EXECUTIVE SUMMARY

> *"As a nation, we seek long-term economic growth that creates jobs while improving and sustaining the environment. Achieving these goals requires an environmental technology strategy that addresses the need to remediate past environmental damage while helping industry shift from waste management to pollution prevention, efficient resource use, and industrial ecology. A forward-looking approach will help companies become more competitive by lowering their energy and resource need while reducing or eliminating waste cleanup and disposal costs."*
>
> *-National Science and Technology Council*

Founded in 1993 by Edward G. Gatliff, Ph.D., Applied Natural Sciences, Inc**.** is a soil and ground water remediation company that utilizes Engineered Agronomic methods to implement the phytoremediation process known as *TreeMediation*®. As a provider of vegetation enhanced environmental remediation services, this company is at the center of the global shift toward creating sustainable environmental technologies.

Applied Natural Sciences is the leading provider of plant-based technologies for the remediation of soil and ground water. As a pioneer in the emerging field of phytoremediation and natural biorestoration, Dr. Gatliff first applied phytoremediation technology on a commercial basis in 1988 and is the only firm to successfully remediate ground water at depths greater than five feet.

TreeMediation, Applied Natural Sciences' patented process for using engineered agronomic technology to cleanup sites, has become synonymous with phytoremediation. The *TreeMediation* process takes advantage of the extensive root systems of trees and other vegetation to extract contaminants from the soil matrix and ground water. In the past few years, the *TreeMediation* program has been expanded for use in the processing of industrial waste water, and in ecosystem restoration of industrially impacted areas.

Applied Natural Sciences, Inc. has been successful in introducing *TreeMediation* as a viable environmental technology and securing regulatory endorsement at both the national and state level, often as the first company to win approval for a phytoremediation program in a given state. In 1999, Applied Natural Sciences was nominated for the Department of Energy's Small Business of the Year Award for an efficient and successful installation of a *TreeMediation* system at Argonne National Laboratory near Chicago, Illinois that afforded a savings several million dollars over the next viable technology.

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INTRODUCTION

Applied Natural Sciences, Inc. (ANS) was founded in 1993 to provide specialized environmental remediation services. Within the arena of environmental remediation, bioremediation dominates the emerging technologies in terms of cost effectiveness, viability and environmental appeal. ANS offers a form of bioremediation technology, commonly termed phytoremediation, that successfully uses vegetation to treat environmental contamination in soil and ground water. The science of Agronomy - which focuses on the growth of plants and their relationship with soil and water - is the predominant science behind phytoremediation. ANS stands out as the leader in this emerging technology, as the one firm uniquely qualified and experienced, with unparalleled data on the validity of this new technology.

In 1995, The United States Environmental Protection Agency identified phytoremediation as one of the promising innovative technologies in its Annual Status Report on Innovative Treatment Technologies.

Dr. Edward G. Gatliff, Ph.D., President and founder of ANS, pioneered the application of agronomic principals to the remediation industry through the trademarked *TreeMediation*® process. As the first company to implement phytoremediation on a commercial basis, ANS has unmatched experience with this emerging technology. Because of this breadth of knowledge and experience, ANS has been selected by Federal, State and Local Regulatory Agencies, Fortune 500 Companies, environmental consulting firms, and real estate developers to implement TreeMediation® programs throughout the U.S.

ANS provides multi-phased phytoremediation and biorestoration services required for each specific site.

Agronomic Assessments: ANS' agronomists review existing site data on soil, ground water, and contaminant levels and combine them with agronomic data. This information is used to determine the applicability of TreeMediation, including vegetation selection, planting scheme development, and required methodology engineering.

Regulatory Negotiations: ANS negotiates with regulatory agencies on behalf of their clients to present up-to-date data on the success of phytoremediation, and seek regulatory endorsement and approval for site closure.

Agronomic Engineering Design: After completion of the agronomic assessment and discussions with regulatory agencies, ANS provides design services, including drawings and documentation, for its engineered agronomic systems.

Design Implementation: ANS' staff implements the planting phase of the phytoremediation program. As with any biological organism, proper preparation of the site and handling of the plants used in the *TreeMediation* program will impact the program's success. ANS owns and maintains all of the specialized rigs, tractors and other equipment necessary to properly prepare and plant each site. With trained agronomists and more commercial field experience than any other phytoremediation firm, ANS is uniquely qualified to perform this stage of the project.

Remedial Progress and Agronomic Monitoring: ANS performs on-going monitoring of site conditions, vegetation conditions, and contaminant levels. This is a critical part of achieving site closure. ANS has the capability to automate a large portion of this phase through remote electronic monitoring systems.

ANS offers a number of opportunities for organizations interested in the *TreeMediation* process. Currently, ANS has licensing agreements with qualified agronomic firms throughout the U.S. For companies who already have engineering consultants under contract, ANS will establish teaming arrangements with engineering and consulting firms that provide complimentary technical services. In addition, ANS offers direct project implementation and management services to the commercial, industrial, real estate and government sectors.

Application of *TreeMediation*® Technology

Applied Natural Sciences, Inc. has been successful in implementing *TreeMediation* programs for soil and ground water remediation at industrial facilities located throughout the United States. In addition, ANS has provided experimental and physical design and monitoring expertise for a coastal wetlands restoration demonstration project sponsored by U.S. Environmental Protection Agency-Region (VI) and the Louisiana Department of Natural Resources. The following is a synopsis of some of the projects that ANS has been involved with to-date.

Cranbury, New Jersey – 1991 (first Phyto in New Jersey)
Nitrate and Ammonium in Soil and Ground Water

This site has the distinction of being the first location in which the *TreeMediation* program was employed. Initially, a *TreeMediation* program site assessment was performed by reviewing previously developed site environmental data, and collecting and evaluating additional soil and ground water data. The *TreeMediation* program was implemented to create a border that would limit the off-site migration of the contaminant plume in a "tight" sandy-clay aquifer. On-going site weather conditions, soil moisture conditions, and ground water elevations continue to be monitored by computer and accessed remotely by modem. Trees have consistently grown at a rate of between 6 and 8 feet per year. Results of annual sampling indicate significant contraction of the nitrate and ammonium plumes in the downgradient aquifer and overall reduction of nitrogen in the ground water.

Anderson, South Carolina – 1992 (first Phyto in South Carolina)
Heavy Metals in Soil and Ground Water

This site contained heavy metals in the subsurface soil and ground water. A *TreeMediation* program site assessment was performed by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. The *TreeMediation* program was implemented to create a sink for rainwater leaching through the soil and to uptake leachable heavy metals to limit their migration and further contamination of the ground water. Ground water levels have dropped since implementation.

Wilmington, North Carolina – 1992 (first Phyto in North Carolina)
Nitrate and Ammonium in Soil and Ground Water

The North Carolina site aquifer contains a contaminant plume migrating off-site. The aquifer is contained in a relatively porous sandy medium overlain with 10-20 feet of coastal sand deposits. A

TreeMediation program site assessment was performed by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. The *TreeMediation* program was implemented to create a border that would limit the off-site migration of the contaminant plume. Site weather conditions, soil moisture conditions, and ground water elevations continue to be monitored remotely on a regular basis by computer. Trees have consistently grown at a rate of between 6 and 8 feet per year. Nitrogen levels in the well downgradient of the trees have steadily fallen following the implementation of the *TreeMediation* program.

Oconee - 1988 and Cantrall, Illinois – 1992 (first Phyto in Illinois)
Nitrate and Ammonium in Soil and Ground Water

These two sites, similarly situated on medium texture silt to silty-clay and gravel aquifers, have contaminant plumes migrating off-site. A *TreeMediation* program site assessment was performed at both sites by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. A partnering effort produced a program that combined *TreeMediation* with a modified Pump and Treat system (with trees as the treating medium). These hybrid programs were implemented to create a border that would limit the off-site migration and the retrieval of the downgradient contaminant plumes. Site weather conditions, soil moisture conditions, and ground water elevations continue to be monitored remotely on a regular basis. Trees have consistently grown at a rate of between 6 and 8 feet per year. Nitrogen levels in the wells downgradient of the trees have steadily fallen following the implementation of the *TreeMediation* program.

Whitewater, Wisconsin – 1992 (first Phyto of its kind in Wisconsin)
Pesticide Contamination

This site, situated on a relatively porous aquifer medium of fractured limestone bedrock, contained a contaminant plume migrating off-site. A *TreeMediation* program site assessment was performed by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. The *TreeMediation* program was implemented to create a border that would limit the off-site migration of the contaminant plume. Site weather conditions, soil moisture conditions, and ground water elevations continue to be monitored by computer and remotely accessed by modem. Trees have consistently grown at a rate of between 3 and 4 feet per year. This slower growth rate reflects the effect of the shorter growing season realized at this site. Pesticide levels in the monitoring well data have dropped below MCLs following the implementation of the *TreeMediation* program.

Uniontown, Pennsylvania – 1993
Sludge Lagoon Study

The accumulation of lagoon sludge presented storage problems at this site. The sludge was evaluated and determined to be suitable for use as a soil amendment at the site. Other activities included conducting laboratory soil column studies evaluating Chromium (VI) movement through various soil types and as affected by treatment solutions. Additionally, field studies were conducted to evaluate herbicide dissipation by natural processes.

Baton Rouge, Louisiana –1993/1994
The Red Mud Coastal Restoration Demonstration Project

The Red Mud Coastal Restoration Demonstration Project was developed to explore the potential for using red mud, a waste product, resulting from the alumina extraction process as a coastal wetlands restoration medium.

Lafayette, Louisiana – 1995 (first Phyto of its kind in Louisiana)
TCE in Ground Water

This project, initiated in 1995, was implemented to evaluate the potential of the *TreeMediation* program for remediating TCE and its derivatives in a shallow aquifer. Diesel Range Organics (DROs) degradation in land-farmed soil was also evaluated. Various treatments were employed to modify the soil in an effort to stimulate greater rates of degradation of DROs. After one and one-half years, contaminants levels are below detectable limits and the site is scheduled for closure.

Edgewood, Maryland – 1996 (first Phyto of its kind in Maryland)
PCE/TCE/Heavy Metals in Soil and Ground Water

The site, situated on the Cheasapeake Bay, is on a relatively porous sandy aquifer medium containing a contaminant plume migrating into the coastal wetlands. A *TreeMediation* program site assessment was performed by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. The *TreeMediation* program was implemented to create a border that would limit the migration of the contaminant plume. Annual sampling of leaf and stem tissues was performed along with evaluation of upgradient and downgradient ground water. TCE levels have been detected in leaf tissue midway through the first year of the program.

Green Bay, Wisconsin – 1996 (first Phyto of its kind in Wisconsin)
TPH in Soil

This project is located at a manufacturing facility that had a petroleum release in the mid-1970's where thousands of gallons of diesel fuel were spilled and leached into the soil. A *TreeMediation* program site assessment was performed by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. A *TreeMediation* program for remediating TPH components in the soil established willow trees in four hotspot areas. After four growing seasons, soil samples were collected and potential reductions in contaminants levels are being determined at this writing.

Freedom, Pennsylvania – 1996 (first Phyto of its kind in Pennsylvania)
BTEX in Ground Water and TPH in Soil

This project is located in Western Pennsylvania at the oldest petroleum refinery site in the United States. Petroleum contaminated soil and BTEX contaminated ground water was implemented to evaluate the potential of the *TreeMediation* program for remediating TCE and its derivatives in a shallow aquifer. Diesel Range Organics (DROs) degradation in land-farmed soil was also evaluated. Various treatments were employed to modify the soil in an effort to stimulate greater rates of degradation of DROs. After one and one-half years, contaminants levels are below detectable limits and the site is scheduled for closure.

Wayne, Michigan - 1996 (first Phyto of its kind in Michigan)
TCE in Ground Water

The site, located in Wayne, Michigan, a Detroit suburb, has a 9 foot deep aquifer with a low concentration TCE contaminant plume. This aquifer is overlain by a relatively porous sandy soil. A *TreeMediation* site assessment was performed by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. The *TreeMediation* program was implemented to create a border that would limit the migration of the contaminant plume. Some sampling of leaf and stem tissues was performed along with an evaluation of upgradient and downgradient ground water. TCE levels have been detected in leaf tissue midway through the first year of the program. Ground water concentrations in the monitoring well of the treatment area dropped from 1300 ppb to 48 ppb the first year after several years of no change. A rebound to ~600 ppb was realized the following spring as a likely result of soil flushing. Subsequent sampling is planned but has not yet occurred.

Reno, Nevada – 1997 (first Phyto of its kind in Nevada)
Waste Water Disposal via Irrigation

The site, in western Nevada, is situated on a 10 acre sand dune of a relatively porous aeolian layered sand deposits. A *TreeMediation* program site assessment was performed by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. The *TreeMediation* program consisted of planting 6 acres of trees to be irrigated with a new manufacturing plant's cooling tower waste water. The objective of this approach was to utilize all of the waste water and insure that no leachate develop to the aquifer located approximately 50 feet below ground surface. The system has functioned exceedingly well with the excellent growth of the trees and corresponding water use.

Findlay, Ohio – 1997 (first Phyto of its kind in Ohio)
Heavy Metals in Soil and TCE in Ground Water

The site, situated on the Findlay, Ohio, was formerly a metal plating facility that used TCE to clean metal parts. A *TreeMediation* site assessment was performed by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. The 10 foot deep aquifer consists of a relatively porous sandy medium and is overlain by silty clay soil. The object of the *TreeMediation* program was to remediate the 30 to 80 mg/L TCE concentration contaminant plume. Two years after trees were installed TCE concentration has fallen to approximately 1/10 of its original values after nearly eight years of virtually no change. Heavy metal contaminated soil has been planted but not evaluated.

Staten Island, New York – 1998 (first Phyto of its kind in New York)
Hydraulic Control of Landfill Leachate Contaminated Ground Water

The site, situated on Staten Island, New York and adjacent to Goethals Pond, a sensitive wetlands system. Two aquifers, one at 10 feet and the other at 30 feet, supply a small amount of water to the Goethals Pond that may be contaminated with landfill leactate. A *TreeMediation* site assessment was performed by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. A TreeMediation/TreeWell program was implemented to create a border that would limit the migration of the two aquifers. More than eight hundred trees were planted on the downgradient boundary of the 30 acre site. The TreeWell™ methodology was utilized to eliminate the effect of the shallow aquifer for the trees planted to control the deeper aquifer.

Augusta, Georgia - 1998
Phyto-Removal of Heavy Metals from landfill leachate

The site, situated at the Richmond County Landfill in Augusta, Georgia, was the setting for an evaluation of a Modular *TreeMediation* Bioreactor System (MTBS) to treat contaminated landfill leachate. Leachate containing relatively high levels of lead was processed through the MTBS cubes containing poplar, willow and paulownia trees as well as gama grass. The root/soil matrix was able to attenuate nearly 100% of the lead in the leachate which could then be disposed of via the public stormwater drainage system.

Logan, Ohio - 1999
Phytocover of Landfill – (first Phyto of its kind in Ohio)

The site, situated in southeast Ohio, on a relatively steep sloping landfill has seeps of contaminated leachate eminating from several points along the toe of the slope. A *TreeMediation* site assessment was performed by collecting and evaluating soil and ground water data and reviewing previously developed site environmental data. A *TreeMediation*-Phytocover program established a tree cover over 1000 trees on the landfill to intercept rainfall and limit the development of leachate.

Argonne, Illinois - 1999
TCE/Tritium in Soil and Ground Water

The site, situated at Argonne National Laboratory, a Department of Energy facility, has tritium and trichloroethylene (TCE) contaminated ground water that resulted past disposal practices. In addition TCE contaminated soil still exists in the historical disposal area. Contaminated ground water is located between 20 to 30 feet below ground surface(bgs) and is overlain with a dense silty clay soil and a shallow perched aquifer at 12 feet bgs. More than eight hundred willow and poplar trees were planted to harvest contaminated soil solutions and ground water and to establish hydraulic control of the aquifer. *TreeWell*™ methodology was employed to eliminate water uptake from a perched shallow aquifer and insure a near 100% efficiency of contaminated ground water removal. Annual sampling of leaf and stem tissues will be performed along with evaluation of upgradient and downgradient ground water.

Research and Development of Treemediation® Technology

Applied Natural Sciences, Inc. is committed to achieving widespread acceptance of phytoremediation as a cost effective alternative technology in the environmental remediation industry. As part of this commitment to propelling the technology forward, Dr. Gatliff has participated in a number of research and development programs designed to identify new applications for phytoremediation and explore ways to improve upon nature's own restorative powers.

Bioremediation of Contaminated Soils by Enhanced Plant Accumulation
Cooperative Research and Development Agreement (CRADA)
Argonne National Laboratory and Applied Natural Sciences, Inc.

Argonne National Laboratories and ANS share a CRADA under which the application of phytoremediation is being evaluated in controlled greenhouse and field experiments. One of the major objectives of the program is to identify the plant species best adapted for the uptake, sequestration, or degradation of specific contaminants and to demonstrate that plant-based cleanup systems are low-cost, low tech, environmentally friendly and will operate economically at actual contaminated sites.

The project team includes Ray R. Hinchman, Ph.D. and M. Christina Negri of Argonne National Laboratory. Dr. Hinchman has over thirty years of research and development experience in the environmental arena. Dr. Hinchman served as the Deputy Director of the Land Reclamation Program from 1977-1982 and earned his Ph.D. in Botany from the University of Chicago. Ms. Negri is a soil scientist and agronomist who has conducted extensive research and prepared technical papers on Phytoremediation and Pyto-dewatering Treatment processes. She earned her Dottore in Scienze Agrarie from the University of Milan, Italy.

Significant recent accomplishments:

Zinc Uptake in Hybrid Poplar Experiments

This greenhouse experiment on heavy metal uptake and sequestration by green plants included an experiment studying zinc uptake in hybrid poplar cuttings growing in inert quartz sand in lysimeter pots. This experiment, initiated in late March 1995, sought to confirm and extend field data collected by ANS which indicates high levels of zinc in the leaf tissue of hybrid poplar growing at a cleanup site that had zinc contamination approximately 4.6m (15 ft) below the surface. Detailed data was collected on contaminant uptake, translocation, and partitioning in plant organs, as well as on evapotranspiration rates, nutrient use, and biomass increase of the rapidly growing poplar shoots. The transpiration rate of potential phytoremediation plants is considered to be a critical factor, because the transpiration rate determines the rate at which contaminated soil solution is drawn into the plant to be processed.

In June 1995, when the poplars were growing well and had developed a normal root system, a series of treatments was started in which three groups of plants were given increasing doses of zinc ion in nutrient solution over a period of about two months. Leachate analyses for zinc by atomic absorption spectrophotometry indicated that in all cases, up to 800 µg/g (ppm) Zn, which was added in nutrient solution, was totally and selectively absorbed and sequestered by the plants in about 4 hours. This occurred during a single pass through the root system contained in the lysimeter pot. At levels of zinc above 1,000 µg/g (ppm) in nutrient added to the pots, leachate levels were always below 100 µg/g (ppm) in samples making one pass through the lysimeter pot and taken the same day as the zinc addition; these levels increased the following day, to concentrations up to 548 µg/g (ppm) for the 2,000 µg/g (ppm) zinc addition, and then decreased sharply the second day after the zinc addition, to concentrations less than 100 µg/g (ppm). Thereafter, the zinc concentration steadily decreased as the plants apparently reabsorbed the zinc as the nutrient was cycled through the pots on subsequent days. During the experiment, this pattern of zinc concentration changes in leachate following a zinc addition was observed twice.

Several leaf harvests were made during the course of the experiment. Initial leaf analyses showed 528 µg/g (ppm) Zn in mature (large) leaves, 300 µg/g Zn in medium-sized leaves, and 140 µg/g Zn in small leaves of plants that received a single dose of 50 µg/g (ppm) Zn in nutrient solution. In aboveground plant parts (leaves and branches) harvested at the end of the experiment, zinc

concentrations did not exceed 2,250 µg/g (ppm) Zn in the dry leaf tissue, or 900 µg/g (ppm) Zn in the woody branches, on a dry-weight basis.

The root tissues harvested at the end of the experiment showed much higher concentrations of accumulated and sequestered metal than did the aboveground parts. Even at the highest zinc uptake levels, there were only subtle visual toxicity symptoms (slight leaf chlorosis and some leaf "drooping") in the aboveground parts of the experimental plants when compared to controls.

The hybrid poplar greenhouse experiments complemented field studies and data collection on zinc uptake by hybrid poplar trees implemented through ANS' *TreeMediation* process. Results from several *TreeMediation* systems that have been in place five years indicate the hydraulic control of a downgradient plume in a tight soil matrix. Currently, fourteen systems are in place in the field, with additional sites being established during 1996. Soil and ground water as deep as 9m (30 ft) are being treated, and plants are under investigation for deeper conditions. With a properly engineered system, such as TreeMediation, rooting activity in the contaminated area has been realized in one to two years.

Zinc Uptake in Eastern Gamagrass

In a current experiment, Eastern gamagrass transplants are being grown in inert quartz sand in lysimeter pots. In April 1996, when the gamagrass was growing well and had developed a normal root system, a series of treatments was started in which three groups of plants, each group consisting of five replicates, were continuously given zinc ion in nutrient solution at concentrations of 160 µg/g Zn, 600 µg/g Zn, and 0 µg/g Zn (control), respectively, over a period of about two months. Detailed data were collected on zinc uptake, translocation, and partitioning in the gamagrass roots and shoots, as well as on evapotranspiration rates, nutrient use, and biomass increase of the rapidly growing plants. Methods were essentially identical to those described for the hybrid poplar experiment.

Leachate analyses for zinc by atomic absorption spectrophotometry indicate that initially plants subjected to both levels of zinc were removing up to 70% of the zinc from the leachate. After two months, the plants receiving 160 µg/g Zn had grown considerably and were almost the same size as the controls (no zinc), but some of the mature leaf blades were rolled; the mean zinc removal rate for these plants was 50% of the zinc in the leachate. The plants receiving 600 µg/g Zn were smaller than the controls after two months, their color was a darker green, most of the mature leaf blades were rolled, and the mean zinc removal rate was about 30% of the zinc in the soil solution (leachate).

In mid-June 1996 three replicates of each Eastern gamagrass treatment were harvested. As was observed in the hybrid poplar zinc uptake experiment, the Eastern gamagrass root tissues harvested in June 1996 showed much higher concentrations of accumulated and sequestered metal than did the aboveground parts. The two remaining replicates in each treatment were allowed to continue growing under the same treatment regime after the tops were pruned back to a length of 10 cm above the substrate surface, to observe regrowth characteristics and any changes in zinc uptake. This phase of the experiment is ongoing.

A reduction of zinc from the soil solution of between 90-50% (Eastern gamagrass), and 99+% (hybrid poplar) when the concentration in the soil solution is several hundred ppm has major implications for the development of effective plant-based cleanup systems for contaminated soils, ground water, and wastewater that is both low-tech and low-cost. These data demonstrate a very effective uptake, bioaccumulation, and sequestration system for zinc in both hybrid poplar and Eastern gamagrass, as well as high evapotranspiration rates and a wide range of adaptability for both of these versatile plants.

Evaluation of Rooting Patterns and Biomass Production of Hybrid Poplar as a Function of Planting Method of Cuttings

This experiment evaluated the rate and success of root generation and aboveground biomass production in hybrid poplar cuttings planted in quartz sand in vertical and horizontal patterns at different depths. This experiment was aimed at developing planting techniques that may enhance or facilitate root recovery during whole-plant harvesting.

Data generated so far confirms that hybrid poplar are a very versatile species whose rooting pattern could be relatively easily molded to match the existing contamination pattern and the needs of the harvesting machines.

Evaluation of TCE and PCE Uptake and Fate in Plants

ANS participated in a research group which developed a rapid and simplified analytical method for the detection and quantitative analysis of TCE, PCE, and their degradation product, TCAA (trichloroacetic acid) in plant tissue. A number of samples of plant tissue have been analyzed using this method, and studies are ongoing to correlate the presence and concentration of TCAA in plants and its contamination "history" in the underlying ground water or soil.

Small Business Innovation Research (SBIR) Program

ANS participated in an SBIR program that evaluated the bioaccumulation of heavy metals from soil and ground water by trees such as poplars and willows. This research program focused on aggressively growing trees that have the potential to impact deeper contaminated soil and ground water and thereby expanding the role of phytoremediation to a greater number of sites. This particular research program involved the ability of such trees to remove arsenic and lead from the soil solution.

REPRESENTATIVE PROJECT EXPERIENCE

LOCATION	SITE CONDITIONS	SERVICES PROVIDED TO DATE
Illinois	General site restoration of pesticide and salt affected soil	Agronomic Assessment Completed Vegetation Planted Regulatory Approval Received Site Closed
South Carolina	General site restoration of pesticide and salt affected soil	Agronomic Assessment Completed Trees Planted On-going Site Monitoring
Oklahoma	Nitrate in soil and ground water (<10ft)	Agronomic Assessment Completed Program implemented in 1990
Pennsylvania	Enhancement of Vegetation on strip mine soil	Agronomic Assessment Completed Vegetation Planted and treated 4th Year of Site Monitoring
New Jersey	Nitrate and Ammonium in soil and ground water (<20ft)	Agronomic Assessment Completed Trees Planted Regulatory Agency Endorsement Program implemented in 1991
Illinois	Nitrate, Ammonium and Pesticides in soil and ground water (<10ft)	Agronomic Assessment Completed Planted Regulatory Agency Endorsement Program implemented in 1992
Wisconsin	Nitrate, Ammonium and Pesticides in soil and ground water (<10ft)	Agronomic Assessment Completed Trees Planted Program implemented in 1992
Louisiana	Revegetation of disturbed soil from extraction process	Agronomic Assessment Completed Vegetation Planted Program implemented in 1992
South Carolina	Heavy metals in soil and ground water (<20ft)	Agronomic Assessment Completed Vegetation Planted Regulatory Agency Endorsement Program implemented in 1992
West Virginia	BTEX in ground water (<10ft)	Agronomic Assessment Completed Poplar Trees Planted Regulatory Agency Endorsement Program implemented in 1993
New York	Hydraulic control of ground water (shallow aquifer 10-15ft-bgs) / (deep aquifer 30-35ft-bgs)	Agronomic Assessment Completed Poplar Trees Planted Regulatory Agency Endorsement Program implemented in 1998
Ohio	Phyto-cover to control landfill leachate	Agronomic Assessment Completed Poplar Trees to be Planted, Spring 1999 Regulatory Agency Endorsement
Illinois	TCE/PCE and Tritium in ground water (20-30ft-bgs)	Agronomic Assessment Completed Poplar Trees to be Planted, Spring 1999 Regulatory Agency Endorsement

LOCATION	SITE CONDITIONS	SERVICES PROVIDED TO DATE
Wisconsin	TPH in soil (0-12ft)	Agronomic Assessment Completed Willow Trees Planted On-going Site Monitoring Regulatory Agency Endorsement Program implemented in 1996
Pennsylvania	TPH/BTEX in soil (0-5ft) and ground water (15ft)	Agronomic Assessment Completed Willow/Poplar/Aspen Trees Planted On-going Site Monitoring Regulatory Agency Endorsement Program implemented in 1996
Maryland	PCE/TCE/Heavy Metals in soil (0-2ft) and Ground Water (4-12ft)	Agronomic Assessment Completed Poplar Trees Planted On-going Site Monitoring Regulatory Agency Endorsement Program implemented in 1996
Mississippi	Heavy Metals in surficial soils	Bench Study Ongoing
Louisiana	TCE/TPH in soil (0-2ft) and ground water (2-6ft)	Agronomic Assessment Completed Willow and Poplar Trees Planted On-going Site Monitoring Program implemented in 1996
Michigan	TCE in ground water (10ft)	Agronomic Assessment Completed Poplar Trees Planted On-going Site Monitoring Regulatory Agency Endorsement Program implemented in 1996
Nevada	Wastewater disposal in soil (0-20ft)	Agronomic Assessment Completed Willow Trees Planted Regulatory Agency Endorsement Program implemented in 1996 & 1997
South Carolina	BTEX in Ground water (15ft)	Agronomic Assessment Completed Willow and/or Poplar Trees to be Planted Program to be implemented in 1997
New Jersey	TCE in ground water (<10ft)	Agronomic Assessment Completed
Wisconsin	Manufactured gas site, TPH/PAH in soil (0-15ft)	Agronomic Assessment Completed
Ohio	TCE/PCE in ground water (4-10ft-bgs)	Agronomic Assessment Completed Willow Trees Planted Regulatory Agency Endorsement Program implemented in 1999
Ohio	TCE/PCE in ground water (10-12ft-bgs)	Agronomic Assessment Completed Poplar Trees Planted Regulatory Agency Endorsement Program implemented in 1997
New Jersey	Picatinny Arsenal - heavy metals in soil (1-3ft)	SBIR Research Project Completed

REPRESENTATIVE CLIENT LIST

Allied Signal Corp.

Ashland Oil

Ashland Chemical

Brush Wellman, Inc.

CSX Corporation

Dames & Moore, Inc.

U.S. Department of Energy

Dowell-Schlumberger

Fluor-Daniel Corp.

Geraghty & Miller, Inc.

Goodyear Corporation

PPG Corporation

Kaiser Aluminum & Chemical Corporation

Pittston Coal Company

Procter & Gamble, Inc.

Tyco Corporation

United States Environmental Protection Agency

Wellman Corporation

Wisconsin Gas

RESUMES OF KEY PERSONNEL

Edward G. Gatliff, Ph.D.
President

Dr. Gatliff has been active in the environmental industry since 1987, primarily applying his understanding of vegetation and agronomic principles to remediate contaminated soil and ground water. In the fall of 1990 he conceived an engineered approach for utilizing trees to remediate deep soil and ground water, now known as *TreeMediation*®. With the implementation of a *TreeMediation* program in the fall of 1991, he became the pioneer in the use of phytoremediation to clean up deep soil and ground water. Through Applied Natural Sciences, Dr. Gatliff continues to lead the nation in the commercial implementation of phytoremediation programs, with over 15 projects in progress and many more pending.

Dr. Gatliff earned his Ph.D. in Agronomy from the University of Nebraska-Lincoln. He was formerly Research Director for Servi-Tech, Inc., the world's largest agricultural consulting and testing firm; as well as the Analytical Sciences Division Director for Bowser-Morner, Inc., an environmental and geotechnical engineering and testing firm.

Research Highlights:

Project Manager of multi-disciplinary environmental assessment and remediation efforts of agricultural chemical affected sites in Illinois, Wisconsin, New Jersey, North Carolina, South Carolina and Oklahoma. Developed and supervised the remediation strategy of soil contaminated with agricultural fertilizers and chemicals utilizing bioremediation techniques including TreeMediation.

Researched the fate of fertilizer phosphorus and nitrogen placed at various depths in the soil and taken up by plants. Radioactive isotope of phosphorus and a stable isotope of nitrogen were utilized in the evaluation.

Directed and conducted regional (High Plains) agricultural and environmental field and laboratory research.

Laboratory experimentation in the movement and fate of Chromium (VI) in various soils.

Researched pesticide degradation in the soil for a variety of agricultural chemicals.

Statistician and Computer Programmer for the development of appropriate statistical techniques for the analysis of soil and ground water data.

Developed a prototype of a modified electrophoretic process for extracting chemicals from soils.

Edward G. Gatliff , Ph.D.
Continued

Report & Article Highlights:

Environmental Audit of PCB's and nitrogen in soils and ground water at a manufacturing facility in Oklahoma. Included temporal evaluation of ground water quality, inventory of existing PCB contamination as well as potential areas of contamination based on historical information. (1992)

Evaluation of *TreeMediation* as a soil and ground water remediation approach with pesticides and fertilizer products as target contaminants. (1993)

“Say It With Trees", October, 1993, Soils, Group III Communications, Inc., Publishers

"Natural Approach Adopted for Remediation", December, 1993, Environmental Protection, Stevens Publishing Co., Inc., Publishers

"Innovative Vegetative Remediation Process Using Trees Offers Advantages Over Traditional Pump and Treat Technologies", May, 1994, Remediation Journal, Executive Enterprises, Publishers, Volume 4, No. 3.

Nyer, E.K. and E.G.Gatliff. 1996. Phytoremediation. Ground Water Monitoring and Remediation 16(1):58-62

Quinn, J.J., M.C. Negri, R.R. Hinchman, L.P. Moos, J.B. Wozniak and E.G. Gatliff. 2000. Predicting the Effect of Deep-Rooted Hybrid Poplars on the Groundwater Flow System at a Large-Scale Phytoremediation Site. International Journal of Phytoremediation (*in publication*)

John W. Zupancic, M.S.

Associate

Mr. Zupancic brings over seventeen years of experience in soil science and agronomy to the *TreeMediation* project team. As an Associate, Mr. Zupancic provides specialized expertise in irrigation, soil characterization, and crop and soil monitoring systems.

Mr. Zupancic has been involved in the research and development and field application of agronomic principals in since the late 1970s. He has successfully applied these concepts to site restoration projects in the environmental, agricultural, and recreational industries.

Mr. Zupancic earned his Master of Science in Agronomy from the University of Nebraska with an emphasis in soil fertility and soil chemistry. He is a Certified Professional Soil Scientist through the American Registry of Certified Professionals in Agronomy, Crops and Soils.

List of Publications:

"Application of Acid-neutralized Ammonia through Sprinkler Irrigation Systems", Mar. 1982, M.S. thesis, Univ. of Nebraska.

"Nitrate Toxicity May Follow Hail", Dec. 1986. Crops and Soils Magazine.

"Irrigation Water Quality Affects Turf Management", Jul. 1991. HeartBeat Newsletter. Heart of America Golf Course Superintendents Assn.

"Determination of Soil Nitrate by Transnitration of Salicylic Acid", 1990. Communications in Soil Science and Plant Analysis, 21(13-16),1705.

"Designing Effective Soil Monitoring Plans for Effluent Application Systems", June 1995. Proceedings of Am. Society of Agricultural Engineers.

"Field Evaluation of Soil Nitrate Profile Removal by Alfalfa", June 1995. Proceedings of Am. Society of Agricultural Engineers

"Case Study of Water Use by Irrigators Who Converted from Surface to Sprinkler Irrigation", 1990. Servi-Tech Research for Valmont Industries.

Bruce W. Pultz
Irrigation Specialist
Associate

Mr. Pultz brings extensive experience in the agricultural industry and a unique technical expertise in crop production and irrigation to the *TreeMediation* project team.

Mr. Pultz has spent a large portion of his career involved in the design, production and marketing of irrigation systems for the agricultural industry. As such, he has a wide network of projects and involvement with local, state and federal government agencies, research facilities, and funding sources.

A number of the systems and methods developed by Mr. Pultz have resulted in dramatic increases in plant population and production yields. In addition, Mr. Pultz' methods have resulted in the reduction of fertilizers use and water consumption as much as thirty to fifty percent.

Mr. Pultz has a Masters of International Management from the American Graduate Schools of International Management. He has traveled extensively for business throughout the world and has taught classes at Cornell and Rutgers Universities.