SPTL)--a three-phase 345 kV ac superconducting cable and pipe-type system, cooled using cryogenic support equipment.

Gas Insulated Transmission Line (GITL)

The GITL is currently in commercial use as an ioslated phase system; i.e., three separate phase cables per circuit (see Figure 1). Each phase consists of two concentric aluminum pipes, the inner one being the conductor. The outer diameter of each phase depends on voltage; for 1100 kV and 500 kV systems, the diameters are approximately 30 and 20 inches (76 and 51 cm), respectively. The pipes are manufactured in sections, coupled end to end in the field, and welded. A semi-flexible, corrugated GITL at 1100 kV with a 30 inch (76 cm) enclosure diameter and thinner walls (1/4 inch or less) has been developed to simplify field installation. A 500 kV system of the same design has an enclosure diameter of 20 inches (51 cm).

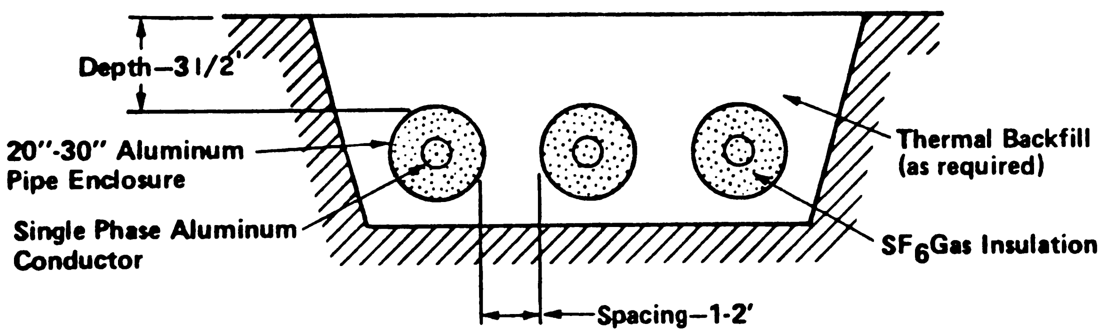

Figure 1. Cross-section of compressed gas insulated cables: rigid GITL (1100 kV) and flexible GITL (500 kV).

A recent concept in GITL design is a configuration of 3 rigid aluminum pipe phase conductors within a single enclosure which at 500 kV has an outer diameter of abour 40 inches (102 cm) (see Figure 2). A 345 kV system of this design was recently energized on a utility system as a joint EPRI/utility demonstration project.

Both the coaxial isolated phase cables and the 3 conductor cables have heavy aluminum enclosures that are typically grounded at the cable terminations, although they may instead (or in addition) be grounded at mid-point or at intervals, depending on the necessity for shielding magnetic fields or for controlling the buildup of induced voltages. Isolated phase cable enclosures grounded at the terminations are generally fully bonded (electrically) there. In some cases the enclosures are sectioned and then cross-bonded in an alternating phase-to-phase arrangement along the line to control induced currents. This scheme is generally applicable to relatively long cables.

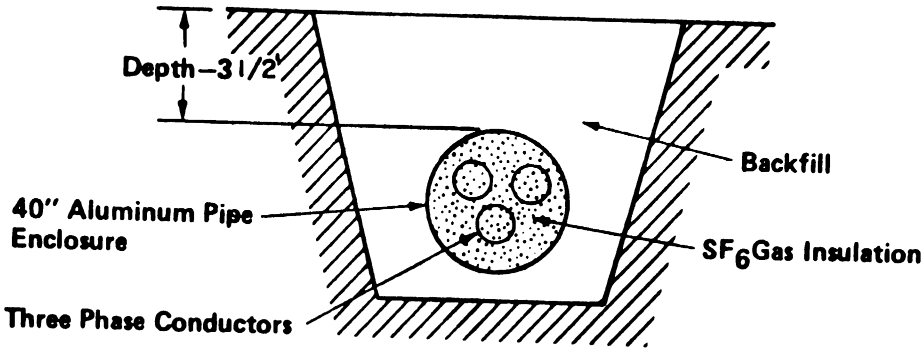

Figure 2. Cross-section of compressed gas insulated cable: three-phase GITL (500 kV).

High Pressure Oil-Filled Pipe-Type Cable (HPOF)

This system consists of a steel pipeline, into which three insulated phase conductors are pulled (see Figure 3). For a 765 kV ac system, the steel pipe has an outer diameter of 10-3/4 or 12-3/4 inches (27.3-32.4 cm).

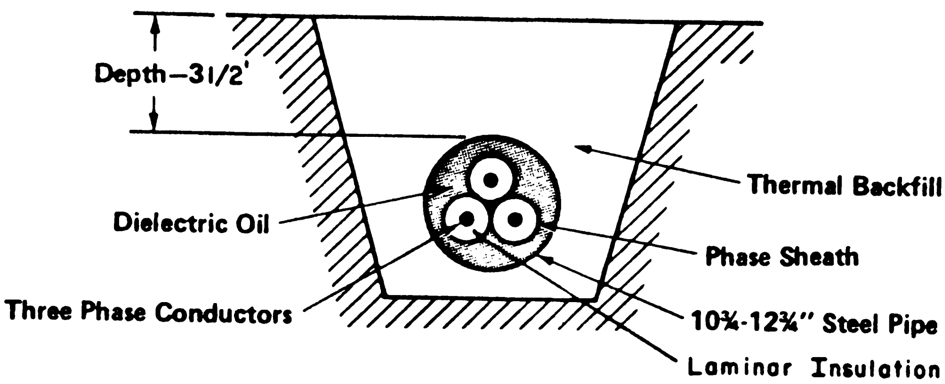

Figure 3. Cross-section of pipe-type cable: HPOF (765 kV).

Each phase consists of a conductor wrapped with insulating tape and covered with a thin conducting foil sheath. Because of the phase proximity, the sheaths are essentially short-circuited and the phase fields tend to cancel at short distances. The sheaths are of comparatively high resistance; however, the steel enclosure is capable of carrying considerable induced currents.

HPOF cable systems have also been considered for dc applications. For a ±600 kV dc HPOF cable, there are two conductors per circuit in a 10-3/4 inch (27.3 cm) pipe, with the possible addition of a dedicated neutral conductor. Without a neutral conductor, inside or outside the pipe, the system ground (earth) will function as neutral. Terminal stations for dc systems require converters and inverters to change between ac and dc. These facilities generally include substantial ground electrodes.

Self-Contained Oil-Filled Cable (SCOF)

The SCOF cable is an isolated phase system; i.e., three separate phase cables per ac circuit (see Figure 4). Each phase is a flexible cable, 6 inches (15.2 cm) in diameter for a 765 kV design, consisting of an insulated conductor, sheathed and protected with a lead or aluminum jacket which is coated to prevent corrosion. The outer diameter of underwater cable may be wrapped with a steel wire armor.

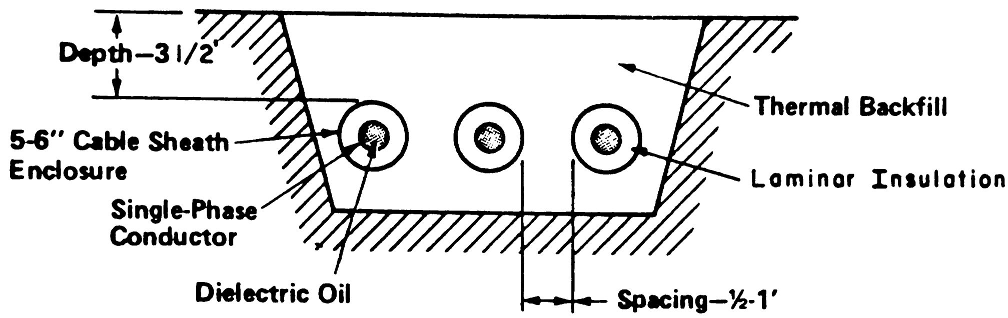

Figure 4. Cross-section of self-contained cable: SCOF (765 kV).

SCOF systems are normally installed so as to minimize induced currents in the sheaths. In general, this is accomplished by cross-bonding and grounding at certain intervals. For short lines, the sheath may be bonded and grounded at one end or at the mid-point only, since the build-up or induced voltages may not be significant.

A SCOF dc cable has been developed, similar in basic design to the ac cable above. This consists of two isolated poles, insulated conductors 5 inches (13 cm) in diameter for a ±600 kV system. In addition, there may be an insulated neutral conductor which carries any unbalance current during normal operation and acts as a metallic return conductor during the loss of one of the poles.

Superconducting Power Transmission Line (SPTL)

Superconducting (SPTL) systems are being developed for both ac and dc transmission. The conductors are maintained in a loss-free state by installing them in a double-walled, thermally insulated cryostat through which liquid helium is circulated. A prototype pipe cryostat for a 345 kV ac system is about 20 inches (51 cm) in diameter. The SPTL is a pipe-type system, in that the double-pipe cryostat is installed in sections and the phase cables are pulled into the completed pipeline (see Figure 5). Each phase is itself coaxial and carries the full return current with virtually no resistance.

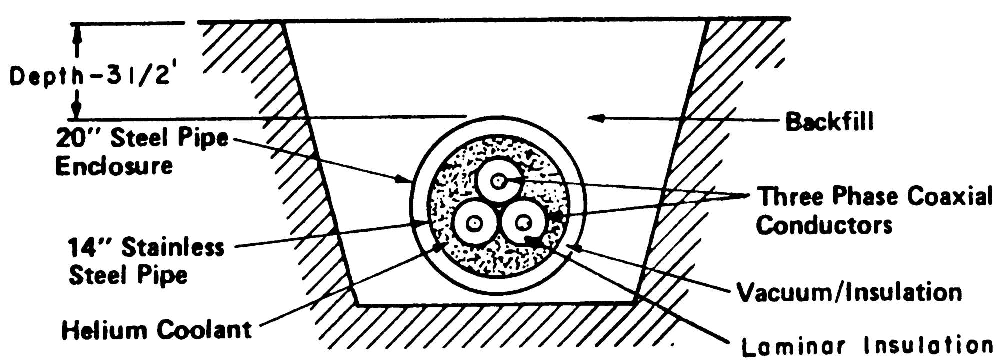

Figure 5. Cross-section of superconducting cable: SPTL (345 kV).

For all types of cables installed underground or underwater, protection of the cable enclosure from corrosion is required. This is achieved by coating the enclosure with an insulating mastic or other protective covering. Cathodic protection is also provided by the use of sacrificial anodes or rectifiers to reduce galvanic action between the metallic cable enclosure and the soil/water environment.

ELECTRIC AND MAGNETIC EFFECTS

As indicated in Figures 1-5, underground designs are radically different from overhead conductors and pose different sources and levels of E/M effects. Underground cables are coaxial and/or sheathed and grounded, thereby eliminating external electric fields. In general, the phase sheaths may carry induced currents serving to shield magnetic fields as well. The resultant magnetic field level will depend on specific parameters for each system: conductor current, shielding efficiency, and phase proximity. GITL systems are high ampacity coaxial cables with the enclosures fully bonded and grounded at intervals, typically at a center point or at the two terminations for most installations since they are generally used for short distances. A 2000 ampere (A) GITL circuit may generate maximum external fields in the range of 0.1 to 1 gauss, depending on the grounding scheme. These values at the ground level fall off rapidly away from the cable because fields from the adjacent phases tend to cancel each other. The SCOF cable sheaths are typically cross-bonded and less efficient conductors. However, the phase proximity effect is more pronounced because the phases are generally installed closer together. For comparable ampacity, maximum local fields may be 1-2 gauss. For the HPOF cables, the phase sheaths are continuously short circuited, the phases are contiguous and the steel pipe may carry considerable induced current. Consequently, for a comparable rating, maximum fields are on the order of 0.1 gauss. HPOF and SCOF direct current (Dc) systems at 2000 A produce maximum fields of about 1/2 and 1 gauss, respectively, increasing to about 3 gauss for monopolar operation. SPTL phase conductors are coaxial with a full return current that completely eliminates external magnetic fields. For all cable types the fields decrease to zero within 50 feet or roughly within the ROW. The estimates given here, of course, scale with the ampacity of the specific installation. By comparison U.S. and Soviet research groups have recommended levels of 200-300 gauss for occupational or extended exposure and 2000 gauss for short exposures on the order of minutes (Llaurado, 1974).

The IEEE has established a study guide for Safety and Substation Grounding (IEEE, 1976) for substation workers subject to high electric potentials during faults. For protection, high capacity cable systems are installed with circuit breakers to interrupt the circuit within a few cycles whenever a fault occurs. Under fault conditions of a duration of 0.1 seconds (6 cycles), typical tolerable electric step potentials are 7000 volts and touch potentials are 2000 volts, based on high resistivity crushed rock surfaces generally used in substations.

During fault conditions, maximum local fields of the order of 10-100 gauss can occur lasting about 0.1 seconds. Also, during faults, an electric potential may be generated in the earth. The magnitude of the effect depends on the particular location and the fault current possible for the system. During faults the current may follow multiple paths, including metal objects and the earth itself. For a 3-mile return to ground (soil resistivity assumed to be 100 ohm-m), a 40-80 kiloampere (kA) fault generates a 100-200 volt potential per meter (V/m) at the maximum and 5-10 V/m 150 feet away; for dc system faults at 2kA, the fault potentials are 5-10 volts maximum at ground level. These values depend on site conditions; higher earth resistivities result in lower earth current densities.

If the cable sheaths are cross-bonded or open circuited, there will be a voltage build-up on the sheath that depends on the conductor current and distance along the line from the grounding point. For a system delivering 2000 A, there will be a sheath voltage of about 500 volts at a distance of 1 mile from the grounding point. If the system were grounded at 1000 foot intervals, the voltage build-up would be limited to about 100 volts. Since the cable enclosures are insulated and the public has no access to the cables, only substation workers are potentially affected, and the systems are screened for protection in cases where the voltage build-up reaches dangerous levels.

IMPACTS OF ELECTRIC AND MAGNETIC EFFECTS

For underground cable systems under normal operating conditions there are no electric fields, and the maximum magnetic fields are below human perception levels. For alternating current (ac) systems these fields are equivalent or similar to those experienced when people operate common household appliances, industrial equipment, and machinery. For direct current systems the fields are on the same order as the earth's magnetic field which ranges from approximately 0.35 gauss at the magnetic equator to 0.7 gauss at the magnetic poles. For all GITL, HPOF, and SCOF systems the fields are only 0.1-1% of the guidelines recommended for extended exposure by researchers, and such fields are confined well within the ROW. For SPTL systems, the fields are zero everywhere. In the event of a cable fault, the magnetic fields are 1-10% of the guidelines.

It is therefore concluded that magnetic fields from underground systems have no adverse impact on public health and safety.

The magnetic fields from dc systems installed underwater with large conductor separation or operated in a monopolar mode can cause an unacceptable error in ship compass readings within a distance of about 400 yards. Consequently, there may be problems in certain cases where installations are routed within and parallel to shipping lanes.

During fault conditions in which a buried cable is short circuited through the earth to ground, the earth potential near the cable will rise instantaneously and, for GITL, HPOF, and SPTL systems, most of the fault current will return to ground through the heavy metal enclosure pipe. Similarly, cable installations in water, on bridges, or in tunnels can have a relatively low resistance path to ground. As indicated above, a worse case event with full return through the earth may generate a 100-200 volt potential across a distance of 3 feet for about 0.1 seconds. This is only 1-3% of the IEEE safety standard, and therefore well within tolerable limits for step potentials; that is, a person standing in the ROW would not experience unsafe electric potentials. Were a person to contact a metallic object grounded at a distance of 12 feet, the 400-800 volt difference would be in the range of touch or grip perception (under normal, dry contact conditions) but still only 20-40% of the IEEE standard for touch potential safety.

Magnetic fields may couple inductively to adjacent metallic objects and induce currents in them. This, in turn, could lead to voltage build-up or interference. In developed areas interference can occur with nearby communication and signal lines. In rural areas induced voltage is possible where long distance cables and petroleum or gas pipelines might share a corridor or where irrigation pipelines or fences run parallel to the cable. There is also the potential for corrosion and interference associated with ground currents from cathodic protection rectifiers or when direct current cables are operated in a monopolar mode with earth return. In developed areas such corrosion is possible in gas and water mains and feeders, and metal conduit buried under streets in close proximity to the cable; interference is possible with signal lines and electric rail grounding systems. In rural areas, dc ground currents may contribute to the corrosion of adjacent pipelines. All of these effects are routinely considered during construction planning, and the corrective measures are part of standard engineering practice.

MITIGATION

As indicated above, mitigation measures for electric or magnetic effects are normally included in the installation design. In developed areas or shared corridors with buried metallic infrastructure, the existing utilities are mapped and incorporated into the project plan. In specific locations where there are special concerns about magnetic effects and inductive coupling with the cable sheath or nearby metallic objects, the cable and/or the object can be grounded continuously or at frequent intervals. Voltage build-up along the cable sheath or enclosure can also be controlled where necessary by the same means. However, fully bonded and closely grounded segments of a system will have higher operating costs over the life of the system because of increased losses from the induced currents. To prevent corrosion, asphaltic coatings and/or cathodic protection devices are standard methods.

In crossing navigable waters, cables may be routed transverse to the shipping lanes or restricted to bipolar operation during times of peak shipping activity. In developed areas, direct current systems may be designed with a dedicated neutral cable or with a metallic return via nearby overhead lines to enable monopolar operation without earth return currents, as may be required during repair times.

CONCLUSIONS

There is no evidence of impacts at the normal field levels generated by cable systems. Certain distinctions typical of the different cable systems are discussed in the text, but specific impacts depend on how the system is installed in each environmental setting. It is important to note that the magnitude of the effects described here depend upon the assumptions given (for example, the typical current and earth resistivity values quoted). It is often assumed that higher field levels portend greater impacts than do low fields; however, these fields may in fact be below the threshold for public health response. Regarding duration, it is known that electric potentials present less hazard the shorter lived they are. In any case, external fields may be shielded and inductive effects can be limited to conform to specified levels at a particular location through standard engineering planning in the design of the cable and the system installation.

ACKNOWLEDGEMENTS

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IRRIGATION SYSTEMS AND THEIR IMPACT UPON EXISTING AND PROPOSED TRANSMISSION LINES

John R. Varner, Jr.[1] and Shashi G. Patel[2]

ABSTRACT.--During the past 3 or 4 years, the rate of growth of irrigation systems used has been skyrocketing. The irrigation systems have become a major obstacle to electric utilities in impacting the routing of new lines as well as a matter of concern to them when the systems are installed near existing transmission lines, especially 500 kV lines.

The purpose of this paper is to cover the two types of irrigation systems which cause the most concern. First, Center Pivot Irrigation Systems and a report on field tests of induced current and voltage measurements on this type of system under a 500 kV line will be discussed. The second system, Traveling Gun Irrigation, is of concern because of safety considerations around 500 kV lines due to leakage current from the line through water streams to ground.

INTRODUCTION

The high cost of growing crops has caused farmers to consider methods of ensuring production and not be strictly dependent on nature for adequate rainfall. Farmers have begun to invest in irrigation systems as a safeguard against drought conditions. Between 1979 and 1980 the amount of acres of crop land under irrigation in the state of Georgia has increased from 842,235 to 1,035,385 or an increase of 23%. This has happened with interest rates on loans approaching 20%.

The increased use of irrigation systems has led to farmers' requests to relocate existing lines as well as a push by farmers in Georgia to pass laws requiring utility companies to give special consideration for relocating transmission lines for irrigation systems.

Georgia Power Company has over 14,000 miles of transmission lines in service, including 900 miles of 500 kV lines. A present planned expansion of the 500 kV system in the farming area of the state is underway with 500 miles of 500 kV lines scheduled to be in service by 1989.

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The growing use of irrigation systems caused the company to investigate the compatability of the major types of irrigation systems with 500 kV transmission lines. There are two major types of irrigation systems widely used by farmers in the state of Georgia, the Center Pivot System and the Travelling Gun System, each of which poses different problems with transmission lines.

DESCRIPTION OF IRRIGATION SYSTEMS

Center Pivot Irrigation

A center pivot irrigation system is made up of tubular sections which are 12 to 14 feet high and stand on rubber tires (Figure 1). These sections are connected together to obtain the desired length of the system. This type of system is attached to a water supply at its core.

The system pivots about the water supply and rotates in a circular motion about the water supply point or pivot point. The wheels or tires are generally driven by electric motors. The rubber tires, which are set to run in a circular pattern, can be turned so the entire system can be towed from one pivot point to another. The center pivot irrigation system does not have to make a complete circle and has controls so it can be stopped and its direction reversed at any point desired.

At the end of the system is a large nozzle which rotates in a 360° circle. Controls allow the nozzle to be programmed to start and stop, thus allowing irrigation of square-cornered fields.

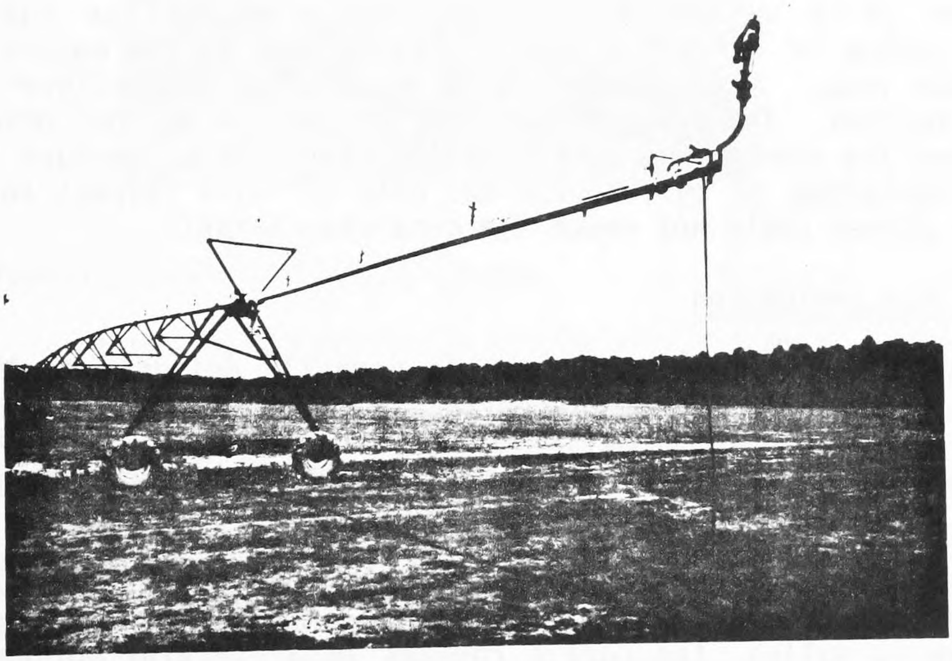

Figure 1. Center pivot irrigation system.

The center pivot type irrigation system presents a physical problem to transmission lines in that the transmission towers can restrict its circular movement, and there may not be sufficient vertical clearance to conductors. It is not uncommon for this irrigation system to have a radius of operation of 1200 to 1500 feet (Figure 2).

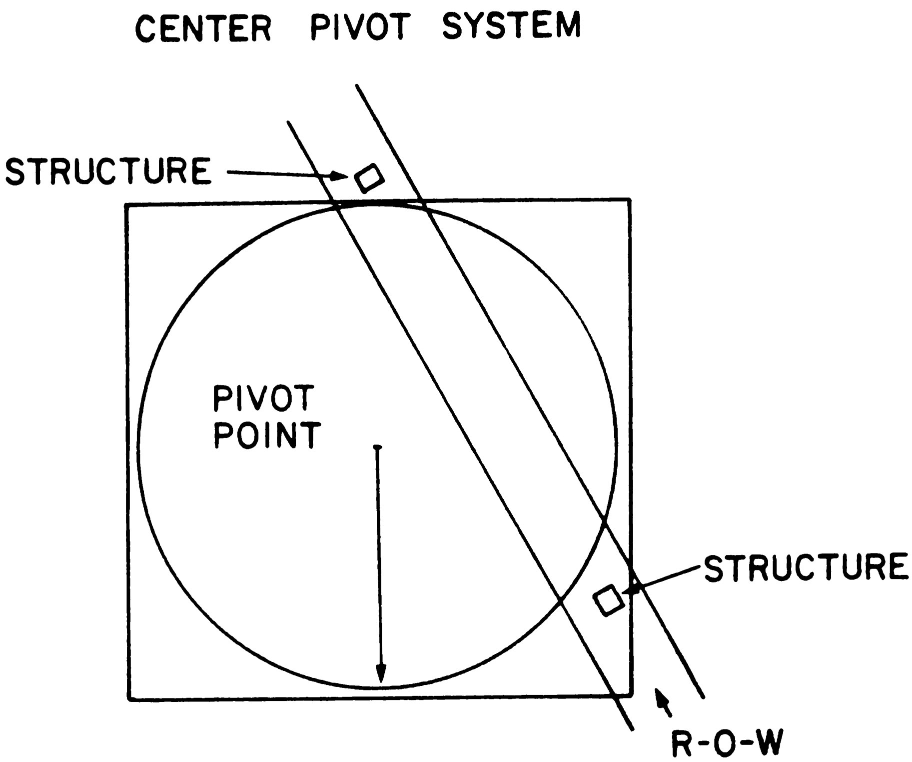

Figure 2.

The center pivot system has a large nozzle mounted on the end which shoots a stream of water for long distances much as the nozzle on the end of a garden hose. This nozzle can be mounted on a cantilever arm on the end of a section. The water stream from the nozzle may not pose a problem at striking the conductors with a solid water stream, because the maximum angle of operation of this nozzle was only 15° with respect to ground and the water stream could not reach the conductor height.

Traveling Gun Irrigation

The traveling gun irrigation system is normally designed so that a large nozzle is mounted on a frame supported by rubber tires. The frame houses a drum with a cable which pulls out to tow the frame. The cable is unwound off the drum and extended to the rod, which is anchored at a desired distance.

When water pressure is turned on or applied, it activates a mechanism which turns the drum and winds the cable up; thus pulling the gun forward. As the gun is pulled, the nozzle rotates in a circular motion and sprays water. One of these types of traveling gun systems is shown in Figure 3.

The traveling gun irrigation system does not pose the same physical problems as the center point system because it travels in a straight line and achieves coverage through the spray of large streams of water long distances as shown in the illustration (Figure 4). This system, however, does use large nozzles and sprays water streams large distances. The angles of the nozzle with respect to ground are large, so that a stream is sprayed high enough that it can strike an energized 500 kV conductor. The induced current on a farm tractor is larger than the induced current on the traveling gun since the gun is on rubber tires and is grounded by the cable tow while in operation.

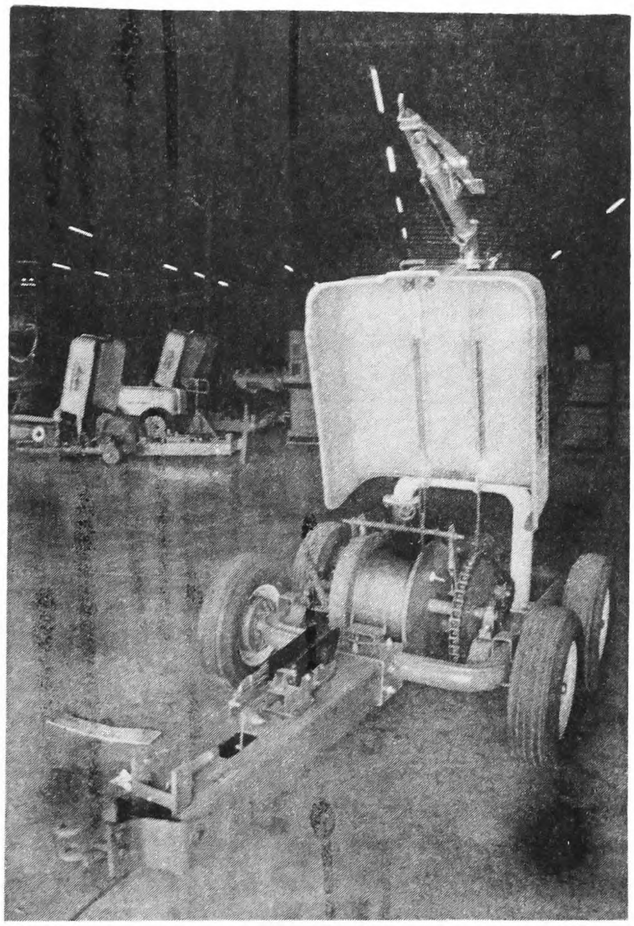

Figure 3. Traveling gun irrigation system.

FIELD MEASUREMENTS ON IRRIGATION SYSTEMS

Field measurements were made on the two systems to quantify the amount of induced current with a center point irrigation system and the leakage current from the spray of water from a traveling gun system on conductors.

Field measurements were taken on an existing center point system near Hazlehurst, Georgia, located near a 500 kV and 230 kV line. The system was tested without spraying water.

The weather was dry and clear with a light breeze. The irrigation system consisted of four sections, each 169 feet (51 m) long (total 676 feet (206 m)). The average height above the ground was about 13 feet (4 m). Figure 5 shows the location of irrigation system with respect to EHV lines. It also shows various positions (A through D) at which the voltage and current readings were obtained.

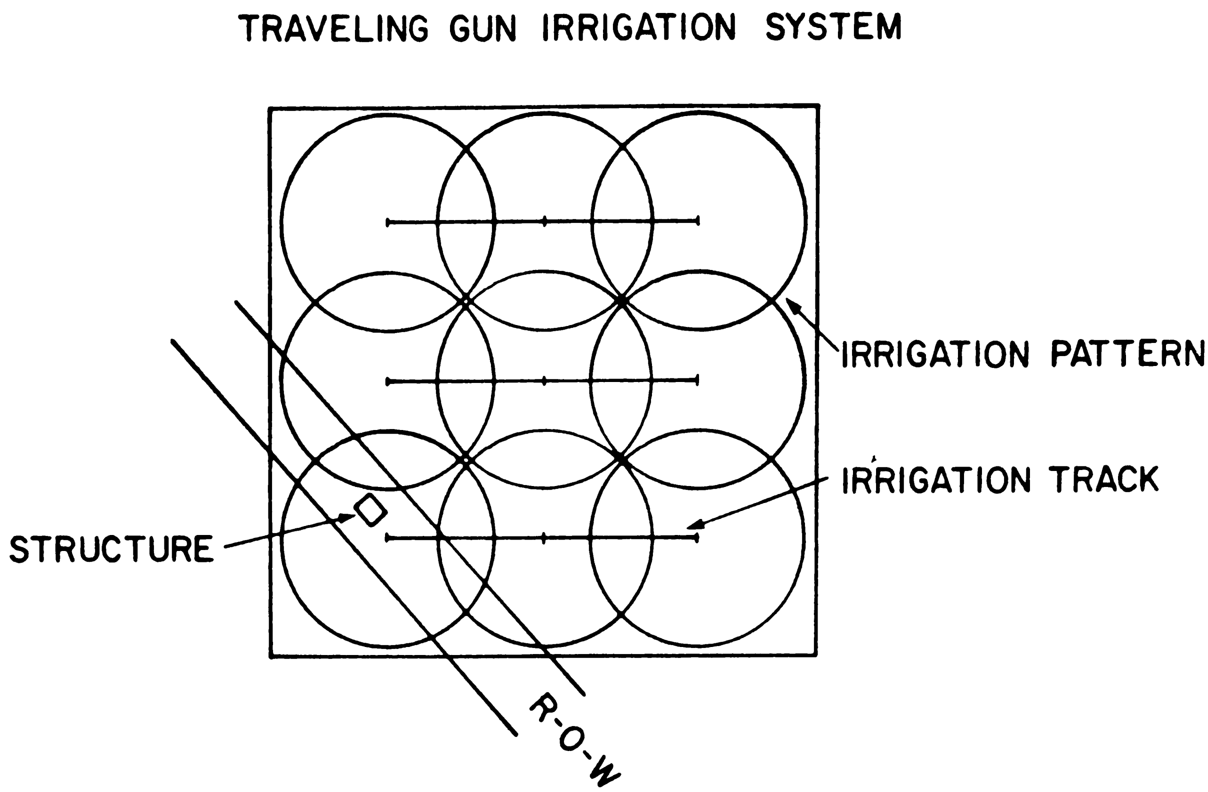

Figure 4.

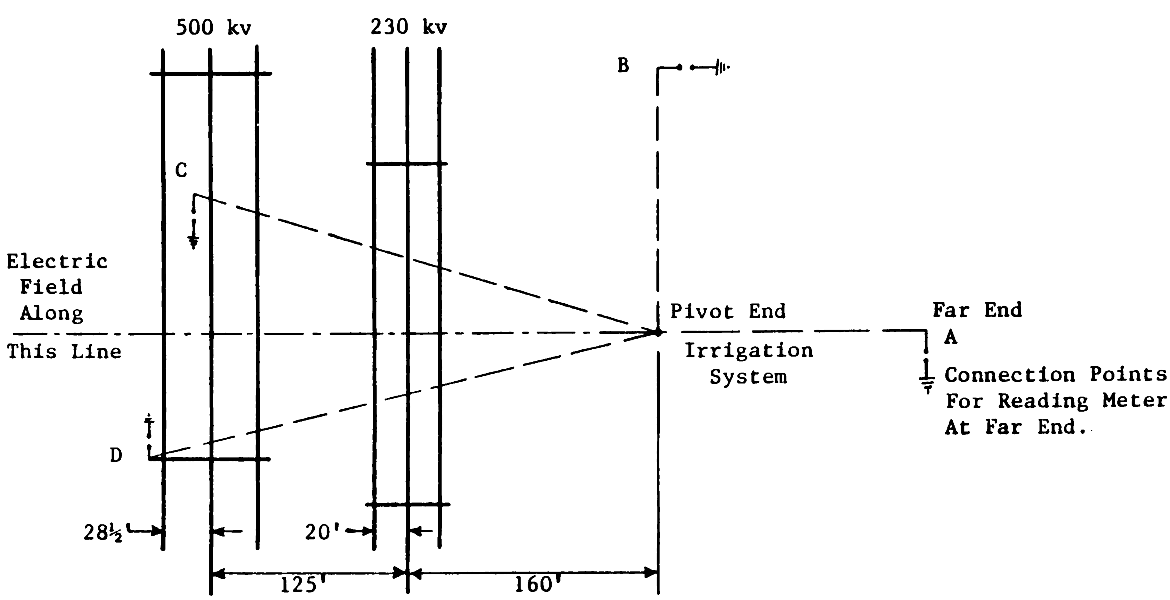

Figure 5. Center pivot irrigation system in relationship to transmission lines.

Table 1.

EHV Lines 500 kV 237 kV	Type of Induction	System to Ground Open Circuit Voltage (volts) Triplett Meter	Polytek Meter	System to Ground Short Circuit Current (Milliamps) Triplett Meter	Polytek Meter
524 kV 237 kV	Electro-static	125	125	6.1	6.0
450 A. 400 A.	Electro-magnetic	1.75	1.75	3.8	3.7

Table 2 shows the maximum voltages and currents obtained at each end. These maxima occurred when the irrigation system was in position "C." Electrostatic voltage and current were measured by Pivot End with Far End ungrounded, while electromagnetic voltage and current were measured at Far End with Pivot End grounded through a driven ground rod.

Table 2.

Distance From Pivot End Toward EHV Lines (feet)	E Field (kVolt/Meter)
0 (at pivot end)	.042
45 (13.7 m)	.100
90 (27.5 m)	.295
130 (40 m)	.950
160 (49 m) center phase 230 kV line)	.380
186 (57 m)	2.710

Field Measurements on Traveling Gun Irrigation System

This irrigation system is located in the same general area and owned by the same farmer. Figure 6 shows the location of the system with respect to Georgia Power Company's 500 kV and 230 kV lines.

Since this type of irrigation system sprays water over and beyond the EHV lines, we were concerned about the leakage current while spraying water as well as the induced voltage and current when the system is operative. The traveling gun was rotated around its vertical axis in order to obtain the maximum voltage and current values while spraying. The water sample when tested in our laboratory indicated resistivity of 3639 ohm-cm. Table 3 shows the maximum readings obtained for this system. Leakage current was not significant though to represent a potential problem to either the operation of the line or the irrigation equipment operation.

CONCLUSION

The field measurements showed that by using some simple grounding applications on the center pivot systems as a precaution, if proper clearance is maintained, and if a solid stream of water is kept from hitting energized

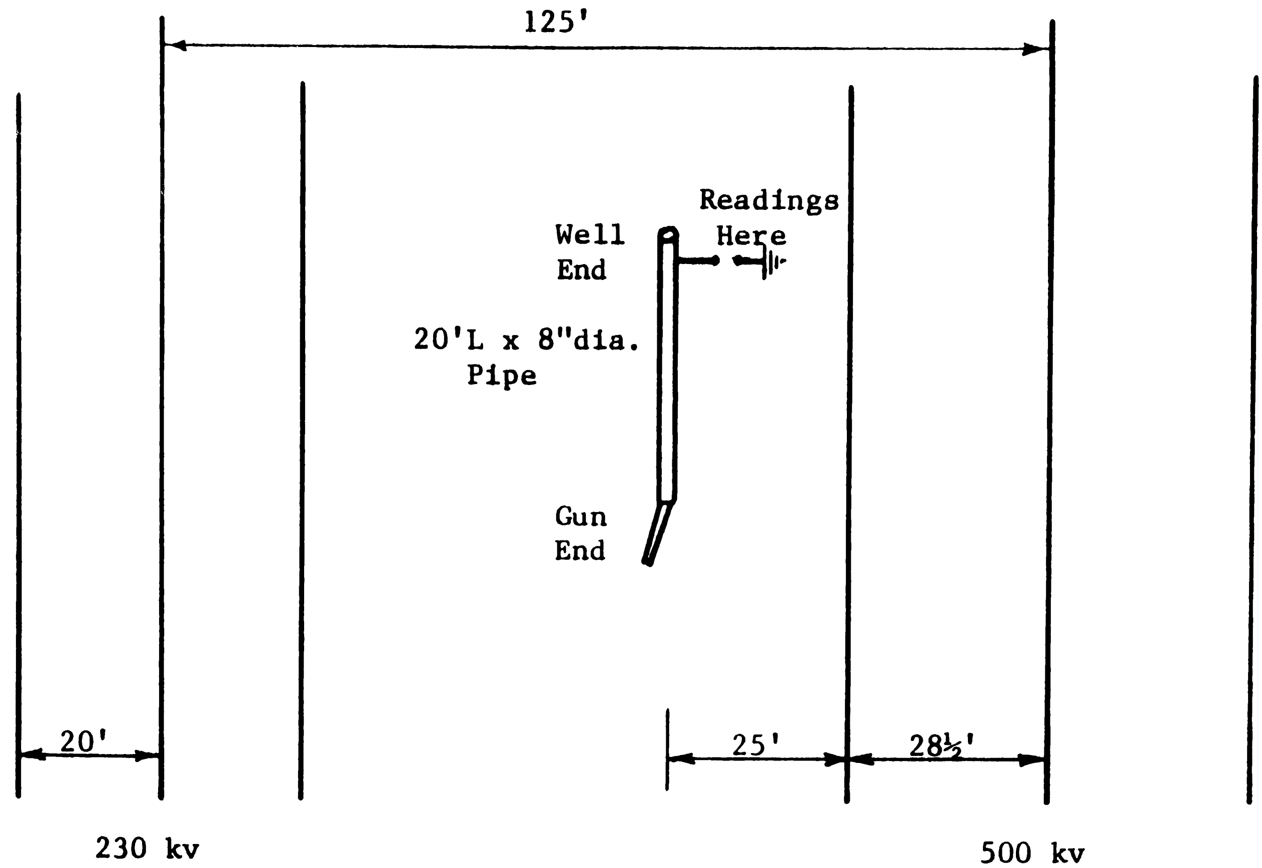

Figure 6. Configuration of water cannon.

Table 3.

Without Spraying		With Spraying	
Voltage (Volts)	Current (Milliamps)	Voltage (Volts)	Current (Milliamps)
0.4	0.185	0.7	1.8

wire, these systems can be compatible with the rights-of-way without significant concerns.

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THE ISSUE OF HEALTH AND SAFETY IN THE SITING OF NEW TRANSMISSION FACILITIES

Frank B. Burggraf[1]

ABSTRACT.--Moving power from remote generators to load centers requires transmission lines. The characteristics of EHV and UHV which make supplying power over great distances possible also make the public concerned. Recent experiences are reviewed.

INTRODUCTION

The amount of energy that can be transferred increases substantially as the operating voltage is increased. While this means taller towers and wider rights-of-way, the net environmental impact is less than the equivalent capacity expressed in many smaller, lower voltage lines. As the cost per kilowatt of generation increases, the dollar value of losses in transmission increases the incentive to employ more efficient, higher voltages. The properties of extra high voltage (EHV) transmission have been well established through experimentation and demonstration. The influences of these properties on people and livestock until recently have been less well documented.

In 1973 the Power Authority of the State of New York (PASNY) filed an application to construct a 765 kV transmission line about 155 miles (250 km) from the Canadian border to a substation in Utica, New York. Rochester Gas & Electric Corporation and Niagara Mohawk Paper Corp. jointly applied for a 765 kV line in the vicinity of Rochester for a distance of 66 miles (106 km). Questions arose concerning issues of public health and safety in both proceedings. A staff motion led to "Common Record Hearings" on Health and Safety of 765 kV Transmission Lines. As the most comprehensive review of these issues ever undertaken in an administrative forum, hearings were conducted that reviewed the levels of noise, ozone, and induced shock currents produced; the potential for inducing biological effects in humans exposed to the electromagnetic fields; the effects of electromagnetic fields on cardiac pacemakers; and the effects of induced shock currents on humans. More than 30 witnesses testified on these issues. More than 130,000 pages of direct testimony and cross examination and more than 100 exhibits were received into evidence. The role of the New York Commission's staff in the proceeding was particularly significant as they assembled witnesses generally in opposition to those of the applicant utilities and, with the staff of the Department of Environmental Conseration, scoped the proceeding.

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Among the witnesses staff presented was Dr. Andrew A. Marino, biophysical researcher from Upstate Medical Center, Syracuse, New York. He testified that electric and magnetic fields of the proposed transmission line would probably cause biological effects in people chronically exposed. Dr. Marino neither argued against the operation of existing transmission lines nor did he aver that the proposed line would have specific deleterious results on human health in his testimony. He did argue for an extraordinary safety factor.

The New York Commission, faced with some unresolved questions relating to the effects of 765 kV transmission lines and wishing to issue a permit: "... so that New Yorkers can enjoy the benefits of 765 kV transmission free of fears that they are doing so at some unknown cost to their well-being ..." adopted the course of action proposed by staff witness Frey: Make the right-of-way for a 765 kV line wide enough so that the field strength at its edge is no greater than that produced by the many existing 345 kV lines at the edge of their ROWs. That way: "... we assure that the risks, if any, of long-term exposure to the 765 kV transmission...will be no greater than those, now widely accepted, of long-term exposure to the 345 kV lines operating throughout the State."

While not stating that 345 kV lines are without risk, it was possible to observe that experience with existing 345 kV was extensive and without opposition. Staff witness Dr. Robert Becker, Project Director and Chief of Orthopedic Surgery, Syracuse Veterans Administration Hospital, testified that he would not recommend turning off existing lines, even where they produce fields that cause him concern, because of the benefits of the electrical services they provide, not the least of which are medical.

A standard 345 kV right-of-way is 150 feet (46 m) wide, though some are narrower. At the edge of a standard 345 kV right-of-way, the calculated electrical field strength (assuming a single circuit line) is approxi= mately 1.6 kV/m. The N.Y.P.S.C. found this to be a reasonable standard on worst case presumptions. The worst case presumptions are especially important.

Worst Case Presumptions

All of the effects which might be hazardous are a function of the amount of energy being conducted, proximity and duration of exposure, and the capacity of the "victim." For that reason the standards that have been prescribed are very conservative and the actual safety factor will be far more generous than the minimum. For example, the highest level of electrical field will occur at the outermost conductor. The field diminishes the greater the distance from the conductor; therefore, the highest exposure could occur only at the point of greatest nearness to the ground or the lowest sag in the line. The sag design to insure clearance will rarely be achieved in practice as it presumes a maximum heating and consequent stretching of the conductor. Heating of the conductor due to current flow would occur during peak demands on the system. Peak demand would have to be coincident with hot weather or the heat would be dissipated to the air, and maximum conductor deflection would not occur.

The person or vehicle experiencing the effect must locate precisely at the sag point when conditions are as stated for the design criterion to be met. Even then one must postulate further worst case conditions; e.g., a vehicle large enough, of aluminum, parked at precisely the optimum place, not grounded for the full effect to develop and a shock hazard to exist. Then a small child, totally grounded, is presumed to be on hand to experience the shock. Taking probabilities into account the risks of exposure are far less than a design based on worst case assumptions.

Commission Actions

In October, 1975, the PSC remanded the 765 kV line proceeding for further hearings to supply a record basis for a partial certification that would not predetermine the final conditions for the facility that would be determined by the continuing health and safety hearings. A staff witness testified that most routing issues could be decided and construction begun on the facility without concluding the health and safety issues. No party controverted that testimony. The PSC on February 6, 1976, authorized right-of-way clearance and access road construction. Record evidence indicated each year of delay in transporting Hydro-Quebec power would mean 45 million dollars in additional fuel costs and 16 million dollars in interest and projected inflation costs. To the extent that the imported power would replace downstate fossil generation there would be obvious environmental benefits, particularly in air quality.

On June 30, 1976, the PSC issued an Opinion and Order authorizing the erection of support structures and conductors, establishing standards on the basis of the prefiled testimony in the health and safety hearings. Some issues, such as ozone, were dismissed out of hand. There had been, for example, nobody willing to predict significant levels of ozone capable of harm. PASNY was instructed to provide a minimum clearance of 63 feet (19 m) over a public road to insure against 4.0 mA induced shock current. Privately owned roads were to have a ground to conductor clearance of 52 feet (16 m), and elsewhere 48 feet (15 m) was to be be standard. The PSC reserved the right to establish operating conditions at the conclusion of the health and safety proceeding.

Opinion No. 78-13 determining the health and safety issues, imposing operating conditions, and authorizing operation pursuant to those conditions was issued June 19, 1978.

The Commission adopted a 350 foot (107 m) right-of-way to reduce the field strength to below that necessary to insure 1.6 kV/m or less, and until a research program finding showed a lesser width was tolerable. A program of grounding of fixed objects and movable objects regularly used on the right-of-way was established and the heights of conductors earlier established was affirmed. Noise standards were established and PASNY was instructed to report to the Commission attempts to resolve all complaints concerning audible noise. The establishment of a research program to resolve the issue of possible long-term effects of EHV operation was also ordered.

Long-Term Effects

The PSC Staff, Marino, and others recommended research on the long-term, effects, and the Commission ordered utility funding of a research program--the extent and nature of which was to determined by a Board of Review comprised of experts. The Board would also report on the progress of the research program as it unfolded. The Scientific Advisory Panel is chaired by Dr. Maria Reichmanis of the NYS Department of Health. The Panel has solicited proposals but there has been early disagreement over the scope of the program as to whether to limit the scope to biological effects on humans or study the full spectrum of biological effects. It has been speculated that these studies will not yield results on which the Commission can make a final determination.

Current Cases

Interrogatories are no longer being limited to areas of demonstrated effect or probable influence. In a recent case there have been demands that the applicant research the behavior of insects on the right-of-way with no showing that a problem is even likely to exist. While the prospect is for a continuing burden to be placed upon each applicant, there appears to be some recognition of work dispelling the misconceptions and fears.

The Public Utilities Commission of South Dakota, while rejecting the Mandan Transmission Line, did not do so on the grounds of health and safety but made a reasoned decision based on study of the testimony of several experts.

Recent research establishes that the risks from EHV and UHV have been overstated. One recent report published in the Scientific American, by Arthur C. Upton, "The Biological Effects of Low-Level Ionizing Radiation," states at the outset: "What is the hazard to human beings of ubiguitous low-level radiation from natural and artificial sources? The evidence so far indicates that compared with other hazards it is slight."

Public Information

Research and hearings to date indicate that the presently accepted standards are sufficient and adequate for a margin of safety and environmental protection, consistent with economy and th present state of technology. However, an effort must be made to inform the public on the true risks to dispel the fears generated by the repetition of exaggerated media claims, including providing printed materials to abutting property owners and making available public demonstrations.