Final Report

Project Title: Excess Manures for Mine Reclamation and Biofuel Production

Timeframe Covered: September 27, 2007 to September 27, 2011

Date of Submission of Report: September 29, 2011

Deliverables Identified on the Grant Agreement:

- Full-scale demonstration of switchgrass and native grassland biofuel production on parallel plots of mine lands using composted poultry manure as a soil amendment.
- Facilitation of a nutrient trade for qualifying poultry producers that export manure to nutrient deficient mine lands.
- Facilitation of sale of harvested biomass fluxes, biomass production and Project methodology for technology transfer and commercial application.

pennsylvania environmental council

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Executive Summary

The Pennsylvania Environmental Council in partnership with the Pennsylvania State University Department of Crop & Soil Sciences successfully demonstrated the enhanced reclamation of 70 acres of four separate former surface mine sites in western Pennsylvania using excess poultry manure in combination with waste paper mill sludge or composted poultry manure as soil amendments for restoring soil health and productivity.

The methodology meets NRCS Conservation Innovation Grant priorities including restoration of soil quality on degraded sites, addressing nutrient impairment in the Chesapeake Bay Watershed and the utilization of a market based approach, water quality trading, to address water quality and surface mine land reclamation.

The Project met the following objectives; export a minimum of 1,600 tons of poultry manure from nutrient impaired watersheds in Schuylkill County and Lancaster County, engage agricultural producers in the nutrient trading program for the Chesapeake Bay Watershed in PA, demonstrate that large quantities of manure (20-35 tons per acre) can be used as a soil amendment on degraded mine lands without adverse water quality impacts, monitor reclamation acreage for quantification of carbon and nutrient sequestration in reclaimed mine soils, monitor biomass productivity on reclaimed acreage, and evaluate economic potential of business model using poultry manure as a soil amendment for surface mine reclamation purposes including biofuel, carbon sequestration and water quality/nutrient trading markets.

The key accomplishments of the Projects are; the reclamation, restoration and productivity of soils on 70 acres for the production of warm season biomass crops at 4 surface mine sites in Western PA, the facilitation of a nutrient trade through the export of 1,500 tons of broiler manure from poultry manure farms in the Chesapeake Bay Watershed in Lancaster County to a former surface mine site outside the Bay Watershed in Elk County, technology transfer program including Field Days at a field research Project site in Schuylkill County and at a 20-acre demonstration Project site in Clearfield County plus numerous Project presentations to members of the agriculture and mining industry in PA, development of a Manure on Mine-lands for Biomass Production business model with the assistance of the Duquesne University MBA Sustainability Program.

As of the writing of this report in September 2011, all of the Project objectives have been met except for the harvest and sale of the biomass crop because the first warm season grass crop was not planted until June 2009 and therefore a commercial yield of over 2 tons per acre is not expected until the summer or fall of 2012. However, field measurements collected in June 2011 indicate that 20 acres reclaimed at 2 adjacent mines in Clearfield County may yield between 1.5 and 2.0 tons per acre in the fall of 2011. If the crop is to be harvested for biomass it is recommended that it be mowed in late November or early December 2011.

The Project was originally scheduled to be completed in September 2010, however the Project was extended until September 2011 to enable the reclamation of a total of 70 acres and the facilitation of a nutrient trade during the summer of 2010.

The Project directly benefits poultry farmers in nutrient impaired watershed by enabling the transfer of poultry manure to nutrient deficient watersheds in western PA. It benefits mine land owners who seek to improve and restore soil health and productivity at degraded surface mine sites and it benefits paper mills seeking to beneficially reuse waste paper mill sludge as a soil amendment rather than conventional disposal in a landfill or as a dewatered fuel in an industrial boiler.

The Project employed an innovative alternative mine reclamation methodology/technology involving the use of waste paper mill sludge in combination with raw poultry manure or composted poultry manure as soil amendments for the purposes warm season grass as biomass energy crops.

The demonstration Project resulted in the transfer of approximately 1,400 tons of poultry manure from nutrient impaired watersheds in Schuylkill and Lancaster Counties to 3 surface mine sites totaling 30 acres in Clearfield County where the manure was applied as a soil amendment.

The transfer of 1,500 tons of raw broiler litter from nutrient impaired watersheds in Lancaster County to 105 acres at a former surface mine site in Elk County. The export of the 1,500 tons of broiler litter resulted in the removal of 84,000 pounds of nitrogen and 84,000 pounds of phosphorous from nutrient impaired watersheds in the Bay Watershed to nutrient deficient mine lands outside the Bay Watershed. 800 of the 1,500 tons were used as a soil amendment on 40 acres in combination with 4,400 tons of paper mill sludge for the production of warm season grasses. The remaining 700 tons of broiler litter was used to topdress 65 separate acres at the SweetSoil site.

The export of the 1,500 tons of broiler manure facilitated a nutrient trade which resulted in the sale of 57,065 nitrogen credits and 7,134 phosphorous credits as part of the PA Nutrient Trading Program in 2010.

The 70 combined acres of reclaimed former mine lands resulting from the Project will produce an annual biomass crop of approximately 210 tons by 2014.

The Project resulted in a business model for the reclamation of degraded former surface mine lands in western PA that could provide an annual return of up to $140 per acre contingent upon the economic availability of poultry manure and paper mill sludge as soil amendments for the mine lands.

The USDA Farm Service Agency Biomass Crop Assistance Program (BCAP) can directly support the production of biomass crops on mine lands reclaimed using the methodology demonstrated by the Project. The NRCS Environmental Quality Incentives Program (EQIP) can also support the implementation of the enhance mine revegetation

methodology by providing support for no-till practices on reclaimed sites. In addition the 2011 NRCS Wildlife Habitat Incentive Program (WHIP) in PA supports the improvement of Grassland Habitat on previously mined lands including Conservation Cover and Upland Wildlife Habitat Management which may be applicable to mine lands reclaimed using the Project methodology.

It is recommended that the PA Nutrient Trading Program promotes the export of poultry manure to nutrient deficient mine lands in cooperation with former mine land owners, mining companies and the PA Bureau of Mining to support the enhanced reclamation of former and active mine lands using excess poultry manure and paper mill sludge as soil amendments for the production of warm season grasses as biomass energy crops. It is also recommended that the state and federal government continue to support the production of biomass energy crops through conservation programs including the BCAP, EQIP, WHIP and the Pennsylvania Alternative Energy Credit Program. Additional research is needed to evaluate the long term biomass productivity of surface mine soils amended with poultry manure and paper mill sludge. Alternative carbonaceous waste streams and materials need to be identified as substitutes for paper mill sludge given its limited supply in mining regions in PA.

Introduction

The US Department of Agriculture Natural Resources Conservation Services Conservation Innovation Grant Program provided funding to the Pennsylvania Environmental Council (PEC), a statewide non-profit environmental research and education organization to implement a 30 acre demonstration Project using raw poultry manure co-applied with paper mill sludge or composted poultry manure for production of switchgrass and other warm season grasses on 3 active coal strip mines in Clearfield County plus a 40-acre demonstration Project using raw poultry manure and paper mill sludge as soil amendment for the production of a mix of switchgrass and atlantic coastal panic grass. The demonstration Projects are supported by a broad partnership including the Foundation for Pennsylvania Watersheds, the Capitol Region Resource Conservation and Development Board, the Chesapeake Bay Foundation, the Eastern Pennsylvania Coalition for Abandoned Mine Lands, Pennsylvania State University, and Wenger's Feed Mill, Inc.

Background

The US Department of Agriculture Natural Resources Conservation Services Conservation Innovation Grant Program provided funding for the Pennsylvania Environmental Council to implement a commercial scale surface mine land reclamation Project using poultry manure as a soil amendment for abandoned mine lands for the production of switchgrass and other warm season grasses and legumes as a biomass energy crop.

The Chesapeake Bay Watershed in Pennsylvania is impaired by excess nutrient loading due to multiple sources including agricultural. Pennsylvania has 180,000 acres of abandoned mine lands and approximately 5,500 acres of active coal mine sites thate require reclamation on an annual basis. Restoration of soil quality and productivity on these degraded lands requires large nutrient and carbon inputs and thus a potential use for excess manure.

Since 2005, The Pennsylvania Environmental Council in partnership with the Pennsylvania State University have been developing a mine reclamation technique using poultry manure stabilized with paper mill residuals or by composting manure to sequester nutrients and allow sustained production of biomass energy crops. If applied on a broad scale in PA this technique can reduce poultry manure land application in the Bay Watershed while simultaneously restoring soils on mined lands.

Beginning in July 2007, the Project partners implemented a 30-acre demonstration Project in Clearfield County and a 40-acre demonstration Project in Elk County while continuing an ongoing field research Project at a 0.5 acre site in Schuylkill County. All of the Projects are located in Pennsylvania.

PEC in partnership with the Pennsylvania State University Department of Crop & Soil Sciences completed a 0.5 acre field research Project in Schuylkill County in September 2010. The research Project evaluated nutrient and carbon inputs, fluxes, and sequestration from manure application and switchgrass growth on a series of multiple test plots that received varying treatments of composted poultry manure, raw poultry manure and waste paper mill sludge and control plots treated with nitrogen and commercial fertilizer. The preliminary results of the research Project informed the design of the 70-acre demonstration Project.

The 30-acre demonstration Project consists of multiple plots of three warm season grass species in mono and mixed cultures on 30 acres of mined land reclaimed with poultry manure mixed with paper mill sludge and composted manure. The 30 acres are expected to produce an annual crop of biomass for the local biomass energy market beginning in 2012. The 40-acre demonstration Project in Elk County was seeded with a mixture of Switchgrass and Atlantic Coastal Panic Grass on soils amended with a mixture of poultry manure and paper mill sludge.

History

Beginning in 2005, PEC and the Project partners set out to address four pressing conservation issues at once: the export and beneficial use of excess poultry manures generated in nutrient impaired watersheds; the reclamation of abandoned mine lands to mitigate water quality impairments resulting from those lands; beneficial use of paper mill sludge waste; and, the cultivation of renewable biomass for energy in PA. Laboratory and field scale research efforts focused on developing the ideal mixture,

application, and cultivation of soil amendments and mine spoil material to maximize biomass production, plant nutrient uptake and minimize nutrient runoff and leachate.

The widespread application of the methodology can improve water resources by transporting manure nutrients out of nutrient dense watersheds. Use and sequestration of the nutrients for mine reclamation will improve water resources in receiving watersheds through soil stabilization, reduction in erosion and potentially reduction in generation of acid mine drainage. Soil resources will be improved by reducing application of excess nutrients to agricultural soils, and by remediation and reclamation of marginal lands in mining regions. Overall soil quality and productivity of mined lands can be improved and returned to productive use. The Project also beneficially reuses paper mill waste and enhances atmospheric resources by increasing carbon sequestration in mine spoils and by production of renewable biomass energy crops.

Initial lab and greenhouse scale investigations determined that poultry manure is a highly effective nutrient source for soil augmentation of former surface mine sites and that paper mill sludge provides an important source of carbon for the soil mixture. In 2006, the field scale research Project was launched at a former surface mine site in Schuylkill County to further refine the methodology of using poultry manure and paper mill sludge or composted poultry manure as soil amendments for mine reclamation.

The field scale research project, completed in September 2010, confirmed greenhouse scale research that degraded soils on former surface mine sites can be restored to produce yields comparable switchgrass yields on undisturbed soils. This research was used to inform the Project design for the demonstration Projects. Additional detail about the field scale research project is included in the Findings section of this report

Personnel

Table 1. Key Personnel Involved in Demonstration Project

NAME	ORGANIZATION	RESPONSIBILITIES
Brian Hill	Pennsylvania Environmental Council	Project manager and principal investigator 2007-2008
Scott Van de Mark	Pennsylvania Environmental Council	Project manager and principal investigator 2008-2010
Jack Ubinger	Pennsylvania Environmental Council	Project Advisor 2008-2010
Richard Stehouwer	Pennsylvania State University	Soil Scientist
Marvin Hall	Pennsylvania State University	Forage Scientist
Ashlee Dere	Pennsylvania State University	Graduate Student - Soil Scientist
Kristen MacDonald	Pennsylvania State University	Research Associate - Soil Scientist
Susan Parry John Dawes Emily Wade Harry Campbell Doug Saylor Peter Hughes	Capital RC&D The Foundation for Pennsylvania Watersheds Wenger Feed Mills, Inc. Chesapeake Bay Foundation DEP Bureau of Mining Moshannon District Office Red Barn Trading Company	All of these people served as Project advisors

Review of Methods - Project Activities

The following narrative describes how the Project objectives were achieved during the course of the Project.

Implement full scale demonstration Project

Beginning in September 2007, the Project team sought to identify candidate sites for the 30-acre commercial scale demonstration Project.

During the winter of 2008, the Project team consulted with the PA Department of Environmental Protection Bureau of Mining Regional Office in Ebensburg about identifying potential 30-acre mine reclamation Projects. Bureau of Mining staff recommended several operating surface mines located near the town of Morrisdale in Clearfield County that were slated for reclamation in the summer of 2008. The Project team coordinated reclamation and revegetation activities with the mine operator that were implemented beginning in the summer of 2008 resulting in the reclamation of 30 combined acres using raw poultry manure combined with waste paper mill sludge or composted poultry manure as soil amendments.

The authorized reclamation plan in the mining permits for the 3 active mines, Lower Emigh, J and Maxton, were modified by the Bureau of Mining in 2008 to allow for the application of poultry manure and paper mill sludge as soil amendments for the purpose of revegetating the surface mines. The application of the paper mill sludge at the Lower Emigh and J sites was permitted under the PA DEP Bureau of Land Recycling and Waste Management General Permit for Processing/Beneficial Use of Residual Waste, Permit No. WMGR002D008.

Project management efforts continued in July and August 2008 with the contracting of a licensed manure hauler and a remediation contractor for the reclamation Projects at the 3 surface mines, Lower Emigh, J and Maxton mines in Morrisdale in Clearfield County. The Project team and partners coordinated the delivery of paper mill sludge, composted poultry manure and raw poultry manure to the Lower Emigh and J sites in September 2008. Delivery of materials and reclamation of the Maxton site occurred in the spring of 2009. Additional detail regarding reclamation activities at the 3 mines is provided below.

<u>Lower Emigh Mine Site – 12 acre Demonstration Project:</u>

5-Acre Demonstration Plot Reclaimed with Raw Manure and Paper Mill Sludge:
In September 2008, approximately 590 tons of paper mill sludge was delivered to the Lower Emigh mine site for use as a soil amendment in combination with layer manure on 5 acres as part of the reclamation Project. The paper mill sludge was delivered from the American Eagle Paper Mills facility in Tyrone, PA.

Also in September 2008 raw layer manure was delivered to the Lower Emigh for use as a soil amendment at an application rate of 30 tons per acre on a 5-acre demonstration plot. The layer manure was delivered from the Hegins Valley Poultry Farm in Hegins in Schuylkill County.

Following the delivery of the poultry manure in September 2008, stockpiled mine spoil material and stockpile topsoil, paper mill sludge (110 tons per acre) and raw layer manure (30 tons per acre) were applied separately and were subsequently mixed utilizing a chisel plow to thoroughly mix the material prior to seeding with oats for the purpose of establishing a viable cover crop through fall of 2008 and winter of 2009.

Between June 4 and June 15, 2009 the 5 acres reclaimed with layer manure and paper mill sludge were divided in to multiple 40' wide strips of varying lengths and were reseeded with monocultures and polyculture stands of swichgrass, big bluestem, Atlantic coastal panic grass. Some of the strip plots were also seeded with the legumes showy tick trefoil and birdsfoot trefoil.

0.6 Acre Research Project:
Also in September 2008, a 0.6 acre parcel at the Lower Emigh site was reclaimed with approximately 20 tons of layer manure and 60 tons of paper mill sludge. A smaller plot within the 0.6 acre research plot was divided in to twelve 30' x 40' research plots which were then divided in to five 8' x 30' sub-plots. Different treatments of manure/pulp mill sludge mix, compost and lime/fertilizer mix were applied to the twelve 40' x 30 plots. Border areas around the plots were amended with lime and fertilizer.

7-Acre Demonstration Plot Reclaimed with Composted Poultry Manure
In September 2008, approximately 450 tons of composted poultry manure was delivered and applied at the Lower Emigh site. The composted manure was provided by the Chesapeake Bay Foundation and was delivered from the Terra-Gro Inc. poultry manure composting facility in Terre Hill in Lancaster County, PA. The composted manure was applied at a rate of approximately 65 tons per acre on 7 acres. A chisel plow was used to mix the composted manure with mine spoil material prior to seeding with oats to establish a viable cover crop through fall of 2008 and winter of 2009.

Between June 4 and June 15, 2009 the 7 acres were divided in to multiple 40' wide strips of varying lengths and were reseeded with monocultures and polyculture stands of swichgrass, big bluestem, Atlantic coastal panic grass. Some of the strip plots were also seeded with legumes showy tick trefoil and birdsfoot trefoil.

Photographs of reclamation activities conducted in June 2009 at the Lower Emigh site are presented below.

Final cover on left is soil material, final cover on right is shale.

Compost spread in foreground, manure+paper mill sludge in background. One pass with chisel plow.

J Mine Site – 8 acre Demonstration Project:

In September 2008, approximately 263 tons of layer manure were delivered to the J mine site from the Hegins Valley Poultry Farm in Schuylkill County.

The 8 acre "J" site was amended with manure plus paper mill sludge. The 8 acre J site received an application of approximately 33 tons of layer manure per acre and 102 tons of paper mill sludge per acre. The site was seeded with oats in September 2008 to establish a viable cover crop through the fall and winter of 2008.

Approximately one half of the 8-acre demonstration plot at the J site was reseeded with a monoculture of switchgrass in early June 2009. The remaining acreage was seeded with a mix of switchgrass, Atlantic coastal panic grass and big bluestem.

Maxton Mine Site – 10 acre Demonstration Project:

The Project team implemented a 10-acre revegetation Project at the Maxton mine site in May and June 2009. The Maxton site is located adjacent to the Lower Emigh mine site near Morrisdale in Clearfield County.

In May 2009, 650 tons of composted poultry manure were delivered to and stockpiled at the Maxton site. The composted manure was provided by the Chesapeake Bay Foundation and was delivered from the Terra-Gro Inc. poultry manure composting facility in Terre Hill in Lancaster County, PA. In June 2009, the composted manure was applied and disc tilled with previously stockpiled mine spoil material and topsoil. The treated acreage was then divided into multiple 40' wide strips of varying lengths which were seeded with monocultures and polyculture stands of switchgrass, big bluestem, Atlantic coastal panic grass.

Sweet Soil Site – 40 acre Demonstration Project

The Project team coordinated the delivery of approximately 1,500 tons of broiler manure to a former surface mine site, the Sweet Soil, Inc. site, during the week of July 19, 2010. The site is located approximately 3 miles north of the town of Brockway in northern Jefferson County.

During the period of July 26 to August 6, 2010, 800 tons of the stockpiled broiler manure was applied to 30 acres at the Sweet Soil, Inc. site and 10 acres at the adjoining Brockway Sportsmen's Club site. Sweet Soil, Inc. leases the property from the Brockway Sportsmen's Club.

The broiler litter was applied at a rate of 20 tons per acre resulting in an application rate of approximately 1,120 pounds of total N and 1,120 pounds of phosphorous as P_2O_5 per acre.

The remaining balance of 700 tons of broiler manure was used to topdress approximately 65 acres at the Sweet Soil, Inc. property. The Sweet Soil, Inc. site is approximately 275 acres.

Approximately 5,000 tons of paper mill sludge produced by American Eagle Paper Mills in Tyrone, PA was stockpiled at the Sweet Soil, Inc. site as of June 30, 2010. Following the application of the broiler litter approximately 110 tons per acre of paper mill sludge were applied on the 40 treated acres for a total application of 4,400 tons. The reclamation contractor then tilled the treated acres using a disc till. The treated acres were then seeded with wheat seed to establish a viable green cover crop for the remainder of 2010.

The Sweet Soil, Inc. site and the Brockway Sportmen's Club sites are located in the Ohio River Basin approximately 12 miles west of the Chesapeake Bay Watershed Boundary in Elk County.

During the spring and early summer of 2011, the Project team coordinated and executed the mowing, spraying and seeding of the reclaimed 30 acres at the Sweet Soil, Inc. site and the reclaimed 10 acres at the adjacent BrockWay Sportsmen's Club site.

The 40 combined acres of winter wheat that were planted in July 2010 at the two sites were mowed and subsequently sprayed with Roundup brand herbicide on June 9 and 10, 2011. During the week of June 13, 2011, the 40 acres were seeded with a no-till drill with a 50% switchgrass and 50% Atlantic coastal panic grass mix to establish a biomass crop. The seed mix was applied at a rate of 9 pounds of combined seed per acre. The 50/50 mix of switchgrass and atlantic coastal panic grass based on the observed comparatively greater biomass productivity of that mix in test plots at the Lower Emigh demonstration Project site in the fall of 2010. Details about the preliminary biomass productivity at the Lower Emigh Site are presented in the Findings section of this report.

In late August 2011, The 40 combined acres were mowed with a brush hog to a height of 10 inches to control weed growth and enable the warm season grass seedlings to compete better with weeds.

Facilitate a Nutrient Trade

In the summer of 2009 the Project team began negotiations with Red Barn Trading, Inc. (http://redbarntrading.com/) for the delivery of an unspecified quantity of broiler manure to the Sweet Soil property, a former strip mine, in Elk County located approximately 2 miles north of Brockway, Pennsylvania. The Sweet Soil site is located in the Ohio River Basin approximately 12 miles west of the Chesapeake Bay Watershed Boundary in Elk County. Red Barn Trading, Inc. specializes in trading nutrient reduction credits in Pennsylvania.

.The Sweet Soil property was identified as a suitable former surface mine site outside the Chesapeake Bay Watershed that could receive a significant quantity of poultry manure (approximately 1,000 tons) as a soil amendment that would also facilitate a nutrient trade through the export of poultry manure from farms eligible to generate nutrient reduction credits under the PA nutrient trading program.

Discussions continued with Red Barn Trading, Inc. through the spring of 2010 resulting in the delivery of approximately 1,500 tons of broiler manure to the Sweet Soil, Inc. site, during the week of July 19, 2010.

During the period of July 26 to August 6, 2010, 800 tons of the stockpiled broiler manure was applied to 30 acres at the Sweet Soil, Inc. site and 10 acres at the adjoining Brockway Sportsmen's Club site. Sweet Soil, Inc. leases the property from the Brockway Sportsmen's Club.

The remaining balance of 700 tons of broiler manure was used to topdress approximately 65 acres at the Sweet Soil, Inc. property. The Sweet Soil, Inc. site is approximately 275 acres.

Six separate chemical and physical analyses of the broiler litter indicated that it contained between 2.5% and 3.2 % total nitrogen with an average concentration of 2.8% total N. The six samples contained similar concentrations of phosphorous as phosphate (P_2O_5) ranging from 2.6% to 3.2% with an average concentration of 2.8% P_2O_5.

The export of the 1,500 tons of manure facilitated 3 nutrient trades resulted in the transfer of 57,065 certified nitrogen credits and 7,134 certified phosphorous credits for the trading year of October 2009 to September 2010.

Information regarding the nutrient trade can be found at the PA DEP nutrient trading website at: http://www.dep.state.pa.us/river/Nutrient%20Trading.htm

Technology Transfer

A summary of all technology transfer, education and outreach efforts for the composted poultry manure on mine lands Project is listed below.

- PEC staff and Penn State University Project partners hosted a field day on October 6, 2009 at the Schuylkill County research site to present results of prior and ongoing research effort and progress of demonstration Projects in Clearfield County. Field day was attended by 42 individuals representing PA Department of Environmental Protection and Bureau of Mining agencies, environmental NGOs, agriculture, composting, mining and biomass industries. A PEC staff member was interviewed by a reporter from Lancaster Farming who featured an article about the research and demonstration Projects in the October 9, 2009 issue of Lancaster Farming, a leading agricultural journal in PA.

- Delivered a powerpoint presentation with Dr. Rick Stehouwer of Penn State University to the Pennsylvania Mining Reclamation Advisory Board on January 8, 2010 at the Rachel Carson State Office Building in Harrisburg, PA. The presentation covered the scientific and technical aspects of the Project progress and business model development progress for the Project.

- Delivered webinar presentation about the Project on March 18, 2010 on the Pennsylvania State University Agriculture and Environment Center "Manure du Jour" webinar series with Dr. Rick Stehouwer of Penn State University to approximately 50 participants.

- Delivered presentation with Dr. Rick Stehouwer of Penn State University on May 6, 2010 at the 5th West Branch Susquehanna Restoration Symposium in Williamsport, PA.

- A PEC staff member delivered a presentation about the research and demonstration project, including detailed results from both the Schuylkill County research effort and the Clearfield County demonstration project, at the U.S. Soil

and Water Conservation Society Annual Conference on July 20, 2010 in St. Louis, MO.

- Hosted a Field Day for multiple stakeholders at the Lower Emigh site on October 15, 2010. The Field Day began with a meeting and a series of presentations about the enhanced mine reclamation methodology and project research results and the Pennsylvania Nutrient Trading Program. The meeting was attended by approximately 30 individuals including PA Department of Environmental Protection and Bureau of Mining agencies, environmental NGOs, mining companies, engineering firms and representatives from 2 local paper mills located in Blair County, PA.

Manure on Mined Lands Business Model

Beginning in January 2009, PEC engaged a team of graduate students at the Duquesne University Sustainability Masters' of Business Administration (SMBA) program in the development of a business model for the reclamation of former mine lands in PA using poultry manure exported from the Chesapeake Bay Watershed for the production of warm season grass biomass energy crops. The Project was conducted in four phases over four semesters. The rotating student Project teams conducted the following sequence of analyses:

Phase I (January –April 2009): Prepared a comparison of costs between conventional mine reclamation using commercial fertilizer, lime and mulch versus reclamation using the raw poultry manure and composted manure alternatives. The cost comparison analysis included a review of recent PA Department of Environmental Protection Abandoned Mine Land Reclamation program RFP bid response databases.

Phase II (May –August 2009): Developed a spreadsheet model calculating the minimum nutrient credit price necessary to fund the transportation of poultry manure from agricultural regions like Lancaster County to mining regions located outside the Chesapeake Bay Watershed in the bituminous and anthracite regions of Pennsylvania. The student team also delivered a research paper about the expected demand and pricing for nutrient reduction credits in Pennsylvania. Preliminary draft results of the analysis show that a nutrient credit sales price as low as $5 per nitrogen credit may be sufficient to fund the export of manure to mine reclamation sites beyond the Chesapeake Bay Watershed boundary in PA.

Phase III (October 2009 – February 2010): Prepare economic feasibility analysis of using poultry manure and paper mill sludge as soil amendments to grow switchgrass for bio-fuel on abandoned mine lands in Pennsylvania.

Analysis included the identification of sources and volumes of waste paper mill sludge and an economic analysis of conventional paper mill sludge disposal. Preliminary draft results of paper mill sludge production in PA indicated that there is a need to identify

alternate sources of carbonaceous materials for use as soil amendments in combination with poultry manure.

Conduct market analysis of potential demand for switchgrass biomass fuel for heat and distributed power generation at municipal, school and commercial facilities in mining regions.

Phase IV (March – August 2010): Conduct review of Phase I, II and III deliverables including powerpoint presentations, reports and cost/revenue modeling tools for the purpose of developing the Poultry Manure/Mine Reclamation/Biofuel Production comprehensive business plan.

In August 2011, the SMBA student team delivered the final business plan and associated Excel based calculation tools. Findings of the business planning effort included the following:

- There are a limited number of paper mills that produce waste paper mill sludge which indicates the need to identify alternate sources of carbonaceous soil amendments to be used in combination with raw poultry manure.

- The success and profitability of a business entity that applies poultry manure on mined lands for biomass production is largely dependent upon early federal or state cost-share and subsidy programs such as the NRCS Environmental Quality Incentives Program, the NRCS Wildlife Habitat Incentives Program and the Farm Service Agency Biomass Crop Assistance Program during the initial start-up phase of the business entity.

- Pending the sufficient demand and price point for nutrient reduction credits, the PA nutrient trading program can provide a sufficient incentive to farmers and nutrient credit brokers to fund the transportation of poultry manure from farms inside the Chesapeake Bay Watershed to surface mine lands in the bituminous and anthracite mining regions in PA located outside the Chesapeake Bay Watershed boundary.

The reports for Phases II, III and IV of the SMBA planning effort are included as Appendices A, C, E of this report. The Phase II, III and IV Excel spreadsheets are included as Excel files as Appendices B, D, F of this report.

Biomass Market Opportunities

As of September 2011, the 30 combined acres of various warm season grass crops at the Lower Emigh, Maxton and J sites are producing a yield of approximately 1.5 to 2 tons of biomass per acre. Given the relatively modest expected yields and the relatively small acreages of the 3 plots combined with the very limited local demand for warm season grasses as a biomass energy crop it will not be economically viable to harvest the warm season grass crops at the 3 sites in 2011.

However given that the plots were seeded in June 2009 it is expected that the average yield per acre should increase to over 2 tons per acre in 2012 which may provide a sufficient return for harvesting the warm season grasses as a biomass crop or as hay for feed in the summer of 2012. Alternatively the crop could be harvested and sold as mulch at a lower price than as a biomass or hay crop. It is expected that the 3 reclamation sites located in Clearfield County will yield approximately 60 tons of biomass on an annual basis and the Elk County reclamation site will yield approximately 80 tons of biomass on annual basis by 2014.

Institutional Biomass Market in the Elk and Clearfield County Region

There are 2 institutional-scale biomass burning facilities in the vicinity of the Clearfield and Elk County demonstration Project sites that could use the warm season grass crop as biomass for fuel.

The Elk Regional Health Center(Center) located in St. Mary's in Elk County, PA currently burns approximately 2,785 tons of wood chips annually. The boiler at the facility produces steam for heat and hot water. The current heating system would require minimal modifications if any, to burn loose shredded warm season grasses rather than wood chips, according to an employee of Advanced Recycling Equipment, Inc. located in St. Mary's.[1] Advanced Recycling Equipment, Inc. manufactured and installed the biomass heating system at the Health Center. It would require no modifications at all to burn pelletized warm season grasses.[2]

In 2008, the Center paid approximately $32 per ton of delivered wood chips in 2008.[3] More recently the Center has paid between $42 and $45 per ton for wood chips delivered to the facility in 2011 The facility is located approximately 30 miles from the 40-acre Sweet Soil, Inc. demonstration Project site and approximately 50 miles from the combined 30-acre demonstration Projects located near Morrisdale in Clearfield County. The Center is located approximately 30 miles from the Sweet Soil reclamation site in Elk County and approximately 50 miles from the 3 reclamation sites located near Morrisdale in Clearfield County.

The biomass heating system at the Middle School was also manufactured and installed by Advanced Recycling Equipment, Inc. and would require little if any modifications to burn warm season grasses rather than wood chips.

The Clearfield Area Middle School located in Clearfield, PA in Clearfield County purchased approximately 640 tons of wood chips for the 2007-2008 heating season at a

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[1] Telephone communications with an employee of Advanced Recycling Equipment Inc., September 14, 2011.
[2] Ibid.
[3] Pennsylvania Fuels for Schools and Beyond, Case Studies Elk Regional Health Center. Web, September 8, 2011 < http://www.pafuelsforschools.psu.edu/case_studies/elk.asp>

cost of $35 per delivered ton of wood chips. The Middle School is located approximately 15 miles from the 3 reclamation sites near Morrisdale in Clearfield County and 32 miles from the Sweet Soil site.

Ernst Conservation Seeds Biomass Pellet Plant, Meadville, PA

As of September 2011, Ernst Conservation Seeds located in Meadville, PA is finalizing the construction of a commercial biomass pelletization facility. They expect the facility to be operational by the end of 2011 or early in 2012. The facility will be capable of densifying a variety of warm season grasses in to pellets or briquettes sutiable for domestic pellet stoves or institutional biomass boilers. Ernst Conservation Seeds intends to utilize the facility to pelletize an annual harvest of switchgrass and other warm season grasses that they grow on up to 6,000 acres in the Meadville, PA region. They also may purchase warm season grasses from local growers at approximately $65 per ton delivered to the facility.

Dan Arnett, Manager of Ernst Biomass, LLC recommended that warm season grasses be delivered in round bales in net wrap.[4] Mr. Arnett also recommended that warm season grasses should be mowed in the late fall and be left on the ground over the winter and then should be baled in the early spring. This method should allow for nutrients to leach in to the soils over the winter and reduce scaling and clinkering in the combustion chamber of pellet stoves and other biomass combustion systems when the warm season grass pellets or briquettes are burned.

The densification facility is located approximately 90 miles from the SweetSoil reclamation site in Elk County and approximately 130 miles from the 3 reclamation sites located near Morrisdale in Cleafield County.

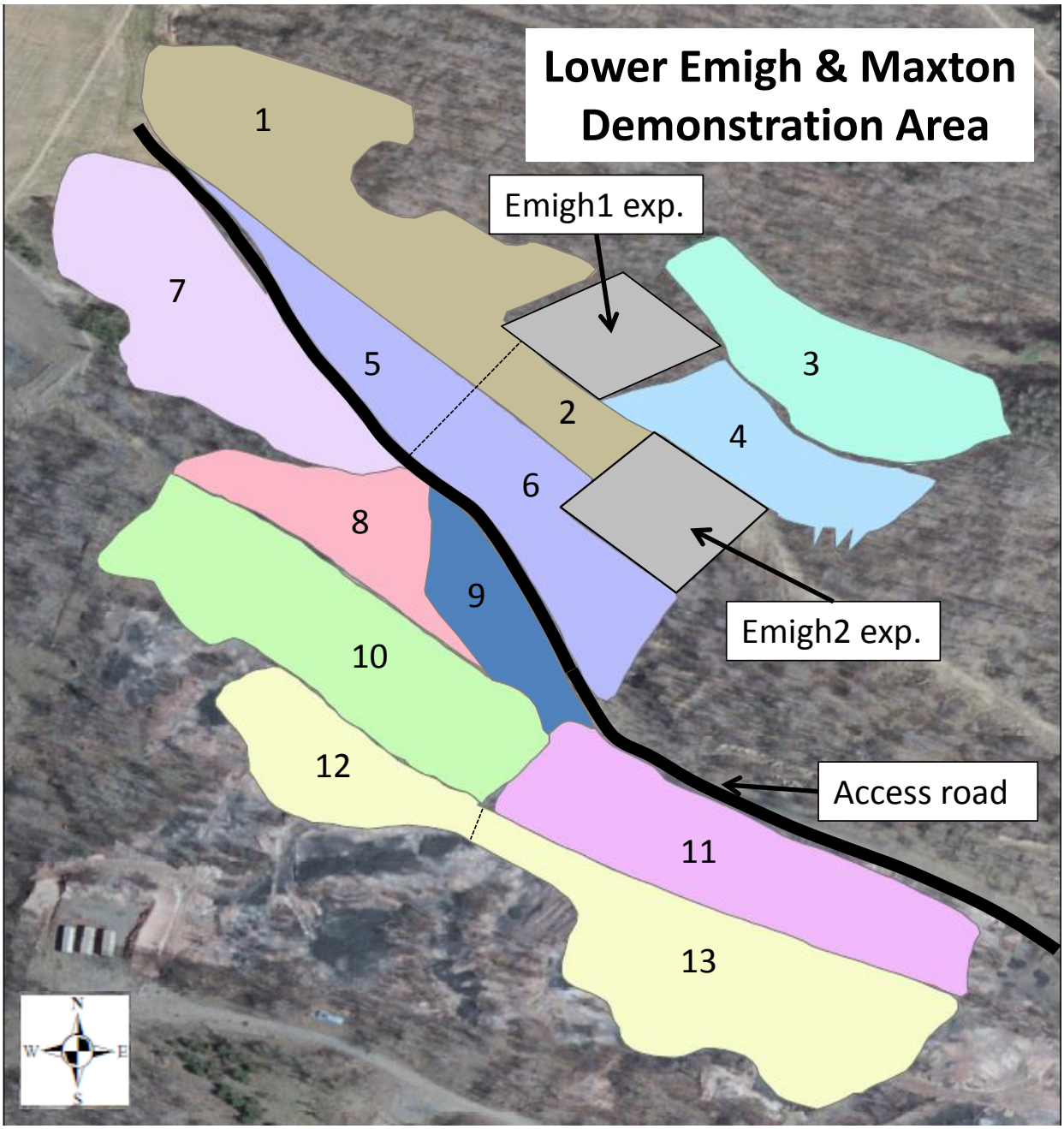
Discussion of Quality Assurance

Project site description: characteristics of the site, sample locations, rationale for locations, map.

Project was conducted at three active mining site permits in Clearfield County, PA: the contiguous Lower Emigh and Maxton permits and the J permit. All three sites were reclaimed surface coal mine operations. Following coal extraction, overburden material (primarily sandstone and shale rock) was backfilled, graded to approximate original contour, and covered with 10-12 inches of fine earth material containing 50-60% coarse fragments. Project was located on disturbed mined land to meet project objectives of assessing warm season grass production potential on mined land reclaimed using agricultural manure based amendments. Most of the area was utilized for demonstration of mine soil amendment with composted manure or with poultry layer manure and paper

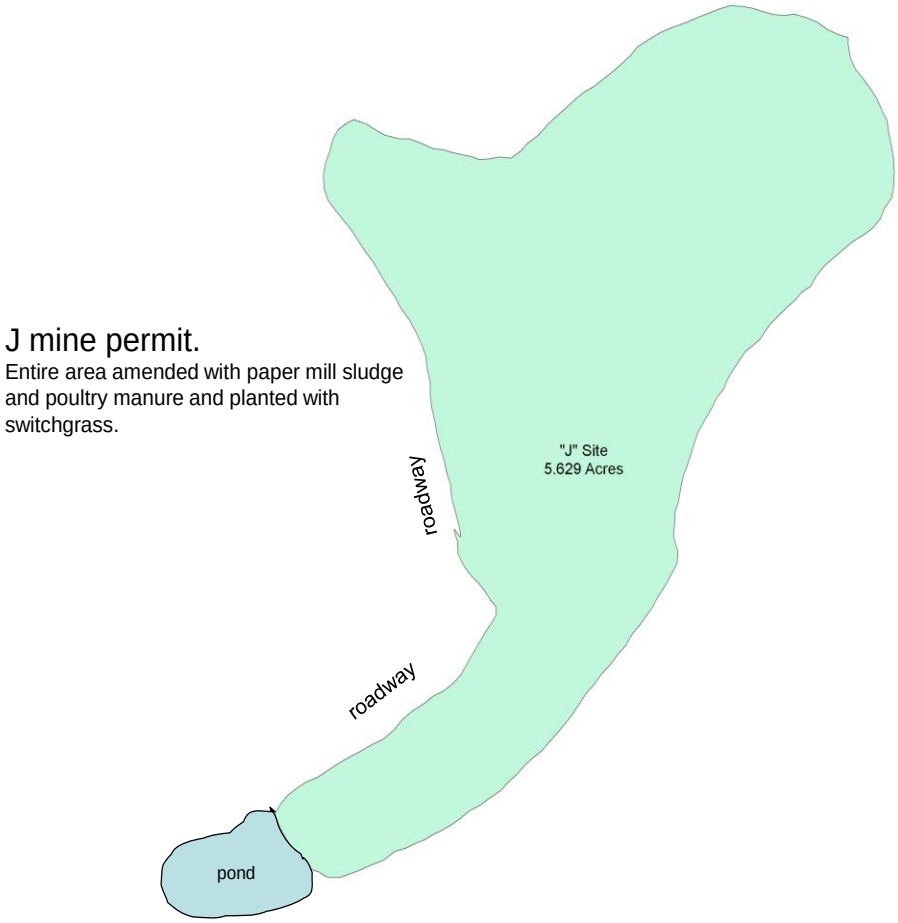
[4] Telephone communications with Mr. Dan Arnett, Manager, Ernst Biomass, LLC, September 9, 2011

mill sludge. Two approximately one acre areas were used for small plot replicated experiments which were utilized for biomass yield measurement.



Key to reclamation and plantings. Soil amendments applied either Fall, 2008 or Spring 2009. All areas were planted in Spring 2009. There is some overlap of amendment areas.

1. Compost F08, Big Bluestem
2. Compost S09, Big Bluestem
3. Manure+PMS F08, Big Bluestem
4. Manure+PMS S09, Big Bluestem
5. Compost F08, Mixed grasses
6. Compost S09, Mixed grasses
7. Compost F08, Mixed grasses
8. Manure+PMS F08, Switchgrass
9. Compost S09, Switchgrass
10. Compost F08, Grasses+Trefoil
11. Compost S09, Grasses+Trefoil
12. Manure+PMS F08, Atlantic Coastal Panic Grass
13. Compost S09, Atlantic Coastal Panic Grass



Sampling design. Include the precision level of measurements, completeness (will data be sufficient), how samples and measurements truly represent what is occurring, and comparability (can the project situation be compared to real-life situations).

Composted manure, poultry layer manure and paper mill sludge were delivered to the work sites and stockpiled. Stockpiled materials were sampled and samples analyzed for nutrient content at Penn State's Agricultural Analytical Services Laboratory (www.aasl.psu.edu). This laboratory follows standard quality assurance protocols as described on their website. Application rates of these materials to the demonstration areas and the experiments were based on laboratory analytical results. Spreading equipment was field calibrated for each type of material by collecting and weighing all material falling on 10x10' tarpaulins during normal spreading operations. These operations were conducted using full-scale agricultural equipment on the demonstration areas assuring results are comparable to real-life situations.

Sampling procedures: Describe collection methods, collection frequency, equipment used, volume or amounts sampled, and how samples are handled, stored, and transported.

The small plot field experiments were used to determine plant biomass production of the warm season grass species and species mixes in response to the 3 reclamation treatments. The experiments utilized a split plot randomized complete block design with 4 replications. Harvests of plant biomass were made in the fall of each year using a small plot harvester with an on-board weighing system to determine the biomass collected from each plot. No transport or storage so samples was required.

Custody procedures: Describe chain-of-custody procedures for samples and data.

Samples of amendment materials were delivered by project personnel directly to the Ag Analytical Services Laboratory. Biomass yield determination involved no sample transport. Yield data were recorded in the field by project personnel.

Calibration: What, if any, field equipment will require calibration & how will it be done.

Amendments were applied using a manure spreader and a lime spreader. This equipment was calibrated in the field as described above. The small plot forage harvester scales were calibrated at Penn State University's Rock Spring Agricultural Research Station.

Sample analysis, quality control: Cite analytical procedures to be used in the field or laboratory, sub-sampling or sample preparation, units of measure to be used. Describe limits of detection.

See www.aasl.psu.edu for the laboratory QA/QC procedures for amendment analysis. Small plot harvester weighs harvested biomass to the nearest 1 lb. Sub-samples of plant biomass were collected in cloth bags at the time of harvest for moisture content determination. Biomass fresh weight was recorded in the field and samples were transported to Penn State campus and dried in a crop drying oven at 55C for 48 hours and weighed again to determine moisture loss. Field measured fresh biomass weight was adjusted to a dry weight basis using the measured moisture content for each species or species mix.

Discuss data reduction, analysis, review, and reporting: How raw data is converted and presented, who reviewed it, and how the final presentation was derived.

Crop yield data were recorded in Excel spreadsheet files and treatment and species responses and interactions were determined using ANOVA for split plot design. All data recording, reduction, analysis and review were conducted by Penn State Soil Science Professor Richard Stehouwer.

Findings

Schuylkill County Field Research Project: The following narrative provides detailed findings for the Schuylkill County Field Research Project which was supported through grants from the PA Department of Agriculture and the PA State Conservation Commission. The Field Research Project was completed in September 2009. The interim findings of the Field Research Project directly informed the design of the full-scale demonstration project supported by the NRCS Conservation Innovation Grant addressed in this report.

The field research experiment in Schuylkill County investigated several different approaches using manure, paper mill sludge and composted manure as soil amendments for mine reclamation and switchgrass production. Normal mine reclamation practices in Pennsylvania will apply inorganic N fertilizer at about 100 lb N/acre. The project team compared this N application rate with much larger N applications from composted layer manure and layer manure mixed with paper mill sludge. Application rates and quantities are listed in table 2.

Table 2. Soil Amendment Application Rates – Schuylkill Field Research Project

Reclamation soil amendment	Quantity of total N added (lb N/acre)
Lime (6 T/A) and Fertilizer	100
Composted poultry manure (35 T/A dry wt)	1890
Composted poultry manure (70 T/A dry wt)	3780
Poultry manure (22 T/A dry wt) mixed with paper mill sludge (46 T/A) to achieve C:N ratio of 20:1	1890
Poultry manure (22 T/A dry wt) mixed with paper mill sludge (82 T/A) to achieve C:N ratio of 30:1	1890

The project team collected leachate water from these amendments for 3 growing seasons and measured nutrient loss via leaching. Switchgrass was established one year after amendments were applied.

The results and data obtained during the second year of research (summer 2007) were used to establish the manure reclamation approach for full scale reclamation demonstration (composting approach and application rate) in Clearfield County Pennsylvania.

Composting poultry manure was a highly effective way to stabilize the added nitrogen and sequester it in the soil. Leachate analysis over three growing seasons showed that less than 1% of N added as compost was lost via leaching during this period, even with the application of 3,780 lb N/acre. Adding fresh poultry layer manure mixed with paper mill sludge was less effective than composting at retaining the added N. Most of the loss was due to nitrate leaching in the late fall of each year. Nitrate leaching was greatest in the first year, much smaller in the second year and almost zero in the third growing season.

Although significant N leaching occurred with the manure plus paper mill sludge amendment, the amount of N lost over 2 growing seasons with the 20:1 ratio treatment is comparable to N leaching losses from 2 seasons of conventionally produced corn on agricultural fields. And while leaching loss has essentially ceased after two years, it is an annual event in production agriculture fields. The manure plus paper mill sludge amendment was also very effective at sequestering added N. The 20:1 treatment lost only 8% N via leaching, and soil analysis confirmed that most of the added N was still present in the soil.

Both composting and manure plus paper mill sludge were very effective at sequestering added P. Leaching loss of P was very small and over two growing seasons amounted to less than 2% of the added P. Both of the organic amendments produced excellent vegetative growth during all three growing seasons. Switchgrass was established in the second growing season (2007). Both compost and manure plus paper mill sludge produced much larger yields than the conventional reclamation practice of lime and inorganic fertilizer. These two year stands of switchgrass are comparable to two year stands on high quality agricultural soils. Additional detail and data regarding biomass productivity of the different treatment plots are presented in the Narrative Evaluation that addresses Project Objectives 2 and 3.

Based on the results of the research project the project team determined that the optimum manure application rate is 14.3 T/A (dry weight, approximately 30 T/A wet weight) for a total N application of 1430 lb/A. The manure was combined with paper mill sludge applied at a rate of 42 T/A (dry weight, approximately 114 T/A wet weight). This application will produce an overall C:N ratio of approximately 20:1 in the applied material. The 35% reduction in the total amount of N applied will further decrease the potential for nitrate leaching while still maintaining adequate nutrient and carbon addition to the soil for good biomass production.

This recommended application rate was used for the application of raw layer manure at the 12 combined acres reclaimed at the demonstration project site in Clearfield County that were reclaimed during springs and summers of 2008 and 2009. 18 acres were reclaimed at the Clearfield County demonstration site using an application of 65 T/A wet weight of composted manure to achieve an approximate application rate of 1430lb/A of N at a C:N ratio of approximately 20:1.

<u>Objective 2:</u> *Quantify organic carbon and nutrient fluxes in the reclaimed system including inputs in reclamation amendments, C additions from vegetative growth, and C and nutrient accumulation in soil organic matter and mineral pools.*

<u>Objective 3:</u> *Quantify biomass and potential biofuel production on reclaimed mined land.*

The following narrative provides a report of the field research project in Schuylkill County including detailed results regarding carbon and nutrient fluxes in the soil and plant biomass based on multiple experimental treatments using control plots and varying

applications of composted poultry manure and mixtures of raw layer manure mixed with paper mill sludge.

The Schuylkill County field research project utilized switchgrass monoculture plots to evaluate the comparative biomass productivity of different soil amendments. With the support of a grant from the USDA Natural Resources Conservation Service Conservation Innovation Grant Program and the Foundation for PA Watersheds, PEC was able to expand the scale of a proposed 5-acre switchgrass demonstration project to a 30-acre demonstration project.

The 30-acre demonstration project provided an opportunity to evaluate the comparative biomass productivity of other warm season grasses in monoculture and polyculture stands in addition to monocultures of switchgrass. Approximately one half of the 30 acre demonstration project acreage was reclaimed with high diversity native perennial stands of grasses, forbes, and legumes. Long-term research conducted on degraded agricultural lands in Minnesota has shown that such stands can be established on degraded lands, that they are sustainable, that they produce more biomass fuel per acre than monocultures of corn or switchgrass, and that they sequester more soil carbon than monocultures (Tilman et al., 2006). High diversity stands also have greater potential than monocultures to serve as wildlife habitat if managed appropriately. Some preliminary information about the comparative biomass productivity of the 30-acre demonstration project is included in the narrative that addresses Objective 4: *Implement Full-Scale Demonstration and Technology Transfer.*

The following narrative includes biomass yield and potential biofuel yield data based on the field research project in Schuylkill County.

Materials and Methods

The multi-year field experiment was initiated in the spring of 2006. The field site is an abandoned coal surface mine from the 1950s located in Schuylkill County, Pa (Fig 1.). The soil is classified as an Udorthent strip mine. Initial site texture was a very channery sandy loam, with an average soil pH of 5.1(1:1 in water) (Eckert and Sims, 1995). Bulk density was estimated at 1.4 g cm^{-3} and initial total soil carbon was measured at 3.1% (Nelson and Sommers, 1996) reflecting the presence of coal fragments in the mine spoil.

Figure 1. View of the AML area in Spring 2006 prior to establishment of the experiment.

Five reclamation treatments were each replicated four times in a randomized complete block design with each plot measuring 6.1 m x 9.1 m (20 x 30 ft). The treatments included the standard reclamation (control) of lime and inorganic fertilizer amendment (112 kg N ha^{-1} as NH_4NO_3; 196 kg P ha^{-1} as triple super phosphate; 186 kg K ha^{-1} as KCl), two rates of composted poultry layer manure, and poultry layer manure blended with paper mill sludge (manure+PMS mixes) to give C:N ratios of 20 and 30. Table 3 gives treatment quantities and compositions, along with their respective soil additions of N and P.

Carbon and N were measured using the combustion method on a Fisons NA 1500 Elemental Analyzer (Nelson and Sommers, 1996). Initial pH of the manure and paper mill sludge was 8.3 and 7.3, respectively. The poultry layer manure was composted by mixing with leaves, shredded wood and water and placed in an open windrow. During active composting the windrow was turned every 7 to 14 days depending on when windrow temperature began to decrease. Following active composting the compost was matured for two months in a static pile. The fresh manure and paper mill sludge treatments were hauled to the experiment site and mixed on site to produce the desired C:N ratio blends. All amendments were surface applied and then incorporated into the upper 5 to 8 cm of the soil using the teeth on a front-end loader bucket. Due to the extremely rocky nature of the site, it was not possible to achieve deeper incorporation.

Table 3. Reclamation treatments used and quantities of material, C and nutrients added with each soil amendment.

Treatment	Additions to minespoil				
	Material	C	N	P	K
	Mg ha^{-1}		kg ha^{-1}		
Lime and fertilizer					
Limestone	13.4	1.61	—	—	—
NH_4NO_3	1.28	—	112	—	—
TSP	4.00	—	—	196	—
KCl	1.50	—	—	—	186
Compost 1	78	27.0	2117	1052	81.3
Compost 2	156	54.1	4234	2104	163
20:1 manure+PMS					
layer manure	50	15.5	2117	1052	216
paper mill sludge	103	27.0	—	—	—
30:1 manure+PMS					
layer manure	50	15.5	2117	1052	216
paper mill sludge	184	48.2	—	—	—

All plots were initially planted with a combination of 11.2 kg ha^{-1} (10 lbs ac^{-1}) of switchgrass v. Cave-in-Rock (*Panicum virgatum* L.) and 2.2 kg ha^{-1} (2 lbs ac^{-1}) of an annual ryegrass (*Lolium rigidum* Gaud.) immediately following amendment application; the ryegrass was included as a nurse crop to provide some rapid cover prior to switchgrass establishment. Following seeding, one bale of straw mulch was applied to each plot. Vigorous ryegrass growth prevented the establishment of switchgrass in the first year after planting; therefore, plots were reseeded with switchgrass in spring 2007. To minimize ryegrass competition in the first year, the plots were mowed at approximately 15 cm (6 in) in May and June of 2007. Biomass yield was measured by clipping all vegetation present in one 1.0-m^2 quadrat randomly located within each plot in October of each year. Harvested plant material was dried at 60C for 48 h and weighed to determine biomass yield. The entire plot area was then mowed and cut biomass was raked off the plot area.

Figure 2. Experiment area in Spring 2006 following application of soil amendments and planting switchgrass and annual ryegrass. In the foreground is a compost amended plot, and center left is a manure+PMS amended plot.

Soil in each plot was sampled at a depth of 0-5 cm prior to reclamation and again in the fall of each year of the study. Sampling was done by compositing 5 cores from each plot and collecting an approximately 1 kg subsample. Soil material was air-dried and passed through a 2-mm sieve prior to analysis for pH and for total C and N by combustion.

Data were analyzed using analysis of variance and single degree of freedom contrasts for planed comparisons using a significance level of $\alpha = 0.05$. All statistical analysis was performed using SAS software (SAS Institute, 2003).

Results and Discussion

Mine soil quality.

Compared to pre-reclamation levels, all soil amendments increased soil pH and C and N pools (Table 4). The smallest increases were given by the lime and fertilizer amendment as expected since this treatment added no organic C and only a small amount of N. The magnitude of the increase in soil N content with lime and fertilizer addition was not expected. Increases in soil C concentration in all treatments reflect addition of C in the amendments along with subsequent input of plant root biomass. The larger increases in C

with compost addition reflect the more stable nature of the added C compared to that added with manure+PMS. Compost amendment also gave the largest increases in N. The larger increase with compost 2 was expected since twice as much N was added with this treatment than with the other manure based treatments. The compost 1 amendment and both manure+PMS amendments all added the same amount of N, but more compost N than manure N was retained in the upper 5 cm of soil. The manure based amendments clearly improved mine soil quality to a greater extent than limestone and fertilizer amendment. However, the apparently smaller increase in soil N pool with manure+PMS has implications for long term sustainability of switchgrass production.

Table 4. Soil pH and total C and N concentration in the 0 – 5 cm depth.

Sample Date and Soil Amendment	pH	Total C	Total N
		g kg^{-1}	g kg^{-1}
Spring 2006 (before reclamation)			
Plot area	5.10	31.8	0.9
Spring 2009 (3 years after reclamation			
Lime and fertilizer	6.99c†	48.1c	2.1b
Compost 1	7.28b	94.2a	6.8a
Compost 2	7.34ab	99.5a	7.5a
Manure+PMS (20)	7.30ab	60.5bc	3.0b
Manure+PMS (30)	7.50a	81.3ab	3.7b

†Within columns values followed by different letters are statistically different at the α=0.05 level.

Biomass production.

The annual ryegrass that was planted in 2006 and was intended to serve as a nurse crop for the more slowly establishing switchgrass, instead out-competed the switchgrass and was by far the dominant species in all treatments (Fig. 3). No switchgrass could be found in any plots in the fall of 2006. While the high fertility in the compost and manure+PMS plots likely contributed to the rapid growth of ryegrass, the same effect was observed with the lower fertility lime and fertilizer amendment. In the fall of 2006 there was no effect of soil amendment on biomass yield (Fig. 4).

Figure 3. Experiment area in July, 2006 showing dense cover of annual ryegrass.

Switchgrass was reseeded in the spring of 2007, and annual ryegrass was mowed twice in early summer of 2007 to remove seed heads before seed could mature. Switchgrass was established during the 2007 growing season, but the mowing and transition from ryegrass to switchgrass resulted in much less biomass production in 2007 than in 2006. Despite the reduced yields, there were small differences among treatments with the 2x compost rate producing greater biomass than the lime and fertilizer treatment (Fig. 5).

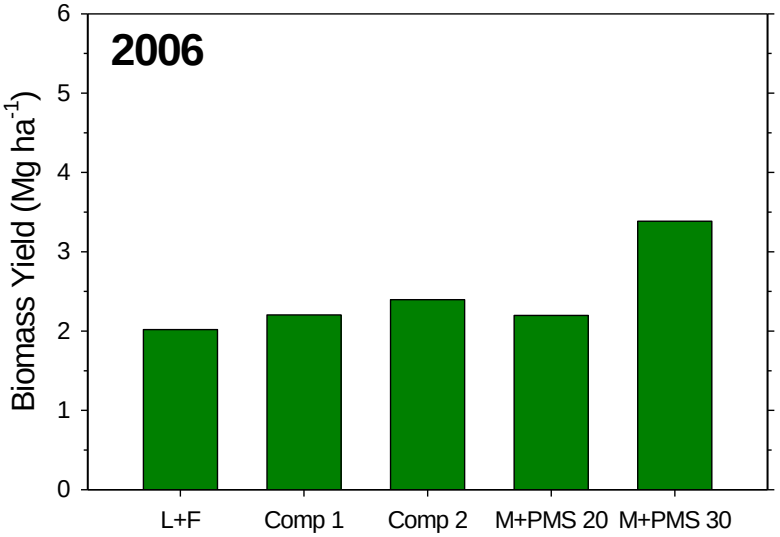


Figure 4. Effect of conventional lime and fertilizer amendment (L+F) and manure based amendments (Comp1, compost 1; Comp2, compost 2; M+PMS20, manure+PMS 20:1; M+PMS30, manure+PMS 30:1) on biomass production in 2006. There were no significant treatment effects on biomass yield in 2006.

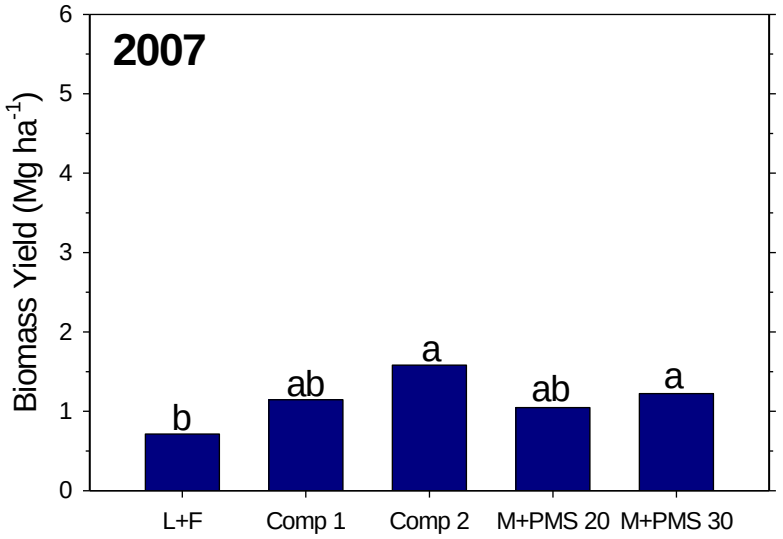


Figure 5. Effect of conventional lime and fertilizer amendment (L+F) and manure based amendments (Comp1, compost 1; Comp2, compost 2; M+PMS20, manure+PMS 20:1; M+PMS30, manure+PMS 30:1) on biomass production in 2007. Bars marked by the same letter are not significantly different.

In 2008, the second year of switchgrass growth, overall biomass production was greater than in the previous two years, and all of the manure based amendments produced greater yields than lime and fertilizer amendment (Figs. 6 and 7). Although some annual ryegrass was present in the early summer, switchgrass was the dominant species from mid-summer onward.

Figure 6. View of experimental plots in July, 2008 showing 2-year stands of switchgrass.

In 2009 vegetation in all plots was predominantly switchgrass (Fig. 8). Biomass production with the third year switchgrass stand was greater than in any previous year and again, yield with the manure based amendments were nearly twice that of the lime and fertilizer amendment (Fig. 9). By comparison, Adler et al. (2006) reported yields of fertilized, mature switchgrass stands on agricultural production soils in central Pennsylvania ranging from 6.7 to 8.6 Mg ha^{-1} (3.0 to 3.8 tons $acre^{-1}$), and yields of mature switchgrass stands on lower quality conservation reserve lands of 2.9 to 5.1 Mg ha^{-1} (1.3 to 2.3 tons $acre^{-1}$). Although yields on this AML site with manure based reclamation have not attained agronomic yield potential, it is possible that production could increase further as the stand matures. No plant nutrients have been added since reclamation and it is possible that topdressing with agronomic rates of inorganic fertilizer or manure could result in further yield increases. Additional research is needed to evaluate future yield sustainability on the test plots by comparing those that don't receive additional nutrients and comparing their yield with yields from plots that receive added nutrition.

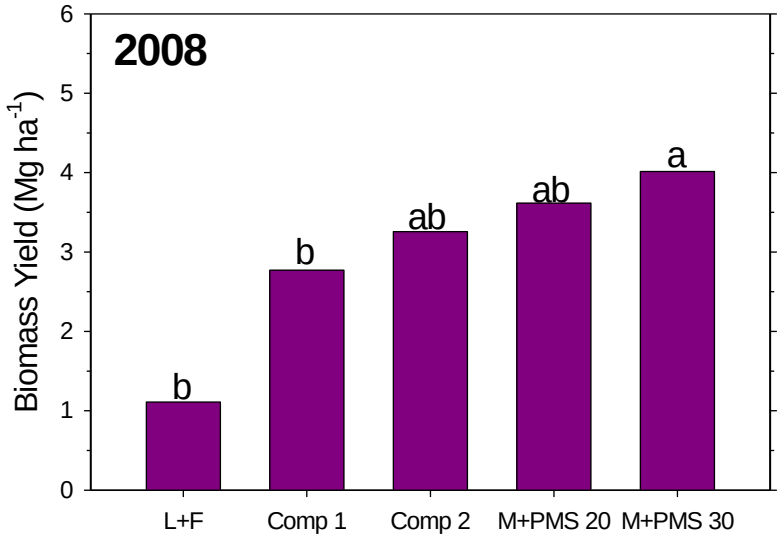


Figure 7. Effect of conventional lime and fertilizer amendment (L+F) and manure based amendments (Comp1, compost 1; Comp2, compost 2; M+PMS20, manure+PMS 20:1; M+PMS30, manure+PMS 30:1) on biomass production in 2008. Bars marked by the same letter are not significantly different.

Figure 8. View of experimental plots in October, 2009 showing 3-year stands of switchgrass.

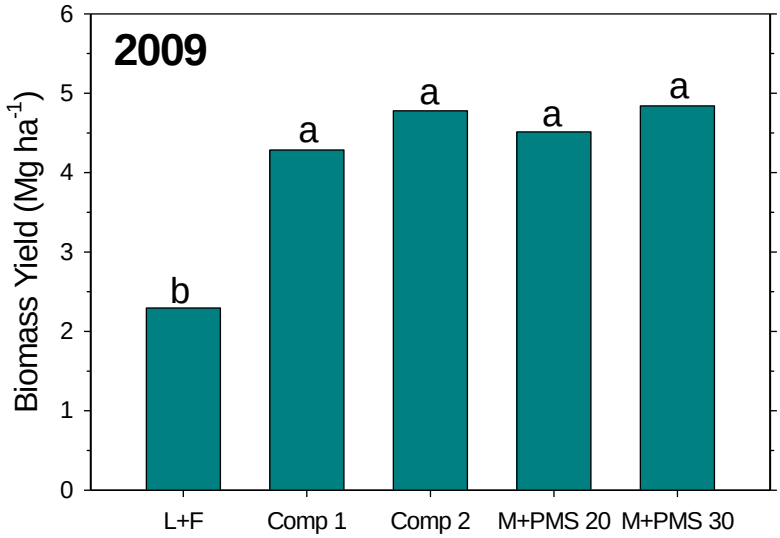


Figure 9. Effect of conventional lime and fertilizer amendment (L+F) and manure based amendments (Comp1, compost 1; Comp2, compost 2; M+PMS20, manure+PMS 20:1; M+PMS30, manure+PMS 30:1) on biomass production in 2009. Bars marked by the same letter are not significantly different.

Tissue analysis.

There were no differences among treatments for tissue N, P or K concentrations (Table 2). Our measured concentrations for N were very close to the critical value of 10 g kg^{-1} reported by Lewandoski and Kircherer (1997). Tissue concentrations in our study were somewhat larger than those reported by Adler et al. (2006) who measured N, P and K concentrations ranging from 3.28 – 6.21, 0.80 – 0.89, and 3.33 – 3.45 g kg^{-1} respectively. In our study we measured similar P removal and somewhat lower N removal (Table 2). Even though the manure amendments added over 2,000 kg N ha^{-1} (1785 lb N $acre^{-1}$), at some point labile N produced from this soil N pool will no longer supply the annual harvest removal of 40 – 50 kg N ha^{-1} (36 to 45 lb N $acre^{-1}$) and additional N input will be needed to maintain yields. Future research should identify the frequency and quantity of N application needed for sustained production.

Table 5. Concentrations and harvest removal of N, P and K in switchgrass grown in 2009 on mine soil amended in 2006 with lime and fertilizer or manure based amendments.

	Tissue concentration			Harvest Removal		
Soil Amendment	N	P	K	N	P	K
	---------- g kg^{-1} ----------			---------- kg ha^{-1} ----------		
Lime and fertilizer	10.6	2.88	8.30	24.3	6.6	19.0
Compost 1	10.4	2.33	8.78	44.6	10.0	37.6
Compost 2	12.2	3.58	10.2	58.3	17.1	48.7
Manure+PMS 20:1	9.25	2.48	8.70	41.7	11.2	39.3
Manure+PMS 30:1	8.95	2.13	7.90	43.3	10.3	38.2

Biomass Productivity at Lower Emigh Reclamation Project Site:

In November 2009, cuttings of different test plots of warm season grasses were taken at the Lower Emigh site test plots to evaluate preliminary biomass productivity of the comparative plots. The test plots were seeded in June 2009 so the yields represent first year production of the biomass crops. Biomass yields for the plots that received applications of raw layer manure and paper mill sludge were substantially more productive than those that received an application of composted poultry manure which were more productive than the control plots that received an application of lime and commercial nitrogen fertilizer (Figure 10). The test plots that received an application of raw layer manure and paper mill sludge seeded with a mixture of switchgrass, Atlantic coastal panic grass and the big bluestem monoculture were observed as the most productive test plots followed by the plot seeded with Atlantic coastal panic grass.

The biomass productivity of the test plots that received treated with raw layer manure and paper mill sludge compare favorably with the biomass productivity observed at the switchgrass test plots at the Schuylkill County research Project as indicated in Figures 8 and 9.

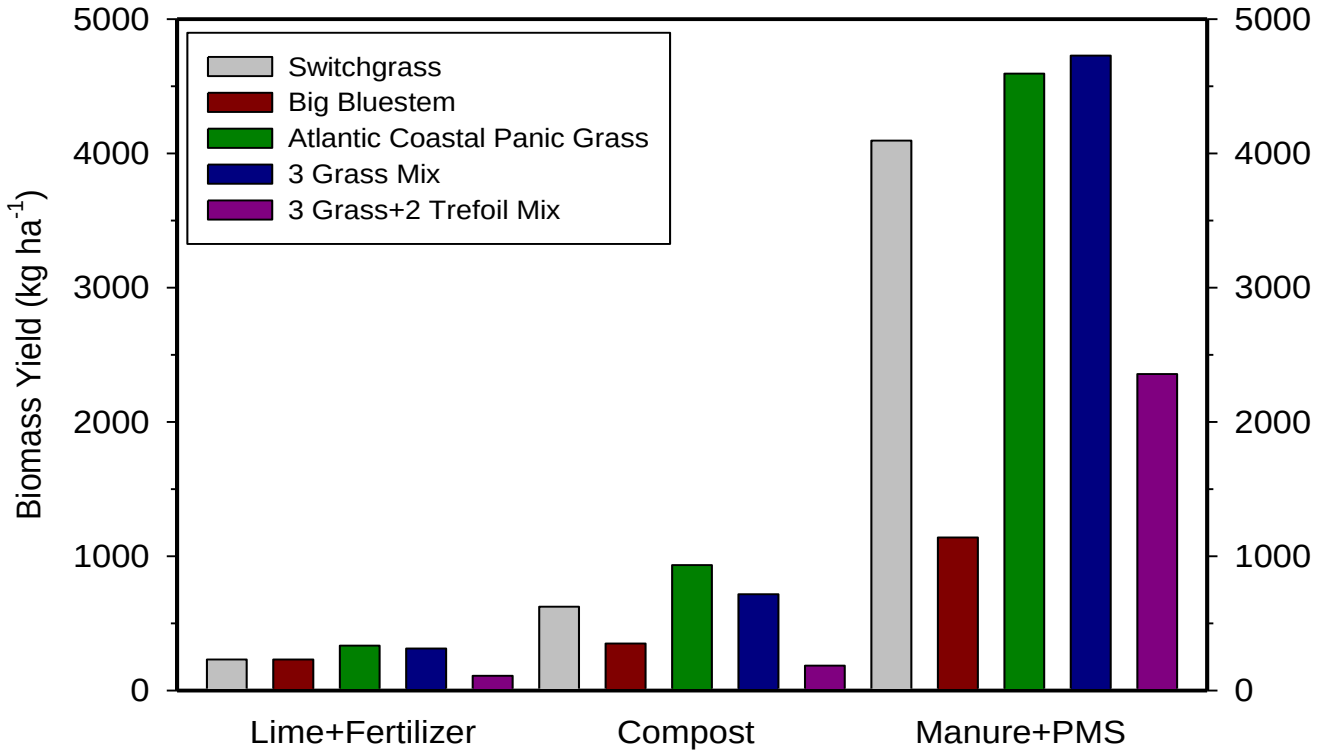


Figure 10. 2009 (first year) Biomass Yield – Lower Emigh Test Plots

Material Inventory for Mine Revegetation Strategy

A 2010 summary of Pennsylvania sources of poultry manure, paper mill sludge and compost plus information about annual mine reclamation and abandoned mine reclamation is included in Appendix G.

Poultry Manure on Mine Lands Environmental & Mining Policy Issues

A set of recommendations developed in May 2010 that would help facilitate the broader application of the enhanced mine reclamation methodology demonstrated by the Project are included in Appendix H of this report. The recommendations are intended for the PA executive and legislative branches and would be administered by the PA Department of Environmental Protection Bureau of Land Recycling and Waste Management and the Bureau of Abandoned Mine Reclamation. One of the recommendations included in Appendix E was passed by the PA House of Representatives in on June 20, 2011 when PA House Bill 608 was approved which authorizes the PA Department of Environmental Protection to encourage the planting of switchgrass and other fast-growing crops to revegetate mine lands.

Publications

- Burke, D.G. and J.E. Dunn (editors). 2010. A Sustainable Chesapeake: Better Models for Conservation. The Conservation Fund, Arlington, VA. 278pp. Stehouwer, R.C. and S. Van de Mark. Converting Poultry Manure from Waster to Resource: Using Manure and Paper Mill Waste to Reclaim Abandoned Mine Lands in Pennsylvania. (195-200).

- Stehouwer, R.C., A.L. Dere, and K. McDonald. 2010. Switchgrass production on abandoned mined land reclaimed with manure based amendments. *In* Prodeedings: 2010 National Meeting of the American Society of Mining and Reclamation, Pittsburgh, PA Bridging Reclamation, Science and the Community June 5 - 11, 2010. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

Conclusions & Recommendations

1. Preliminary first-year biomass growth on test plots amended with poultry manure and paper mill sludge observed at the 30-acre demonstration Project was observed to be substantially greater than test plots amended with nitrogen fertilizer and lime.

2. Our field scale research Project determined that former mined lands amended with composted poultry manure and raw manure mixed with paper mill sludge can produce biomass yields significantly greater than control plots amended with nitrogen fertilizer and lime.

3. Nitrogen runoff and leachate levels observed at the research Project in Schuylkill County diminished to very low levels by the 3rd year following the application of composted manure and raw poultry manure mixed with paper mill sludge.

4. The PA nutrient trading program can provide a sufficient incentive to poultry farmers and nutrient credit brokers to fund the transportation of poultry manure for use as a soil amendment to mining regions located outside the Chesapeake Bay Watershed boundary in PA.

5. Operating surface mine sites and former mine lands with marginally productive soils can be reclaimed using poultry manure and carbonaceous materials to restore productive soils for the production of warm season grass biomass crops.

6. Additional research is needed regarding the long term productivity of soils and periodic nutrient requirements for soils at former mine sites reclaimed with poultry manure.

7. Research is needed regarding the productivity of soils at former mine sites reclaimed with poultry manure for the production of short rotation woody crops for use as biomass energy crops, pulp and as feedstocks for finished wood products.

8. There is a limited quantity of waste paper mill sludge production in PA and therefore substitute sources of carbonaceous materials such as leaf litter and agricultural residues are needed as soil amendments for use in combination with poultry manure if it is to be used on a broad scale as a soil amendment for restoring soils on former mine lands in PA.

9. The restoration of productive soils at abandoned mine lands, active mine lands and marginally productive former mine lands that were reclaimed after passage of Surface Mining Control and Reclamation Act of 1977 is needed to meet the growing and competing demands for biomass, pulp and finished wood products in PA.

In conclusion the Project was a success by restoring productive soils for commercial scale production of switchgrass and other warm season grasses at 3 recently active surface mine sites in Clearfield County and at a former surface mine site in Elk County. The reclamation project in Elk County facilitated the export of 1,600 tons of broiler litter from poultry farms in nutrient impaired watersheds in the Chesapeake Bay Watershed to outside the Bay Watershed in Elk County which resulted in a nutrient trade. The Project partners seek to implement continuing research and demonstration efforts utilizing and refining the alternative mine revegetation technique for the production of warm season grasses and short rotation woody crops that can help meet the growing demand for biomass for energy.