2005 Conservation Innovation Grant: Demonstration of a Complete Approach to Manure Management: Improving Nutrient Use and Creating Value-Added Products for Dairy Farmers

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Introduction

Background: The University of Delaware, College of Agriculture and Natural Resources (CANR) Newark Research and Education Center (NREC) Farm has 260 acres of crop and pasture land and a moderately sized dairy herd of 100 cows used for the College's academic, research, and outreach efforts. In 1999, the Delaware General Assembly passed a nutrient management law requiring farmers and animal producers to have a nutrient management or animal waste plan that includes best management practices to reduce nutrient losses to the environment. The NREC developed a nutrient management plan in compliance with this law, but required significant upgrades to current manure management practices to meet the requirements of this plan. Specifically, as is the case with most dairy farms, a nutrient surplus existed on the NREC farm. Achieving an environmentally sound farm nutrient balance required off-site transport of dairy manures. Such transport is costly and the agricultural land base for field application of manures in nearby areas is limited due to increasing urban development. Proper manure management at NREC required improved storage and processing of dairy manure into a value-added organic product that can be transported economically and that has more diverse end-uses.

With this grant, the University of Delaware's intent was to improve dairy manure handling at the CANR-NREC by: (i) installing innovative mechanical equipment to separate dairy manure into re-usable sand, organic solids, and liquids; (ii) improving storage for all separated components; and (iii) developing composting methods and value-added products from the organic manure solids. With the removal of sand and liquid, expectations were that manure organic solids would be reduced in volume (1/3 ft^3/cow/day) and would be dry enough (about 40% solids) to compost. The manure separation technology proposed is unique for this region and for dairy operations of this size, but the technology is proven and has been successfully installed at dairies in other areas.

As part of upgrading CANR-NREC's manure handling, the intent was to develop a composting process that converts manure solids into a high quality, value-added organic product useful for a variety of landscape horticulture applications.

Installation of this equipment and process would not only address CANR-NREC's manure handling concerns, but would demonstrate a potential solution to others in the region facing similar problems. Most dairy farmers have the same liquid manure handling and nutrient surplus problems, but are unlikely to risk high-end investment on a practice that is not established and proven in this area. This is especially true for smaller dairy operations similar to the CANR. The University setting for this demonstration also provides a unique opportunity for information transfer to EQIP-eligible land owners. The CANR-NREC is conveniently located for field tours for farmers and representatives of the horticulture industry and also for the education of our students, who will be future agricultural professionals.

Location and Size of Project Area: The University of Delaware, College of Agriculture and Natural Resources (CANR) Newark Research and Education Center (NREC) Farm is located in New Castle County, Delaware, mostly within the limits of the City of Newark. Most of the farm drains to Cool Run, a tributary of the White Clay Creek Watershed, which in turn drains to the Christina River. There are 260 acres of crop and pasture land on the farms, divided into about 50 fields. The dairy operation, in particular, is comprised of a 2.8 acre site where structures and facilities are surrounded by 18 acres of pasture. More than 120 acres of crop land at NREC are devoted to growing all forage required by the dairy cows and other livestock. Figure 1 provides the farm's location within Delaware, the farm layout, and an aerial photo illustrating the farm's immediate interface with commercial, industrial, and residential land uses.

Producer Participation: Difficulties in achieving sound manure management practices at NREC are shared by other dairy producers in the region. Overall, Delaware has about 11,000 cows maintained on 70 dairy operations. With the exception of a few large operations, about half of the dairies fall in the mid-size range of 100-300 head and half are smaller farms. Most of the large operations and about three-quarters of the mid-sized operations use sand bedding. The remaining mid-sized operations and most of the small operations rely on organic bedding. Because sand results in fewer diseases than organic bedding, most farmers would prefer to use sand but are limited due to resulting manure handling concerns including the necessity for liquid storage rather than solid stacking and excessive wear on equipment from sand abrasion.

The CANR-NREC Farm is closely located to the bordering states of Maryland and Pennsylvania, both with substantial dairy industries that would benefit from research and educational efforts provided by the University of Delaware. Sand bedding is common in the region and both states have a mix of operations with larger operations tending toward sand bedding and smaller operations varying between sand and organic bedding materials. According to the USDA's National Agricultural Statistics Service 2002 census information, the counties on the nearby Eastern Shore Maryland have 112 dairy farms, 30 of those having 100 – 199 head. Census information indicates that the two Pennsylvania Counties nearest the CANR-NREC, Chester and Lancaster, have a combined 2,223 dairy farms with 119 of them in the 100 -199 head range. Both states have nutrient management laws that require farmers to develop nutrient management or animal waste plans. Farmers in both states are challenged by diminishing agricultural land for field application of manures due to urban and residential development.

Though farmers in this region have the same problem to solve, they are unlikely to risk high-end investment on a practice that is not established in this area. That is especially true for smaller dairy operations similar to the University's. The University setting provides a unique opportunity for information transfer to EQIP-eligible land owners because the CANR-NREC is conveniently located for field tours and, as a land-grant college, we have an established Cooperative Extension System experienced in technology transfer to commercial operators, those who serve dairy farmers, and the green industry.

Benefits, Results Expected, Transferability: Benefits to the CANR-NREC will include: (1) achievement of nutrient balance on the farm, meeting the goals of our nutrient management plan and preventing further over-application of nutrients to cropland on the farm; (2) improved dairy manure management that allows for more effective application rates and timings of manures and less soil compaction, and (3) recycling of sand and export of value-added organic products.

Benefits to regional EQIP-eligible landowners will be testing, demonstration and evaluation of innovative and transferable technology for manure handling at sand bedding-based operations; regional farmers will be able to observe the process first hand and obtain information on its operation. Familiarity will allow for a more educated decision regarding a significant investment by the farmers in advanced manure-handling systems. Creation and marketing of value-added organic products for the green industry, that also provide economic returns to dairy farmers, will be evaluated and results disseminated widely. Successful demonstration of this new manure handling technique will provide organic bedding based operations the option of transitioning to sand-based bedding systems that many prefer. Providing dairy farmers with options to land application will undoubtedly help with on-farm nutrient imbalances, particularly for farms in proximity to urbanizing areas. This technology would provide a tool that helps farmers meet the requirements of nutrient management laws through improved ability (both in travel cost and en-user options) to transport excess nutrients off-site.

This project will benefit the local environment because of the CANR-NREC's impacts on the Cool Run headwaters and the region because manures and nutrients are a water quality issue throughout the Chesapeake Bay as well as sub-watersheds of the Christina Basin.

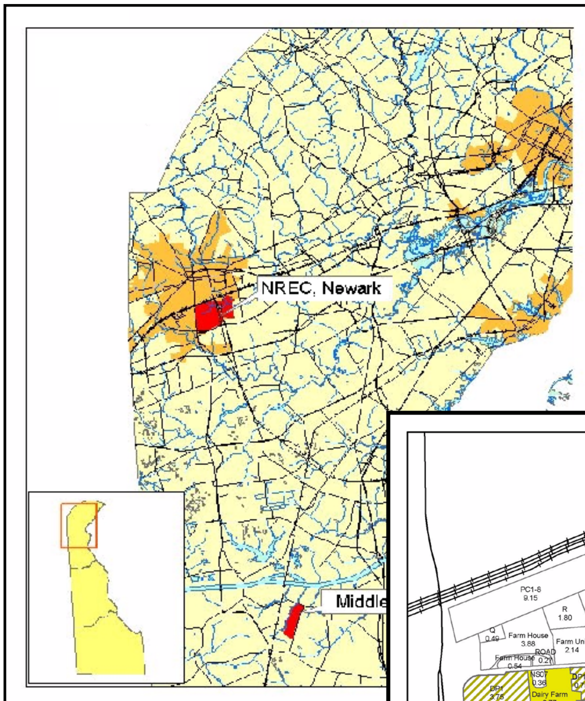
Project Evaluation:

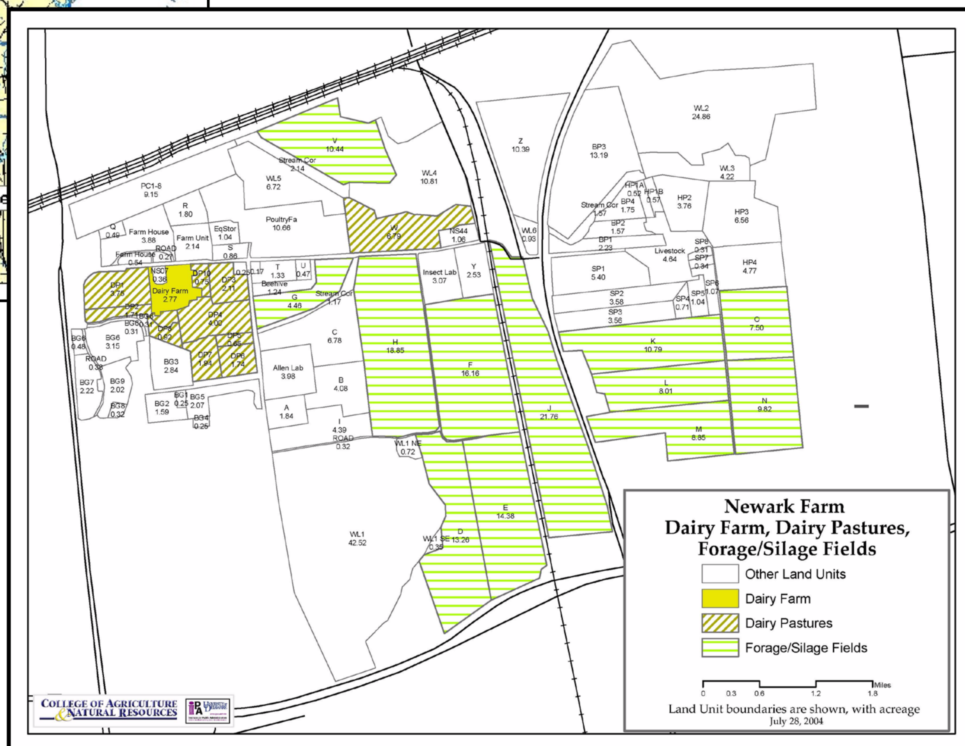
1. Maintain records for equipment: e.g., equipment operational time and maintenance activities; operational costs, including electricity, maintenance, and staff time.
2. Evaluate end product quantity, quality and nutrient content: for example, volume of sand reclaimed, manure generated, and liquid collected; quality of reclaimed sand as bedding; moisture content of manure; nutrient content of manure and liquid.
3. Compare composting options and evaluate costs, reliability, and consistency
4. Evaluate off-site end-uses for manure product
5. Document expenses and cost defrayment of end-product use: e.g,, savings from sand re-use, costs or income from processing manure into value-added product and providing for use off-site, costs of land applying liquids.
6. Quantify changes in farm nutrient balance as a means to evaluate improved nutrient management practices and potential reductions in water quality impacts.

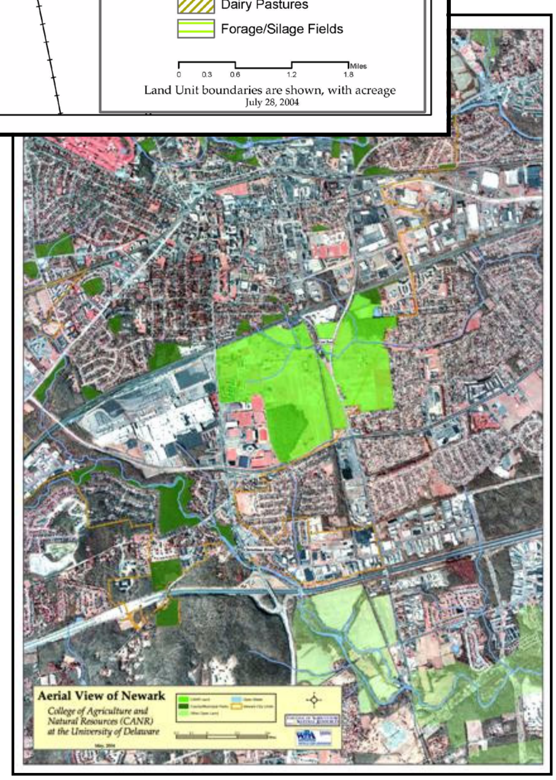
Environmental Impacts: Of the five natural resource conservation concerns outlined in the Conservation Innovation Grant guidance, this project will implement a new technology and approach that protects water quality by prevention of nutrient and pathogen transport to surface and ground water. Fields on the CANR-NREC drain to White Clay Creek, a Wild and Scenic River, located in the Christina Basin for which bacteria and nutrient TMDL's are established. The University and the City of Newark are working to address NPDES stormwater mandates. The CANR-NREC is located in ground-water and wellhead protection areas, designations that require special protection of ground and drinking water through careful land use management.

The CANR-NREC shares with other regional dairy farmers the increasing dilemma of urbanization and subsequent reduced land base for reuse of manure nutrients. Regional nutrient balance must be achieved in these areas by diversifying the uses for manures to include non-agricultural options. The University intends to address its own imbalance by processing dairy manure into a easily transportable, value-added horticulturally acceptable material and to address the regional concern by making that expertise accessible to other dairy operators with similar concerns. The CANR-NREC is optimally located to reach out to EQIP- eligible farmers and the green industry in three states located within two large basins (Christina, Chesapeake) nationally prioritized for water quality protection. Transfer of sound management practices for dairy manure handling to regional farmers will contribute to on-going water protection initiatives.

Figure 1: University of Delaware Newark Research and Education Center,
Location and Farm Layout







Top Left: Location of Newark Research and Education Center (NREC) within Delaware.

Center: CANR- NREC field delineations and identification of dairy related fields, pastures, and operations

Bottom Right: 2002 aerial photo of Newark area; farm, delineated by bright green shading in center, is surrounded by commercial, industrial, and residential land use.

Installation

The University contracted with McLanahan Corporation, a manure separation equipment manufacturer, for engineering designs and the purchase of all necessary equipment. USDA-NRCS provided review of plans to ensure they met NRCS standards and designed necessary guttering and tile drains to ensure proper soil erosion control and stormwater management. The intent was for construction of structures and installation of manure handling equipment to be completed in 2005.

Construction: In addition to the usual construction issues that must be addressed when building on farm sites, the University-Newark farm has additional considerations that would not typically be found in more rural areas. As apparent in Figure 1, the Newark farm is located within City limits and is surrounded by campus, commercial, residential and industrial development. Being situated within this urban setting means that building and construction must meet City codes which are at times less adapted to agricultural settings. Additionally, a significant number of utility lines and pipes run through the farm. Directly behind the main dairy structures, for instance, is a 16" high-pressure gas line as well as a catchbasin and stormdrain that hem in building options. Meeting protocol and standards for building on a university campus adds further complexity to the effort. While engineers may have been familiar with NRCS standards and State code, City and University considerations provided for a new level of creative problem solving. Finally, the construction contractor who won the bid had no previous experience with agricultural installations resulting in a less familiar working relationship between them and project engineers.

In addition to these unique considerations, the project grew in scope significantly from the original concept to include extensive work noted in the stormwater section as well as changes to the design to account for construction of a new milking parlor. The location of the parlor resulted in changes to concrete work and piping to capture milking parlor washwater. The combination of these issues caused delays in breaking ground of a year and a half. Construction and equipment installation was intended to be completed by the end of 2005 and instead start-up did not occur until December of 2007.

Equipment:

<u>Description</u>: Figures 2 and 3 show a process flow chart and floor plan for the University's separation equipment. Manure is pushed from the loafing barn, across a concrete pad, into a reception pit (sized for three to four days of storage to get through the weekend) where it is lifted by an inclined auger into a sand-manure separator for removal of coarse and medium sand. Effluent from that process is piped to a tank then into a hydrocyclone unit where fine sands are removed. Remaining water and manure solids are piped to a second tank and then pumped to a solids separator. A portion of the solids are removed and remaining liquid is piped to a third tank. The third tank also receives stormwater runoff from a portion of the concrete feeding pad as well as milking parlor wash water. Having stormwater captured and directed to the third tank, rather than flowing into the reception pit, maintains manure at an adequate thickness for proper auger efficiency. Effluent from the third tank is reused in the sand separation process then pumped to a 1.2 million-gallon capacity above-ground storage tank. Two bays were

constructed to store sand and manure solids individually. The bays were roofed so that manure solids would not be re-saturated by precipitation.

Figure 2. Dairy Manure Separation Process Flow Chart
Provided by McLanahan Corporation

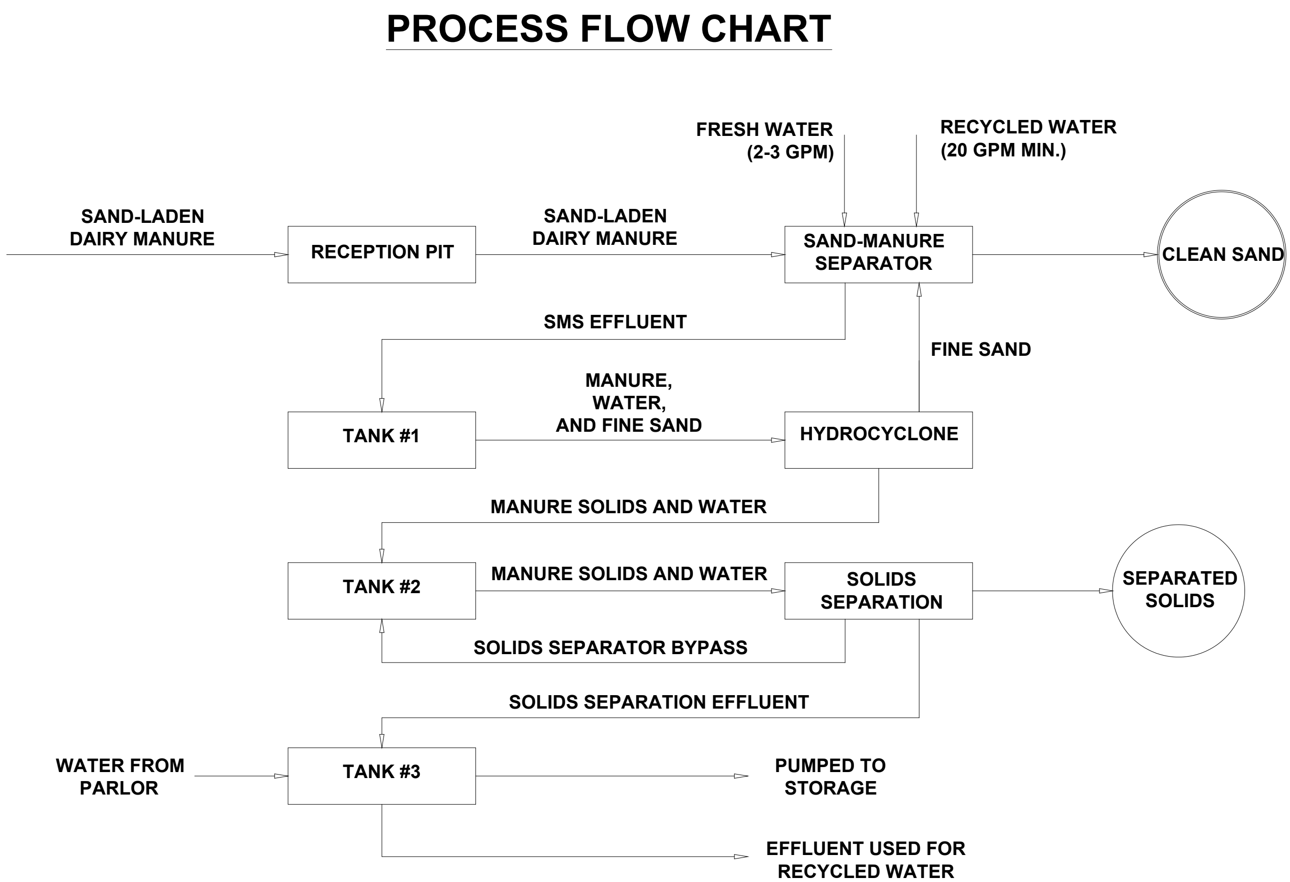
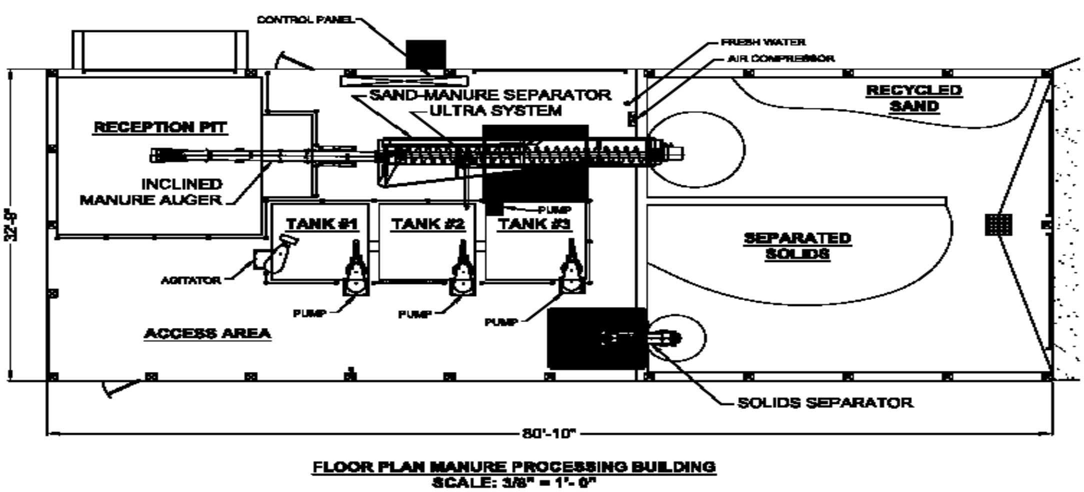


Figure 3. Dairy Manure Separation Equipment Building
Provided by McLanahan Corporation



Operation: Manure separation equipment is run six days per week, six to seven hours per day. Minimal adjustment or oversight is required with dairy staff checking on equipment hourly. Some training was provided at start-up but the finer points of operation were learned over time. During the first winter, staff encountered difficulty processing thick and frozen manure on cold days. Winters are not typically severe in Delaware but temperatures regularly dip below freezing. (According to USDA weather statistics, January is typically the coldest month with average daily minimum and maximum temperatures of 23.8°F and 39.8°F respectively for New Castle County. The coldest day on record dipped to -14°F in 1985.) With consultation from a McLanahan representative, a strategy was developed where frozen manure would not be pushed into the reception pit. Typically, even when temperatures do not rise above freezing, the sun will warm the manure enough to process later in the day. Also, the reception pit was kept relatively full. Once manure is in the pit, only the surface freezes, allowing the auger to draw still-flowing manure from underneath. Additionally, heat tape was installed on the fresh-water rinse equipment to keep water from freezing.

Maintenance: Regular care of equipment has been minor. All grease fittings and oil levels on pumps are checked every few days, requiring about ten minutes. Screens of the solids separator require cleaning monthly, taking about 1.5 hours.

Sediment has been removed twice from the third tank using a mini excavator and two people in the pit shoveling. Subsequently, staff members have reduced the rate of sedimentation using agitation by temporarily diverting flow to the storage tank back into the third tank. The second tank has required similar management to avoid sediment deposition. For the first tank, this problem was avoided because an agitator was installed during initial construction. In hindsight, it may have been useful to include an agitator in the second tank. The consideration is relative to where it is easiest to clean the sand out since good agitation in the separation tanks will result in more sand transported to the storage tank.

We anticipate the need to remove sand and sediment from the storage tank in the future, though the rate of deposition is unknown. Evidence of banked sand near the intake was noted when the tank was nearly emptied in 2008. To reduce the rate of deposition, the tractor PTO is used between tanker loadings to agitate effluent in the storage tank; sediments are re-suspended and either pumped out when the tanker is filled or at least distributed more evenly across the bottom of the storage tank. A second opening and valve were included on the opposite side of the tank during installation and, if sedimentation continues, we may need to install pumping equipment at that valve so that effluent can be agitated from two locations to increase effectiveness.

Repairs: Replacement of parts has been significant and beyond expectations for the first two years, and are listed here in Table 1:

Table 1. Equipment Repairs Required in the First 24 Months of Operations

Repair	Months After Start-up	Parts Cost	Repair Time (staff hours)
Replace gray boot under hydrocyclone	12 and 24	$85/	1
Heavy duty screen in solids separator	14	$4,200	1
Air compressor for sand separator	18	$1,300	2
Pump to solids separator	20	$850	16*
Auger and second screen in solids separator	24	$6,100	4
Total		**$12,620**	**25**

** includes travel time for parts pick-up*

Parts for the solids separator may have worn out prematurely because the air vent was not hooked up initially and the separator was run for seven months before this was discovered.

Energy and water requirements: When all equipment is running, the system draws about 18 kWh electricity, which would result in an annual power requirement of 36,504 kWhs. At a charge to the University of 10.5¢/kWh, the annual electric cost would be $4,015. About $1,100 of that power cost has recently been defrayed by installation of a 9 kWh solar power unit on the equipment building roof.

Most of the water used in the process comes from recycling the effluent in the third tank (20 gallons/minute). Effluent in the third tank is somewhat diluted by relatively clean wash water from the milking parlor. Fresh water, at a rate of 2 – 3 gallons/minute, is required for the final sand rinse. Our water is purchased from the City at 3.2¢/ft^3 (~24¢/gallon) and will cost $487 annually.

Lessons learned: Since start-up two years ago, about 50 farmers considering this option have visited to evaluate our operation. Doing so is highly advisable so that informed decisions can be made during construction and those responsible can be prepared for operation.

Stormwater Management Improvements: As with many dairies in the region, the University's dairy was built decades before water quality protection and related stormwater management practices were refined to current standards. To bring our dairy up to today's environmental standards required that we collect all "dirty" stormwater from concrete areas for storage and appropriate land application and install guttering to divert "clean" roof water to fields or stormdrains.

To capture stormwater from concrete areas required repouring about 1,200 ft^2 of concrete for proper sloping, forming diversion curbs to direct runoff, and installing a 15,000-gallon capacity detention basin. Because of the dairy layout, the area was split into two sections each with collection points. Runoff from about 9,400 ft^2 of concrete area was collected and piped to tank three in the separation equipment building. Runoff from an area of about 11,800 ft^2, plus leachate from two silos, was diverted to the new detention basin. Effluent from both the basin and tank three were then piped to the storage tank, which was increased in capacity by 32,422 ft^3 for impervious surface runoff and 23 ft^3/day for silage leachate. Figure 4 provides a layout of the dairy. Left of the two silos is a dotted line showing the break in flow of stormwater with runoff to the left flowing with the aid of curbing into a detention basin below the single silo; runoff to the right flows to a drain in front of the manure separation building and is conveyed to tank 3 inside.

To divert clean stormwater from roof tops, 400 ft of guttering was installed on three barns, transporting flow so that contact with manure was avoided. A portion of the roof water was diverted to pasture areas for infiltration and a portion was diverted to a stormwater catchbasin.

Storage: Storage for separated sand and manure solids was modest. A roofed area approximately 1,025 ft^2 with a dividing wall was added to the manure separation equipment building for storing the manure solids and sand separately. Roofing was added to the design at the University's request so that manure solids would not be saturated by precipitation. The manure solids area was sized to hold up to a month's manure solids production. In practice, effective storage is closer to three weeks of production. Sand is moved from the roofed storage area about twice a week to an open area on the concrete lot for storage until it is re-used for bedding. Runoff from the open sand pile is captured and diverted to the detention basin.

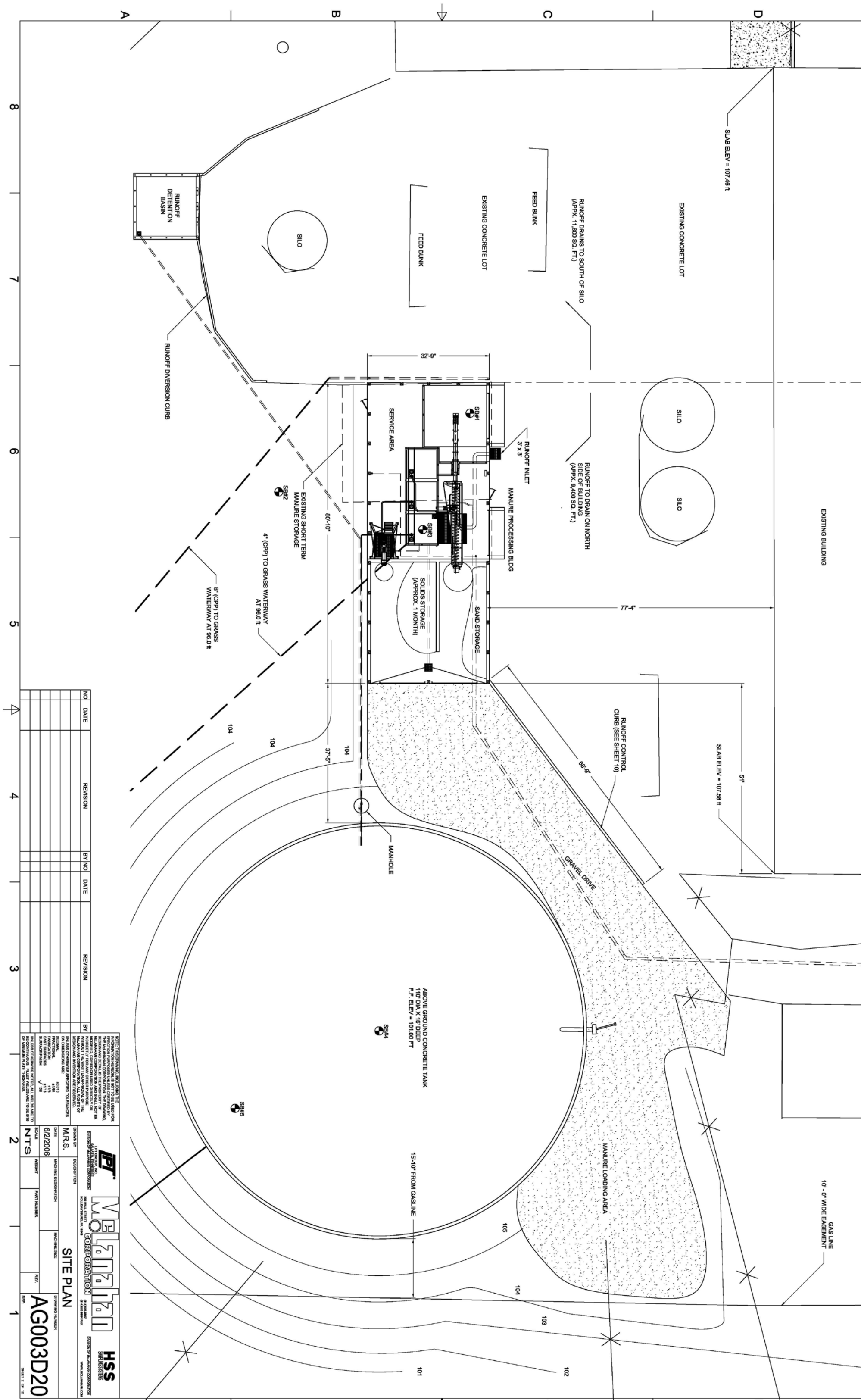
Storage for the manure liquids was significant. Detailed calculations are provided in Appendix I. Due to space and environmental restrictions, a 1.2 million-gallon capacity tank, 110 ft in diameter and 16 ft deep (4 ft below surface, 12 ft above surface) was constructed to hold nearly 6 months of liquid manure, stormwater runoff from concreted areas, and milking parlor wash water. The intent was to build enough capacity so that manure would only need to be spread in the spring and fall for main-season and cover crops. Capacity was originally calculated without inclusion of stormwater collection; when added in, the height of the tank was increased from 12 to 16 ft and the number of storage days was reduced from 180 to 170.

For the two years since start-up, the tank has filled faster than anticipated requiring land application more than twice a year. A significant source of water that had not been intended was cooling water from the milking parlor. The milk holding tank in the new parlor is cooled with single-pass fresh water that was captured and directed to the storage tank. Subsequently, that water has been redirected and fed to the cows. The storage tank continues to fill somewhat faster than anticipated, however, and collected stormwater runoff volume is thought to be the cause, though this is unsubstantiated. Precipitation has been normal for the last two years. Average annual rainfall is about 43 inches.

Land application issues add to the difficulty. A large tanker truck was contracted to inject liquid manure on corn acreage. The liquid manure was dilute enough that one pass did not allow maximum nutrient application. A second pass was not possible because the first application made the ground too soft. Liquid manure use has been expanded to include surface application over alfalfa acreage after cutting.

Odors have become an occasional problem since installation of the storage tank, as expected. Before, manure was land applied almost daily so that manure was not allowed to become anaerobic and odorous. Now that liquids are stored for extended periods, odors are pronounced whenever the contents are disturbed as fluids are pumped into or out of the tank. To date, no complaints have been lodged. This is highly significant because the University is very intent on being a "good neighbor" to surrounding residents and there are residential neighborhoods immediately north of the dairy, which is downwind in summer months.

Figure 4. Dairy Layout Showing Stormwater Collection



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Budget: Total expenses for the manure separation, storage, and stormwater runoff installations was $1,059,760. Approximate itemized costs within that total include:

Site work	$103,000
Concrete	$195,500
Pole barn	$67,200
Electrical and plumbing	$207,000
Equipment	$183,250

The CIG grant provided $121,000 toward construction, State cost share contributed $211,000, and the College provided the remaining $727,760.

The guttering and piping for roof water separation added an additional $11,550. State cost-share contributed 75% funding.

Sand, Solids, and Liquids

Sand: Critical to our environmental goals for the farm was to change land application practices from near-daily application year-round to only applying manure appropriately for crop nutrient uptake. Removing sand allowed us to achieve that goal by reducing the size of the storage structure we needed to install and also reduced staff time devoted to manure spreading.

We followed McLanahan's advice to use construction sand for maximum sand removal from manure. Prior to manure-sand separation, we purchased 690 tons of sand each year at a cost of $9,900 annually. We now purchase 92 tons of sand yearly with an annual cost savings of $8,566. Consequently, we are no longer land applying 600 tons of sand each year and we can store it with minimal effort, stockpiled on a concrete pad away from water bodies. Handling time is a total of a half hour weekly to move the sand from under the sand separator drop shoot and out of the bay to another storage location about twice a week.

Pathogenic concerns: Sand was analyzed for pathogens in April, 2008 by Dr. Michaela Kristula, Associate Professor of Medicine at the University of Pennsylvania and Field Service Chief for the New Bolton Center. Levels were found to be acceptable and Dr. Kristula noted that the quality of the recycled sand was excellent. A pile of the separated sand was sampled three times, first directly as it came off the equipment, then two and ten days after separation. Results can be found in Appendix II and summarized below.
<u>Coliform bacteria</u> – For all three samples, Coliform bacteria were 1,000 cfu/g. Dr. Kristula recommends that counts should be below 10,000 cfu/g.
<u>Gram negative bacteria</u> – Counts were at 1,000 cfu/g on day one and two, then 7,000 cfu/g on day ten. Dr. Kristula notes that this number is typically higher than the coliform count and these values are considered low.
<u>Klebsiella spp</u> – Values for all three samples were 1,000 cfu/g which is well below Dr. Kristula's recommended maximum of 5,000 cfu/g.
<u>Streptococcus spp</u> – Values were 124,000, 93,000, and 9,000 cfu/g for days one, two, and ten respectively. Dr. Kristula notes that streptococcus numbers can be over a few million after cows have had access to sand for 24 hours. Initially, she recommends that values be below 100,000, the lower the better, with 50,000 being achievable. The values from this series of samples suggest that stockpiling the sand for a while before using may be useful in reducing streptococcus counts.

Manure Solids and Liquids: Table 2 provides average nutrient values for manure prior to installation of separation equipment, then manure liquids and solids once equipment became operational. Individual analyses can be found in appendix III.

Table 2. Average Nutrient Values for Unseparated Manure, Manure Liquids, and Manure Solids

Manure Type	Units	Number of Samples	Total N	NH_4-N	P_2O_5	K_2O
Unseparated manure, before 12/07	Lbs/T	4	8.23	2.87	6.63	5.50
Unseparated manure*	Lbs/T	1	3.73	0.56	2.82	4.15
Manure liquids	Lbs/1000G	3	9.79	4.46	4.27	10.79
Manure solids	Lbs/T	4	6.53	0.19	2.16	3.21

* sample taken from reception pit by McLanahan staff

Though total annual production of solids and liquids are not measured at separation, records are kept on annual land application and export and summarized in Table 3. While manure separation began in December 2007, values for land application of unseparated manure are included within the 2008 column because totals are for the crop year that includes land application from fall of the previous year for some crops. Likewise, manure solids export is lower than anticipated in the 2008 crop year since, manure application for that crop year spans from fall 2007 to fall 2008 and does not represent a full year of operation. Some dairy manure solids were land applied the first year of operation where appropriate for soil tilth. The values are also be somewhat high because land application records did not initially delineate between manure solids and other types of dairy manures. Final values for the 2009 crop season are not yet available though land application of manure solids will be minimal

Table 3. Land Application and Export of Unseparated Dairy Manure, Manure Liquids, and Manure Solids for 2007 and 2008 Crop Years

Manure Type	Unit	Practice	2007*	2008*
Unseparated manure before 12/07	Tons	Land Applied	3,812	668
Manure solids	Tons	Land Applied		248
Manure liquids	Gallons	Land Applied		987,500
Manure solids	Tons	Exported		90

* Crop years starting in fall of previous year for some fields, depending on crop rotation

<u>Manure solids</u>: Surprisingly, while moisture content averages 73%, the manure solids are remarkably “dry” to the touch and do not release leachate when stockpiled. Solids are very consistent and have good handling properties. Weight for transport is estimated to be 0.3 tons per cubic yard. That value may include some additional moisture from precipitation. Composting qualities are excellent and discussed with greater detail in that section of this report.

Several evaluations were done on the effects of dairy manure solids on plant growth. In two initial studies, modified procedures for biological assays to screen for the presence of phytotoxins in compost were taken from "Test Methods for the Examination of Composting and Compost", jointly published by the USDA and US Composting Council Research and Education Foundation (Wayne H. Thompson, Ed.).

The first was an *in vitro* germination evaluation using extracts of the dairy manure solids and cured experimental compost made from dairy manure solids. For the dairy solids, a 10:1 water:material ratio by volume was used, and for the compost, 5:1. Germination was seriously inhibited by both extracts. The likely cause is thought to be high salt concentration, although a salt-tolerant cucumber variety was used. Cucumber is a good indicator species for these tests because of its high salt tolerance, large seed size, distinct cotyledon shape and intolerance of volatile fatty acids.

The second was a growth chamber bioassay for seedling germination and relative growth. Dairy manure solids and compost were each mixed with vermiculite 1:1. Straight Metro Mix was used as a positive control and straight vermiculite was used as the negative control. Germination was 100% for all mixes. All compost seedlings were below average height of the positive control, but no deformities were observed and all cotyledons were turgid. The dairy solids seedlings were about equal on average to the positive control.

These assays were not repeated and will require further evaluation before being considered conclusive. They were done to see how easy it would be to use them for regular monitoring of the compost products we intend to create. Pictures of the assay results can be found in Appendix IV.

In a formal study, a greenhouse test was done to compare the effects of raw separated dairy manure solids on seedling emergence, plant growth, elemental uptake, soil phosphorous, and soil physical properties in two Delaware soils. Corn (*Zea mays* L.) was grown using six rates of dairy solids (zero, 45, 90, 135 and 180 Mg ha-1) incorporated into a Sassafras loam soil and an Evesboro loamy sand. Initial results indicate that dairy solids could enhance plant growth in certain soils, especially sandy soils, as a result of increased organic matter and moisture holding capacity. A poster was presented at the Soil Science Society of America conference in 2008 and the contents of that poster can be found in Appendix V.

Qualitatively, manure solids have been directly applied to vegetable plant beds at agronomic rates resulting in good growth and no salt damage to the vegetable crops. Further evaluation is anticipated.

Manure liquids: During planning, our intent was to inject liquids twice yearly for main-season corn and fall cover crops. Available crop land requires us to apply at maximum nutrient rates to achieve this goal. However, using a 7,900-gallon capacity tanker and injecting manure liquids only allowed for one pass because the ground became saturated and too soft for any further equipment crossing. Single-pass application rates did not meet planned nutrient application rates and did not allow us to empty the storage tank. To manage our liquid manure storage, alfalfa fields are now top-dressed after cutting during the summer.

Because stormwater runoff and parlor cleaning water are included in the storage tank with manure liquids, liquid manure from this facility is likely more dilute than liquid manure alone would be. Sample results provided by McLanahan from another facility are compared in Table 4 below to three liquid manure samples from here. UD-1 and UD-2 were taken from the storage tank while UD-McL was taken by McLanahan staff from tank 3 within the manure separation building. That sample would include parlor washwater, stormwater runoff from about 9,400 ft2 of the feedlot, and manure liquids after sand and solids separation. All values from the UD samples are significantly lower than those from the one provided from another system. Choosing to incorporate stormwater runoff and parlor washwater has increased our costs for storage and land application.

Table 4. Comparison of Dairy Manure Liquid Sample Values from UD and from from Another Manure Separation Facility

	Date	Total N	P_2O_5	K_2O	Solids
		----------------lbs/1000 gal---------------			%
McL-Other[1]	2005	26.4	9.4	30.8	4.5
UD-1[2]	2008	11.0	4.7	8.6	2.2
UD-2[2]	2009	4.9	1.4	9.3	0.7
UD-McL[3]	2008	13.5	3.0	14.4	3.1

1. sample results provided by McLanahan from another facility
2. sample results from storage tank by UD staff
3. sample result from tank 3 in manure separation building by McLanahan staff

Farm Nutrient Balance:

The university farm has three challenges to manage in achieving our goal of a nutrient management and environmental protection plan that sets an outstanding example for the agricultural community: (1) improving manure application practices, (2) achieving a farm level nutrient balance, and (3) reducing runoff of nutrient-laden stormwater runoff.

While there is some fluctuation, we have about 76 acres in corn and 57 acres in alfalfa each year, with an additional 66 acres in pasture and remaining 61 acres in research crops and hay. Manure is generated by 100 – 150 dairy cows and small numbers of beef, sheep, horses, and poultry. Years of manure application managed according to disposal needs within set crop rotations led to considerable acreage with high-phosphorus soils across the farm. Nutrient export and improved storage was mandatory toward improving nutrient balance and proper land application.

Manure separation and a 1.2 million-gallon storage tank have successfully helped the College make improvements in the farm nutrient balance as well as land application practices. Storage has helped application and stormwater runoff management. We can apply nutrients when best suited to crop uptake and no longer land apply during winter months or on frozen ground while manure runoff from the feed lot area has been eliminated. Sand separation has reduced the amount of manure to be handled and applied. Solids separation has allowed export of excess nutrients.

Nutrient export of manure solids began in 2008. Small amounts of other livestock manure were also exported as well. Table 5 shows the first-year reductions in nutrient applications. As the composting program expands, allowing incorporation and export of manure and bedding from other livestock as well as degraded silage and haylage, nutrient applications overall and individual field rates will continue to be reduced.

Table 5. Total Farm Nutrients Applied For Crop Seasons Before and After Manure Separation Began

	Total N	P_2O_5	K_2O
	--------------lbs-----------		
2007, Before Separation	49,929	31,974	45,853
2008, After Separation*	29,392	14,184	28,128
Reductions	20,537	17,790	17,725
Nutrients Exported	2,712	938	2,190

* Crop season includes manure management before and after manure separation began

Composting and Marketing:

Compost: To gain an understanding of composting practices, our farm superintendent, who is responsible for overseeing the composting program, attended the week-long Compost Facility Operator Training course at Louisiana State University. The knowledge, resources, and contacts obtained at this conference have been immensely helpful. Additionally, key staff visited the Penn State and Terra Gro composting facilities to learn from established, successful composting programs, one a university based model and the other a commercial model.

While our intent was to have a fully developed composting program at this juncture, costs associated with starting an environmentally sound operation are more significant than anticipated. Consequently, manure solids have been transported for composting at Terra-Gro and exported for land application at another farm. Recently, a small concrete pad has become available on site and composting has begun on a modest scale, with space for three windrows, 50 feet in length. This is not adequate for composting the volume of manure solids generated. To accommodate adequate raw material storage, windrow space, and equipment maneuvering space, a 200 X 200 ft impervious pad will be required.

<u>Manure solids composting characteristics</u>: Solids generated from the manure separation equipment have good characteristics for composting. Average values for key characteristics are noted in Table 6. Originally, our intent was to identify local carbon sources to mix with manure solids, anticipating a low carbon:nitrogen ratio. However, the C:N ratio of the manure solids alone are within the acceptable range for composting. Bulk density is acceptable but moisture content is high.

Table 6. Recommended Composting Characteristics for Raw Materials*
and UD Manure Solids Characteristics

Characteristic	Acceptable Range	Preferred Range	UD Manure Solids
C:N Ratio	20:1 – 40:1	25:1 – 30:1	36:1
Bulk Density, lbs/yd^3	<1,100	------	647
Moisture Content, %	40 - 65	50 - 60	73
pH	5.5 – 9.0	6.5 – 8.5	No data

* Acceptable and preferred characteristic ranges from Robert Rynk, On-Farm Composting Handbook (NRAES-54), 1992, by Northeast Regional Agricultural Engineering Service

<u>Observations from on-site composting</u>:

- Compost piles benefit from addition of larger carbon material to create larger pore spaces and improve aeration. Wood chips are added to manure solids at a rate of 30% for this purpose. Other materials, including beef, sheep, and horse pack have been successfully added in small amounts.
- Windrowed manure solids heat up rapidly and require almost-daily turning in the first two weeks to manage temperature.
- As the composting process slows and windrows are no longer losing moisture from steaming, the compost soaks up and holds precipitation, making the material heavy and handling more arduous.

- We are currently looking into a consistent approach to determining when compost is "finished" and ready for safe use.

Lessons learned:

- Locating a composting site is critical when using nutrient-rich materials. An environmentally sound pad will be impervious and have a leachate collection system to avoid nutrient contamination of ground or surface waters. This is of special concern at our farm because portions are designated as "well-head protection areas" or "ground-water recharge areas" and have mandated protection ordinances. Installing this type of facility with adequate square footage is costly. A rough estimated cost for an adequately sized facility meeting NRCS design standards was $150,000. Having an existing impervious area of adequate size would have been helpful.
- Likewise, equipment needed for efficiency and production of high-quality compost can be expensive. A turner significantly improves both the efficiency of handling windrows and enhances the composting process. We recently purchased a new compost turner for $37,000. A consistent material particle size, free of large-sized materials and debris is a major characteristic of a quality product and requires a screener. New screeners can cost $10,000 to $50,000 depending on the style and capacity. Finding good-condition used equipment would be beneficial.
- As compost piles mature, the aerobic process slows and allows piles to absorb moisture, creating a very heavy, saturated material that is difficult to handle. Having a large shed or hoop building would be beneficial for storing finished compost to maintain good handling quality.

Exploring Products and Markets: While marketable compost has not yet been produced, work is on-going to characterize possible products and markets and to develop interest for compost in general within the green industry. Producers and marketers were contacted not only as research but also for possible collaboration as an alternative to on-site composting. Partnering was found either to be cost prohibitive or lacking compatibility. Though there are many promising markets, a number of them will require developing a high level of consistency, meeting specific product characteristics, and, for some markets, concerted outreach to overcome lack of or poor experience with compost products.

Producers and marketers: Current compost producers and retailers were solicited for insight on market status. In Delaware, there are two distributors of bulk compost purchased from producers and a number of marketers distributing bagged compost. A major composting facility promises to be online imminently. Nearby in Pennsylvania, there are several bulk compost producer-marketers.
Distributor – One option for marketing a UD compost would be to sell through a distributor. Dick Pack of Grizzly's notes his difficulty in obtaining a consistent product, both in material characteristics and availability.
Producer-Marketers– Within 25 miles, Terra-Gro, Inc., in Lancaster, PA, is a composting facility developed by Pineview Enterprises to handle spent horse bedding removed from clients to whom they supply fresh bedding materials. The bedding is mixed with dairy and poultry manure to create a high-quality finished product which is sold in bulk to

developers, schools, colleges, landscaper/nursery businesses, and golf courses. General Manager, Loren Martin feels that there is no profit in bagging and intends to continue with bulk sales.

About 13 miles away in Avondale, PA, Laurel Valley Soils was created by a collective of mushroom growers to create products from mushroom soil. They provide a model for product development tailored to each market. Compost is screened and either sold alone or mixed with other materials to create products specifically targeted for turf, horticultural use, container media, blower spreading, and green roof media. They are wholesalers only and products are available through several local retailers in our area.

In the near future a major composting facility, Peninsula Compost Group, will begin operation about 15 miles away in Wilmington, DE. The private company will use the GORE cover system to compost food, yard, and wood waste materials. They will charge tipping fees for waste materials and sell finished compost.

Bagged compost marketers – While producers of only compost may not find bagging to be cost effective, Frey Brothers, about 27 miles away in Quarryville, PA, utilizes bagging equipment for a range of products, including mulch, soil mixes, sand, and leaf compost. Frey Brothers developed from the logging and lumber industry, began bagging mulch, and added compost bagging as an auxiliary product. They obtain compost from the mushroom industry and do not compost themselves. This size and breadth is likely necessary to overcome the costs of equipment, labor, and permitting required for bagging. This model would not be practical for the College.

Should the College reach an agreement in the future with a contract bagger, the market for bagged compost would be best targeted toward smaller, local gardening centers where bagged compost can be sold as a tie-in sale when providing expertise to customers. Large “box store” garden centers are more challenging to work with because products and management are more strongly affected by regional managers who are less focused on local products. Likewise, staff may not have the knowledge to guide homeowners on compost use. Small-scale efforts for on-campus sale may be possible by hand-bagging but this market would have limited use and require considerable labor. Additionally, bagged compost requires greater management for product odor control and adequate curing would be critical.

Possible partnering – The College explored opportunities to partner with existing producers, baggers, and marketers and did not find an opportunity that would make economic sense. Distributing through Grizzly’s would be challenging due to a transport distance of more than 85 miles. Laurel Valley has precise product recipes that do not include dairy manure. Peninsula would accept our dairy solids but standard transport and tipping fees would be charged, making this option uneconomic. Frey Brothers was contacted for bagging our product but dairy solids and dairy compost do not fit with their current compost product line. Terra Gro has been utilized for manure solids export. For the cost of transportation, they pick up our solids and incorporate them into their own composting process. They would also compost our solids separately if we wished, providing us with our own product. There would be an additional fee to buy back the finished product and, combined with transport fees, this option would not be affordable.

<u>End users</u>: The strongest markets for compost in this area are developers and landscapers as a soil enhancement for disturbed grounds and managers of golf courses and sports

fields who use compost for topdressing. Other markets are modest and will require considerable product development and educational outreach to be profitable.

Developers, Landscapers, Department of Transportation – The challenge to those wishing to use compost for soil enhancement or as a seeding media is access to appropriate equipment and a compost product with the right characteristics for mixing and spreading. Compost products for this market need to be consistent, relatively fine, weed-seed free, and light. For blowers, lightness and a higher fiber content is critical to avoid clogging. Developing a product that is weed-seed free and of the right moisture content for this application would require a high level of expertise, process control, and equipment.

Extensive work has been done by researchers in our College on roadside landscaping. While compost can be used as a seed media in this application, sawdust has been found to be superior both in spreadability and weed control suggesting that this may not be a preferred compost market to develop.

Turf management, sports fields and golf courses – Turf managers typically use compost for topdressing, using a manure spreader for distribution. While manure spreaders are not as demanding as blowers, a consistent, lighter product is preferred. Again, a high level of process management and quality control is necessary to develop an appropriate product for this market use. Provided a high quality product can be created, this is a market with good potential.

Greenhouses and nurseries – Very little compost is used by greenhouse and nursery businesses. Greenhouse managers are concerned that using compost in containers leads to poor production due to salt burning. Any product developed for this market would need, not only to be highly controlled regarding particle size, but would also require strong quality control to ensure compost is finished and has aged adequately to reduce salt content. One liner nursery is currently experimenting with use of spent horse bedding to side-dress field plants. Field use of compost at nurseries is promising but would require a strong focus on product consistency and outreach to develop interest.

Home owners - Homeowners in this area have the option of going to garden centers for bulk or bagged compost; going to the City of Newark's yard waste compost site for free, self-serve bulk compost; or having bulk compost- typically mushroom soil- delivered. Our farm has the advantage of close proximity to many residential neighborhoods, making it convenient for bulk pick-up. To develop this market, a compost product would need to be of a quality and consistency that is better than compost they can obtain for free and priced competitively with products available in the area. Product development would need to be targeted to specific types of use and associated educational materials developed since home owners may want organic materials for turf use, establishing horticultural plantings, or vegetable gardening.

<u>UD campus and cities of Newark and Wilmington as potential material suppliers/end users</u>:

UD campus – The Penn State composting program provided an applicable model for a university-based composting program. As explained by Nadine Davitt who manages the program, tipping fees are charged to Penn State grounds and dining service departments for materials dropped off at the composting facility. Because tipping fees are less than those at the landfill, using the composting facility is advantageous. In turn, finished compost is sold to the PSU grounds department at a cubic-yard price that is less than what is charged by commercial distributers. The composting program is economically self sustaining with the income of tipping fees and compost sales. University policy requires that the landscape maintenance and dining services departments take plant and food waste materials to the composting facility and that compost be bought from there as well. Compost has not been sold off-campus.

The University of Delaware is comparable to Penn State in that our farm is in close proximity to the main campus, allowing cost effective transport of materials to and from a compost facility at the farm. Significant hurdles must be overcome, however, to achieve similar policy support at the University level, as well as the ability to charge tipping fees or sell compost to other university departments that would lead to economic sustainability.

The University campus turf and horticultural areas are managed by the Facilities Grounds department with one group responsible for maintenance and a separate individual responsible for design and installation of new landscapes. Our College is surrounded by the UD-Botanic Gardens which are uniquely maintained by our faculty, interns and professionals.

The UD maintenance group is responsible for all grounds upkeep, including turf maintenance, shrubbery and tree trimming or removal, mulching, and leaf collection. Typically, landscape debris from maintenance activities is collected at a storage site, chipped using a tub grinder when convenient, then used as mulch in low visibility areas as needed. The intent is to manage plant debris as cost effectively as possible. Consequently a high priority is not set on separation of materials or creating a consistent, controlled product. During initial discussions there was some confusion regarding the difference between this material and true compost products. Considerable effort will be required to develop an interest by Grounds staff in using compost, both to understand possible uses for compost and how to apply compost for those uses. Should that interest be created, raising interest to a level where they perceive enough value in the product to purchase it would be another hurdle.

Disposing of landscape waste at a farm-based composting facility would be advantageous for the Grounds department since these materials represent a drain to their resources to process into lower grade mulch though they recognize some savings in mulch purchase by its re-use. At this time, Grounds staff are willing to drop off un-chipped woody debris but not if they are charged tipping fees as tipping fees are perceived as an increase to their budget expenses. Receiving unprocessed materials would require us to separate materials and purchase or rent a tub grinder offsetting any value the raw materials would have for us. Currently we are able to obtain wood chips for free from local commercial landscapers.

The individual responsible for establishing new landscapes has used compost from Laurel Farms to create meadows and horticultural beds. This use, though not substantial in size is promising should we be able to generate a comparable product and a competitive price.

As noted in the composting section, we face several difficulties, primarily financial, in establishing a composting pad of adequate size. While processing food waste was not initially considered due to increased management and odor considerations, partnering with the University Dining Services department to handle their food waste might lead to a more university-wide interest in composting and open greater opportunity. This department currently pays tipping fees for Grounds to collect and transport their food refuse to the landfill. Competitive tipping fees charged by our composting program would not represent a budgetary increase for them and would represent a savings if we charged less. However, storage and transport of separated food waste to a farm-based composting facility present problems that are insurmountable at this time.

Municipal – The University farm is located within the City of Newark. The City has a residential collection program for grass, leaves, and woody debris. Materials are composted and the compost is made available for free pick-up to anyone interested. Their composting program is managed as a system for handling waste rather than as a program for creating a product. Minimal space, equipment, and labor is devoted to the effort and an inconsistent material is produced. At the same time that the State has instated a ban on landfilling yard waste and increasing residential interest in the City's collection program, the City is experiencing budgetary difficulties typical of municipalities currently. The City would be interested in providing yard waste to a University composting site, though tipping fees would be difficult to negotiate. Also, because our manure solids have an adequate carbon:nitrogen ratio, carbon sources such as leaves are not needed unless we choose to compost food waste.

The City of Wilmington also collects leaves and would be interested in providing leaves to us for composting. The same considerations that are encountered with the City of Newark apply.

Technology Transfer and Outreach:

Dairy Outreach: The dairy has been a focus of outreach to a variety of audiences including dairy farmers, conservation and engineering professionals, students, and the public.

Prior to start-up, a number of farm tours were provided that included a stop at the dairy where construction was under way. This provided an excellent opportunity to feature this project and its goals:

- Christina Basin Bus Tour September 2006
- Delmarva Wetland Conference October 2006
- American Farmland Trust National Conference, November 2006

A number of smaller group tours occurred in 2007 and the project was made known to local residents taking hayrides through the farm as part of Ag Day, the College's premier community outreach event held every April and attended by thousands of residents from the area. After start-up in December, the facility has been featured as part of an event devoted to the facility alone as well as events of wider scope.

Students: The project has been introduced to animal science students yearly who spend time at the dairy as part animal science labs and several labs focused on environmental protection and conservation practices for animal production farms.

Professional events:

- On March 1st, 2008 the Delaware Holstein Association's annual meeting was hosted here so that dairy farmers could view the manure separation system and response was favorable.
- An open house was hosted by McLanahan Corporation on July 10th, 2008 that showcased the system to farmers and other agricultural professionals.
- Dairy Days was held on November 10, 2008 at the dairy facility, showcasing the manure separation and stormwater collection system for a range of producers and conservation professionals. The event was covered by community media as well as farm and dairy publications.
- The NRCS Sand-laden Manure Tour hosted about 30 engineers, farmers, NRCS staff, and District employees from four states, December 2008.
- The NOPHNRCSE tour (National Organization of Professional Hispanic NRCS employees) on August 5, 2009 allowed about 25 participants from across the country to learn about the facility first-hand.

Other opportunities:

- Cooperative Extension's Master Gardeners were brought in to learn about the manure separation process and are, in turn, using manure solids in composting demonstrations at their facility.
- As noted, a major annual outreach event for our college is Ag Day which provides an opportunity for thousands of local residents to learn about our college activities and serves to provide exposure to agriculture in a region that is predominantly developed. For 2008, a raised bed vegetable garden was place in a high traffic area near the plant sale and a display was provided to introduce the manure solids and to explain the

environmental importance of the entire project. The display poster is attached in Appendix VI.

- The UD Sustainability Task Force farm tour in November 2008 allowed us to share this project with interested individuals from the university community who had no experience with environmental practices in a farm setting.

General: A dairy brochure has been developed by our College that provides an overview of the dairy including this installation and is provided as part of all educational and outreach events and to interested prospective students. The brochure can be viewed in Appendix VII.

Composting Outreach: With composting only recently initiated, minimal outreach has occurred that is directly related to our compost. However, work has been ongoing to promote compost use and interest in general while noting the College's composting plans. The Extension professional hired to work on this project, Valann Budischak, developed considerable networking with professionals from environmental agencies, composting facilities, and green industry businesses. As executive director of the Delaware Nursery and Landscape Association and a staff member with UD-Cooperative Extension and UD Botanic Gardens, Valann is perfectly situated to interact with a wide range of individuals. Composting was also covered in several 4-H and Master Gardeners programs.

Delaware Nursery and Landscape Association:

- DE Horticulture Industry Expo, January 2007, Dover DE - Frank Gouin, University of MD, spoke on "Soil Amendments for Landscape Contractors". 290 Attendees
- DNLA Summer Turf & Nursery Expo, August 2007, Millsboro, DE – Cameron Marcelle & Aaron Jackson discussed "Experimenting with Composting" and provided tours of their site. 173 attendees
- Ornamental & Turf Workshop, November 2007, Hockessin, DE - Jake Chalfin, Laurel Valley Soils, "Down & Dirty with Soil Renovation". 104 attendees
- Summer Turf and Nursery Expo, August 2008, UD Botanic Gardens. A small batch composting study and raised bed vegetable garden using manure solids was displayed to highlight use of our manure solids to green industry professionals from the region. Also viewed a student landscape establishment study using mushroom compost. 152 attendees
- DE Horticulture Industry Expo, January 2009, Dover DE – Carrie Murphy & Dot Abbott, "Soil Augmentation: Organic Amendments". 300 attendees
- DE Horticulture Industry Expo, coming up in January 2010. Recruited Terra-Gro to exhibit

Cooperative Extension:

- Compost education outreach efforts in NCC meeting with Master Gardeners, and Cooperative Extension to address proposed State yard waste ban
- "Economics of Composting" short course, March 2007, Nadine Davitt of PSU part of 2007 Cooperative Extension Short Course Series

Coordination with other agencies and composting managers:

- Mid-Atlantic Composting Association directory updated to include DE info October 2006
- Coordinated with Nadine Davitt to visit PSU composting site in 2006 as well as subsequent follow-up communications 2007 - 2009
- UD-Cooperative Extension met with DE-DNREC and DE Solid Waste Authority to discuss expanding educational outreach efforts on composting in preparation for potential yard waste ban, Fall 2006; worked with DNREC consultant developing Delaware-specific composting production and use information.
- Attended PSU seminar, "Landscape Uses of Mushroom Compost" December 2006
- Visited the Arden community composting site with organizer Hetty Franke, January 2007
- Roadside seeding project initiated, June 2008, on SR1 comparing mushroom compost and kiln-dried sawdust as broadcast mediums with seed. This is being compared to truax-seeding. Data was taken throughout 2008 and 2009 growing season.

Conclusions:

Cost, general: Purely on business criteria, this process is not cost effective for this size operation. When factoring in environmental protection goals and legal mandates, the cost becomes more relative. Still, without cost-share funding, the decision to install this level of equipment, storage, and especially to address stormwater management concerns would be difficult to make.

Equipment: There is a moderate learning curve to operating the equipment effectively. It runs well with minimal planned maintenance and minimal oversight. Repairs were higher than expected ($6,500/year on average). The annual cost for fresh water is $487 and the cost for electric before solar power reductions is $4,014.

Construction: For the university farm, construction was complicated by UD policies and City ordinances. Time and expense will likely be less for a private farmer in a rural setting. Stormwater runoff collection was a significant capital expense for the NREC farm, including larger storage capacity, repouring concrete pads, installing curbs, and adding a detention basin as well as several pumps. For pictures of project construction, please see Appendix VIII.

Manure liquids: Adding stormwater runoff and parlor washwater has increased cost and complexity to land application of manure liquids. In addition to capital costs for increased storage, dilution of manure liquids results in greater expense for land application. For our farm, desired application levels could not be met with one pass and a second pass is not possible.

Manure liquids storage: Improved storage was critical to solving our runoff and land application concerns. With high bacteria counts downstream, mitigating runoff is important to our environmental protection goals. At a minimum we needed to eliminate winter applications but to meet proper land application practices overall, we also needed the ability to time application with crop needs. We have met those goals. Even at 1.2M gallon capacity, however, storage capacity is a challenge requiring more field applications that anticipated. This is likely due to stormwater runoff collection.

Sand: Sand separation has provided a savings of $8,500/year in sand purchase and recycled sand is of good quality, causing no animal health concerns. Recycling sand means that we are reducing the time and expense of land applying it.

Manure solids: Quality was greater than expected. No free liquids or leachate and minimal odor make the material excellent to handle. Characteristics are good for composting. Three weeks roofed storage is helpful. Without a comprehensive composting program in place yet, export costs are considerable. Without separation, however, no one in this area would accept our dairy manure and if we had found a destination, transport of materials for equal nutrient content would have been greater. Creating markets for uncomposted manure should be explored since initial evaluations suggest good soil amendment and plant growth qualities.

Composting: While our intent was to start modestly and develop a program that composts our own agricultural materials exclusively, this may not be the appropriate model. Without an existing impervious pad of adequate size, the cost of initiating a composting program at the level needed to handle the volume of manure solids generated on our farm in an environmentally sound manner has been cost prohibitive. We have too many solids to be small-scale, and not enough material on the farm to be large-scale. Absent the right economic balance, policy support at the University level would be necessary but does not exist currently. The answer may be in developing a model that combines aspects of the Penn State program with those of commercial businesses in the area. The Penn State program is established so that the tipping fees and compost charges are competitive while the grounds department understands, values, and uses compost products. Commercial compost businesses have typically developed from turning a waste material into its own business, often by combining multiple waste sources of the same type, as with Laurel Valley developing as a mushroom industry cooperative, or by expanding to include other materials and products. Terra Gro combined their spent horse bedding with dairy and poultry manure while Frey Brothers made bagging their lumber waste more cost effective by also bagging sand and compost. In each case, a commitment was made to start-up costs and staffing for establishing a commercial business. For the College to succeed in composting, we may need to develop a cooperative for combining our farm materials with food and yard wastes from the University and the City while creating a greater interest in compost use among grounds programs within the University and City, in addition to local home owners and green industry businesses.

Technical support and outreach: Interest in the manure separation process has been considerable by conservation professionals and farmers considering this option. Composting outreach has been limited to raising interest in general and will continue in that direction until we have established a composting operation able to generate a significant volume of consistent product. At that time, outreach will shift to educating and developing markets.

Farm nutrient balance: The university farm has three challenges to manage in achieving our goal of example setting nutrient management and environmental protection: (1) improving manure application practices, (2) achieving a farm level nutrient balance, and (3) reducing runoff of nutrient-laden stormwater. This process has contributed to achieving our goal. Manure application practices have shifted from near-daily land application oriented on waste management to proper application to meet plant nutrient needs. This is a major achievement as a result of the improved storage and reducing application to the liquid portion of dairy manure only, as well as composting a variety of manures, including beef, horse, and sheep pack, with dairy solids. The farm level nutrient balance has been improved by separating manure solids into a more manageable and transportable material for export, thereby reducing nutrient application on our farm. Nutrient-laden runoff from the dairy was significant due to 21,200 square feet of concrete feeding area and poor guttering that allowed roof runoff to mix and further transport manure nutrients, pathogens, and organic matter to nearby surface waters of Cool Run.

Roof runoff is now directed away from manure for infiltration or to a stormdrain while all manure runoff is now collected and stored for proper land application. Water quality monitoring downstream will continue and our hope is that detrimental pathogen and nutrient values will be reduced over time. While this installation is not cost effective from a strictly business standpoint, if the cost of protecting the environment is considered, this project has increased our ability to improve our sustainability.

Appendix I. Storage Calculations

Manure Volume Calculations for UD Dairy Unit

FARM DATA

Contact:	J. McDermott	
Location:	UD Dairy	
Date:	1-May-06	rev(2) 2-May-06

MANURE PRODUCTION

			Mature milking cows	
			150	
Raw manure density	63	lb/cu.ft.		
Raw manure TS	11.5	%		
Raw manure volume	2.5	cu.ft./cow-day	375	cu.ft./day
Raw manure mass	157.5	lb/cow-day	23625	lb/day
Bedding	sand			
Bedding density	110	lb/cu.ft.		
Bedding TS	95	%		
Bedding volume reduction factor (porosity)	50	%		
Bedding mass	50	lb/cow-day	7500	lb/day
Bedding volume (equivalent, pores filled)	0.23	cu.ft./cow-day	34	cu.ft./day
Sand-laden manure density	76.1	lb/cu.ft		
Sand-laden manure volume	2.73	cu.ft./cow-day		
Sand-laden manure mass	207.5	lb/cow-day		
			409	**cu.ft./day**

			Young stock	
			0	
Density	62	lb/cu.ft.		
TS content	11	%		
Volume	1.3	cu.ft./cow-day	0	cu.ft./day
Mass	80.6	lb/cow-day	0	lb/day
Bedding	none			
Density	2.5	lb/cu.ft.		
TS content	90	%		
Volume reduction factor	50	%		
Mass	5.7	lb/cow-day	0	lb/day
Volume	1.14	cu.ft./cow-day	0	cu.ft./day
			0	**cu.ft./day**

BARN MANAGEMENT

Number of milking groups	0	
Number of drinkers	8	
Drinker volume	35	gal
Dump frequency	7	day cycle
Total dump volume	40	gal/day
	5.3	**cu.ft./day**

MILKING CENTER

Process water	1000.0	gal/day		
			134	**cu.ft./day**

SILAGE LEACHATE

Low-flow tank pump-out	**1200.0**	**gal/wk**		
			23	**cu.ft./day**

FLUSH SYSTEM				
Flush frequency	0	X per day		
Number of alleys	8			
Alley length	350	ft		
Alley width	8	ft		
Wave velocity	3.0	ft/s		
Wave depth	3.50	in		
Alley cover	0.50	*100%		
Flush volume	382.81	cu.ft.		
	2863.82	gal		
Flush volumetric flowrate	6.56	cu.ft./s		
	2953.13	gpm		
Release time	0.97	min		
Flush water TS	1.00	%		
Fresh water	1.40	gal/hd-day		
Total flush water required daily			0.00	gal/day
			0	**cu.ft./day**
			0	gal/hd-day
			0	lb/hd-day

SAND-MANURE SEPARATOR				
Separator inflow	31125	lb/day		
SMS processing rate	120	lb/min		
Recycled water flow rate	40	gpm		
	333	lb/min		
Sand recovery	90	%		
		61	**cu.ft./day**	

MANURE FIBER SEPARATOR				
Separator inflow	120	gpm		
Dry solids mass	18.1125	lb/cow-day		
Raw manure volume				
Separation efficiency	25	%		
Wet solids TS	25	%		
Wet solids density	35	lb/cu.ft.		
Wet mass of solids	72.5	lb/day		
Wet mass of solids to storage	54.3	lb/day		
Wet mass of separated solids	18.1	lb/day		
Volume of wet solids removed	**0.5**	**cu.ft./cow**	**78**	**cu.ft./day**

PRECIPITATION & RUNOFF				
Impervious area	19206	sq.ft.		
Precip. or storage duration	20.5	in		
Runoff from normal precip.			32422	cu.ft.
Evap. For storage duration	9.72	in		
Net. Precip for storage duration	10.78	in		
Runoff from 25 year, 24 hr storm	5.99	in	9206	cu.ft.
Total runoff volume	CN	98	**42397**	**cu.ft.**
	S=	0.204		

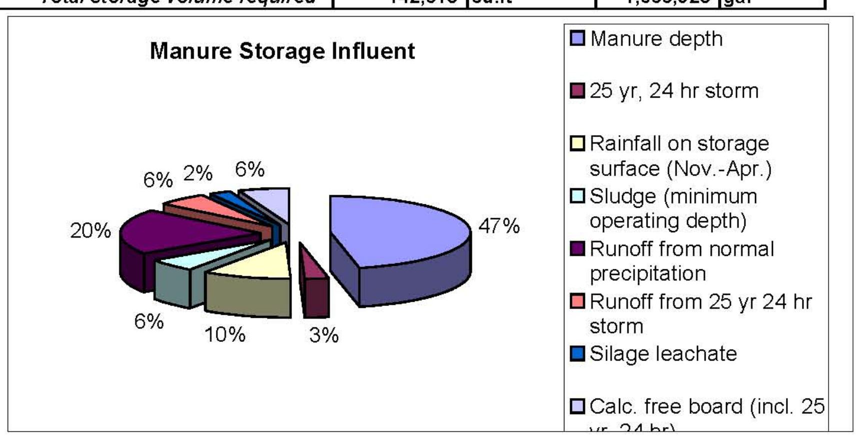
WASTE VOLUME SUMMARY — 150 mature milking animals

Storage time	170	days	
Raw manure		69545	cu.ft.
Raw manure, young stock		0	cu.ft.
Fresh water		4772	cu.ft.
Sand removed		-10432	cu.ft.
Manure solids removed		-13196	cu.ft.
Flush water (one day)		0	cu.ft.
Dumped drinker volume		909	cu.ft.
Milking center wastewater		22724	cu.ft.
Runoff from normal precip		32422	cu.ft.
Runoff from 25 yr, 24 hr storm		9206	cu.ft.
Silage leachate		3896	cu.ft.
Waste volume for storage period less runoff=		**74,323**	
		556,008	
Total waste volume for storage period (incl. runoff)=		***119,846***	***cu.ft.***
		896,565	***gal***
		705	**cu.ft./day**
		5,274	**gal/day**

FINAL STORAGE VOLUME

# Tanks	1			
Diameter	110	ft	**Nominal tank size**	
depth, total	16	ft	**1,136,932**	**gal total**
Surface area	9499	sq.ft.		
Manure depth	7.82	ft		
25 yr, 24 hr storm	0.50	ft		
Rainfall on storage surface (Nov.-Apr.)	1.71	ft		
Sludge (minimum operating depth)	1	ft		
Runoff from normal precipitation	3.41	ft		
Runoff from 25 yr 24 hr storm	0.97	ft		
Silage leachate	0.41	ft		
Calc. free board (incl. 25 yr, 24 hr)	0.99	ft		
Evaporation (Nov.-Apr.)	-0.81	ft		
Volume	**151,976**	**cu.ft**	**151,976**	**cu.ft. total**
	1,136,932	**gal/basin**	**1,136,932**	**gal total**

Total storage volume available=	**151,976**	**cu.ft**	**1,136,932**	**gal**
Total storage volume required=	**142,618**	**cu.ft**	**1,066,928**	**gal**



Appendix II. Results for Sand Pathogen Testing

OARDC Mastitis Lab: Bedding Bacterial Counts

University of Delaware

Type	Sample Date	%Dry Matter	Bacteria	bacteria/g of dry bedding
Recycled Sand Day 10				
	07-Apr-08			
			Coliform bacteria	1,000
			Gram Neg. bacteria	7,000
			Klebsiella spp.	1,000
			Streptococcus spp.	9,000
Recycled Sand Day 2				
	07-Apr-08			
			Coliform bacteria	1,000
			Gram Neg. bacteria	1,000
			Klebsiella spp.	1,000
			Streptococcus spp.	93,000
Recycled Sand Pile				
	07-Apr-08			
			Coliform bacteria	1,000
			Gram Neg. bacteria	1,000
			Klebsiella spp.	1,000
			Streptococcus spp.	124,000

Values of "1,000" indicate bacterial concentration was below detection level

Appendix III. Manure Analysis Results

-

Delaware Department of
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Michael T. Scuse
Secretary

Harry D. Shockley
Deputy Secretary

SUBMITTED FERTILIZER REPORT

Submitted by: Karen Gartley
Soil Testing Program
152 Townsend Hall
Newark, DE 19717

Lab Id: 07L-S01195 **Lab Number:** 07-948
Brand: Dairy Biosolids (12/5/07)
Code: None
Date Submitted: Dec 20, 2007 **Approved:** Jan 7, 2008
Container: BAG **Weight/container:**

Analysis	Units	Guaranteed	Found	Remark
Total Nitrogen (N)	%		0.29	
Total Nitrogen (N)	lbs/Ton		5.74	
Ammoniacal Nitrogen	%		0.01	
Ammoniacal Nitrogen	lbs/Ton		0.20	
Total Phosphate (P2O5)	%		0.10	
Total Phosphate (P2O5)	lbs/Ton		1.97	
Total Phosphorus (P)	%		0.04	
Total Phosphorus (P)	lbs/Ton		0.86	
Total Potash (K2O)	%		0.16	
Total Potash (K2O)	lbs/Ton		3.10	
Total Potassium (K)	%		0.13	
Total Potassium (K)	lbs/Ton		2.58	
Calcium (Ca)	%		0.14	
Calcium (Ca)	lbs/Ton		2.70	

SUBMITTED FERTILIZER REPORT

Lab ID: 07L-S01195 **Lab Number:** 07-948

Analysis	Units	Guaranteed	Found	Remark
Magnesium (Mg)	%		0.07	
Magnesium (Mg)	lbs/Ton		1.32	
Sulfur (S)	%		0.04	
Sulfur (S)	lbs/Ton		0.89	
Aluminum (Al)	ppm		343.90	
Aluminum (Al)	lbs/Ton		0.69	
Boron (B)	ppm		5.20	
Boron (B)	lbs/Ton		0.01	
Copper (Cu)	ppm		3.29	
Copper (Cu)	lbs/Ton		0.01	
Iron (Fe)	ppm		550.63	
Iron (Fe)	lbs/Ton		1.10	
Manganese (Mn)	ppm		27.98	
Manganese (Mn)	lbs/Ton		0.06	
Zinc (Zn)	ppm		19.20	
Zinc (Zn)	lbs/Ton		0.04	
Moisture	%		75.03	
Dry Matter	%		24.97	
Carbon	%		10.54	

REMARKS: **Analysis based upon Submitted Sample.**
All results reported as received (wet basis).

Teresa A. Crenshaw

Note: *Any claim of errors should be made within 10 days in order that they may be promptly investigated.*

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Deputy Secretary

SUBMITTED FERTILIZER REPORT

Submitted by: Karen Gartley
Soil Testing Program
152 Townsend Hall
Newark, DE 19717

Lab Id: 08L-S00244 **Lab Number:** 08-200
Brand: Dairy Liquid Manure - UD 1/22/08
Code: None
Date Submitted: Feb 21, 2008 **Approved:** Mar 6, 2008
Container: BAG **Weight/container:**

Analysis	Units	Guaranteed	Found	Remark
Total Nitrogen (N)	%		0.13	
Total Nitrogen (N)	lbs/1000 G		11.00	
Ammoniacal Nitrogen	%		0.07	
Ammoniacal Nitrogen	lbs/1000 G		5.79	
Total Phosphate (P2O5)	%		0.06	
Total Phosphate (P2O5)	lbs/1000 G		4.67	
Total Phosphorus (P)	%		0.02	
Total Phosphorus (P)	lbs/1000 G		2.04	
Total Potash (K2O)	%		0.10	
Total Potash (K2O)	lbs/1000 G		8.62	
Total Potassium (K)	%		0.09	
Total Potassium (K)	lbs/1000 G		7.16	
Calcium (Ca)	%		0.07	
Calcium (Ca)	lbs/1000 G		5.75	

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SUBMITTED FERTILIZER REPORT

Lab ID: 08L-S00244 **Lab Number:** 08-200

Analysis	Units	Guaranteed	Found	Remark
Magnesium (Mg)	%		0.03	
Magnesium (Mg)	lbs/1000 G		2.71	
Sulfur (S)	%		0.01	
Sulfur (S)	lbs/1000 G		1.08	
Aluminum (Al)	ppm		104.26	
Aluminum (Al)	lbs/1000 G		0.87	
Boron (B)	ppm		0.79	
Boron (B)	lbs/1000 G		0.01	
Copper (Cu)	ppm		1.01	
Copper (Cu)	lbs/1000 G		0.01	
Iron (Fe)	ppm		113.24	
Iron (Fe)	lbs/1000 G		0.94	
Manganese (Mn)	ppm		8.70	
Manganese (Mn)	lbs/1000 G		0.07	
Zinc (Zn)	ppm		7.07	
Zinc (Zn)	lbs/1000 G		0.06	
Total Solids	%		2.19	

REMARKS: **Analysis based upon Submitted Sample.**
All results reported as received (wet basis).

Teresa A.
Crenshaw

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Deputy Secretary

SUBMITTED FERTILIZER REPORT

Submitted by: Karen Gartley
Soil Testing Program
152 Townsend Hall
Newark, DE 19717

Lab Id: 08L-S00242 **Lab Number:** 08-199
Brand: Dairy Biosolids - UD 1/22/08
Code: None
Date Submitted: Feb 21, 2008 **Approved:** Mar 6, 2008
Container: BAG **Weight/container:**

Analysis	Units	Guaranteed	Found	Remark
Total Nitrogen (N)	%		0.28	
Total Nitrogen (N)	lbs/Ton		5.53	
Ammoniacal Nitrogen	%		0.02	
Ammoniacal Nitrogen	lbs/Ton		0.43	
Total Phosphate (P2O5)	%		0.09	
Total Phosphate (P2O5)	lbs/Ton		1.77	
Total Phosphorus (P)	%		0.04	
Total Phosphorus (P)	lbs/Ton		0.77	
Total Potash (K2O)	%		0.15	
Total Potash (K2O)	lbs/Ton		3.01	
Total Potassium (K)	%		0.13	
Total Potassium (K)	lbs/Ton		2.50	
Calcium (Ca)	%		0.15	
Calcium (Ca)	lbs/Ton		2.98	

SUBMITTED FERTILIZER REPORT

Lab ID: 08L-S00242 **Lab Number:** 08-199

Analysis	Units	Guaranteed	Found	Remark
Magnesium (Mg)	%		0.06	
Magnesium (Mg)	lbs/Ton		1.16	
Sulfur (S)	%		0.04	
Sulfur (S)	lbs/Ton		0.82	
Aluminum (Al)	ppm		241.35	
Aluminum (Al)	lbs/Ton		0.48	
Boron (B)	ppm		5.60	
Boron (B)	lbs/Ton		0.01	
Copper (Cu)	ppm		2.67	
Copper (Cu)	lbs/Ton		0.01	
Iron (Fe)	ppm		424.78	
Iron (Fe)	lbs/Ton		0.85	
Manganese (Mn)	ppm		18.53	
Manganese (Mn)	lbs/Ton		0.04	
Zinc (Zn)	ppm		15.67	
Zinc (Zn)	lbs/Ton		0.03	
Moisture	%		77.26	
Dry Matter	%		22.74	
Carbon	%		10.27	

REMARKS: **Analysis based upon Submitted Sample.**
All results reported as received (wet basis).

Teresa A.
Crenshaw

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Ed Kee
Secretary of Agriculture

SUBMITTED FERTILIZER REPORT

Submitted by: Karen Gartley
Soil Testing Program
152 Townsend Hall
Newark, DE 19717

Lab Id: 08L-S00683 **Lab Number:** 08-555
Brand: Cow Manure - UD-4 #1 Sand Laden Manure, McClanahan (6/30/08)
Code: None
Date Submitted: Jul 11, 2008 **Approved:** Jul 21, 2008
Container: Plastic Jar **Weight/container:**

Analysis	Units	Guaranteed	Found	Remark
Total Nitrogen (N)	%		0.19	
Total Nitrogen (N)	lbs/Ton		3.73	
Ammoniacal Nitrogen	%		0.03	
Ammoniacal Nitrogen	lbs/Ton		0.56	
Total Phosphate (P2O5)	%		0.14	
Total Phosphate (P2O5)	lbs/Ton		2.82	
Total Phosphorus (P)	%		0.06	
Total Phosphorus (P)	lbs/Ton		1.28	
Total Potash (K2O)	%		0.21	
Total Potash (K2O)	lbs/Ton		4.15	
Total Potassium (K)	%		0.17	
Total Potassium (K)	lbs/Ton		3.44	
Calcium (Ca)	%		0.13	
Calcium (Ca)	lbs/Ton		2.58	

SUBMITTED FERTILIZER REPORT

Lab ID: 08L-S00683 **Lab Number:** 08-555

Analysis	Units	Guaranteed	Found	Remark
Magnesium (Mg)	%		0.07	
Magnesium (Mg)	lbs/Ton		1.44	
Sulfur (S)	%		0.04	
Sulfur (S)	lbs/Ton		0.77	
Aluminum (Al)	ppm		843.29	
Aluminum (Al)	lbs/Ton		1.69	
Boron (B)	ppm		12.31	
Boron (B)	lbs/Ton		0.02	
Copper (Cu)	ppm		5.74	
Copper (Cu)	lbs/Ton		0.01	
Iron (Fe)	ppm		1592.11	
Iron (Fe)	lbs/Ton		3.18	
Manganese (Mn)	ppm		34.33	
Manganese (Mn)	lbs/Ton		0.07	
Zinc (Zn)	ppm		21.86	
Zinc (Zn)	lbs/Ton		0.04	
Moisture	%		48.44	
Carbon	%		3.34	

REMARKS: **Analysis based upon Submitted Sample.**

Teresa A. Crenshaw
State Chemist

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SUBMITTED FERTILIZER REPORT

Submitted by: Karen Gartley
Soil Testing Program
152 Townsend Hall
Newark, DE 19717

Lab Id: 08L-S00684 **Lab Number:** 08-556
Brand: Cow Manure - UD-5 #2 Fan Solids, McClanahan (6/30/08)
Code: None
Date Submitted: Jul 11, 2008 **Approved:** Jul 21, 2008
Container: Jar **Weight/container:**

Analysis	Units	Guaranteed	Found	Remark
Total Nitrogen (N)	%		0.43	
Total Nitrogen (N)	lbs/Ton		8.54	
Ammoniacal Nitrogen	%		0.00	
Ammoniacal Nitrogen	lbs/Ton		0.00	
Total Phosphate (P2O5)	%		0.15	
Total Phosphate (P2O5)	lbs/Ton		2.96	
Total Phosphorus (P)	%		0.07	
Total Phosphorus (P)	lbs/Ton		1.34	
Total Potash (K2O)	%		0.16	
Total Potash (K2O)	lbs/Ton		3.25	
Total Potassium (K)	%		0.14	
Total Potassium (K)	lbs/Ton		2.70	
Calcium (Ca)	%		0.19	
Calcium (Ca)	lbs/Ton		3.84	

SUBMITTED FERTILIZER REPORT

Lab ID: 08L-S00684 **Lab Number:** 08-556

Analysis	Units	Guaranteed	Found	Remark
Magnesium (Mg)	%		0.07	
Magnesium (Mg)	lbs/Ton		1.33	
Sulfur (S)	%		0.07	
Sulfur (S)	lbs/Ton		1.36	
Aluminum (Al)	ppm		275.93	
Aluminum (Al)	lbs/Ton		0.55	
Boron (B)	ppm		7.86	
Boron (B)	lbs/Ton		0.02	
Copper (Cu)	ppm		7.90	
Copper (Cu)	lbs/Ton		0.02	
Iron (Fe)	ppm		466.99	
Iron (Fe)	lbs/Ton		0.93	
Manganese (Mn)	ppm		24.18	
Manganese (Mn)	lbs/Ton		0.05	
Zinc (Zn)	ppm		37.11	
Zinc (Zn)	lbs/Ton		0.07	
Moisture	%		71.67	
Carbon	%		13.74	

REMARKS: **Analysis based upon Submitted Sample.**

Teresa A. Crenshaw
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SUBMITTED FERTILIZER REPORT

Submitted by: Karen Gartley
Soil Testing Program
152 Townsend Hall
Newark, DE 19717

Lab Id: 08L-S00685 **Lab Number:** 08-557
Brand: Cow Manure - UD-6 #3 Fan Liquid, McClanahan (6/30/08)
Code: None
Date Submitted: Jul 11, 2008 **Approved:** Jul 21, 2008
Container: LIQUID **Weight/container:**

Analysis	Units	Guaranteed	Found	Remark
Total Nitrogen (N)	%		0.16	
Total Nitrogen (N)	lbs/1000 G		13.45	
Ammoniacal Nitrogen	%		0.06	
Ammoniacal Nitrogen	lbs/1000 G		4.75	
Total Phosphate (P2O5)	%		0.08	
Total Phosphate (P2O5)	lbs/1000 G		6.78	
Total Phosphorus (P)	%		0.04	
Total Phosphorus (P)	lbs/Ton		2.96	
Total Potash (K2O)	%		0.17	
Total Potash (K2O)	lbs/1000 G		14.41	
Total Potassium (K)	%		0.14	
Total Potassium (K)	lbs/Ton		11.97	
Calcium (Ca)	%		0.08	
Calcium (Ca)	lbs/1000 G		6.62	

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SUBMITTED FERTILIZER REPORT

Lab ID: 08L-S00685 **Lab Number:** 08-557

Analysis	Units	Guaranteed	Found	Remark
Magnesium (Mg)	%		0.04	
Magnesium (Mg)	lbs/1000 G		3.46	
Sulfur (S)	%		0.02	
Sulfur (S)	lbs/1000 G		1.63	
Aluminum (Al)	ppm		143.05	
Aluminum (Al)	lbs/1000 G		1.19	
Boron (B)	ppm		2.35	
Boron (B)	lbs/1000 G		0.02	
Copper (Cu)	ppm		3.34	
Copper (Cu)	lbs/1000 G		0.03	
Iron (Fe)	ppm		145.45	
Iron (Fe)	lbs/1000 G		1.21	
Manganese (Mn)	ppm		12.16	
Manganese (Mn)	lbs/1000 G		0.10	
Zinc (Zn)	ppm		11.27	
Zinc (Zn)	lbs/1000 G		0.09	
Total Solids	%		3.14	

REMARKS: **Analysis based upon Submitted Sample.**

Teresa A. Crenshaw
State Chemist

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Ed Kee
Secretary of Agriculture

SUBMITTED MANURE REPORT

Submitted by: Karen Gartley
Soil Testing Program
152 Townsend Hall
Newark, DE 19717

Lab Id: 09L-S01025 **Lab Number:** 09-885
Brand: Manure Waste - Dairy Biosolids, UD-26
Code: None
Date Submitted: Dec 3, 2009 **Approved:** Dec 16, 2009
Container: BAG **Weight/container:**

Analysis	Units	Guaranteed	Found	Remark
Total Nitrogen (N)	%		0.32	
Total Nitrogen (N)	lbs/Ton		6.29	
Ammoniacal Nitrogen	%		0.01	
Ammoniacal Nitrogen	lbs/Ton		0.14	
Total Phosphate (P2O5)	%		0.10	
Total Phosphate (P2O5)	lbs/Ton		1.92	
Total Phosphorus (P)	%		0.04	
Total Phosphorus (P)	lbs/Ton		0.87	
Total Potash (K2O)	%		0.17	
Total Potash (K2O)	lbs/Ton		3.47	
Total Potassium (K)	%		0.14	
Total Potassium (K)	lbs/Ton		2.88	
Calcium (Ca)	%		0.15	
Calcium (Ca)	lbs/Ton		2.92	

SUBMITTED MANURE REPORT

Lab ID: 09L-S01025 **Lab Number:** 09-885

Analysis	Units	Guaranteed	Found	Remark
Magnesium (Mg)	%		0.07	
Magnesium (Mg)	lbs/Ton		1.36	
Sulfur (S)	%		0.05	
Sulfur (S)	lbs/Ton		1.02	
Aluminum (Al)	ppm		242.19	
Aluminum (Al)	lbs/Ton		0.48	
Boron (B)	ppm		4.51	
Boron (B)	lbs/Ton		0.01	
Copper (Cu)	ppm		19.54	
Copper (Cu)	lbs/Ton		0.04	
Iron (Fe)	ppm		498.01	
Iron (Fe)	lbs/Ton		1.00	
Manganese (Mn)	ppm		17.93	
Manganese (Mn)	lbs/Ton		0.04	
Zinc (Zn)	ppm		20.52	
Zinc (Zn)	lbs/Ton		0.04	
Moisture	%		69.53	
Carbon	%		13.15	

REMARKS: **Analysis based upon Submitted Sample.**
All results reported as received (wet basis).

Teresa A. Crenshaw
State Chemist

Note: *Any claim of errors should be made within 10 days in order that they may be promptly investigated.*

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SUBMITTED MANURE REPORT

Submitted by: Karen Gartley
Soil Testing Program
152 Townsend Hall
Newark, DE 19717

Lab Id: 09L-S01014 **Lab Number:** 09-874
Brand: Manure Waste - Dairy Liquid, UD-28
Code: None
Date Submitted: Dec 3, 2009 **Approved:** Dec 16, 2009
Container: LIQUID **Weight/container:**

Analysis	Units	Guaranteed	Found	Remark
Total Nitrogen (N)	%		0.06	
Total Nitrogen (N)	lbs/1000 G		4.91	
Ammoniacal Nitrogen	%		0.03	
Ammoniacal Nitrogen	lbs/1000 G		2.83	
Total Phosphate (P2O5)	%		0.02	
Total Phosphate (P2O5)	lbs/1000 G		1.39	
Total Phosphorus (P)	%		0.01	
Total Phosphorus (P)	lbs/1000 G		0.61	
Total Potash (K2O)	%		0.11	
Total Potash (K2O)	lbs/1000 G		9.33	
Total Potassium (K)	%		0.09	
Total Potassium (K)	lbs/1000 G		7.75	
Calcium (Ca)	%		0.03	
Calcium (Ca)	lbs/1000 G		2.67	

SUBMITTED MANURE REPORT

Lab ID: 09L-S01014 **Lab Number:** 09-874

Analysis	Units	Guaranteed	Found	Remark
Magnesium (Mg)	%		0.02	
Magnesium (Mg)	lbs/1000 G		1.67	
Sulfur (S)	%		0.01	
Sulfur (S)	lbs/1000 G		0.54	
Aluminum (Al)	ppm		10.48	
Aluminum (Al)	lbs/1000 G		0.09	
Boron (B)	ppm		1.02	
Boron (B)	lbs/1000 G		0.01	
Copper (Cu)	ppm		2.57	
Copper (Cu)	lbs/1000 G		0.02	
Iron (Fe)	ppm		22.82	
Iron (Fe)	lbs/1000 G		0.19	
Manganese (Mn)	ppm		2.43	
Manganese (Mn)	lbs/1000 G		0.02	
Zinc (Zn)	ppm		4.41	
Zinc (Zn)	lbs/1000 G		0.04	
Total Solids	%		0.71	

REMARKS: **Analysis based upon Submitted Sample.**
All results reported as received (wet basis).

Teresa A. Crenshaw
State Chemist

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Appendix IV. Images of Dairy Manure Solids and Compost Assays for Seed Germination and Plant Health

Seedling Germination on Compost Extract

dairy manure solids

curing compost

DI water

Metro Mix (+ control) curing compost/vermiculite (1:1) vermiculite (- control)

Metro Mix (+ control)

raw dairy solids/vermiculite (1:1)

vermiculite (- control)

Appendix V. Poster Presented at Soil Science Society of America: **Assessing the Value of Separated Dairy Solids for Agronomic and Horticultural Use**

Separate Powerpoint File:
"SSSA_poster_2008"

Appendix VI. UD-CANR Dairy Science Program Brochure

Separate PDF File:
"Ag Day Sustainability Dairy Poster 2008-handoutsize"

Appendix VII. Ag Day Sustainability Dairy Poster

Separate Powerpoint File:
“Dairy Science Program Brochure”

Appendix VIII. Photographs of Facility Construction

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

Prior to installation of a new storage tank, dairy manure was pushed into a paddock and land applied every other day.

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

Storage Tank Construction

- 1.2MG capacity
- 12' above ground
- 4' below ground
- 110' diameter

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

NRCS staff test concrete

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

Pole Barn

Construction

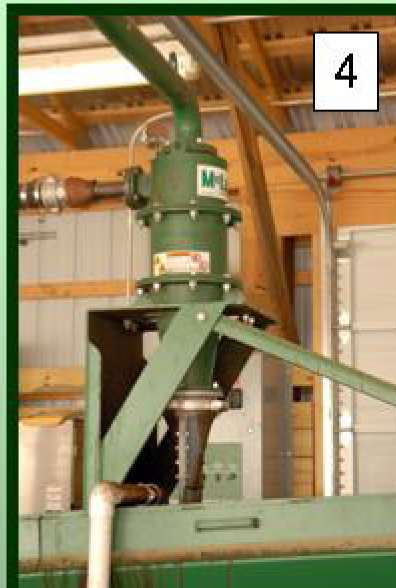
Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

Solar Panel Installation, 9.2 kWh

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

Manure is pushed from the loafing barn, across a concrete pad, into a reception pit (sized for three to four days of storage to get through the weekend) where it is lifted by an inclined auger into a sand-manure separator for removal of coarse and medium sand.

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware



1. Incline auger and sand separation equipment; effluent tanks 1, 2, & 3
2. Side view of sand separation equipment
3. Manure transferred to medium and course sand separator
4. Cyclone separator for fine sand separation

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

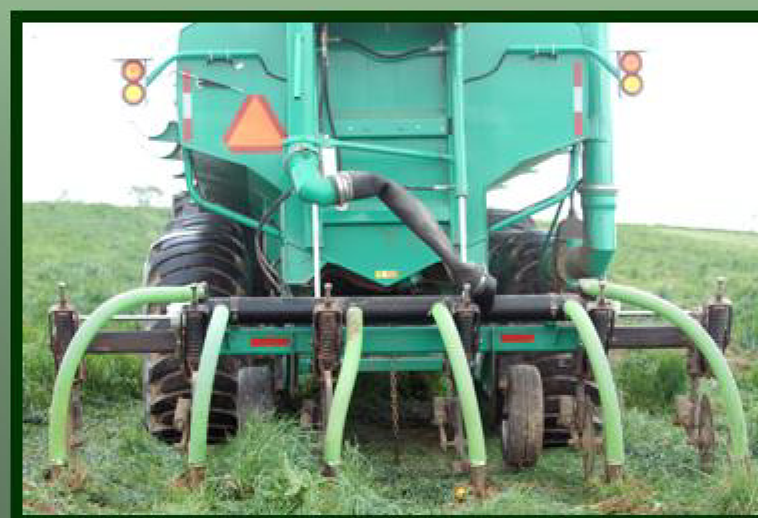
Separated sand dropping from chute, stored outdoors, and reused as bedding

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

Manure solids separator, manure solids dropping from chute, stored for transport

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

Land Application of Liquid Manure, subsurface injection



Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

Feeding areas before improvements to capture stormwater runoff

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

Recontoured concrete, curbing, and detention basin to collect stormwater runoff; underground pipe conveys to storage tank

Demonstration of a Complete Approach to Manure Management at the College of Agriculture and Natural Resources, University of Delaware

Guttering installed on barns to convey roof stormwater to fields for infiltration or to stormdrain without manure contact