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MEMORANDUM OF AGREEMENT
BETWEEN THE NJ PINELANDS COMMISSION
AND THE NEW JERSEY DEPARTMENT OF
ENVIRONMENTAL PROTECTION AND ENERGY

Introduction

The New Jersey Department of Environmental Protection and Energy (DEPE) has recently adopted a solid waste management policy aggressively promoting reuse and recycling, resulting in the reevaluation of many waste management issues, including sewage sludge. In 1992, following the imposition of a ban on ocean disposal of sewage sludge, the DEPE adopted a sludge management hierarchy which promotes the beneficial use of the nutrient value inherent in sludge, and discourages sludge disposal. The policy's focus -- enhancement of pollution prevention and pretreatment strategies to improve sludge quality, continued research to evaluate the appropriateness of current sludge standards and protection of land and groundwater for future uses -- clearly acknowledges the DEPE's concerns regarding environmentally sensitive ecosystems such as the Pinelands.

The Pinelands encompasses approximately one million acres of pine-oak forests, cedar swamps and extensive surface and groundwater resources of high quality that provide a unique native habitat for a wide diversity of indigenous, and rare, threatened and endangered plant and animal species. While no present scientific documentation supports the conclusion that the controlled application of sewage sludge and sludge-derived product is contrary to the management of this valuable, pristine resource, legitimate scientific interests, and general public concern for the unique and sensitive Pinelands environment, warrant prudent review and oversight of continued applications of sewage sludge and sludge-derived products in the Pinelands. Such review and oversight will provide valuable information toward the implementation of the state's beneficial use sludge management policy, and will enhance public confidence in land application and beneficial use of sludge.

Therefore, the DEPE and the Pinelands Commission have negotiated the following Memorandum of Agreement related to the use of sludge and sludge-derived products in the Pinelands.

Purpose and Applicability

This Memorandum of Agreement between the New Jersey Department of Environmental Protection and Energy (hereinafter referred to as the "Department") and the New Jersey Pinelands Commission (hereinafter referred to as the

"Commission") is intended to formalize a framework to coordinate the review procedures and controls proposed for the use of sludge or sludge-derived products on lands within the Pinelands Area, with respect to the Pinelands Comprehensive Management Plan (N.J.A.C. 7:50-1.1 et seq.), the Pinelands Protection Act (N.J.S.A. 13:18A-1 et seq.) and the New Jersey Pollutant Discharge Elimination System Regulations (N.J.A.C. 7:14A-1 et seq.). In accordance with N.J.S.A. 13:18A-6, the Commission enters this Memorandum of Agreement under its authority to enter into any and all agreements or contracts, execute any and all instruments, and do and perform any and all things necessary, convenient, or desirable for the purposes of the Commission. The authority for the Department to enter into this MOA is N.J.S.A. 13:1D-9(g).

Findings

1. The use of sludge and sludge-derived products as fertilizer and soil conditioners is conducted in conformance with and pursuant to the Sludge Management Policy Guidelines and the Statewide Sludge Management Plan (SSMP), a component of the State Solid Waste Plan and mandated by State statute under the Solid Waste Management Act, N.J.S.A. 13:1E-1 et seq.

2. Consistent with the SSMP, sites that utilize sludge-derived products are exempted from permitting requirements under the New Jersey Pollutant Discharge Elimination System Regulations(NJPDES) (N.J.A.C. 7:14A-1 et seq.).

3. The Pinelands Area comprises pine-oak forests, cedar swamps, and extensive surface and ground water resources of high quality which provide a unique habitat for a wide diversity of rare, threatened and endangered plant and animal species and contains many other significant and unique natural ecological, agricultural, scenic, cultural and recreational resources.

4. The Preservation Area District and Special Agricultural Production Areas are especially vulnerable to the environmental degradation of surface and ground waters and native vegetation communities which would be occasioned by the improper development or use thereof.

5. Processing operations that generate sludge-derived products are controlled by NJPDES permits which require sludge-derived products to be routinely tested, and specify the conditions under which sludge-derived products meeting requirements under 40 CFR 257 and the Statewide Sludge Management Plan for a "Process to Further Reduce Pathogens" may be applied to lands of New Jersey.

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6. Sludge and sludge-derived products generated under NJPDES permits for use as fertilizer and soil conditioners are routinely analyzed for heavy metals and various organic compounds of New Jersey Sludge Quality Assurance Regulations (N.J.A.C. 7:14-4 et seq.), which prescribe the method and frequency of sludge sampling required of all sewage treatment works in New Jersey.

Mutual Understandings and Agreements

A. Definitions

1. "Composted Sludge" means any additional material which is produced by the treatment of sewage sludge from a domestic treatment works using the within-vessel, aerated static pile, or windrow composting methods and such that it is no longer noxious, putrescent, or vector attracting and it meets the requirements of a "Process to Further Reduce Pathogens" as defined at 40 CFR 257 and Part 4-I of the SSMP as determined by the Department or United States Environmental Protection Agency (USEPA).

2. "Domestic Treatment Works" (DTW) means a publicly or privately owned treatment works and shall include a treatment works processing domestic wastes together with any ground water, surface water, storm water, or industrial process wastewater that may be present.

3. "Land Application" means the controlled discharge of materials onto or into the soil surface in such a manner that the materials are treated by and become incorporated into and blended with the soil.

4. "NJPDES Permit Exemption" means the letter issued by the Department pursuant to N.J.A.C. 7:14A-10.8(b), which determines that a proposed General Distribution Program is in compliance with Department criteria as stated in Parts 4-I and 4-III of the Statewide Sludge Management Plan and is exempt from permitting.

5. "Sewage sludge" means the solid residue and associated liquid resulting from the physical, chemical and/or biological treatment of wastewater in a domestic treatment works.

6. "Sludge-derived product" means any material which is produced by the treatment of sewage sludge through various processes which cause significant change to the physical and/or chemical characteristics of

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the original sludge such that it is no longer noxious, putrescent, or vector attracting. Such products are suitable for marketing and use as a product. Where such products are intended for use as a fertilizer, soil conditioner, or liming agent, they must also meet the requirements of a "Process to Further Reduce Pathogens" as defined at 40 CFR 257 and Part 4-I of the SSMP as determined by the Department or United States Environmental Protection Agency (USEPA).

B. Pursuant to N.J.S.A. 13:18A-10, no state approval for development within the Pinelands Area may be granted unless such an approval conforms to the provisions of the Pinelands Comprehensive Management Plan.

C. The land application and/or storage of sewage sludge within the Pinelands Area requires the completion of an application with the Pinelands Commission and the issuance of a NJPDES permit by the Department. Sewage sludge may be land applied within the Pinelands Area only as part of an agricultural use (N.J.A.C. 7:50-6.77) and only if it meets all the requirements of the Pinelands Comprehensive Management Plan and the guidance of the New Jersey Agricultural Extension Service.

D. No submission to the Department is required for a NJPDES permit or a NJPDES permit exemption for any application or storage of sludge-derived product involving 100 cubic yards or less. No submission to the Pinelands Commission is required for any application or storage of sludge-derived product involving 100 cubic yards or less, unless an application for development is otherwise required, or unless the application or storage is proposed to occur in the Pinelands Preservation Area District or a Special Agricultural Production Area as defined by the Pinelands Comprehensive Management Plan (see map on Appendix A). No application of sludge-derived product in excess of 100 cubic yards shall occur within said Pinelands Preservation Area District or Special Agricultural Production Area except as otherwise regulated by the Pinelands Commission.

E. The following activities require approval of the Commission and the proper NJPDES permits:

1. All activities relating to the production, distribution and application of composted sludge within the Pinelands Area that require the issuance of a NJPDES permit by the Department;

2. Any activity which is inconsistent with any provision of this agreement;

3. Any temporary or permanent storage of composted sludge in excess of 100 cubic yards for distribution to sites other than the parcel on

which the storage is occurring; and

4. Any activity involving any sludge-derived product, other than composted sludge, which requires either a NJPDES permit or NJPDES permit exemption.

No permit or permit exemption issued by the Department for any such activity shall take effect until a Certificate of Filing, Certificate of Compliance, or development approval for the proposed activity has been issued by the Commission. No permit shall be approved by the Department unless the Pinelands Commission has determined that the proposed application of composted sludge is consistent with the Pinelands Comprehensive Management Plan (as cited in N.J.A.C. 7:50-4.81 and the Pinelands Protection Act, N.J.S.A. 13:18A-1 et seq.)

F. For any proposal within the Pinelands Area involving applications of sludge-derived product in excess of 100 cubic yards, the Department shall require that the applicant give notice of the proposed application of sludge-derived product to the appropriate county and municipal clerks, county board of health and municipal environmental commission, if any. This notice shall be given within 10 days of the submission to the Department for a NJPDES permit exemption. The Department will not act on the NJPDES permit exemption without documentation that the required notice has been provided. The Department will mail a copy of the NJPDES permit exemption within 10 days of issuance to the appropriate county and municipal clerks, county board of health and municipal environmental commission, if any.

G. With regard to proposals for the land application of composted sludge at sites within the Pinelands Area that do not require the issuance of a NJPDES permit but do require the issuance of NJPDES permit exemption, and which are consistent with the requirements of this agreement, the Commission and the Department understand that:

1. This activity will not require a formal application to the Commission; however, the Department will provide the Commission with the following information when the Department receives a request for permission to land apply composted sludge:

a. A copy of the description of the proposed activity and the location of the application site including the tax lot and block description.

b. A copy of a U.S.G.S. quadrangle map indicating the location of the proposed activity.

2. Within 20 days of the receipt of the information set forth in G.1, above, the Commission will notify the Department as to whether the proposal raises any issues with respect to the standards of the Pinelands Comprehensive Management Plan. The Department will not issue a NJPDES Permit Exemption for the land application of composted sludge within the Pinelands until such notice is provided or the 20 days have elapsed.

3. If the Commission indicates that the proposal is inconsistent with the standards of the Pinelands Comprehensive Management Plan, the Commission and the Department will meet to seek resolution of such inconsistencies. The Department will issue permit exemptions only after the Commission determines that inconsistencies with the Pinelands Comprehensive Management Plan have been resolved. In cases where inconsistencies cannot be resolved, a permit exemption request will be denied. If no comments are received from the Commission within the 20-day time period, the Department shall assume that the Commission concurs with the issuance of the NJPDES permit exemption for the project.

4. Public education efforts shall be developed cooperatively between the Commission and the Department to establish basic levels of understanding of the policies, science and regulations guiding use of sludge in the Pinelands. These efforts may include written materials and public forums for county and municipal clerks, county board of health and environmental commissioners, and other interested officials and citizens. Materials will be locally available and forums will be held as needed, but no less than seven days prior to the commencement of land application of composted sludge at any site within the Pinelands Area. Notice of such forums will be posted locally and announced through the media.

   The Department shall transmit notice of approval for the NJPDES exemption including terms and conditions, and appropriate timetables, to the Commission, the appropriate county and municipal clerks, county board of health and environmental commission, if any, at least seven (7) days prior to the commencement of initial land application of composted sludge at any site within the Pinelands Area.

H. The Department will impose the following requirements on all proposed land applications of composted sludge in the Pinelands Area approved pursuant to E and G. above:

1. The Department will not require pH adjustments in conjunction with

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the land application of composted sludge, except as required by Federal regulations for application as part of an agricultural use.

2. No composted sludge shall be stored or applied on any land within 300 feet of wetlands as defined by the Pinelands Comprehensive Management Plan (N.J.A.C. 7:50-6.3).

3. The quality of the composted sludge shall be tested at the processing site at least on a quarterly basis in accordance with the testing procedures required by the Department. The composted sludge shall be analyzed for at least the parameters listed in the research and monitoring program listed in Appendix B. Copies of the testing results will be provided to the Commission by the Department.

4. Composted sludge that does not meet the Class A or Class B Sludge quality criteria contained in Statewide Sludge Management Plan shall not be land applied within the Pinelands Area, except as expressly authorized by both the Commission and the Department.

5. Except for agricultural operations or as part of the research and monitoring program described in I. below, the composted sludge product shall be applied at a rate that does not exceed 70 cubic yards per acre (½ inch average depth). For agricultural operations, the application rate shall not exceed the agronomic rate of application required for the particular crop to be grown. For monitoring sites the rate of application shall not exceed 280 cubic yards per acre (2 inch average depth). For all sites the composted sludge product shall be incorporated within the top 6 inches of soil.

I. The Department shall implement an ecological research and monitoring program to assess the impact of various land application rates of composted sludge in the Pinelands, as defined in Appendix B. The design of said program has been undertaken in cooperation with the Commission. The program provides for direct and indirect monitoring of ground water impacts and monitoring of vegetation species composition in the study area. The vegetation component shall cover a period of three years, with the conclusion of the ground water monitoring research to be completed by the end of year two.

J. Following the completion of the research and monitoring program, the Department and the Commission may make such modifications to this agreement as are appropriate based on the research results.

Until that time, the Department will not authorize the land application of

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composted sludge on more than 500 acres of land in the Pinelands Area in any calendar year. The land application of composted sludge as part of an agricultural operation shall not be included in calculating the 500 acres nor shall this stipulation apply to NJ Department of Transportation practices, which are subject to separate application to the Commission.

K. Should future inconsistencies between the Pinelands Comprehensive Management Plan and the Department's rules and policies be identified, the Pinelands Commission and the Department shall work together to make the two sets of policies more complementary, including, if necessary, eliminating inconsistencies through amendments to either or both sets of rules and policies or to this Memorandum of Agreement.

EFFECTIVE DATE AND DURATION

A. This Memorandum of Agreement shall take effect upon approval by the authorized representative of both parties and subsequent to the Governor's statutory period for review of the Commission's minutes.

B. This agreement shall expire with completion of the research and monitoring program, or September 30, 1996, whichever comes first.

C. This agreement shall remain in effect until otherwise amended or terminated by either party upon sixty (60) days written notice.

SIGNATURES

Terrence D. Moore Executive Director NJ Pinelands Commission	Richard V. Sinding Assistant Commissioner NJ Dept. of Env. Protection and Energy
Attest: 12/23/93 (Date)	Attest: 1/14/94 (Date)

Approved as to form by:

Deputy Attorney General
State of New Jersey
Date 3/4/93

Attachment B

Research Proposal: "Efficacy of Composted Sludge Application in NJ Pinelands for Disturbed Site Recovery"

Part 1: "Fate of Metals and Nutrients Due to Application of Composted Sludge and Commercial Fertilizer Application in NJ Pinelands"

Part 2: "Comparison of Soil Amendments for Revegetation of Disturbed Sites in NJ Pinelands"

I. Problem Statement/Needs Assessment

Disturbed sites occur in the Pinelands due to sand mining and other soil/sand removal operations. Several methods have been employed to recover these sites, specifically reapplication of surficial soils that had been removed and stored prior to excavation of the site coupled with fertilizer application, and application of composted sewage sludge. Regardless of soil treatment used, sites are planted with native grass seed and pine species at recommended rates.

Each of these recovery methods has benefits and limitations that must be considered when deciding which method is best suited to ecological restoration of the indigenous Pinelands community.

The benefits of reapplication of surficial soils combined with vegetation planting in the Pinelands have not been documented due to the highly variable nature of stored top soil. These materials contain low or non-detectable levels of metals, thus, concerns regarding leaching of metals are eliminated. (Fields, et.al. 1992, See Table 1A). However, nutrients may also leach from stored top soil and microbiotic communities may be disrupted unless careful soil storage measures are followed.

Recovery of community function may be achieved, possibly in a more timely manner, by using either chemical fertilizers or sludge compost, combined with vegetation planting. The area can be immediately stabilized for erosion control purposes using indigenous grasses. Concurrent planting of native trees can reduce the prevalence of invading species, and speed the production of habitat for Pinelands fauna. However, depending on the amount and type of soil amendment used, soil conditions, and climate, leaching of nutrients and metals can occur.

Whatever method is chosen, revegetation in this sensitive ecosystem must be done with care to protect the precious and relatively pristine ground water and to prevent the introduction of non-indigenous plant species. Length of time for ecosystem recovery must also be considered when choosing a revegetation method. Detrimental effects of lengthy recovery time include erosion, invasion by non-indigenous species, loss of suitable habitat and loss of aesthetic beauty.

Providing soil conditions that will promote growth and permanent establishment of native vegetation is a primary concern in disturbed site rehabilitation. Chemical fertilizers are often applied to disturbed sites to enhance soil fertility. This soil amendment is readily available, easily applied and generally accepted by the public. However, nutrients, particularly NO_3 and K, may be highly mobile, organic matter and elements other than N, P, and K are not directly added to the soil, and physical properties of the soil (i.e. moisture holding capacity, infiltration rates and soil aeration) are not improved over the short term. In addition, heavy metal contaminants in fertilizers could pose risks to ground water and the food chain.

Compost adds organic matter, improves physical properties of the soil, and growth benefits are long term due to low mineralization rates. However, potential for heavy metal contamination of the ground water and food chain as well as nutrient leaching must be recognized.

Until studies are undertaken to determine the fate of composted sludge constituents and their effects on plant establishment, the use of composted sludge for disturbed site recovery in the Pinelands will be limited as described in the Memorandum of Agreement between these parties.

Therefore, NJDEPE and the Pinelands Commission propose the following study to examine leaching of metals and nutrients from small applications of high quality sludge compost and conventional fertilizer to soil pore water and ground water. The effects of these treatments on vegetation as measured by percent survival, growth, species richness and diversity will also be examined. The study has been designed to allow statistical interpretation of the data.

II. Background Information

The following background information is provided to summarize literature regarding the use of sludge and sludge compost for land reclamation, and potential problems due to leaching of nutrients and metals.

A. Land Reclamation

The use of sludge and sludge compost for land reclamation has been studied by several researchers. Specifically, R. Fimbel (1992) compared the sewage sludge compost (compost) and slow-release fertilizer (SRF) for revegetation lands severely disturbed by bomb-target practices in the pygmy pine-oak forest in the Pinelands. Plots were planted with native vegetation, including dwarf pines and scrub oak. The influence of mulch, with and without addition of a ectomycorrhizial fungus important to nutrient uptake, was studied. The effect of planting bayberry, a nitrogen fixing shrub, was also examined. Nitrogen yields of 16 metric tons per hectare (mt/ha) compost and Osmocote brand SRF were approximately equal.

Compost additions at the highest application rate studied (16 mt/ha = 0.25 inches) supported the best above and below ground growth of conditions tested. Amendments of ectomycorrhizial fungus and mulch did not enhance plant establishment; planting of N-2 fixing shrubs also did not enhance growth of pines.

Based on his two-year study, Fimbel recommended the use of 16 mt/ha of compost, disked in to 6 inches on graded sites. Sites should be planted with pitch pine and oak in late March or early April. (Fimbel, 1992). Leaching of nutrients or metals was not examined in this study. Long term establishment of vegetation on these sites was not addressed in the two-year study.

Berry (1987) reported excellent results using sludge for the establishment of pine species (Virginia, shortleaf, and loblolly) on sandy soils in the southeast. Trees on sludge-amended plots were taller and had larger stem diameters. Higher nitrogen concentrations were observed in sludge-amended plots than in fertilizer-amended plots after 10 years. Sludge-amended plots also had higher cation exchange capacity (C.E.C.), greater organic matter content, and higher P, K, and Ca. Initial nitrogen concentrations on sludge-amended plots were greater than on fertilizer-amended plots. However, it is not clear if the application rates of compost and fertilizer were based on available N. Leaching of metals was not considered in this study.

Moss, et. al. (1989) used sludge; sawdust and slow release fertilizer; and top soil and fertilizer to revegetate mine soils. Sawdust proved to be a superior amendment to sludge. Mn deficiency was suggested as the cause of poor performance of sludge-amended plots.

B. Leaching of Metals and Nutrients

Leaching of metals from sludge and sludge-derived products has been examined in field and laboratory settings. Typically, when studies are done in agricultural settings, soils are usually limed. Laboratory studies often provide descriptions of metals behavior in several soils over a wide pH range. Although the results of these studies cannot be used to precisely predict the behavior of metals in Pinelands soils, general trends can be inferred that will be useful in study design.

EPA and USGS conducted a study of metals and nutrient behavior during 3 years of sludge application (1973- 1975) in the Pinelands. (EPA, 1980; USGS, 1978). Class C (Zn > 2400 mg/kg) liquid sludge was applied at 22.4, 44.8 and 89.6 metric tons/hectare/year (mt/ha/yr) for three years to limed soils. Sludge was not incorporated into the soil, grass crops were grown. Sludge was also applied to wooded sites at 44.8 mt/ha/yr. Yields of grasses increased with increasing sludge application, and plant uptake of Cd and Pb due to sludge application did not occur, but increases in plant levels of Cu, Zn occurred at the 44.8 and 89.6 mt/ha/yr application rates. Very slight increases of Ni were also observed in vegetation samples from the 44.8 and 89.6 mt/ha/yr application rates. Cu, Ni and Zn, accumulated in surficial soils during the study.

Ground water was monitored by a transect of wells located on each plot and down gradient. Wells on the plots were nested to track pollutant plumes. Wells located on the plots were contaminated by NO_3. Low levels of Cu, Ni and Zn were also observed in some wells. Other metals were not detectable during the study period. NO_3 travelled through a 15 foot vadose zone and reached ground water about 9 months after the first sludge application.

Motto (1987) revisited these plots in 1986 and determined metals levels as a function of depth in soil profiles. These data show that the pH of the soil had returned to native condition. Pb was still present in surficial soils and had not moved downward. Cd and Zn had moved downward in the soil profile. Ground water was not sampled in this study.

Currently, the Division of Science and Research (DSR) is again revisiting these sites. Metals profiles in 6' soil cores and ground water data are being collected. Data from the study are not available yet.

During the development of revised standards for sludge regulation, the Division of Science and Research conducted an extensive review of the literature related to Cd, Cu, Pb and pathogens in sludge and sludge derived products (NJDEPE, draft, 1992). The results of this review are summarized below and related to the discussion of the use of compost to revegetate disturbed areas in the Pinelands.

McBride (1989) reported that chemisorption of heavy metals by metal (iron and manganese) oxides and hydroxides, amorphous alumino-silicates and organic matter usually results in rendering the metals nonexchangeable and hence unavailable to plants and animals. Metal affinities for iron oxides are reported as follows: $Pb^{2+} > Cu^{2+} > Zn^{2+} > Ni^{2+} > Cd^{2+}$. Affinities for aluminum oxides were reported to be: $Pb^{2+} > Cu^{2+} > Co^{2+} > Zn^{2+} > Ni^{2+} = Cd^{2+}$. Elliot, et.al. (1986) echo these results for mineral soils with varying acid content.

Chaney, et. al. (1989) have shown that Pb is strongly adsorbed by iron oxides and organic materials in soil. Baron, et. al. (1990) reported low affinity for Cd to organic matter, and Corey et. al. (1987) reported that Ca can readily displace Cd. Neal and Sposito (1986) showed that sorption of Cd to sludge-amended soils was inversely proportional to concentration.

Gangaiya and Bache (1988) reported that Cu formed the most stable complexes with available ligands, mostly insoluble organic ligands, although some complexing with soluble inorganic ligands did occur.

These researchers also reported that although Pb was present in relatively high concentrations (480 mg/kg in sludge), virtually no desorption occurred over the pH range of 4-7, indicating highly stable, insoluble complexes of Pb.

Perez, et.al. (1988) discuss the relative mobility of CrIII and CrVI. A sandy soil that contained 0% clay was included in the lab study. Results showed that CrVI is both more mobile and more toxic than the reduced state, CrIII, and that under the study conditions, CrVI was readily reduced to the relatively immobile, and less toxic, CrIII.

Mortvedt, et.al. described Cd uptake by wheat from three diammonium phosphate fertilizers containing 2, 74, and 153 ppm Cd. Results suggested that Cd uptake by crops from fertilizers on limed soils was not a significant concern, however, leaching of Cd was not considered. Zn and Ni concentrations were also elevated in these fertilizers. Ni concentrations were 10, 156 and 120 ppm Ni; Zn concentrations were 1, 1260 and 1290 ppm Zn.

As part of the development of revised standards for land application of sewage sludge, the Technical Standards and Research Committee modeled the transport of Cd, Cu and Pb to ground water in order to calculate the maximum allowable soil concentrations that would not cause exceedences of ground water standards. (NJDEPE, draft, 1992). While the results of the model are not directly applicable to Pinelands ground water standards, which prohibit any development except agriculture that degrades ground water quality, useful information regarding differential behavior of metals is obtained.

Adsorption coefficients for Cd, and Pb specific to Lakewood sand, a NJ soil, and Cu using a Delaware sandy loam, were used as inputs to the model (Lee, 1991). Adsorption coefficients for Cd, Cu and Pb were 10, 30, and 50 μg/g, respectively. The adsorption coefficients were developed using batch experiments with metal salts. However, metals applied in sludge or compost may have significantly higher adsorption coefficients due to available binding sites on organic matter. Unfortunately, adsorption coefficients specific to sludge are not available at this time. Therefore, conservative adsorption coefficients (i.e. the lowest) were used in this model.

Other model parameters included soil pH of 4.5, depth to ground water of 10 feet, ground water velocity of 3"/day. A 30 year run time was used. New Jersey ground water standards: Cd 4 ppm; Cu 1000 ppm; and Pb 8 ppm, were used.

Under model conditions, the allowable soil concentrations for Cd, Cu and Pb were 3, >1000, >100, respectively. Calculated increases in parameter concentrations after compost addition were developed based on incorporation of CCMUA compost into 6" of typical

Pinelands soil. Results are shown on Table 1A. Calculated increases in soil metals are: Cd <1 ppm; Cu <30 ppm; and Pb <12 ppm. Although the allowable soil concentrations determined by the model for these three metals were based on NJ ground water standards, not Pinelands ground water standards, the projected increases in soil concentrations due to compost application are small. This study will assess ground water impacts as measured by the Pinelands anti-degradation standard.

Cappon (1991) provides a review of Se in sludges. This metal is both a nutrient and a toxin, depending on concentration and form. However, there are no documented cases of Se contamination of ground water due to long term application of sludge. Se may not leach very readily since it has a high affinity for -SH on proteinaceous materials. Additionally, calculations provided in Table 1 show that the amount of Se added via compost will be very low, and probably will not be detectable in soils.

Alloway and Jackson (1991) reviewed the literature on the behavior of heavy metals in sludge-amended soils. Results from most studies indicated that metals are relatively immobile in soils, but this conclusion is tempered by climatic conditions, soil type and vegetation. Short-term studies do not address the long residence times of metals in soils.

The literature regarding the behavior of As and Hg in sludge-amended soils was lacking.

Contamination of ground water due to leaching of fertilizer-derived nutrients in agricultural settings is a well-documented problem. See Hubbard and Sheridan (1989) for an excellent review. However, literature on leaching of nutrients from compost and fertilizer in non-agricultural settings is scarce. Tester (1990) examined physical and chemical changes to Evesboro loamy sand (a Maryland soil) and found that after cropping for 5 yrs with fescue, compost-amended soils had higher organic matter, total N, and total P than fertilizer-amended soils. Data on initial soil loadings were not provided.

Commercial fertilizer regulations do not specify the maximum allowable levels of heavy metals, but do specify the minimum levels of N, P and K and nutrient metals. Of interest are the minimum requirements for 0.05 % (500 ppm) each Cu and Zn in fertilizer. (NJDEPE, draft, 1992).

C. Incorporation of Research Results into Study Design

Depending on background soil concentration, and compost used, the calculated increases in soil concentrations for some metals are expected to be very low, particularly for As, Hg and Se. (See Table 1A).

The research results presented above, particularly the model results, provide a basis for monitoring of metals individually. Cd and NO_3 are likely to leach relatively quickly. It is doubtful that during the 2.5 year study period Pb will move from the top layer of soil. The other metals will move at some undetermined rate through the vadose zone. In the previous study of sludge application in the Pinelands (EPA and USGS), depth to water table was less than 15 feet, elevated levels of NO_3 were not detected in ground water for nine months. This study included repeated applications, at much higher rates, of wet sludge.

Many types of commercially available fertilizers are available, including slow release fertilizers (SRF). However, the cost of SRF may be prohibitively high at large sites. Therefore the use of conventional fertilizer is suggested for this study. As noted above, Cd, Cu, Ni and Zn may be present in significant quantities in diammonium phosphate fertilizers. Due to lack of organic matter in anthropogenic fertilizers, these metals may leach more readily than metals bound to compost. In addition, leaching of NO_3 may occur more readily from commercially available fertilizers than from sludge derived products.

III. Objectives

As part of a Memorandum of Agreement between the Pinelands Commission and DEPE, this study serves to address the following questions:

Part 1: "Fate of Metals and Nutrients Due to Application of Composted Sludge and Commercial Fertilizer Application in NJ Pinelands"

- Do metals and/or nutrients leach to ground water from small amounts of high quality composted sludge or conventional fertilizer and is the rate of leaching related to amendment type and rate of application?

  This question will be addressed through the monitoring of soil pore water and ground water, and soils of compost and fertilizer-amended plots for a minimum of 2.5 years.

Part 2: "Comparison of Soil Amendments for Revegetation of Disturbed Sites in NJ Pinelands"

- What effect, if any, does the addition of composted sludge or fertilizer have on total plant cover, species composition, richness and diversity and growth of planted tree species?

  This question will be addressed by monitoring the parameters listed above on amended, planted plots for three years.

IV. Methods

It is expected that NJDEPE will be responsible for funding the project, which will be managed jointly by the Pinelands Commission and NJDEPE, and will be carried out by a mutually agreeable contractor.

A general study design is presented here. The Department, in mutual agreement with the Pinelands Commission, will arrange to have an independant university statistician recommend an appropriate statistically-based experimental design and evaluate the final proposal.

Briefly, site hydrology and geology will be characterized in detail. Chemical constituents in soil, soil amendments (sludge compost and fertilizer) and ground water will be determined before and after amendment application. Lysimeters and wells will be used to characterize movement of contaminants through the vadose zone to the ground water over a 2.5 year period. Native grasses and trees will be planted after soil amendment application. Survival and growth, species composition, richness and diversity of vegetation will be monitored for 3 years.

A tentative project schedule is as follows: Site selection and hydrological characterization will take place during the summer of 1993, soil amendment application and vegetation planting will occur in the fall of 1993. Chemical monitoring will begin after planting and continue through 3 recharge seasons (i.e. spring 1996). Vegetation monitoring will continue through October 1996.

A. Site Selection/ Preparation

One suitable location will be used for both Part 1 (Fate) and Part 2 (Vegetation) of the study. A typical disturbed site, such as an old sand mine, will be considered for site selection. The site will be mutually agreeable to the Pinelands Commission, NJDEPE and the contractor. Site selection criteria will include, but not be limited to: hydrology, geology, type of disturbance, site security and access, and ability to study the site longer than the 3 year project term. Site selection and characterization will be done by a qualified hydrogeologist.

The aquifer at the site should be unconfined, eliminating contaminant interaction with clays as a factor in the study. Depth to the water table should be about 10 feet. If possible, the site will be located on a ground water divide, so that lateral movement of the ground water will be minimal. To prevent erosion and cross-contamination of the study plots, the site will be graded to blend with the contour of the surrounding area. The site should be fenced (or otherwise secured) to prevent animal foraging, which will interfere with vegetative data collection, and disturbance by vandals.

1. **Characterization of Site and Amendments**

Prior to soil amendment applications, the hydrology, soils and amendment constituents will be characterized as follows:

a. **Hydrogeologic Characterization**

The water table will be mapped and direction and rate of ground water movement will be determined. If time allows, water table fluctuations due to recharge will be determined. Soil porosity and field capacity will be determined. Rain gages will also be installed to monitor water input.

b. **Plot Installation**

A sufficient number of plots will be installed for subsequent treatment with compost and fertilizer. Unamended control plots will also be installed. If the site is located on a ground water divide, plots will be placed in a line along the divide. Site hydrogeology will determine how the plots are placed on the site.

A sufficient number of soil samples will be collected to characterize ambient levels of metals and nutrients (as per Table 2) in surficial soils prior to amendment application.

c. **Lysimeter and Well Installation**

Gravity lysimeters and small wells will be installed on each plot. Lysimeters will be located approximately 1 meter below the ground surface. Small wells (1 inch diameter) will be installed on each plot and screened just below the water table and about 10 feet below the water table. This design will allow monitoring of constituents as they travel through the vadose zone to the water table, and transport in the water table. Again, a qualified hydrogeologist will be responsible for well placement and installation.

Background levels in ground water of all constituents listed on Table 2 will be determined from a subset of the wells prior to amendment application.

d. **Soil Amendment Characterization**

Levels of all constituents listed on Table 2 will be determined in composite samples taken from each batch of compost and fertilizer prior to amendment application.

2. **Amendment Application**

Soil amendments will be completed in the fall and plots will be seeded and planted immediately, preventing runoff.

a. Compost Application

Class B, unscreened, sludge compost will be applied to the plots and incorporated into the soil to 6", or 15 cm at the following rates: 0.5", 2" (or 70 tons/acre, and 280 tons/acre, respectively).

NOTE: The 1" application rate was eliminated at the suggestion of USGS, as we discussed at our 2/16/93 meeting. If this is not acceptable, and if funds allow, it can be reinstated.

b. Fertilizer Application

Commercially available fertilizer will be applied to plots to yield available N application rates similar to 0.5" and 2" of compost. Application will be done according to manufacturers recommendations. Prior to initiating the experiment, the type of conventional fertilizer will be specified. (Note: For purposes of leaching and growth comparisons with compost-amended plots, fertilizer application rates were based on comparable available N levels in compost and fertilizer. SCS recommends fertilizer application rates that are significantly higher for disturbed site recovery in the Pinelands.)

c. Unamended Control Plots

Control plots will be established on mined soil that has not been amended. These plots will provide a reference point for leaching and vegetation regrowth monitoring, i.e. a baseline.

3. Vegetation Planting

All plots will be seeded at recommended rates with indigenous grass seed (i.e. little bluestem, deertongue, red top) according to SCS guidelines to prevent erosion. Seeding will be done in the fall before the first frost. These grasses are commercially available.

Plots will be planted with 1 yr old pitch pine seedlings, at rates recommended by the Pinelands Commission. If possible, oak seedlings should also be planted.

B. Chemical Data Collection

1. Sample Collection

a. Soils

Deep soils cores (to lysimeter depth) will be collected on all plots immediately after amendment application. Cores should be sectioned, 6" intervals are suggested, longer intervals may be acceptable for deeper soils depending on results of field inspection and composited by layers (3-6 cores per composite). Composites within treatment type and application rate, from 0-6" layer on all plots and a representative number of composites from deeper layers will be analyzed for constituents listed on Table 2.

Samples will also be collected, sectioned and composited as above midway through the study and at its completion. Aliquots of all soil samples should be frozen and archived for possible future analysis.

b. Soil Column Studies

(Note: this portion of the study may be conducted under separate contract, and the researcher will be expected to provide specifics for this portion of the study.)

The purpose of this portion of the study is to assess potential long term leaching of metals from compost and fertilizer-amended plots. Small columns (e.g. 5 cm i.d. and 15 cm long) should be used. Amended surficial soils should be packed in replicate columns to approximate field bulk density. Standard simulated acid rain will be used. This is a commercially available product that simulates ionic strength and sources of acidity found in ambient acid rain. Water input data from rain gages and long term meteorological data will be used to estimate rain inputs over time. Estimates of leaching of metals of interest in compost and fertilizer after 1, 10 and 100 years are suggested. Since pH of the plots is expected to decrease with time, pH should be varied in these experiments using dilute acids. Leachate and/or soil column sections will be analyzed for extractable metals listed on Table 2. Metals analysis of fertilizer column samples can be limited to metals of concern as determined by initial fertilizer analysis.

c. Ground Water Monitoring

Ground water monitoring should be concentrated during periods of ground water recharge (winter/spring), with supplemental monitoring during other seasons. Wells will be evacuated using a slow peristaltic pump to minimize ground water disturbance. Nutrient, metal, and pH samples will be collected and field preserved as appropriate and analyzed as outlined below. Monitoring will continue for 2.5 years. A qualified hydrogeologist will provide a detailed sampling schedule that will be approved by the Department and the Pinelands Commission prior to study commencement.

d. Pore Water Monitoring

Pore water will be sampled after precipitation events to allow collection of sufficient sample volume while minimizing the time samples remain unpreserved in the field. If possible, data will be collected on a monthly basis, following precipitation events. Monitoring will continue for 2.5 years. A qualified hydrogeologist will provide a detailed sampling plan that will be approved by the Department and the Pinelands Commission prior to study commencement.

2. Chemical Sample Analysis

Samples will be analyzed by standard procedures in an NJDEPE certified laboratory. All samples will be analyzed by the same laboratory, using the same extraction and analysis method.

As stated previously, levels of all compounds of interest listed on Table 2 will be determined in soil, soil amendments, and ground water prior to the start of the study. Chemical monitoring will continue for 2.5 years.

a. Metals

Levels of total metals in waters and extractable metals in soils/solid samples should be determined by graphite furnace AA (GFAA) or ICP-MS. Achievable detection limits for soil and water using these instruments are shown on Table 1A.

b. Nutrients

Nutrient analysis can be completed using continuous flow autoanalyzers or ion exchange techniques. A certified laboratory should be employed and standard methods (i.e. SW-846 for solid samples) should be used for all analysis.

c. Other Parameters

Standard field and laboratory methods should be used for the analysis of these parameters.

C. Vegetative Data Collection

Analysis for this portion of the study will continue for 3 years to allow more time for plant establishment and growth.

1. Species Occurrence

An appropriate number of permanent quadrants will be placed at random on each plot and plant species composition and measures of abundance will be made by qualified personnel. Data will be collected three times during the growing season, late spring, mid-summer and late summer. Species abundance (cover and/or stem counts) will be measured to determine species composition, richness and diversity. The occurrence of non-indigenous species (types and frequency) is of special interest.

2. **Plant Growth and Survival**

The survival and growth of pitch pine seedlings during the course of the study will be monitored on each plot by measuring plant height and stem diameter for a representative subset of plants on each plot.

3. **Soil Nutrients**

Soil constituent analysis for year 3 will consist of: pH, total nitrogen, total phosphorus, potassium, calcium, magnesium, percent organic matter. These parameters should be determined at the beginning and end of the growing season and can be limited to the upper 6" of soil.

D. **Quality Assurance**

1. **Site Specific**

Site security must be maintained to avoid vandalism, and confounding factors such as relief of the land should be considered during site selection.

Compost application and incorporation must be done with care to ensure a known application rate and to avoid cross contamination of the plots. Runoff must be avoided during the study.

2. **Field QA Measures**

One blind duplicate sample should analyzed for every 20 - 30 chemistry samples in each matrix (i.e. soils, pore water and ground water from compost and fertilizer-amended plots and control plots.) Field blanks and field spikes should also be included in the study at a rate of one each for every 20-30 chemistry samples.

Appropriate measures should be taken if contamination is apparent. Of particular concern is the collection of nutrient and pH samples using lysimeters. Sampling of lysimeters will be limited to periods immediately following precipitation events to minimize changes in sample integrity. Quality assurance samples of nutrients, metals and if possible, pH, will be prepared and allowed to remain under field conditions to assess changes in sample quality during collection in lysimeters.

Field equipment should be cleaned appropriately using DEPE-approved procedures. Replicated plots were included in the study as a QA measure. Five columns for each soil amendment/ application rate should be prepared for the soil column studies.

3. Laboratory QA Measures

Calibration, spiked samples and replicate samples should be performed at the recommended intervals and steps to correct deficiencies should be made immediately as problems arise.

A Quality Assurance Project Plan, prepared by the contractor, will be due shortly after the contract award.

V. Data Analysis

A. Part 1: Fate of Metals and Nutrients

Data will be stored on disk using Lotus 123, Paradox or some other suitable data management program.

Data will be analyzed statistically to determine 1. if ground water contamination due to soil amendments occurred; 2. if so, can the occurrence of contamination be related to treatment type and level. Specifics regarding the analysis of data will depend on the plot configuration and sampling strategy proposed by the hydrogeologist. Data analysis will be approved by both the Department and the Pinelands Commission prior to study commencement.

Results from column leaching will be compared to field leaching and if a correlation is established, column leaching study results will be used to predict leaching over time.

B. Part 2: Vegetative Regrowth

Data will be stored on disk as described above.

Separate Analyses of Variance (ANOVA) will be conducted on (a) Pinelands species richness and cover, (b) non-Pinelands species richness and cover for the 3 year study period and individual growing seasons, (c) percent survival and (d) growth. The independent variables will be Soil Amendment Level and Block. Sampling Date will be included as a repeated measure. This will allow for trend testing as well as testing for differences due to Soil Amendment Level. Graphical presentation of the trends and group differences will be used to supplement the statistical analyses. The vegetation data will be classified and ordinated using appropriate dimensional reduction techniques to evaluate vegetation patterns.

If possible, the data will be used to make judgements about the most appropriate soil amendment to use for enhanced vegetative recovery of these sites.

VI. Reporting

Biannual reports should be submitted to the Department and the Pinelands Commission, and other interested parties. The project should be conducted on an interactive basis, with substantial input from the Department and Pinelands Commission. A presentation should be made to interested parties at the conclusion of the study.

Upon completion of the project, the investigator should provide recommendations regarding the ecological impacts and usefulness of compost or fertilizer application for disturbed site recovery in the Pine Barrens.

VII. References

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Table 1A

Increases in Soil Metals Concentrations After Compost Incorporation

Application Rates: 70 yd^3/ ac (0.5"); 140 yd^3/ ac (1.0"); 280 yd^3/ ac (2.0")

CONC IN PPM

PARM [1]	COMPOST CONC [2]	BG SOIL CONC [3]	INC IN SOIL CONC 0.5" [4]	INC IN SOIL CONC 1.0"	INC IN SOIL CONC 2.0"	SOIL MDL AA/ICP [5]	WATER MDL AA/ICP
As	4.40	0.11	0.05	0.1	0.2	0.5/10	0.005/0.1
Cd*	13.0	0.007	0.15	0.3	0.6	NR/0.3	0.002/0.003
Cr	81.0	1.15	0.94	1.9	3.8	NR/1	NR/0.01
Cu*	607	0.92	7.0	14.0	28.0	NR/2.5	0.001/0.025
Pb*	165.9	5.1	1.9	3.8	7.7	0.5/10	0.005/0.10
Hg	1.7	<0.01	0.019	0.038	0.08	0.1	0.0002
Ni*	35.5	<1.2	0.41	0.82	1.64	0.5/4	0.005/0.040
Se	2.54	<0.01	0.03	0.06	0.12	0.5/10	0.005/0.5
Zn*	718	3.67	8.3	16.6	33.24	NR/2	NR/0.02

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1 * Indicates constituent monitored in compost

2 Average concentration in CCMUA compost* or sludge (7/91-7/92). Note that sludge concentrations are usually higher than compost concentrations due to dilution of compost with wood chips.

3 Background soils concentrations of metals from 3 Pinelands Soils reported in Fields, et. al. (1991).

4 Increase in soil concentration after addition of compost was calculated as follows: (Assuming incorporation into 6" of soil) [metal (mg/kg) * 0.002205 * application rate (cu yd/ac) * 1000 lbs/cu yd * 0.5 (water content) * 0.6 (dilution with chips) * ton/2000 lb * 1E6 mg/kg]/ 2E6 lbs soil/ac = mg/kg increase in soil conc.

5 Graphite furnace AA and ICP mdl's as reported by a certified laboratory. NR = not reported.

Table 1B
Increases in Soil Nutrients Concentrations After Compost Application

CONC IN PPM

PARM[1]	COMPOST CONC[2]	BG SOIL CONC[3]	INC IN SOIL CONC 0.5"[4]	INC IN SOIL CONC 1.0"	INC IN SOIL CONC 2.0"
TKN*	276,000	ND	320	639	1278
NO_3*	43	5.4	0.5	1.0	2.0
NH4*	3,925	9.7	46	91	182
P*	16,160	3.3	187	374	748
K*	2,830	8.8	33	66	131
Ca	12,659	197	146	293	586
Mg	2,213	87	26	51	102

[1] * indicates constituent monitored in compost.

[2] Average concentration in CCMUA compost* or sludge (7/91-7/92). Note that sludge concentrations are usually higher than compost concentrations due to dilution of compost with wood chips.

[3] Background soil concentrations from EPA (1980) raw data.

[4] Increase in soil concentration after addition of compost calculated as per Table 1A.

Table 2
Parameter List

NOTE: In addition to the parameters listed below on Table 2, the following field parameters will be obtained: for soils: field pH, for ground water: pH, temperature and conductivity, height of water table, for pore water: pH, temperature and conductivity.

Soil/ Composted Sludge/ Fertilizer

Total Metals	**Nutrients**
Arsenic	♦Total Nitrogen*
Cadmium*	Nitrate Nitrogen
Chromium	Ammonia Nitrogen
Copper*	♦Total Phosphorus*
Lead	♦Calcium
Mercury	♦Magnesium
Nickel*	♦Potassium*
Selenium	
Zinc*	

(Soil and Amended Soil Only)
♦pH
♦C.E.C.
♦Percent Organic Matter
♦Soil Moisture (March to Oct, only)

Pore Water/ Ground Water

Total Metals	**Nutrients**
Arsenic	
Cadmium	Nitrate Nitrogen
Chromium	
Copper	
Lead	
Mercury	
Nickel	
Selenium	
Zinc	

Field Parameters
pH
Conductivity
Temperature

♦ Will be analyzed for 3 years, all others will be analyzed for 2.5 years.

* Possible contaminants on fertilizer-amended plots.

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