**TOWN OF COLONIE SANITARY LANDFILL
LEACHATE MANAGEMENT SYSTEM**

**Final Report for
1992 and 1993 Spraying Seasons**

Prepared for

**THE NEW YORK STATE
ENERGY RESEARCH AND DEVELOPMENT AUTHORITY**

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1045-ERER-ER-88

NYSERDA
Report 96-10

August 1996

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SUMMARY

The Town of Colonie Landfill Leachate Management System (LLMS), NYSERDA Agreement No. 1045-ERER-ER-85, was a research project designed to study the viability of on-site treatment of leachate at a municipal solid waste landfill. The treatment method consisted of spraying leachate over the closed landfill's surface to facilitate evaporation and transpiration into the native vegetation. Other facets of the project included evaluating environmental impacts on the soil and air, vegetative uptake of pollutants, and resultant soil moisture.

The project demonstrated the viability of using spray evapotranspiration as a means of treating leachate, as well as the economic limitations of constructing and operating a leachate-spraying system. During two three-month spray periods, more than 1,120,000 gallons of leachate were disposed of at an average cost of \$0.0588 per gallon, including all energy, operating, and capital costs. If the cost of new lagoon construction were excluded from the capital costs, the treatment cost would be reduced to approximately \$0.032 per gallon of leachate disposed, compared with a cost of \$0.048 per gallon to haul and treat the leachate at a conventional wastewater-treatment plant. The new lagoon was required for normal operation of the landfill, but also was required to provide sufficient storage volume to supply the LLMS during the summer spraying season.

The energy usage for this leachate-spraying system, including energy for construction, was approximately twice the energy needed to transport and treat leachate at a conventional wastewater-treatment plant.

Environmental impacts of leachate spray evapotranspiration proved to be minimal, with negligible amounts of pollutants being transported off site, as determined by air-sample collection and analysis. In addition, site vegetation consumed some pollutants, while other pollutants were deposited in the soil in low concentrations. The leachate did not kill or inhibit the growth of site vegetation.

The greatest value of this study may be the identification of myriad operational problems associated with a fully operational and automated spray system. Many improvements were made in the field during operation, while some improvements, such as better control software and system communication, can easily be incorporated into future versions of this project. Design and operation of this system was complicated by the need to monitor and record many parameters for study purposes. Future designs may greatly simplify operation of the system and reduce capital costs.

Section 1

INTRODUCTION

HISTORY OF PROJECT

The development, construction, and operation of the Colonie Landfill Leachate Management System (LLMS) was first conceived as a two-year project in 1987, but took more than six years to reach the final reporting stage, during which time substantial regulatory hurdles were encountered and overcome.

During the summer of 1987, a work plan for the project was developed. It was determined that a pilot leachate-spraying study should be undertaken to provide additional information on the potential environmental impacts due to surface runoff and moisture front penetration through the landfill cap. To achieve this, a 1/4-acre (100' x 100') test area was prepared and equipped with a single leachate spray head, a collection point for runoff, a rain gage, and four pan lysimeters (at depths of 6", 12", 18", and 24") to measure moisture advancement through the cap. A similarly equipped control area, minus the spray head, was prepared nearby.

While the environmental information gleaned from the pilot study was sufficient to satisfy regulatory demands, another finding was that pan lysimeters were not an accurate or convenient means for evaluating soil moisture. Not only were the lysimeters highly sensitive to differences in construction installation, they also tended to gather more moisture from condensation than from actual moisture advancement due to spraying. This led to a decision to use a gypsum block technology to measure soil moisture based on the principle that electrical resistance through the gypsum varies inversely with the moisture of the surrounding soil.

Continuing efforts to re-permit the landfill combined with environmental questions surrounding the project delayed the construction of Colonie's LLMS for another two years. Finally, on August 7, 1990, the Notice to Proceed was issued for the construction of the LLMS pump station, piping and spraying equipment, and monitoring and control systems. Construction took place during the winter and spring of 1991. Another portion of the LLMS project consisted of construction of a one-million-gallon leachate-collection basin to furnish an adequate supply of leachate. Construction of the basin was begun in May 1991 and completed in late 1991, with time only for testing and decommissioning before winter. In addition, two existing lagoons were reconstructed into one 900,000-gallon leachate-collection basin, starting in August 1992 and ending in October 1992. This additional lagoon, while not an official part of the LLMS project, provided additional leachate-storage capacity for the project. The summers of 1992 and 1993 were the actual demonstration period for the Colonie Landfill Leachate Management

System, a system that would demonstrate the feasibility of managing landfill leachate on site using spraying, evaporation, and transpiration of liquids in native vegetation.

GOALS OF PROJECT

The Town of Colonie Landfill Leachate Management System (LLMS) project was undertaken to evaluate alternate means of on-site landfill leachate disposal. The main goal of the project was to evaluate the feasibility of using an evapotranspiration system in which leachate would be sprayed during the summer months over a portion of a closed landfill cap and allowed to evaporate into the air and transpire into vegetation. In addition, the system was designed to permit the injection of leachate directly into the landfill mass to promote further degradation of the solid waste. However, the leachate injection portion was not approved for operation by the New York State Department of Environmental Conservation (NYSDEC).

Other project goals included evaluating the effects of leachate application on the surrounding environment, including changes in air quality and pollutant levels in vegetation and soils, and any detrimental effects on the compacted clay landfill cap. In addition, the project was to compare energy usage and cost, as well as overall operating cost versus the energy consumption and cost of transportation to and treatment and disposal at a wastewater-treatment plant. An additional goal was to evaluate the range of acceptable and unacceptable operating conditions for the system.

Determining the general relationship between the leachate-generation rate from the landfill and the LLMS practical spray rate was another goal. Due to a faulty flowmeter used during the 1992 spraying season and damage to the pump station caused by a lightning strike during the 1993 spraying season, determining an accurate site-specific relationship between the leachate-generation rate and the LLMS spray rate was not possible. However, the LLMS was observed to have the capability of spraying the entire volume of leachate stored in the lagoons over each spraying season. It would be feasible to increase the number of spray heads, with a possible change in pump selection, to allow spraying of leachate over the entire closed section of the landfill to dispose of a substantial percentage of the annual volume of site-generated leachate. This expansion of the LLMS system could require additional storage capacity to store leachate throughout the year for disposal during the spraying season.

When the LLMS was being designed, accurate data was not available to determine the leachate-generation rates, which vary by season, for comparison to proposed pumping rates. In addition, the practical operational pumping rate through the series of spray heads laid out over the landfill cap could not be determined during design due to the unknown effects of long-term leachate spray on the cap. These unknowns included potential erosion of the landfill cap, possible runoff of excess leachate spray

not evaporated or consumed by vegetation, possible "poisoning" of the cap vegetation, and the effect of prolonged moisture exposure on the integrity of the landfill cap.

FUTURE USES AND APPLICATIONS OF PROJECT

Future uses or applications of this project include construction of similar systems at numerous landfills throughout the State where on-site disposal would be more economical than transportation and treatment at a wastewater-treatment plant. Implementing a leachate-management system should be limited to lined landfills with leachate-collection and storage facilities, and would be subject to regulation by NYSDEC. Using a leachate-spraying system would not affect requirements for the landfill cap, which must be constructed in accordance with NYSDEC Part 360 regulations.

Section 2

GENERAL SYSTEM OPERATION

The LLMS was designed to be an automated system controlled by a host computer with display, monitoring, data-gathering, and supervisory capabilities to oversee pump controls; spray-head application cycles, rates, and operation; weather station instrumentation and conditions; and daily lagoon levels. Although the project was not authorized by NYSDEC to use a proposed leachate-injection system, the LLMS system had the capability to inject leachate into the landfill's solid waste mass to enhance degradation of the solid waste, controlled by a supervisory control and data-acquisition (SCADA) system.

As originally designed, the operation of the LLMS was accomplished by a SCADA computer-controlled pump station that regulated pumping rates and flow duration through a series of 12 individually controlled irrigation-style sprinkler heads located on a vegetated portion of the capped landfill. Each spray head discharged an average flow rate of approximately 35 gallons per minute (gpm) over the landfill cap, with varying flow duration times depending upon the specific spray-head locations and site topography. A one-million-gallon lagoon was constructed as part of this project to provide sufficient leachate-reservoir storage for the LLMS.

For the 1993 spraying season, municipal employees increased the number of spray heads from 12 to 22 to minimize ponding and erosion problems. Spray heads were relocated away from slopes and low-level areas prone to ponding. The type of spray head was changed from one with a stream-spray pattern to a fog-spray pattern to minimize spray-head clogging and improve spray distribution over the site. The net pumping rate of the system remained substantially unchanged from the original layout.

The SCADA system was designed to simultaneously monitor numerous weather conditions (including precipitation rate and quantity, air temperature, wind speed and direction, rain start and stop times, relative humidity, and time and duration of all weather-induced interruptions to the spray system cycle). The system also monitored system operating conditions, including pump flow rate and discharge pressure, lagoon levels, individual spray-head operational status, spray-head cycle times, total hours of system operation, and total quantity of leachate sprayed.

The SCADA system had the capability of suspending the spray operation in the event of precipitation, or if the operating setpoint parameters were exceeded.

The leachate-spray pump took leachate from two interconnected NYSDEC-approved containment lagoons hard-piped to an electric centrifugal pump. Leachate then was pumped through the distribution

pipng to a network of individually controllable spray heads on top of a closed portion of landfill cap covered with vegetation. The landfill cap consisted of 24 inches of compacted native clays.

The basic system operational concept was to spray leachate in controlled intervals over specific areas of the project site during the summer months to facilitate evaporation into the atmosphere, with any remaining liquid consumed by site vegetation. Prevention of leachate runoff was managed by limiting spray-head cycle on-times and by discharging leachate over a wide area through numerous spray heads. The SCADA system allowed the operator to adjust spray-cycle times to varying daily weather conditions to maximize system output and efficiency. During less-than-ideal conditions, the operator could shorten cycle on-times to prevent ponding and runoff and also maximize system output and efficiency for the existing conditions.

The software package and control system had the capability of monitoring weather around the clock with timer-controlled spray-system cycles that controlled system operation based upon the time of day and day of the week. Daily reports that included printouts of all data collected could be printed automatically at an operator-selected time of day. The computer system could store up to approximately one season of operational data before having to be downloaded to a magnetic floppy diskette. This feature was not used during the study due to the level of software experience necessary to use the storage program successfully. Also, the operators chose not to leave the system operating when no personnel were on site.

The LLMS system also could be operated by bypassing the SCADA system and manually turning the pump on and off at the beginning and end of the spraying session. This operating mode was used during the 1993 spraying season due to extensive lightning damage to the control systems.

Section 3

DESCRIPTION OF ENVIRONMENTAL MONITORING PROGRAM

Evaluating the LLMS project with regard to environmental issues and system economics, efficiency, and performance required a field observation and monitoring program to provide sufficient data for study and analysis. The program consisted of three phases: (1) monitoring the moisture front penetration into the landfill cap, (2) monitoring project soil and vegetation for pollutant uptake from leachate, and (3) monitoring ambient air for airborne pollutants emitted during spraying.

Phase 1 involved monitoring the moisture front penetration into the 2-foot-thick compacted-clay landfill cap, which was accomplished by installing moisture-sensitive gypsum blocks at different depths in the cap and periodically recording impedance readings. The gypsum blocks were manufactured with two parallel electrodes totally embedded in gypsum plaster of paris and connected to wire leads extending above the ground surface. The system is based on the blocks' ability to absorb moisture in direct relation to the surrounding soil. Conductivity increases as the gypsum-block collects more moisture and decreases as the gypsum-block moisture content decreases. Data from the gypsum-block monitoring program was supplemented by test-pit excavations in selected areas to visually examine moisture penetration and verify soil conditions. Two control gypsum-block stations were installed outside the spray area and monitored along with the stations in the spray area.

The gypsum-block data was collected periodically by connecting multimeter test leads to the wire leads from the gypsum blocks and recording the resulting impedance value. A new station was established in 1992 and monitored as a control station located remotely from the leachate-spray area to determine relative changes in moisture content of soil not subject to leachate spray. An additional remote station was established before the 1993 spraying season as a back-up control station. The final station was established because results from the second station in 1992 significantly differed from results within the spray area.

The data for the gypsum-block monitoring program was compiled and reviewed along with results of test-pit excavations and site-weather data in an attempt to determine moisture levels at various soil depths over the spraying seasons.

The moisture front penetration monitoring program was originally envisioned as using pan lysimeters installed at various depths. Pan lysimeters collect moisture in a pan, with the liquid then flowing by gravity into a connected containment vessel. These devices were tested during an on-site pilot project the summer before this project began. During the pilot test, moisture-content measurement by pan

lysimeters was found to be inaccurate due to the propensity for condensation to form in the containment vessel, yielding inflated moisture-content volumes.

Phase 2 of the monitoring program included collection and laboratory analysis of soil and vegetation samples. Samples of vegetation and soil were collected from the spray and adjacent control areas to determine the presence and concentration of pollutants commonly found in normal site-generated leachate during periodic NYSDEC-required leachate analysis. In addition, visual observations and analysis of compounds in site leachate were done to assess the leachate's ability to sustain vegetation growth over the spraying season. Vegetation and soil sampling and analysis were conducted once during the 1992 spraying season and twice during the 1993 spraying season.

Phase 3 encompassed ambient air monitoring in the leachate-spray and adjacent control areas to determine the concentrations of various pollutants in the air versus their concentrations in the leachate. Air sampling was accomplished by installing monitoring pumps containing charcoal collection media at specific locations just outside the leachate-spray radius downwind of the spray areas. These representative locations were selected to allow for maximum collection of airborne vapors during the two-hour sampling period without collecting water and voiding the sample. To ensure sampling accuracy and control, the monitoring pump was calibrated prior to the monitoring and also post-calibrated at approximately 200 cubic centimeters per minute. Additional monitoring pumps were installed in perimeter areas outside the spray area to collect control samples.

The samples, control samples, a sample blank, and a liquid leachate sample were analyzed in the laboratory to determine the presence and concentrations of pollutants known to exist in site leachate. The lagoons did not provide any leachate pre-treatment other than minor oxidation and settling out of iron.

Section 4

RESULTS OF ENVIRONMENTAL MONITORING PROGRAM

After two seasons of LLMS operation, evapotranspiration of leachate over a closed landfill cap appeared to be a viable alternative when compared with transportation to and treatment at a conventional wastewater-treatment plant.

GYPSUM-BLOCK MONITORING PROGRAM

A review of two seasons of gypsum-block data, field visual observations, and test-hole excavations led to the following conclusions:

- a. The moisture level within the top six-inch layer of the landfill cap noticeably increased during periods of precipitation and in areas where substantial quantities of leachate were applied.
- b. The moisture levels in these areas did not significantly increase during drier, hotter periods and low leachate application.
- c. Relative changes in moisture levels and gypsum-block readings from periods of precipitation varied slightly at a depth of 12 inches when compared to periods of minimal or no precipitation.
- d. Moisture levels and relative changes in gypsum-block readings at lower depths where ponding occurred indicated near-saturated conditions, verified by test-site excavations.
- e. Relative changes in moisture levels and relative gypsum-block readings at the lower depths tended to be insignificant during periods of minimal or no precipitation, with no water-ponding permitted.
- f. Relative moisture levels for stations installed within the spray area were generally higher than those for control areas outside the spray area.
- g. Areas that experienced complete saturation due to limited ponding tended to retain higher moisture levels at lower depths for longer periods. The upper six-inch layer held less moisture due to wind and sun exposure.

- h. Leachate-spray application on side slopes with minimal vegetation contributed to localized erosion of the cap. Emission-control measures implemented for the 1993 spraying season included relocating specific spray heads, limiting spray flow rates and quantities, and planting vegetation.

Test-hole excavations showed that small areas in which ponded water was allowed to stand for days demonstrated saturated soil conditions in the upper layers of the clay cap and increased moisture at lower depths. While these conditions were not typical of the project area, they did demonstrate the importance of proper site grading.

After the 1993 spraying season, four gypsum blocks from random representative locations were retrieved from the landfill cap to determine their condition after burial for up to 15 months and potential exposure to leachate over one or two spraying seasons. Only one block appeared to be intact and unbroken.

The gypsum blocks were constructed with parallel electrodes to yield electrical-resistant data based on the block configuration. The relative data gathered for a particular gypsum block might be inaccurate if the block developed cracks or broke apart, with the inaccuracies attributable to electrode short circuits. Additional data inaccuracies could result if the chemical composition of the gypsum block was altered due to free ions present in the leachate. This could result in a changed block conductivity and inaccurate relative impedance readings. The gypsum blocks were constructed and factory-calibrated to generate readings when exposed to clean water used for agricultural irrigation. A third possible testing inaccuracy may have resulted from corroded wire leads that could affect meter connections and resulting meter readings.

Based upon the physical condition of the retrieved gypsum blocks and the potential inaccuracies associated with gypsum-block monitoring, the data collected is considered questionable. See Appendix 1 for results of the gypsum-block monitoring program.

SOIL AND VEGETATION ANALYSIS

Vegetation and soil samples were collected and analyzed three times over the course of the project to determine the effects of long-term exposure to various pollutants in the leachate. Grab samples of soil and vegetation were collected in representative areas exposed to long-term leachate application and also in control areas remote from the spray areas. Laboratory analysis was performed on the samples to determine the relative change in selected representative pollutants. The data also was compared to laboratory analytical data on liquid leachate.

The soil and vegetation samples were analyzed for the following pollutant parameters:

antimony	selenium
arsenic	silver
beryllium	thallium
cadmium	zinc
chromium	benzene
copper	toluene
lead	xylene
mercury	ethylbenzene
nickel	total hydrocarbons

Data from the laboratory analysis supported the conclusion that, at the beginning of the spraying season, a majority of the pollutant parameters were absorbed and partially consumed by the site vegetation, with minimal concentration increases of these parameters in the soil. Testing performed during the latter part of the 1993 spraying season revealed continued pollutant absorption by vegetation, with increased concentrations of some of the pollutants in the soil (as compared to control samples). Some pollutants appeared to be consumed by vegetation, while pollutants that could not be consumed by vegetation were essentially deposited in the soil.

The possible impact of compounds or elements (which are essentially salts) on the growth of vegetation on the landfill cap was evaluated by comparing laboratory analysis results of site leachate versus recommended guideline concentration limits for irrigation water. The suitability of water for irrigation depends on the level of parameter concentration in the water and the resulting parameter concentration in the soil. If the buildup of "salts" in the soil exceeds a "threshold," vegetation will be killed and the soil will not sustain vegetation growth until remedial action takes place. Soil remediation would require leaching the top four to eight inches of soil or replacing this top layer of soil.

Results of site leachate laboratory analysis performed during 1992, 1993, and 1994 were compared to guideline concentrations for assessing the suitability of water for irrigation purposes. Concentrations of chloride, sodium, and boron were compared to determine if "poisoning" of the vegetation could possibly occur, and, if so, to estimate when deleterious impacts would begin.

Chloride concentrations in the two on-site storage lagoons varied between the lagoons for same-date samples. In addition, chloride concentration levels varied between sampling dates.

Based upon a comparison with "Selected Guidelines For Assessing The Suitability of Water For Irrigation Purposes,"¹ the recommended degree of restricting leachate use for irrigation due to chlorides varies from none to severe. For the January 10, 1992, sampling, the chloride level in the north lagoon required no irrigation restrictions, while the south lagoon basin chloride level required moderate restrictions. Based on a March 26, 1993, sampling, both lagoons required severe (recommended) restrictions due to chloride concentrations.

Leachate sodium concentration also was evaluated to determine its impact on vegetation growth. Sodium can cause clay soils, such as those used in the landfill cap, to disperse due to the large radius of sodium hydration. When clay soils are dispersed, soil pore size and permeability are reduced, restricting water transmission to vegetation roots, which could cause the vegetation to die. This phenomenon results from positive sodium, calcium, and magnesium ions being absorbed on negatively charged clay surfaces.

Acceptable sodium-absorption ratio (SAR) values for irrigation water are a function of particular soil characteristics. In general, water with an SAR value of less than three is considered "low risk" for irrigation purposes. Water with an SAR value greater than six requires considerable care.² Water with an SAR value greater than nine is considered "high risk" for irrigation purposes.²

The SAR values for the leachate samples analyzed ranged from approximately 0.5 to 5.2. The resulting degree of restriction of use, based upon SAR values, is none to moderate, with low to moderate use risk.

The leachate also was evaluated for the effects of boron on vegetation growth. Boron can be toxic to many plants at concentrations below 1 g/cm³(mg/L). Moderate restriction of water use for irrigation purposes should take place for concentration levels up to 2.0 mg/L, and severe use restrictions should be implemented for concentration levels in excess of 2.0 mg/L.

The boron concentration levels in site leachate, as determined by laboratory analysis, ranged from approximately 0.05 mg/L to 2 mg/L. The resulting degree of use restriction due to boron concentrations ranged from none to moderate.

The possible impact on vegetation of compounds or elements including chlorides, sodium, and boron in site-generated leachate varied, depending on the relative concentrations and parameters present in the

¹ Tchobanoglous, George and Edward D. Schroeder, Water Quality, Addison Wesley Publishing Company, 1985, Table 3.11.

² Tchobanoglous, George, and Edward D. Schroeder, Water Quality, Addison Wesley Publishing Company, 1985.

leachate stream at a particular time. Comparing the concentration levels for each parameter present during sampling revealed that concentration levels in samples taken at least once from the south lagoon were within acceptable ranges, with low risk to vegetation and no necessary restrictions on irrigation. North lagoon leachate sampled and analyzed simultaneously, required moderate use restrictions for irrigation purposes. The samples collected and analyzed in 1993 revealed significant and severe risk of "poisoning" the soil and vegetation on the landfill cap.

Based on the sampling and laboratory analysis for different time periods, the leachate's suitability for irrigation and support of vegetation varied. The long-term effect of spraying leachate over the landfill cap's vegetation was difficult to determine due to varying concentration levels of chloride, sodium, and boron in the leachate. Continued leachate analysis to monitor these parameters' concentration levels would be necessary.

The results of the soil and vegetation analyses and leachate analysis for "salts" can be found in Appendix No. 2.

AMBIENT AIR MONITORING

An air monitoring program was used to measure the effects of leachate evaporation by collecting and analyzing representative air samples for the presence of selected pollutants. A sub-contractor was retained to install monitoring pumps with charcoal collection media at representative sites just outside and down wind of the spray area. In addition, leachate grab samples were obtained for analysis and comparison. Volatile organic compounds (VOCs) in both lagoon and sprayed leachate were not compared directly. However, VOC levels were compared among leachate samples taken at a spray nozzle, and air samples taken downwind of the spray heads and at control areas outside the spray area. The samples were analyzed in the laboratory for the following VOCs:

benzene	xylene
ethylbenzene	total hydrocarbons
toluene	

Results of the air monitoring program were as follows:

- a. Parameter concentrations within the spray area did not exceed control sample concentrations during both testing dates in 1993.

- b. Some VOC pollutant concentrations directly downwind of the spray area exceeded concentrations within the control areas by 1 to 44 percent during the 1992 spraying season.
- c. Testing all leachate pollutants was not possible. However, results for the parameters tested indicated that a majority of the pollutants did not appear to have been transported via air off site during the evapotranspiration process and pollutants in the leachate spray did not adversely affect air quality. Some VOCs also may have volatilized from the leachate lagoon surface, but this was not tested.

The results of the air-monitoring program were subject to weather conditions, including wind, temperature, and humidity. Test locations were selected to maximize polluted air sample collection at worst-case representative locations. VOC concentrations dropped off as the sampling distance from the spray area increases, due to dilution with air. Quantities of the tested VOCs may not be measurable at the site property line, which is approximately 800 feet from the spray area.

Data and results from the ambient air-monitoring program can be found in Appendix 3.

Section 5

ECONOMIC ANALYSIS OF LLMS OPERATION

The LLMS system, which was operated over two seasons for a total of approximately 7-1/2 months, disposed of a total of approximately 1,120,000 gallons of leachate. The owner's cost for transporting, treating and disposing of this much leachate would be approximately \$54,400 for two seasons, or approximately \$0.048 per gallon of leachate.

The LLMS' total construction cost was \$394,542, including \$170,968 for the lagoon and \$223,574 for the LLMS. Amortizing the construction cost over an estimated useful life of 15 years yields an average annual capital construction cost of approximately \$26,302, which includes \$14,905 for the lagoon and \$11,397 for the LLMS. The two-year operating cost includes \$270 in 1992 and \$475 in 1993 for electricity, and \$5,000 in 1992 and \$7,500 in 1993 for labor. The total cost, including all capital and operating expenses for 1992 and 1993, was \$31,572 and \$34,277, respectively.

The LLMS' total operating cost is presented in two tables, with Table 5-1 presenting the costs of constructing and operating an LLMS with a new lagoon, and Table 5-2 the costs without a new lagoon. For each case, the civil works are assumed to have a 15-year useful life, with the construction cost accounted for by averaging it over the facilities' life.

Table 5-1

Total Cost of LLMS			
<u>Item</u>	<u>1992 Season</u>	<u>1993 Season</u>	<u>Cost Per Gallon</u>
Lagoon Construction (avg. over 15 yrs)	\$14,905	\$14,905	
LLMS Construction (avg. over 15 yrs.)	11,397	11,397	
Electric Costs	270	475	
Required Labor* Per Season	<u>5,000</u>	<u>7,500</u>	
Total Cost	\$31,572	\$34,277	
Total Cost for Two Seasons (Cost to Dispose of 1,120,000 Gallons)		\$65,849	\$0.0588
Additional cost when compared to traditional treatment at a wastewater-treatment plant			22%
* Estimate based on an average requirement of three hours per day, plus one week of startup, two weeks for system shutdown, and periodic maintenance.			

Table 5-2

Total Cost of LLMS, Excluding Construction Cost of Lagoon			
<u>Item</u>	<u>1992 Season</u>	<u>1993 Season</u>	<u>Cost Per Gallon</u>
LLMS Construction (avg. over 15 yrs)	\$11,397	\$11,397	
Electrical Bills	270	475	
Required Labor Per Season*	<u>5,000</u>	<u>7,500</u>	
Total Cost	\$16,667	\$19,372	
Total Cost for Two Seasons (Cost to Dispose of 1,120,000 Gallons)		\$36,039	\$0.032
Cost when compared to traditional treatment at a wastewater-treatment plant			33%
* Estimate based on an average requirement of three hours per day, plus one week of startup, two weeks for system shutdown, and periodic maintenance.			

The cost per gallon of leachate sprayed over the two seasons is approximately \$0.0118, excluding the system and lagoon construction costs. The present cost for transporting leachate off site and treating it at a wastewater treatment plant, including sludge disposal and incineration, is approximately \$0.048 per gallon. For this project, the sludge was incinerated; therefore, there was no impact on sludge disposal cost or quality. Because the system's useful life, with proper maintenance and upkeep, was approximately 15 years, construction costs could be amortized over its life. The resulting cost, including LLMS and lagoon construction, would be approximately \$0.059 per gallon, or approximately 22 percent more than for transporting and treating the leachate at a wastewater treatment plant. However, the cost for disposing of leachate on site with the LLMS, excluding the new lagoon, was approximately \$0.032 per gallon, which amounts to a cost savings of approximately 33 percent when compared to traditional transportation and treatment at a wastewater-treatment plant.

However, the operational cost of the LLMS is more easily controlled than contracted private disposal at off-site treatment sources not managed by the municipality.

ENERGY BENEFIT EVALUATION

The cost-effectiveness and energy benefit of operating a LLMS versus traditional transportation and treatment at a conventional wastewater-treatment facility can best be summarized by comparing total energy consumption and associated costs for both methods of leachate disposal.

The total energy consumed to operate the LLMS over the two seasons was approximately 5572 kilowatt hours (kWh), at a cost of approximately \$745. One kWh of electricity is approximately equivalent to 3,412 Btu of useful energy. Operating the LLMS consumed approximately 19,011,664 Btu of energy over two operating seasons.

Energy consumed for construction of the lagoon and LLMS can be estimated to be approximately 1.02 kWh per dollar value of construction², based upon 1992 construction values. The energy consumed to construct the lagoon was approximately 228,045 kWh, or 778,091,177 Btu. The energy consumed to construct the LLMS was approximately 174,386 kWh, or approximately 595,006,190 Btu. Because the useful life of the LLMS is estimated at 15 years, the energy consumption cost to construct the LLMS should be amortized over its life. This results in an annual energy consumption of approximately

² Metcalf and Eddy, Inc. Wastewater Engineering, Treatment, Disposal, Reuse, 2nd edition New York, McGraw Hill, Inc. 1979.

51,872,745 Btu for the lagoon, and approximately 39,667,000 Btu for the LLMS. The total amortized energy consumption for constructing and operating the LLMS, including the lagoon, over two spraying seasons is approximately 110,551,400 Btu.

The energy consumption and total energy cost for off-site disposal and treatment of leachate includes the energy consumed and associated costs for both transportation and treatment. Leachate transportation in tanker-truck quantities of approximately 5,000 gallons per load requires approximately \$1.20 in fuel every four miles, or approximately \$4.80 in diesel fuel for an average round trip of 20 miles. Based on an estimated useful energy content of 84,000 Btu per gallon of diesel fuel, each truckload consumes 336,000 Btu of energy. The total energy consumption to transport 1,120,000 gallons of leachate would be approximately 75,264,000 Btu for a total of approximately 224 truckloads, resulting in a total transportation energy cost of \$1,075.

Treating leachate at a wastewater-treatment plant costs approximately \$0.048 per gallon, including transportation. Treatment at an activated-sludge wastewater-treatment plant requires an average of approximately 0.0033 kWh of energy per gallon of leachate treated.³ For a typical large commercial electrical customer, the average cost per kilowatt hour, exclusive of demand charges, varies from \$0.058 to \$0.062 per kWh. Based upon this, the leachate treatment cost would be approximately \$0.00020 per gallon.

The total energy needed to treat 1,120,000 gallons of leachate at a wastewater-treatment plant is approximately 3,696 kWh of electricity. Because one kilowatt hour of electricity is equivalent to approximately 3,412 Btu of useful energy, treating leachate at the wastewater-treatment plant consumed approximately 12,610,750 Btu of energy. The total energy consumption for transportation and treatment at the wastewater-treatment plant is approximately 87,874,750 Btu. Thus, treating the leachate at a wastewater-treatment plant requires approximately 43 percent of the energy required to construct the LLMS and operate it for two seasons. This comparison is presented in Table 5-3.

³ Metcalf and Eddy, Inc. Wastewater Engineering, Treatment, Disposal, Reuse, 2nd edition New York, McGraw Hill, Inc. 1979.

Table 5-3

Total Energy Consumption (Btu) for Two Treatment Methods		
	<u>LLMS</u>	<u>Treatment at Wastewater-Treatment Plant</u>
Energy for construction of LLMS and lagoon (amortized over 15 years) for 2 seasons	183,079,490	-
Energy for LLMS operation over 2 seasons	19,011,664	-
Energy for transportation	-	75,264,000
Energy for treatment, including wastewater-treatment plant construction and operation & maintenance	-	<u>12,610,750</u>
	<u>202,091,154</u>	<u>87,874,750</u>
TOTAL ENERGY CONSUMED		

The above analysis is very sensitive to the estimated construction energy consumption. Values used to compute the construction energy component are based upon typical wastewater-treatment plant average energy consumptions for construction, maintenance, and operation. These values may not be representative of the wastewater-treatment plant that normally treats the leachate.

For lack of a better source of information, these average construction energy-consumption values were applied to the construction of the LLMS, which may compromise the accuracy of the results. Since the construction energy component for the LLMS is approximately 90 percent of the total LLMS energy-consumption figure, the comparison of energy consumption between the LLMS and the treatment plant could change significantly if more accurate data became available.

Section 6

NOTED SUCCESSES AND FAILURES OF THE PROJECT

After two operating seasons, the LLMS project proved to be a practical leachate-disposal alternative worthy of continued study and monitoring. When properly functioning in automated mode under optimum conditions, the system as originally constructed and modified can dispose of approximately 15,000 gallons of leachate per eight-hour work day.

The LLMS was designed as a research project to gather data on the feasibility of on-site evapo-transpiration of leachate during the summer. As with most research, some portions of the original design concept functioned as intended, while others did not. Numerous problems, failures, and successes were noted.

The LLMS experienced operational problems due to a lightning strike in the early 1993 spraying season that limited data acquisition and required additional work. However, even with the increased labor and other problems, the system still was a practical alternative to traditional off-site leachate treatment. Operational problems and recommended solutions are discussed in detail below.

PROBLEMS AND PROPOSED SOLUTIONS

Several problems encountered during the project that ideally should have been rectified before the system began operating, should be resolved for any future similar projects.

1. Problem: The LLMS system was extensively damaged by a lightning strike during early July 1993. The pump station, including pump controls, weather station, and remote-control panel, were out of commission for the remainder of the 1993 spray season, necessitating manual control and operation of the spray system by landfill personnel. Losing the automated controls limited the ability to control spray heads and gather useful data. Surge protection was in place at the LLMS station.

Solution: Because a lightning strike is a force of nature, prevention of such an event is not entirely possible. However, installing an extensive grounding grid and possibly stockpiling vital backup-system components could improve station survivability and minimize damage.

2. Problem: Following a factory recall, the electromagnetic flow meter was determined to be inaccurate and sent back to the factory for repair and calibration. Loss of flow-metering capabilities limited the ability to monitor flow rates and total daily flows for 1993.

Solution: This project's research and data-gathering mission required installation of a flow meter to monitor flow rates and total daily flows. For similar future projects, data acquisition may not be necessary. However, despite the problem in this case, electromagnetic flow meters generally have an excellent reputation for accuracy.

3. Problem: Approximately once a month, the spray heads experienced periodic clogging during the spray season. This resulted in diminished flow rates and total daily flows until the spray heads were cleaned.

Solution: Spray head clogging could be minimized and potentially eliminated by installing an in-line strainer on the pump discharge. In addition, a preventive maintenance program should be established to clean spray heads periodically.

4. Problem: The level-control bubbler tubes clogged periodically, resulting in false high-lagoon-level readings.

Solution: This clogging could be minimized by preventive maintenance, including an air compressor with appropriate fittings used to blow out the bubbler lines.

5. Problem: The computer software used to control the spray system was complex and difficult to use. During the long delay between completion the project being designed and constructed, more sophisticated, user-friendly software packages arrived on the market that would have improved system operation and control. Also, the weather station did not interface well with the computer software and was difficult to control via computer.

Solution: Newer, user-friendly versions of operating software are available on the market to improve system operation. A simplified operating system without weather station and flow-monitoring capabilities may be desirable for projects where such data acquisition is not needed. A formal training program should be established to train personnel on system operation.

6. Problem: Moving the distribution piping installed above the landfill caused pipe cracking and leakage problems.

Solution: Installing additional ground anchors along the pipe lines and laterals would have controlled this problem.

7. Problem: The system experienced startup difficulties after a few days of dormancy, due to air entering the distribution piping.
- Solution: A valve should be installed at appropriate high points to relieve air binding in the distribution piping.
8. Problem: The heat generated by mechanical equipment in the pump station frequently exceeded the air conditioner's capacity on very hot days.
- Solution: Climate control inside the pump station could be improved by installing a larger air-conditioning unit, or by installing the pump and accessories in a separate room from the climate-sensitive controls and computer system.
9. Problem: The automated system's control computer was installed inside the pump station with no remote-monitoring computer station. The system required more supervisory time than anticipated to generate reports due to difficulties the operators had in learning the software.
- Solution: More efficient system operation could be achieved by the installing a modem and telephone line to communicate between the on-site host computer and a more conveniently located remote computer with remote printer for report generation. The remote computer, with system operational software, also could act as a backup host computer in the event of damage to the host computer by lightning or other weather. A satisfactory system also might be constructed using a timed golf-course irrigation-type system if data acquisition were not required.
10. Problem: Failure of a flexible pipe connection to one of the storage lagoon's discharge pipes allowed silt and rock pebbles to pass through the pump and into the distribution system. As originally constructed, the flexible pipe floated on the surface of the lagoon, removing leachate above the silt deposits. The piping connection could not be repaired until the lagoon was completely dewatered. Passing silt and rocks through the pump was averted by using one lagoon to supply the LLMS and using a manual portable pump with surface suction to pump from the unusable lagoon to the LLMS supply one.
- Solution: The piping connection failure could have been averted by preventive maintenance. The connection was improved by using a less failure-prone compression-type coupling connector.

11. **Problem:** Manual LLMS operation after the lightning damage limited the ability to control spray-head operation, including spraying cycles and frequency of operation. Losing automated control necessitated manually turning individual spray heads on and off, resulting in infrequent operational cycle changes and uneven application of leachate over the project area so that some spray areas had significantly more moisture than others.

Solution: Manual LLMS operation could be improved by installing secondary valving on spray-head branch lines, thus allowing control of a run of spray heads by one or two valves, rather than operating each spray head individually.

12. **Problem:** The remote control station on top of the landfill experienced ground fault interrupter (GFI) tripping problems during moist periods.

Solution: The GFI tripping problem could be solved by locating and repairing any conduit leaks leading to the remote station.

13. **Problem:** Spray heads on side hills with minimal vegetative cover contributed to erosion of the clay cap.

Solution: The landfill cap's erosion problem was mitigated by relocating the spray heads, establishing vegetation in areas with minimal or no vegetation, and limiting leachate flow to spray heads on side slopes.

14. **Problem:** Distribution system flows were poorly balanced due to excessive differences in spray-head pipe serving branches.

Solution: A revised system layout with balancing valves to regulate flows on each branch line would ameliorate this problem.

Section 7

RECOMMENDED DESIGN CRITERIA

Numerous site-specific design parameters should be considered and analyzed when evaluating a particular landfill's suitability for a leachate-recirculation and evapotranspiration system for on-site leachate disposal. These parameters include physical site layout conditions, and landfill construction, environmental, economic, and staffing criteria. Design criteria include:

1. The proposed landfill should meet accepted NYSDEC standards requiring a lined landfill base and a sealed clay landfill cap over the proposed project area.
2. The site should be properly graded without excessive slopes (i.e., no more than seven to eight percent) to control potential leachate runoff. In addition, the site should not exhibit signs of continued differential settlement that could contribute to leachate ponding.
3. The site requires a leachate-collection system with lagoon or containment structure to supply leachate to system pumps.
4. The site should not permit potential runoff or damage to environmentally sensitive or populated areas.
5. The proposed site should be sufficient in size and layout to permit a satisfactory spray-head layout and distribution system in order to minimize runoff potential and maximize evapotranspiration.
6. The proposed site should be evaluated to determine if it would be economically feasible to construct and operate an LLMS when compared to the costs of traditional leachate disposal.
7. Access to the site should be controlled, with no other uses that would have an impact on or be affected by leachate spray.
8. The site should be located where it can be monitored properly by the landfill staff. Also, sufficient staff capable of operating the system need to be available.
9. Site leachate should be laboratory-analyzed periodically to determine its suitability for irrigation. Leachate that consistently exhibits high concentrations of chlorides, sodium, boron, or any other toxic compounds or elements should be evaluated carefully before installing a

spray system to minimize potential kill-off of vegetation and "poisoning" of the top layer of soil.

10. In milder climates, the size of associated lagoons might be reduced due to the longer spraying season. The required lagoon size depends on the site's seasonal leachate-generation rate. Sites where leachate is predominantly generated during seasons in which spraying may not take place would require more storage. Sites that generate a substantial portion of their leachate during the spraying season would not require as much leachate storage volume, so the storage lagoons' size could be reduced. This would reduce the cost of constructing an LLMS, but would increase operating costs due to the longer spraying season.

Section 8

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on two seasons of operation, data acquisition, and evaluation, a leachate evapotranspiration and spray system was proven to be practical for on-site leachate disposal during the summer. Similar systems could be used to manage leachate at other clay-lined and capped landfills with lined storage lagoons. Each site requires site-specific construction modifications, economic analyses, and environmental impact studies to determine the suitability, cost-effectiveness, and desirability of installing and operating an LLMS.

The cost of constructing and operating the LLMS over two spray seasons, including construction of a new storage lagoon, after averaging the construction costs over an estimated useful life of 15 years, is approximately 22 percent more than for transportation to and treatment at a wastewater-treatment plant. The cost of constructing and operating an LLMS, excluding the cost of constructing a new lined storage lagoon, after averaging the construction cost over an estimated useful life of 15 years, is approximately 33 percent less than for transportation to and treatment at a wastewater-treatment plant. Energy consumption for conventional leachate treatment at a wastewater-treatment plant is approximately 43 percent of that required to construct and operate the leachate-spraying system over two seasons.

The environmental impact on the project site and surrounding areas, including changes in air quality, vegetation, and soil, were minimal. Air testing and analysis revealed negligible concentrations of pollutants remaining in the air stream that did not exceed the concentrations of these same pollutants in control samples. Vegetation and soil-sample analyses revealed that site vegetation generally consumed those pollutant components that it could use. Remaining pollutant components were deposited at low concentrations in site soils. Spray area vegetation continued to thrive and grow throughout the two spraying seasons with no visible signs of vegetation kill-off.

Site erosion control was best accomplished by proper siting of spray heads, coupled with regulation of flow rates and duration. Planting vegetation on the landfill cap, especially on side slopes, helped in controlling erosion.

The pollutant parameters tested for were selected as representative pollutants found in larger quantities in site-generated leachate, as verified by periodic analysis of NYSDEC-required leachate grab samples.

Based on a review of leachate analysis reports for the two years studied, soil, vegetation, and air testing should be performed in the future to determine relative changes in concentration levels for the following parameters:

alkalinity	ammonia-N
benzene	boron
calcium	chloride
ethylbenzene	iron
magnesium	manganese
nitrate-N	potassium
sodium	toluene
total Kjeldahl nitrogen	

Numerous operational problems were encountered during the project. To the extent they can be, such problems should be rectified or mitigated before construction of a similar project. These problems included extensive lightning damage, flow-meter inaccuracy, clogging of spray heads and level-control bubbler lines, difficulty in operating computer software, pipe movement and leakage, pump station overheating, and lack of remote operating capability.

Establishing a range of acceptable and unacceptable conditions for LLMS operation was a secondary project goal. Throughout the project, weather conditions were observed as they related to the ability to spray leachate and allow it to transpire. Conditions under which spraying should not take place also were noted, as well as those that might contribute to detrimental environmental consequences.

Unfavorable spraying conditions generally existed during periods of low evaporation potential, including times when there was high humidity, low sunshine, low ground-surface temperature, precipitation or impending precipitation, or lack of wind in the spray area. In addition, spraying should not take place immediately after precipitation when the ground is saturated or when the ground is frozen, due to potential leachate runoff.

Ideal spraying conditions existed during periods of low humidity, maximum sunshine, warm ground-surface temperature, light to moderate winds with wind direction oriented so as to minimize transportation of airborne vapors off site, and no precipitation, with none forecast for 24 hours.

Due to weather variability over the two spraying seasons and the ineffectiveness of the pump-station-mounted weather station, definitive setpoints for weather conditions to allow computer control of the spraying system for all weather conditions could not be established. Human judgment, based on

knowledge of site conditions, current weather, and short-term weather forecasts, is needed to determine whether or not to proceed with spraying. Further research is needed to identify definitive weather conditions under which spraying of leachate should be permitted, including humidity, wind speed and direction, temperature, and amount of precipitation.

RECOMMENDATIONS

This project proved that spray evapotranspiration of leachate is a practical alternative to conventional treatment that is worthy of further study on a site-specific basis. The feasibility of constructing and operating a leachate-spraying system should be investigated at landfill sites with clay liner and cap construction and storage lagoons meeting NYSDEC Part 360 regulations. Each site should be evaluated independently to determine the environmental impact, cost-effectiveness, and practicality of using a spray system to dispose of site-generated leachate. Sites that did not require data acquisition could use a simplified operating system similar to those used for golf course irrigation systems. These systems are very simple to operate and relatively inexpensive to construct.

Using a leachate-spraying system similar to the LLMS at suitable landfills with impervious caps meeting Part 360 requirements could provide a cost-effective, environmentally acceptable alternative for leachate disposal.

APPENDIX 1. — RESULTS OF GYPSUM BLOCK MONITORING PROGRAM

**TOWN OF COLONIE
SANITARY LANDFILL LEACHATE LAGOON SYSTEM
MOISTURE SENSITIVE GYPSUM BLOCKS
IMPEDENCE DATA FOR 1992 SPRAYING SEASON**

DATE	DEPTH FROM GROUND (IN)	STATION NUMBERS 1 TO 5 IMPEDENCE READING (OHMS)				CONTROL STA 5
		STA 1	STA 2	STA 3	STA 4	
29-Jul	6	3500	5500	6000	5000	9000
06-Aug	6	3000	3400	5000	5800	9000
18-Aug	6	6000	3000	2600	3000	12000
24-Aug	6	8000	2600	1800	2000	10000
01-Sep	6	12000	2800	2000	2000	12000
10-Sep	6	11500	4000	1500	3000	18000
15-Sep	6	6500	3500	1500	2200	16000
21-Sep	6	10000	5500	1700	1700	15000
29-Sep	6	6500	6500	1800	2800	6000
14-Oct	6	BROKEN	14000	1800	2000	6000
29-Jul	12	3500	4000	5500	4500	9000
06-Aug	12	2800	3600	4800	4200	8000
18-Aug	12	4000	2000	4200	2200	12000
24-Aug	12	5800	2000	2600	2200	11000
01-Sep	12	8000	2200	1600	2000	11000
10-Sep	12	9000	1800	1200	2000	15000
15-Sep	12	5500	2200	1500	1600	14000
21-Sep	12	7000	2000	1200	1700	15000
29-Sep	12	6000	2200	1300	1600	6000
14-Oct	12	BROKEN	2000	1200	1600	6000
29-Jul	18	2000	3500	5500	5000	7000
06-Aug	18	3400	3400	4400	4400	5800
18-Aug	18	2600	2400	4600	2600	6000
24-Aug	18	4200	2200	5000	2800	6500
01-Sep	18	5600	2200	2000	2000	4000
10-Sep	18	7000	2400	5000	2200	4600
15-Sep	18	4500	1800	5500	2600	4500
21-Sep	18	5500	1500	3500	2500	4800
29-Sep	18	6000	2200	3600	1800	4400
14-Oct	18	BROKEN	1700	4000	2000	3000

**TOWN OF COLONIE
SANITARY LANDFILL LEACHATE LAGOON SYSTEM
MOISTURE SENSITIVE GYPSUM BLOCKS
IMPEDENCE DATA FOR 1993 SPRAYING SEASON**

DATE	DEPTH FROM GROUND (IN.)	STATION NUMBERS 1 TO 6 IMPEDENCE READINGS IN OHMS				CONTROL	
		STA 1	STA 2	STA 3	STA 4	STA 5	STA 6
21-JUL	6	300,000	20,000	N/A	N/A	50,000	9,000
22-JUL	6	220,000	20,000	10,000	0	40,000	10,000
23-JUL	6	200,000	30,000	12,000	4,000	25,000	18,000
28-JUL	6	200,000	20,000	4,000	4,000	28,000	26,000
04-AUG	6	200,000	27,000	50,000	80,000	20,000	195,000
06-AUG	6	247,000	40,000	62,000	67,000	40,000	235,000
10-AUG	6	200,000	40,000	58,000	72,000	200,000	200,000
13-AUG	6	200,000	46,000	93,000	72,000	190,000	200,000
20-AUG	6	200,000	34,000	59,000	75,000	200,000	918,000
30-SEP	6	1,550,000	40,000	72,000	67,000	5,000	1,300,000
21-JUL	12	80,000	0	N/A	N/A	40,000	40,000
22-JUL	12	90,000	0	4,000	0	35,000	12,000
23-JUL	12	90,000	0	4,000	0	15,000	35,000
28-JUL	12	50,000	0	4,000	0	20,000	28,000
04-AUG	12	440,000	15,000	40,000	70,000	60,000	280,000
06-AUG	12	500,000	27,000	56,000	120,000	80,000	285,000
10-AUG	12	200,000	91,000	50,000	118,000	320,000	200,000
13-AUG	12	200,000	90,000	48,000	100,000	300,000	200,000
20-AUG	12	445,000	94,000	49,000	120,000	325,000	195,000
30-SEP	12	BROKEN	14,000	77,000	8,000	65,000	128,000
21-JUL	18	40,000	0	N/A	N/A	17,000	20,000
22-JUL	18	40,000	0	4,000	0	10,000	30,000
23-JUL	18	50,000	0	4,000	0	1,000	20,000
28-JUL	18	30,000	0	5,000	0	1,000	30,000
04-AUG	18	514,000	6,000	71,000	200,000	240,000	650,000
06-AUG	18	800,000	11,000	104,000	205,000	270,000	652,000
10-AUG	18	200,000	18,000	105,000	200,000	238,000	200,000
13-AUG	18	200,000	18,000	108,000	200,000	230,000	200,000
20-AUG	18	516,000	15,000	107,000	200,000	240,000	560,000
30-SEP	18	1,230,000	14,000	100,000	10,000	100,000	130,000

NOTES:

1. STA NOS 3 & 4 WERE SATURATED DUE TO OVER WATERING ON MANUAL OPERATION DUE TO LIGHTNING DAMAGE.

2. STA NO. 1 IS A REPLACEMENT STATION FOR STA 1 WHICH WAS DAMAGED LAST YEAR

APPENDIX 2. — RESULTS OF VEGETATION AND SOIL ANALYSES

**TOWN OF COLONIE LLMS
VEGETATION AND SOIL ANALYSIS RESULTS
1993 SPRAYING SEASON**

ALL DATA IS PRESENTED IN ug/g

PARAMETER	RESULTS OF SOIL SAMPLES		RESULTS OF VEGETATION SAMPLES		LEACHATE SAMPLE
	INSIDE SPRAY HEAD AREA	CONTROL AREA SAMPLE	INSIDE SPRAY HEAD AREA	CONTROL AREA SAMPLE	

SAMPLING PERFORMED ON JULY 29, 1993

ANTIMONY	24	31.7	20.9	16	45.9
ARSENIC	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
BERYLLIUM	0.39	0.71	< 0.25	< 0.25	< 0.25
CADMIUM	< 0.25	< 0.25	0.46	< 0.25	< 0.25
CHROMIUM	14.5	17.7	4.3	2.3	1.3
COPPER	27.3	32.4	11.6	4.9	< 2.5
LEAD	6.8	7.5	2.6	1.3	< 0.25
MERCURY	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
NICKEL	18.5	26.7	3.3	< 2.5	5.8
SELENIUM	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
SILVER	< 1	< 1	< 1	< 1	< 1
THALLIUM	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
ZINC	94.6	151	55.8	43.7	3.6
BENZENE	< 0.2	< 0.2	< 0.2	< 0.2	1
TOLUENE	< 0.2	< 0.2	< 0.2	0.44	29
XYLENES	< 0.2	< 0.2	1.3	8.4	3
ETHYLBENZENE	< 0.2	< 0.2	< 0.2	< 0.2	< 1
TOTAL HYDROCARBONS	3.9	3.6	330	430	88

**TOWN OF COLONIE LLMS
VEGETATION AND SOIL ANALYSIS RESULTS
1993 SPRAYING SEASON**

ALL DATA IS PRESENTED IN ug/g

PARAMETER	RESULTS OF SOIL SAMPLES		RESULTS OF VEGETATION SAMPLES		LEACHATE SAMPLE
	INSIDE SPRAY HEAD AREA	CONTROL AREA SAMPLE	INSIDE SPRAY HEAD AREA	CONTROL AREA SAMPLE	

SAMPLING PERFORMED ON AUGUST 19, 1993

ANTIMONY	23	13	11	14.5	<	0.06
ARSENIC	< 0.25	< 0.25	< 0.25	< 0.25	<	5
BERYLLIUM	0.35	0.3	< 0.25	< 0.25	<	5
CADMIUM	< 0.25	< 0.25	< 0.25	< 0.25	<	5
CHROMIUM	9.5	7.5	< 0.25	0.4	<	5
COPPER	19.5	12	< 2.5	4	<	50
LEAD	3.8	5.1	< 0.5	< 0.5	<	10
MERCURY	< 0.02	< 0.02	< 0.02	< 0.02	<	0.4
NICKEL	14	10	< 2.5	< 2.5		60
SELENIUM	< 0.25	< 0.25	< 0.25	< 0.25	<	5
SILVER	< 1	< 1	< 1	< 1	<	20
THALLIUM	< 0.5	< 0.5	< 0.5	< 0.5	<	10
ZINC	72.5	55	13	26	<	80
BENZENE	< 0.2	< 0.2	< 0.2	< 0.2		1
TOLUENE	< 0.2	< 0.2	< 0.2	< 0.2		12
XYLENES	< 0.2	< 0.2	4.9	2.6	<	1
ETHYLBENZENE	< 0.2	< 0.2	< 0.2	1.1	<	1
TOTAL HYDROCARBONS	0.51	1.5	380	100		20

**TOWN OF COLONIE LLMS
VEGETATION AND SOIL ANALYSIS RESULTS
1992 SPRAYING SEASON**

ALL DATA IS PRESENTED IN ug/g

PARAMETER	RESULTS OF SOIL SAMPLES			RESULTS OF VEGETATION SAMPLES		
	INSIDE SPRAY HEAD AREA	BTWN SPRAY HEAD AREAS	CONTROL AREA SAMPLE	INSIDE SPRAY HEAD AREA	BTWN SPRAY HEAD AREAS	CONTROL AREA SAMPLE

SAMPLING PERFORMED ON SEPTEMBER 04, 1992

ANTIMONY	<	3 <	3 <	3	<	0.3 <	0.3 <	0.3
ARSENIC		1.8	4.2	6.4		0.1	0.16 <	0.025
BERYLLIUM	<	0.25	0.8	0.6	<	0.025 <	0.025	0.025
CADMIUM		0.48	0.33 <	0.25		0.1 <	0.25 <	0.25
CHROMIUM		8	18	16.5		0.2	0.4	0.25
COPPER		11.5	22	24.5		0.55	0.95	1
LEAD		31	15.5	7.2		0.11 <	0.05 <	0.05
MERCURY	<	0.02 <	0.02 <	0.02	<	0.02 <	0.02 <	0.02
NICKEL		25	25	25		0.9	1.45	0.9
SELENIUM	<	0.25	0.3	0.4		0.04	0.04	0.04
SILVER	<	1 <	1 <	1	<	0.1	0.1 <	0.1
THALLIUM	<	0.5	0.85	0.9	<	0.05 <	0.05 <	0.05
ZINC		64.5	60.5	65.5		7.85	2.9	8.35

TOWN OF COLONIE LLMS

TOXICITY ANALYSIS OF CHLORIDE ON VEGETATION

PARAMETER	DATE	EQUIV	CONC.	CONC.	BASIN	DEGREE OF RESTRICTION OF USE		
	OF	MASS	OF	OF	DESCRIP.	(CONC. OF CHLORIDE IN meq/l)		
	ANALYSIS	(g/eq)	PARAMETER	PARAMETER		NONE	MODERATE	SEVERE
			(mg/l)	(meq/l)				
<u>CHLORIDE</u>	10-Jan-92	35.45	278	7.84	SOUTH BASIN	4	10	10.1
	10-Jan-92	35.45	6.6	0.19	NORTH BASIN	4	10	10.1
	26-Mar-93	35.45	405	11.42	NORTH BASIN	4	10	10.1
	26-Mar-93	35.45	555	15.66	SOUTH BASIN	4	10	10.1
	05-Apr-94	35.45	275	7.76	SOUTH BASIN	4	10	10.1
	05-Apr-94	35.45	250	7.05	NORTH BASIN	4	10	10.1

TOWN OF COLONIE LLMS

TOXICITY OF CHLORIDE ON VEGETATION

TOWN OF COLONIE LLMS

TOXICITY ANALYSIS OF SODIUM ON VEGETATION

PARAMETER	DATE	LOCATION	SODIUM CONCENTRATION			CALCIUM CONCENTRATION			MAGNESIUM CONCENTRATION			SODIUM ABSORPTION RATIO	DEGREE OF RESTRICTION OF USE		
			EQUIV.	CONC.	COND.	EQUIV.	CONC.	COND.	EQUIV.	CONC.	COND.		NONE	MODERATE	SEVERE
			MASS			MASS			MASS				(SAR)	(SAR)	(SAR)
			(g/eq)	(mg/l)	(eq/cm)	(g/eq)	(mg/l)	(eq/cm)	(g/eq)	(mg/l)	(eq/cm)		(SAR)	(SAR)	(SAR)
<u>SODIUM</u>	10-Jan-92	NORTH LAGOON	23	11.3	0.49	20	28.6	1.43	12.15	3.7	0.30	0.53	3	9	9.1
	10-Jan-92	SOUTH LAGOON	23	127	5.52	20	237	11.85	12.15	32.2	2.65	2.05	3	9	9.1
	26-Mar-93	NORTH LAGOON	23	6.5	0.28	20	10	0.50	12.15	2.1	0.17	0.49	3	9	9.1
	26-Mar-93	SOUTH LAGOON	23	139	6.04	20	85	4.25	12.15	41	3.37	3.10	3	9	9.1
	05-Apr-94	NORTH LAGOON	23	173	7.52	20	20.6	1.03	12.15	37.9	3.12	5.22	3	9	9.1
	05-Apr-94	SOUTH LAGOON	23	219	9.52	20	122	6.10	12.15	56.2	4.63	4.11	3	9	9.1

TOWN OF COLONIE LLMS

TOXICITY OF SODIUM ON VEGETATION

TOWN OF COLONIE LLMS
TOXICITY ANALYSIS OF BORON ON VEGETATION

PARAMETER	DATE	LOCATION	CONC OF BORON IN LEACHATE (mg/l)	DEGREE OF RESTRICTED USE		
	OF ANALYSIS	SAMPLE OBTAINED		NONE (mg/l)	MODERATE (mg/l)	SEVERE (mg/l)
BORON	10-Jan-92	NORTH LAGOON	< 0.05	0.70	2	2.1
	10-Jan-92	SOUTH LAGOON	0.12	0.70	2	2.1
	05-Apr-94	NORTH LAGOON	1.55	0.70	2	2.1
	05-Apr-94	SOUTH LAGOON	2.02	0.70	2	2.1

TOWN OF COLONIE LLMS

TOXICITY OF BORON ON VEGETATION

APPENDIX 3. — RESULTS OF AMBIENT AIR MONITORING

DATE OF SAMPLING: JULY 29, 1993

[illegible]

AMBIENT AIR MONITORING RESULTS FOR 1993

ALL DATA IS PRESENTED IN ug/l

[illegible]

ALL DATA IS PRESENTED IN ug/l

[illegible]