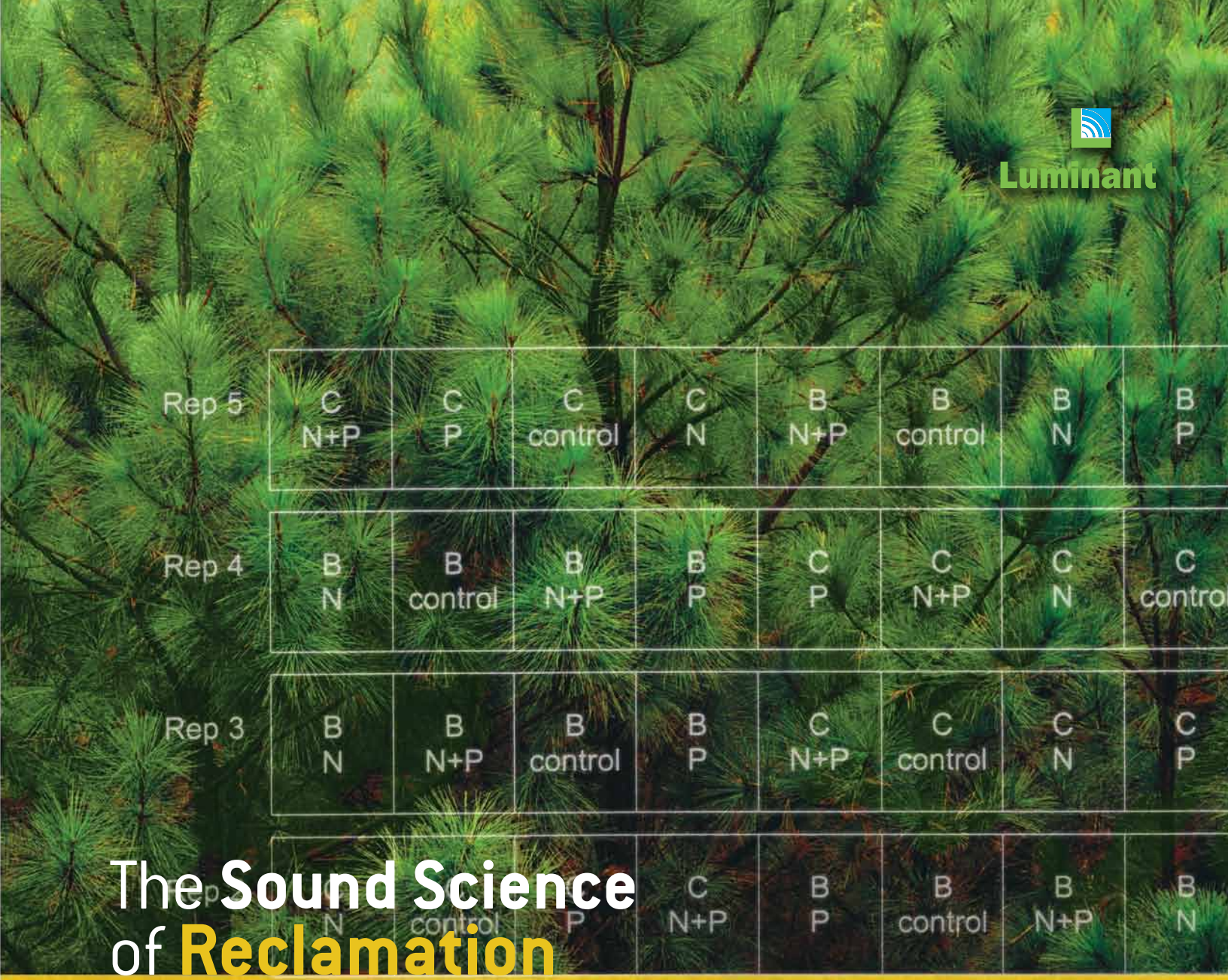


Luminant

The **Sound Science** of **Reclamation**

The Luminant Environmental Research Program

May 2011

ABOUT LUMINANT Luminant, a subsidiary of Energy Future Holdings (EFH), is a competitive power generation business, including mining, wholesale marketing and trading, and development. The company has more than 15,400 MW of generation in Texas, including 2,300 MW of nuclear and 8,000 MW of coal-fueled generation capacity. Luminant is also the largest purchaser of wind-generated electricity in Texas and fifth largest in the United States. EFH is a Dallas-based energy holding company with a portfolio of competitive and regulated energy subsidiaries. Visit www.luminant.com for more information.

HISTORY OF LUMINANT MINING & RECLAMATION

Luminant began mining lignite at the Big Brown Mine, near Fairfield, Texas, in 1971. The company now holds 11 surface-mine permits in East and Central Texas. In 2010, these operations mined approximately 1,900 acres and recovered 27.5 million tons of lignite. All Luminant mines are mine-mouth operations, delivering lignite to its nearby power plants, which generate electricity for a large part of the population of Texas.

THE LUMINANT ENVIRONMENTAL RESEARCH PROGRAM

The Challenge

In 1971, Luminant began pioneering the modern use of lignite to generate affordable, reliable electricity for Texans. With almost no rules or guidelines to follow (Texas passed a law regulating surface mining in 1975, and the U.S. Congress passed a similar law in 1977), the company encountered many questions in developing its environmental strategy for mining and reclamation. As Luminant began research and field trials to assess various reclamation methods, major unknowns included the impact of surface mining on water resources, how to return mined lands to productive use and impacts to wildlife, soils and other parts of the environment.

On the cover: Reclaimed land on Luminant property in east Texas. The chart is from Luminant Research Program Fellow Mary Anne McGuire *(McGuire, 1998)*: *Figure 5. Randomized plot layout for bareroot and container longleaf pine seedlings planted in January 1996, at Martin Lake Mine, Panola County, Texas.*

Forests, wildlife habitat and water resources are emphasized in Luminant's reclamation efforts.

The Program

Company officials saw an opportunity to better understand the environmental effects of what would become growing operations in east-central Texas with sound science and ongoing research. In 1969, they envisioned a long-term, ongoing research-based program – independent from company direction – that would provide a scientific approach to the challenges of mining, reclaiming and using lignite as a baseload electric fuel.

To address the unique challenges of mine reclamation in Texas and to foster ongoing research, the company formally established a stand-alone research program and center in 1971 that continues to operate today – 40 years later. The research center (including a lab and living quarters) is located near the company's Big Brown mine and generating facility and promotes quality graduate education and sound on the ground environmental research of natural resources.

Independent & Objective

Today, Luminant's Environmental Research Program (ERP) is unlike any other – funded by the company but designed for university graduate students to conduct research independently. To ensure continued objectivity in both research and reporting findings, an autonomous Steering Committee composed of leading scientists, educators and advisors guides the program. This group, acting separately from Luminant, approves research topics, awards fellowships and supports students and professors in publishing the results. See the list of Steering Committee members on page 2.

This is how it works:

- Luminant and the Steering Committee publicize funding and the opportunity for graduate students to use company facilities for natural resource research related to Luminant's operations.
- Students, directed by their own supervisory professors at their respective universities, apply for Luminant-funded fellowships that provide funds for a monthly stipend, tuition, equipment and travel.
- Students conduct independent studies on soils, groundwater, wildlife, vegetation and other topics critical for successful mine reclamation and the minimization of environmental impacts.
- Luminant provides access to company experts and locations and has access – along with the general public – to results. Luminant exercises no control, review, editing or publishing rights to the program's findings, and all of the work is published by research fellows in open literature. Results help shape the basis for the company's reclamation activities and contribute to the science of mine reclamation on a national scale.

Results Matter: Contributing to Science

Luminant has provided over $4 million in funding since 1971 for the completion of 100 independent, published student theses and dissertations on various potential effects of surface lignite mining, electric power generation and electric power delivery on the environment. This student-provided research has not only influenced Luminant's environmental policies and practices but has also provided a technical resource for regulatory agencies and helped establish industry-wide practices. Summaries of a few of these studies – along with appropriate data – are presented on the following pages.

Student research has benefited Luminant's environmental program and the industry's practices.

Increasing Acreage of Prime Farmland Soils

One of the first graduate studies in the research program resulted in a tremendous, ongoing impact. Prior to Patrick Angel's study *(Angel, 1973)*, the accepted method of ensuring successful mine soil reclamation was to segregate the topsoil and subsoil and replace them exactly as they were removed. This was a costly and time-consuming process with sometimes limited certainty of environmental benefit – especially with Texas soils. Angel's research revealed that selected overburden can often provide a better growth medium than native soils.

As a result of this research, prime farmland soils, the Natural Resource Conservation Service designation for highly productive soils, have increased dramatically on Luminant's mined land through the practice of using mixed selected overburden materials as postmine soils (see Table 1). The process has resulted in improvement in both soil pH and texture (see Table 2). This practice continues to save the company more than $20 million each year while also improving agricultural productivity.

Improving Livestock Forage Production

Livestock grazing is an important land use around the mining areas of Texas. Studies conducted by Frank Hons *(Hons, 1980)* investigated forage plant growth and production. His studies showed good yields of both grasses and legumes at the company's Big Brown mine location when mine soils were fertilized with adequate amounts of nitrogen, especially nitrate, and phosphorus. Studies subsequent to Hons' work indicated reclaimed land required lower maintenance fertilization than unmined lands for production of forage grasses.

Jeff Skousen's study *(Skousen, 1986)* showed that coastal bermudagrass could have increased value as forage when diverse broadleaf forages and grasses were seeded into established stands of coastal bermudagrass on mine soil.

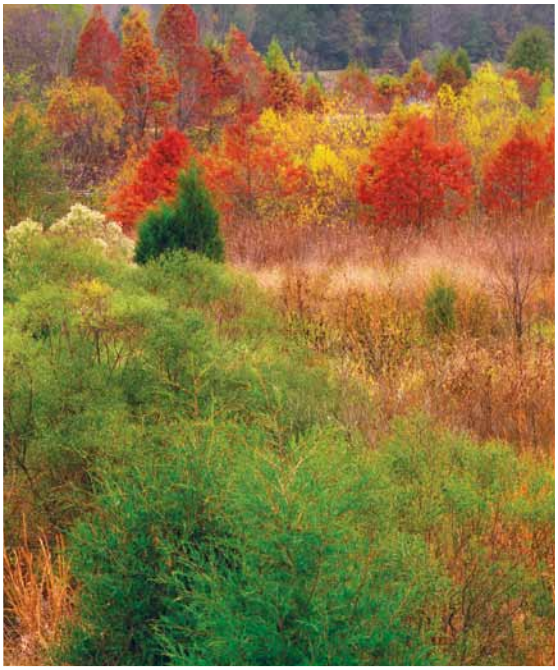
LUMINANT ENVIRONMENTAL RESEARCH PROGRAM STEERING COMMITTEE

"By working with university research scientists to support the basic environmental research of graduate students, the program not only produces future outstanding scientists and environmental professionals but also generates data which can be used to minimize the environmental impacts of company operations."

— Dr. Robert F. McMahon, *Professor Emeritus, Department of Biology, University of Texas at Arlington and Luminant Environmental Research Program Steering Committee Emeritus Member*

Steering Committee Members

Members	Expertise	Institutional Affiliation	Year Joined
Dr. David Allen	Chemical Engineering (Air)	University of Texas at Austin	2005
Dr. Moses Attrep	Nuclear	Los Alamos National Laboratory (Retired)	1973
Mrs. Debbie Boyle	Sponsor	Oncor	2009
Dr. Jonathan Campbell	Biology	University of Texas at Arlington	2009
Dr. "Chip" Groat	Geology	University of Texas at Austin	1974
Dr. Melanie Sattler	Civil Engineering (Air)	University of Texas at Arlington	2005
Dr. "Jack" Sharp	Geology	University of Texas at Austin	2001
Dr. Nova Silvy	Wildlife	Texas A&M University	1995
Dr. Fred Smeins	Rangeland Ecology	Texas A&M University	1995
Mr. Sid Stroud	Director	Luminant	2007
Dr. Hans Williams	Forestry	Stephen F. Austin State University	2009
Dr. Dave Zuberer	Soils	Texas A&M University	2003
Emeritus Members			
Dr. Scott Beasley	Forestry	Stephen F. Austin State University	1992
Dr. Tom Hellier	Biology	University of Texas at Arlington	1971
Dr. Lloyd Hossner	Soils	Texas A&M University	1978
Dr. Bob McMahon	Invertebrates	University of Texas at Arlington	2000
Dr. Jim Teer	Wildlife	Texas A&M University	1971
Mr. John Tilton	Biology	Luminant	1971
Dr. Milt Weller	Wetlands	Texas A&M University	1990
Mr. Dick White	Fishery	Luminant	1971
Dr. Paul Zweiacker	Fishery	Luminant	1997



Forested wetlands are an important part of Luminant's wetland restoration program.

He found that establishment of a variety of legumes and non-legumes within bermudagrass stands provided a more diverse plant community for wildlife and recreational opportunities and produced forage that was often more nutritious and resilient to weather than bermudagrass alone.

These results have significantly influenced Luminant's land management practices, helping Luminant obtain beneficial results as show in Table 3.

Managing Wildlife Populations

Andrew Kasner *(Kasner, 2004)* examined the foraging and nesting ecology of interior least terns nesting on reclaimed surface coal mine spoil at Luminant's Big Brown Mine. This research was very important in establishing a scientific basis for establishing a management plan for this endangered species' long-term recovery and habitat needs on company property. Since 2004, Luminant's implementation of a management plan has enhanced the nesting success of this species on mined land.

Understanding the Effects of Soil Compaction

Li Yao *(Yao, 1994)* studied the effects of soil compaction by reclamation equipment. His study quantified the effects of compaction on soil properties that influence reclamation success. The results demonstrated the need for measures to minimize or eliminate soil compaction during the reclamation process.

Improving Reforestation

Martin Shupe *(Shupe, 1986)* studied the effects of combining nitrogen and phosphorus fertilizers on a loblolly pine plantation on a mine spoil of the Martin Lake mine in east Texas. The results were an increase in the diameter and height of the two-year-old trees, but research also suggested that fertilizer applications in addition to those normally applied for initial cover crop establishment were not necessary for tree establishment and early growth.

Table 1. **Percentage of prime farmland soils**

	Percent of Premine Area	Percent of Postmine Area
Big Brown Mine	4.7	58.6
Monticello Winfield Mine	38.8	65.9

Table 2. **Mean values for premine and postmine soils**

	Native Soils	Postmine Soils	Native Soils	Postmine Soils
	0–12"		12–48"	
Big Brown				
pH	5.6	6.5	5.4	6.4
ABA	0.5	3.2	–0.3	2.7
Sand	69	35	44	34
Clay	17	27	41	28
Monticello Winfield				
pH	4.9	6.9	4.9	7.0
ABA	–0.5	5.9	–2.7	5.3
Sand	72	31	54	30
Clay	12	28	30	28

Photo from Paul Askenasy *(Askenasy, 1977). Figure 9. Grain sorghum heads being covered with plastic mesh screens to prevent bird damage.*

Gerald Wood *(Wood, 1985)* found that the additional cost of seedling inoculation with bacterial fungi did not appreciably enhance loblolly pine survival and growth on east Texas mine soils. His findings helped the company decide on a strategic direction since seedling inoculation had shown promise in other mining regions. This research provided valuable experience for Gerald, who has been employed by Luminant for the past 25 years as a reclamation specialist.

Many other studies completed by program participants have demonstrated the potential for reforestation success on mine soils. Research findings by Janet Musgraves *(Musgraves, 1995)* and Mary Anne McGuire *(McGuire, 1998)* found that East Texas overburden material had the ability to support various vegetation types. The results of these studies helped shape a reforestation program that has become a very important part of the company's reclamation activities.

TRANSFERABILITY

Research fellows publish their theses and dissertations through their respective institutions and also in scholarly journals. In addition, graduates of the program have shared their expertise throughout the world by holding career positions at universities in 13 states, the U.S. Fish & Wildlife Service, various state water and air agencies, the Railroad Commission of Texas, the Bureau of Land Management, the U.S. Department of the Interior (including the Office of Surface Mining), the U.S. Environmental Protection Agency, the U.S. Forest Service, the U.S. Geological Service and in the utility, mining, chemical, oil, timber, environmental consulting and engineering industries.

LONG-TERM BENEFITS

Results from the Luminant Environmental Research Program have helped Luminant make the following quantifiable environmental improvements:

- Reclaimed nearly 68,000 acres for uses such as forests, pastureland and wildlife habitat.
- Increased prime farmland soils at the Big Brown facility from about 5 percent to more than 58 percent.
- Increased prime farmland soils at the Monticello Winfield facility from 38 percent to more than 65 percent.
- Achieved full performance bond release of more than 29,800 acres of postmine land.

Table 3. **Big Brown postmine soil yield comparison vs. other premine soils**

Soil	Coastal Bermuda (tons/acre)	Wheat (bushels/acre)
Big Brown	3.0	52
Crockett	2.0	35
Edge	1.9	28
Gasil	2.2	28
Gredge	2.0	–
Nahatche-Hatliff	2.1	–
Padina	1.8	–
Silawa	1.9	–
Silstid	1.9	–

- Planted more than 30 million trees on company land now certified as a Tree Farm by the Texas Forest Service and the Texas Forestry Association. About 60 percent of the acres reclaimed each year by Luminant are being reforested.
- Created or enhanced more than 5,100 acres of wetlands, ponds and stream channels.
- The Luminant program has also furthered scholarship and professionalism: Some 100 theses and dissertations from researchers in Luminant's Environmental Research Program have been completed and are available to the public adding to the general public knowledge base on reclamation.
- Numerous scholarly articles have been published using research from this program.
- A significant benefit of the process is the worldwide placement of graduates in key positions where they can continue application of the knowledge and training achieved through this program.
- Research from this program has been shared with the regulatory community across the nation to help provide a scientific basis for reclamation practices.

TRANSFERRING KNOWLEDGE

In 1983 Jeffrey G. Skousen *(Skousen, 1986)* began his research work on reclaimed mine soils as a fellow in Luminant's Environmental Research Program while earning his doctorate at Texas A&M University. Today, Dr. Skousen is a professor of Soil Science at West Virginia University where he is a land reclamation specialist. He continues to publish extensively on a variety of reclamation topics and has also contributed to the industry and academia as associate editor with the *Journal of Environmental Quality* and president of the American Society for Mining and Reclamation.

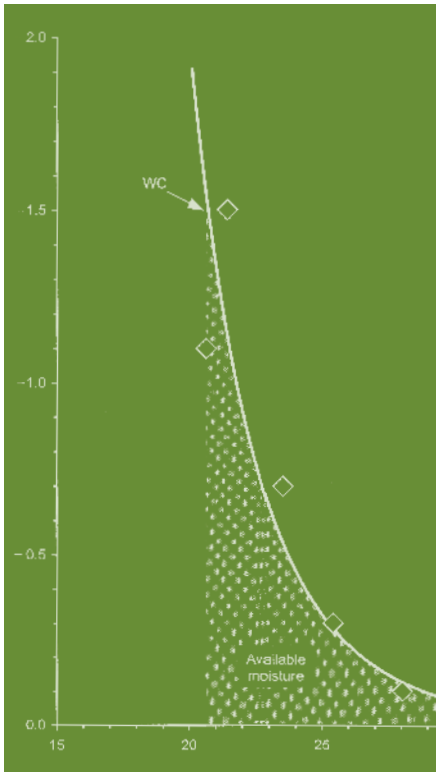


Chart from Mary Anne McGuire *(McGuire, 1998)*. *Figure 1. Moisture content and tension of lignite minespoil at a longleaf pine planting site at Martin Lake Mine, Panola County, Texas, measured with a pressure plate apparatus.*

LITERATURE CITED

The following studies are all from Luminant Environmental Research Program Fellows:

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Complete abstracts of studies conducted through the Luminant Environmental Research Program are available at www. luminant.com.