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Economic Analysis of Mechanical Sand-Manure Separation of Flushed Sand-Laden Dairy Manure

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Abstract. *An economic analysis was performed using a model developed in Microsoft® Excel of an integrated manure treatment system that included mechanical separation of bedding sand from dairy manure by commercially available equipment. For this analysis, sand-laden dairy manure was removed from a dairy barn by hydraulic conveyance (flushed). Other major manure treatment systems components included: liquid-manure separation and anaerobic/facultative long-term storage. The analysis was done for various herd sizes ranging from 250 to 1,750 cows with sand procurement prices ranging between $3.50 and $14.00 per ton. The resulting economic costs from the analysis were utilized to provide a basis for analyzing decisions associated with sand, manure, and treatments. The analysis showed that the potential exists, from an economic perspective (based on limiting the benefits of sand-manure separation to reclaiming sand for re-bedding of stalls), for this treatment system to be utilized on dairy farms. For larger farms that can more fully utilize the system or farms that have mid to high sand procurement costs, the benefits of the system would even be greater and may actually reduce the sand bedding expense for the farm. Individual farms should start with this system's approach and take into account their particular circumstances in determining if an investment in this treatment system should be made.*

Keywords. Sand-laden dairy manure, Sand-manure separation, Sand bedding, Dairy manure, Dairy profitability

Economic Analysis of Mechanical Sand-Manure Separation of Flushed Sand-Laden Dairy Manure

by

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INTRODUCTION

Sand has been used for bedding dairy freestalls since the inception of the freestall. Producer testimony and scientific research alike have substantiated the benefits of sand bedding for cows. Sand is low in opportunistic pathogen loading, readily drains moisture and leaked milk (enhanced if sand with minimal fines is used), is labor efficient to add and maintain in stalls, and is readily available in many parts of the country. From the cows' perspective, it is comfortable to lie on, provides uniform body frame support during both lying as well as reclining and rising maneuvers, is cool in the summer, is non-abrasive when piled in the stalls to a depth of 6 to 8 inches, and offers comfortable, confident footing.

Sand has traditionally had one major negative issue against near universal acceptance: when combined with dairy manure, it can cause manure handling challenges that some producers are not willing to face. Historically, these challenges were mostly a result of improper system design or management, and/or the lack of properly designed dairy waste handling equipment, all of which rightfully created much pessimism. The major disadvantages historically included:

- increased load and wear on equipment used to clean barn alleys
- accelerated wear on equipment used to mechanically transport manure to storage or for field applications
- clogged pipes and channels
- inability to completely agitate and pump-out sand-laden dairy manure storage structures
- unsuccessful sand-manure separation attempts
- increased compaction of crop-producing fields due to heavy axle loads

However, more recently with the development of commercially available equipment designed to handle and process sand-laden dairy manure (SLDM), many producers are incorporating sand bedding into their new dairy facilities and retrofitting it into existing facilities alike.

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The objective of this paper is to provide economic information for a systems approach to processing SLDM that is removed by hydraulic flushing from a freestall barn and is subsequently processed with a series of commercially available equipment, including equipment that is specifically designed to remove sand from dairy manure. Some of the values for independent and dependent variables in such a system were taken from a farm that has been employing a similar system in Northwest Iowa since September 2000.

Determining if the annual economic costs associated with an investment along with the operational costs associated with the system is becoming more crucial. Long-term dairy profit margins continue to tighten, making poor investment decisions one of the primary reasons why some dairy producers struggle financially.

In performing the analysis the annual economic costs associated with the capital investment along with the annual operating costs associated with the system are calculated for different herd sizes. This type of analysis is most commonly utilized when determining the financial feasibility of an investment and reflects the system's economic costs to the business on an annual basis.

Manure handling system variables analyzed for this analysis included initial capital, operation, maintenance and repair, and labor costs.

LITERATURE REVIEW

Little economic information is available relative to the complete systems cost of processing dairy manure and wastewater. However, with decreasing profit margins in today's dairy business climate, it is imperative that the true cost of system operation be fully understood prior to making capital investments in equipment.

Gooch et al., (2002) performed an economic analysis of an integrated sand-manure separation system that employed mechanical separation of sand-laden dairy manure using a spreadsheet developed in Excel. The analysis showed that the savings in procurement of new bedding sand does offset the cost of the treatment system in many scenarios with the payoff trend being towards farms with more cows and higher sand procurement cost. No additional benefits of using sand, from a cow's perspective, were included in the analysis.

BACKGROUND

<u>Waste Treatment System Overview</u>

The waste handling system analyzed represents a viable option that a medium to larger dairy producer could consider utilizing if sand is used for freestall bedding. A schematic overview of this system is shown in Figure 1. The system consists of flush cleaning SLDM from the barn alleys and processing this material with a series of appropriate equipment specifically used to perform targeted tasks. The processing sequence includes, in sequential order: 1) sand-manure separation (SMS) to remove

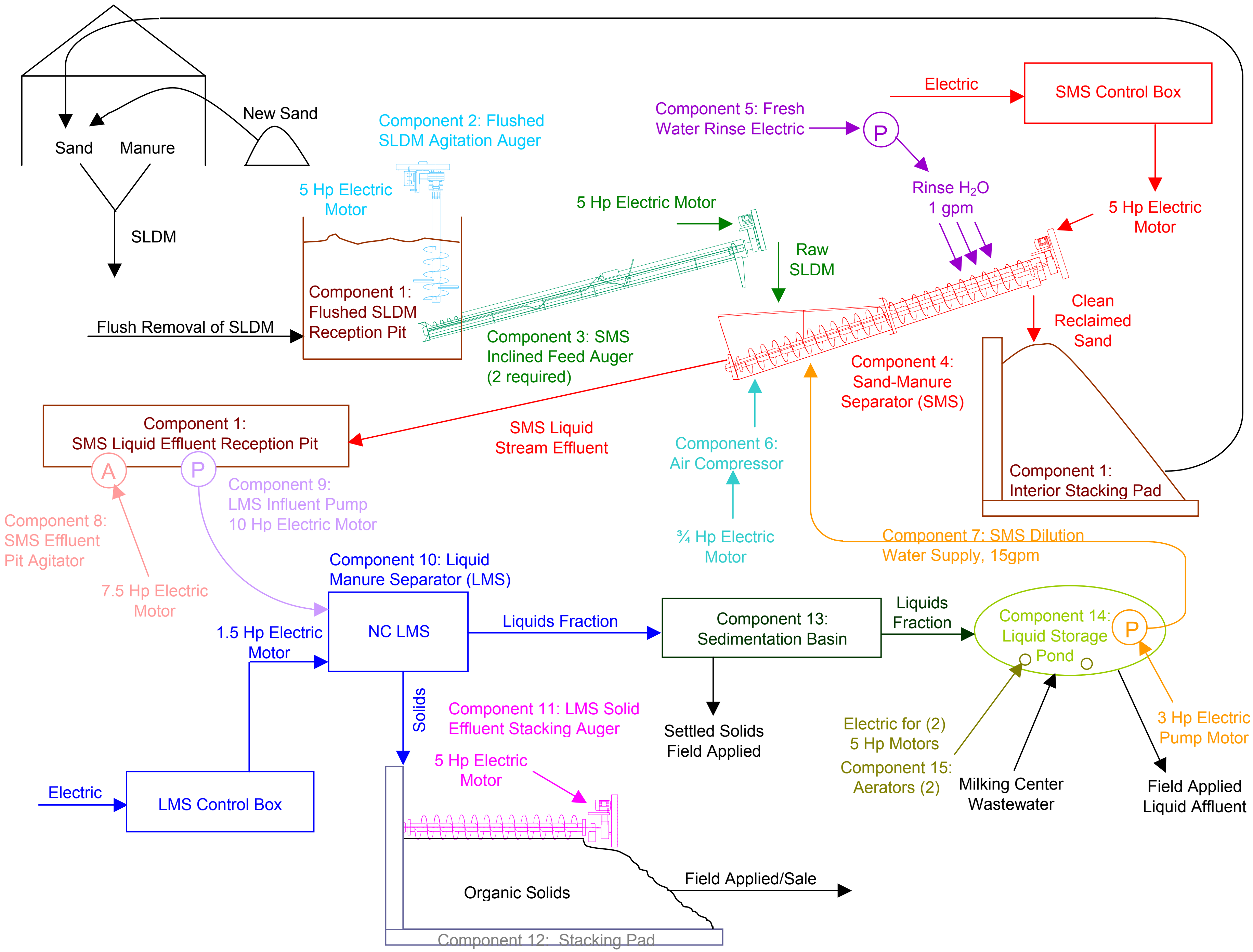

Figure 1. Flow diagram for manure processing system using sand-manure separation.

bedding sand from manure, 2) liquid-manure separation (LMS) targeted to remove organic solids from the SMS liquid stream effluent, sedimentation to remove residual sand and a portion of the remaining organic matter from the liquid stream that passed through the SMS and LMS, and 3) anaerobic/facultative treatment of liquids a) to provide long-term storage to comply with confined animal feeding operations (CAFO) requirements, b) as a means to reduce odors, and c) to provide a source of dilution water for SMS.

Outflow of materials from system components includes reclaimed sand for use in stall beds, de-watered settled solids spread on crop land, separated manure solids for composting, field spreading or sale, and facultative wastewater for field application. De-watered solids and separated manure solids can be field applied with a conventional box spreader or “V” body spreader. Liquids can be applied by liquid tankers (top spread or injected), surface irrigated, or drag hose injected. Removal of sand and many of the manure solids allows liquids to be pumped far distances in appropriately sized pipes.

<u>Equipment Overview</u>

There is a noticeable distinction between manure equipment and sand handling equipment. Manure equipment is usually constructed from mild steel whereas sand equipment is comprised of abrasion resistant iron and steel alloys. Manure equipment relies on close tolerances and high speeds whereas sand equipment uses larger tolerances that prevent sand grains from grinding between metal surfaces and operates at comparatively relatively slower operating speeds.

A line of commercially available mining-duty sand processing equipment was reconfigured to process SLDM and several on-farm installations have taken place since 1996. Field observation results from these installations reveal that sand-manure separators and inclined feed augers used to deliver SLDM to the SMS will withstand the abrasive nature of SLDM for many years without the need for replacement. Further information relative to the performance and capabilities of this equipment can be obtained by reviewing Wedel and Bickert, 1998.

Sand-manure separators are currently offered in three (3) size configurations with increased daily throughput as size increases. For this analysis, a 20” x 22’ SMS is used and is supplied SLDM by two (2) 11” x 22’ inclined augers. Also needed for flushed SLDM processing is a vertical lifting auger located adjacent to the inclined augers. The function of the vertical lifting auger is to preclude the bridging of sand over the inlet of the inclined augers. The throughput for this intermediate range equipment is 1.25 cow’s worth of manure combined with bedding sand per minute per day (i.e. one (1) SMS processes the SLDM from 600 cows in 8 hours of operation per day).

The other equipment used in the analysis consists of readily available, agricultural-duty manure pumping and liquid-solids separation equipment. Favorable durability of this equipment is contingent on utilization of an SMS to initially remove a high percentage of bedding sand prior to further processing and pipeline transport to long-term storage.

ECONOMIC ANALYSIS

Overview

The economic analysis presented herein is based on all system component costs associated with processing SLDM, including mechanical sand-manure separation, from the point where the SLDM enters the reception pit for the SMS up to and including the long-term storage structure. Costs associated with filling stall beds with sand, flushing SLDM to the SMS reception pit, and field-applying processed waste are not included in the analysis. These limits of analysis were established based on the broadness of methods to bed stalls, flush clean barn alleys, and apply processed manure to agricultural fields. Values for variables that represent these pre- and post-treatment costs can be determined on a per farm basis and added to the information presented here to develop a complete system cost specific for a particular farm.

In Figure 1, the major items of the overall system are identified by component with 15 components being defined. A list of each component along with its economic cost determination can be found in Appendix A.

Analysis

Handling dairy manure on almost all farms is considered a cost of doing business. Only in few isolated cases does a dairy producer generate a net positive income when analyzing their waste handling system costs. This generally occurs with an on-farm treatment system that generates a quality manure compost material in an urban location that will bear a seller-favorable market price. Some dairy operations may benefit by reducing their annual cost per cow for bedding material by processing the manure to remove solids and then using it as a bedding material. This can include organic solids and reclaimed sand bedding. The authors discourage the practice of using raw, untreated manure solids as freestall bedding material due to documented utter health concerns. Until now, the cost benefit impact for incorporating SMS into the overall waste handling systems for flushed SLDM has not been formally established.

The procedure followed was to first determine the required sand mass needed annually for bedding freestalls. Next, based on separation efficiency of an SMS, the annual sand bedding mass that can be reclaimed from manure and reused as bedding was determined. Complete manure treatment system costs were calculated, within the limits previously stated, to determine the annual cost for the system. Annual cost for the system was then compared to cost savings from reduced sand procurement in order to determine the cost benefit impacts. Each step of this procedure is described in detail below.

Annual Bedding Costs

The overall cost benefit received by the producer is a function of many variables including the price paid to procure bedding sand to the farm. The annual cost to bed stalls, assuming one cow per stall, as a function of sand cost and the number of cows (number of stalls) is shown in Table 1. The sand prices used in the table are mostly based on the range of retail price information obtained by conducting a sand procurement cost survey in 2002 of all certified suppliers of mason and concrete sand in New York State.

Table 1. Annual cost to procure sand with various sand source costs based on herd size with a sand usage of 40 lbs. per stall per day.

Ave. No. Cows	Annual Sand Use (lbs.)	Annual Sand Use (tons)	No. 20 Ton Loads/yr.	Annual Cost To Procure Sand ($) — Sand Procurement Cost ($/Ton) 3.5	5	6.5	8	9.5	11	12.5	14
250	3,650,000	1,825	91	6,388	9,125	11,863	14,600	17,338	20,075	22,813	25,550
500	7,300,000	3,650	183	12,775	18,250	23,725	29,200	34,675	40,150	45,625	51,100
750	10,950,000	5,475	274	19,163	27,375	35,588	43,800	52,013	60,225	68,438	76,650
1,000	14,600,000	7,300	365	25,550	36,500	47,450	58,400	69,350	80,300	91,250	102,200
1,250	18,250,000	9,125	456	31,938	45,625	59,313	73,000	86,688	100,375	114,063	127,750
1,500	21,900,000	10,950	548	38,325	54,750	71,175	87,600	104,025	120,450	136,875	153,300
1,750	25,550,000	12,775	639	44,713	63,875	83,038	102,200	121,363	140,525	159,688	178,850

Annual Mass of Sand Reclaimed

Many benefits are the direct result of removing sand from manure as a primary manure processing technique by mechanical SMS. They include significantly reduced mechanical wear on downstream pumps and manure hauling and spreading equipment, less load-induced wear on hauling equipment, more flexibility in performing secondary processing techniques (i.e. methane digestion), less concern with clogged transport pipes, reduced soil compaction from loaded spreaders, and the ability to use reclaimed sand as a quality bedding material.

Use of reclaimed sand as a bedding material has the most tangible cost benefit, as the cost savings in procurement of sand can easily be calculated based on reclamation efficiency of an SMS. The separation efficiency of an SMS has been tested to be 80 percent for mason sand (ASTM C-144) and 90 percent for concrete sand (ASTM C-33) (Wedel and Bickert, 1998). These separation efficiencies are used to determine the annual cost savings in sand procurement based on sand procurement cost as shown in Table 2a (for mason sand) and Table 2b (for concrete sand). The tables clearly indicate that a large mass of sand on an annual basis can be reused for bedding material. Since one (1) 20” x 22’ SMS can process flushed SLDM generated from up to 1,800 lactating Holstein dairy cows, farms with more cows serviced per separator have a larger annual sand bedding cost savings, which increase as sand procurement costs rise.

Annual Treatment System Cost

Treatment system costs include capital cost to purchase and install facilities and equipment; costs to operate, maintain, and repair facilities and equipment; and labor costs associated with the system. Components of a system are generally grouped together that have common life of service, and similar preventative maintenance and repair schedules when performing an economic analysis. For this manure treatment system, few similarities existed between equipment relative to cost and service life so

Table 2a. Annual cost savings, based on herd size, in procurement of mason sand for various sand source costs. Sand reclaim rate for mason sand (ASTM C-144) = 80 percent (Wedel and Bickert, 1998).

Ave. No. Cows	Annual Mason Sand Tonnage Reclaimed & Reused for Bedding	Annual Saving in Sand Procurement ($) Sand Procurement Cost ($/Ton)							
		3.5	5	6.5	8	9.5	11	12.5	14
250	1,460	5,110	7,300	9,490	11,680	13,870	16,060	18,250	20,440
500	2,920	10,220	14,600	18,980	23,360	27,740	32,120	36,500	40,880
750	4,380	15,330	21,900	28,470	35,040	41,610	48,180	54,750	61,320
1,000	5,840	20,440	29,200	37,960	46,720	55,480	64,240	73,000	81,760
1,250	7,300	25,550	36,500	47,450	58,400	69,350	80,300	91,250	102,200
1,500	8,760	30,660	43,800	56,940	70,080	83,220	96,360	109,500	122,640
1,750	10,220	35,770	51,100	66,430	81,760	97,090	112,420	127,750	143,080

Table 2b. Annual cost savings, based on herd size, in procurement of concrete sand for various sand source costs. Sand reclaim rate for concrete sand (ASTM C-33) = 90 percent (Wedel and Bickert, 1998).

Ave. No. Cows	Annual Concrete Sand Tonnage Reclaimed & Reused for Bedding	Annual Saving in Sand Procurement ($) Sand Procurement Cost ($/Ton)							
		3.5	5	6.5	8	9.5	11	12.5	14
250	1,642.5	5,749	8,213	10,676	13,140	15,604	18,068	20,531	22,995
500	3,285.0	11,498	16,425	21,353	26,280	31,208	36,135	41,063	45,990
750	4,927.5	17,246	24,638	32,029	39,420	46,811	54,203	61,594	68,985
1,000	6,570.0	22,995	32,850	42,705	52,560	62,415	72,270	82,125	91,980
1,250	8,212.5	28,744	41,063	53,381	65,700	78,019	90,338	102,656	114,975
1,500	9,855.0	34,493	49,275	64,058	78,840	93,623	108,405	123,188	137,970
1,750	11,497.5	40,241	57,488	74,734	91,980	109,226	126,473	143,719	160,965

several components were identified and analyzed accordingly. As previously stated, the 15 components analyzed specifically for this system are listed in Appendix A along with pertinent data and information needed for the analysis.

A spreadsheet was developed using Microsoft® Excel to perform the economic analysis for the system. Each component defined was analyzed individually to determine its annual cost. The sum of the annual costs for each component was totaled to determine the annual costs for the complete system. The results of one treatment component in the analysis spreadsheet are shown in Appendix B for the scenario of 500 cows serviced with an average daily electrical cost of $0.1 per kW-hr. The line items in Appendix B that have a thin-lined box encompassing a number represent a variable entered by the user. The heavy-lined box at the bottom represents the total annual cost for that component while the larger, doubled-lined box at the top represents the total annual cost for all components (the other 14 components are not shown). The remaining line items that are not boxed in represent empirically calculated values from the input variable values.

Depreciation and interest on investment are utilized to expense the capital investment over time and comprises the fixed costs. Depreciation is calculated utilizing straight-line depreciation with a user determined salvage value (10 percent of initial cost was used in the analysis for most items). The annual depreciation expense represents the annual charge over the life of the asset for the capital investment including installation costs. Interest on investment represents the opportunity cost associated with investing capital into the SMS system versus using the money elsewhere and is calculated by multiplying the average investment level over the useful life by the opportunity cost of five percent. Five percent represents a long-term real rate of interest earned in other investment options.

Operating costs represent the costs associated with running, maintaining, and managing the SMS system. Electricity costs, repair costs, and labor costs for the system are estimated and placed on an annual basis. Table 3 summarizes output from the developed spreadsheet based on changing the average number of cows serviced daily on an annual basis and the average daily electrical cost.

The total annual fixed and operating costs for the SMS system represent the economic costs incurred by the farm by choosing this system. These costs are not just cash costs, as depreciation and interest on investment are not cash costs. This number also does not represent the debt service requirement per year if the system was fully financed. For decision-making and comparing different options, first look at the total economic costs associated with a particular system.

Table 3. Annual manure treatment system cost for various average number of cows serviced.

	Annual Est. System Cost ($)			Annual Cost
Ave. No.	Electrical Cost ($/kW-hr.)			Per Cow With
Cows	0.075	0.1	0.125	E.C. = 0.1 $/kW-hr.
250	41,484	44,773	48,062	$179.09
500	44,422	48,549	52,677	$97.10
750	47,360	52,326	57,292	$69.77
1,000	50,298	56,102	61,907	$56.10
1,250	53,236	59,879	66,522	$47.90
1,500	56,173	63,655	71,137	$42.44
1,750	59,111	67,432	75,753	$38.53

Cost-Benefit Impacts

As the herd size increased, the operating costs associated with the system also increased, but the fixed costs change very little, leading to a higher total annual cost but a lower total annual cost per cow. Tables 4a and 4b list the net annual costs of the SMS system after reflecting the benefit of using reclaimed sand for bedding. For the smaller herd sizes and the lower sand procurement costs, the sand procurement savings do not offset the annual cost of the overall treatment system (represented by positive table values). For the larger farms and the higher sand costs, the reclaimed sand savings offsets the cost of the overall treatment system and lowers the overall cost of sand procurement for the farm (represented by negative table values).

A complete economic analysis of all the potential impacts of choosing the described treatment system is complex and difficult to fully quantify. While an analysis of the fixed and operating costs associated with the analyzed system can be quantified and the amount of sand reclaimed can be determined, other benefits associated with using sand as a bedding material and sand separators to reduce or eliminate

Table 4a. Net annual total system cost ($) as a function of herd size and initial sand procurement price of mason sand using an average daily electrical cost = $0.1 per kW-hr.

Ave. No. Cows	Net Annual System Cost ($) When Using Mason Sand							
	Procurement Sand Cost ($/Ton)							
	3.5	5	6.5	8	9.5	11	12.5	14
250	39,663	37,473	35,283	33,093	30,903	28,713	26,523	24,333
500	38,329	33,949	29,569	25,189	20,809	16,429	12,049	7,669
750	36,996	30,426	23,856	17,286	10,716	4,146	-2,424	-8,994
1,000	35,662	26,902	18,142	9,382	622	-8,138	-16,898	-25,658
1,250	34,329	23,379	12,429	1,479	-9,471	-20,421	-31,371	-42,321
1,500	32,995	19,855	6,715	-6,425	-19,565	-32,705	-45,845	-58,985
1,750	31,662	16,332	1,002	-14,328	-29,658	-44,988	-60,318	-75,648

Table 4b. Net annual total system cost ($) as a function of herd size and initial sand procurement price of concrete sand using an average daily electrical cost = $0.1 per kW-hr.

Ave. No. Cows	Net Annual Cost ($) When Using Concrete Sand							
	Procurement Sand Cost ($/Ton)							
	3.5	5	6.5	8	9.5	11	12.5	14
250	39,024	36,561	34,097	31,633	29,169	26,706	24,242	21,778
500	37,052	32,124	27,197	22,269	17,342	12,414	7,487	2,559
750	35,080	27,689	20,297	12,906	5,515	-1,877	-9,268	-16,659
1,000	33,107	23,252	13,397	3,542	-6,313	-16,168	-26,023	-35,878
1,250	31,135	18,817	6,498	-5,821	-18,140	-30,459	-42,777	-55,096
1,500	29,163	14,380	-403	-15,185	-29,968	-44,750	-59,533	-74,315
1,750	27,191	9,945	-7,302	-24,548	-41,794	-59,041	-76,287	-93,533

historical SLDM handling problems were not quantified. Areas associated with using sand as bedding, removing sand from manure before handling with traditional manure equipment, soil compaction, and other potential decreases or increases in business expenses all can impact the total costs and benefits. These areas are dependent on individual farm management decisions. Depending on these issues, the costs associated with employing this treatment system may be enhanced or reduced. Individual producers need to consider all these issues when analyzing investment options.

SUMMARY

An integrated manure treatment system, including mechanical sand-manure separation, was economically evaluated with a developed spreadsheet model. The resulting economic costs developed can be used to provide a basis for analyzing decisions associated with sand-laden dairy manure treatment. Based on anecdotal experience and research driven data, the potential exists, from an economic perspective (based on limiting the benefits of SMS to reclaiming sand re-bedding of stalls), for this treatment system to be utilized on dairy farms. For larger farms that can more fully utilize the system or farms that have high sand procurement costs, the benefits of the system would even be greater and may actually reduce the sand bedding expense for the farm. Individual farms should start with this system's approach and take into account their particular circumstances in determining if a SMS investment should be made.

CONCLUSIONS

- A complete economic analysis of all the potential impacts of choosing the described treatment system is complex and difficult to fully quantify. While an analysis of the fixed and operating costs associated with the analyzed system can be quantified and the amount of sand reclaimed can be determined, other benefits associated with using sand as a bedding material and sand separators to reduce or eliminate historical SLDM handling problems were not quantified.

- For the smaller herd sizes and the lower sand procurement costs, the sand procurement savings do not offset the annual cost of the overall treatment system.

- Due to full utilization of separator capacity, for the larger farms and the middle to higher sand costs, the reclaimed sand savings offsets the cost of the overall treatment system and lowers the overall cost of sand procurement for the farm.

- The developed spreadsheet economic analysis model can be used to evaluate variations of this manure treatment system (e.g., obtaining SMS dilution water from other, less costly means) for comparison purposes. It can also be adapted to analyze different manure handling methods.

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APPENDIX A

List of system components with relevant information for pricing determination.

Component 1: Building and Interior Concrete
Initial cost based on estimated price for 36' x 48' building @ 40/ft. sq. = $69,120

Utility Service Installation = $1,000

Annual Preventative Maintenance = $50 for non-specific repairs

Repairs Over Useful Life = $200 (doors, windows, heater, light bulbs, etc.)

Annual Electric = 3,000 BTU heater operating 24 hrs./day for 4 winter months + 300 Watt light system operating 5 hrs. each month

Annual Labor = 8 hrs. for general maintenance

Component No. 2: Vertical Agitation Auger
Initial Capital Investment – Manufacturer's suggested retail price = $9,900

Installation = $200

Annual Preventative Maintenance = $20 annual for grease

Repairs Over Useful Life (converted to an annual value) = $750 for flight wear shoes replaced every 7 years, $200 for 5 Hp electric motor, replaced every 7 years, and $1,000 every 10 years for a main gearbox replacement

Annual Electrical Cost = (No. cows serviced per day) x (0.80 min operation/cow serviced per day) x (365 days/yr.) x (1 hr./60min.) x (motor Hp x 1 kw/1 Hp) x (electrical cost in $/kW-hr.) Uses a 5 Hp electric motor.

Labor (converted to an annual value) = 8 hrs. for wear shoe replacement every 7 years, 1 hr for motor replace every 7years, 2 hrs. for replacement of main gear box every 10 years, and 10 minutes a month for lubrication

Component No. 3: (2) 11" x 22' SMS Inclined Feed Augers
Initial Capital Investment – Manufacturer's suggested retail price = $13,900 each, total of $27,800

Installation = $400 each

Annual Preventative Maintenance = $20 annual for grease and $25 annual for belts

Repairs Over Useful Life (converted to an annual value) = [$350 for submerged main bearing rebuild every year, $4,500 screw shaft replaced every 4 years, and $200 for 5 Hp electric motor, replaced every 7 years] x 2

Annual Electrical Cost = [(No. cows serviced per day) x (0.80 min operation/cow serviced per day) x (365 days/yr.) x (1 hr./60 min.) x (motor Hp x 1 kw/1 Hp) x (electrical cost in $/kW-hr.)] x 2. Each auger uses a 5 Hp electric motor.

Labor (converted to an annual value) = [4 hrs. for submerged main bearing every year, 8 hrs. for screw shaft every 4 years, 1 hr for motor replace every 7years, and 10 minutes a month for lubrication] x 2.

<u>Component No. 4: 20" x 22' Sand-Manure Separator</u>

Initial Capital Investment – Manufacturer's suggested retail price = $33,000

Installation = $400

Annual Preventative Maintenance = $20 annual for grease and $25 annual for belts

Repairs Over Useful Life (converted to an annual value) = $1,900 for flight wear shoes replaced every 20 years, $200 for electric motor, replaced every 7 years, and $400 every 10 years for a main bearing rebuild kit

Annual Electrical Cost = (No. cows serviced per day) x (0.80 min operation/cow serviced per day) x (365 days/yr.) x (1 hr./60min.) x (motor Hp x 1 kw/1 Hp) x (electrical cost in $/kW-hr.). Uses a 5 Hp electric motor.

Labor (converted to an annual value) = 8 hrs. for wear shoe replacement every 20 years, 1 hr for motor replace every 7years, 4 hrs. for rebuild of main submerged bearing every 10 years, and 10 minutes a month for lubrication and general check of the system

<u>Component No. 5: Fresh Water Rinse</u>

Zero cost used for this analysis.

<u>Component No. 6: Air Compressor</u>

Initial Capital Investment – Manufacturer's suggested retail price = $750

Installation = $50

Annual Preventative Maintenance = $10 for oil

Repairs Over Useful Life = $0

Annual Electrical Cost = (No. cows serviced per day) x (0.80 min operation/cow serviced) x (365 days/yr.) x (1 hr./60 min.) x (motor Hp x 1 kw/1 Hp) x (electrical cost in $/kW-hr.)

Labor (converted to an annual value) = 10 minutes a month for general service

Component No. 7: Dilution Water Supply

Initial Capital Investment = $1,250 for pump, and $1,150 for 350’ of PVC pipe at $3/ft

Installation = $4,050 for electric supply connection, control wiring, pipe fittings, pump house construction

Annual Preventative Maintenance = $52 for non-specific repair parts (float switch, motor starter, connection plumbing, etc.)

Repairs Over Useful Life = $50 for general repairs annually and $250 to rebuild 3 Hp pump every 5 years

Annual Electric Cost = (No. cows serviced per day) x (0.80 min operation/cow serviced) x (365 days/yr.) x (1 hr./60 min.) x (motor Hp x 1 kw/1 Hp) x (electrical cost in $/kW-hr.)

Labor (converted to an annual value) = 20 minutes a month for general service and 4 hours every 5 years to rebuild pump

Component No. 8: SMS Effluent Pit Agitator

Initial Capital Investment = Manufacturer’s suggested retail price = $3,150

Installation Cost = $500

Annual Preventative Maintenance = $50 for non-specific repairs (float switch, motor starter, connection plumbing, etc.)

Repairs Over Useful Life = $750 for motor replacement every 7 years and $50 annually for general repairs

Annual Electric Cost = ((No. cows serviced per day x 2.25 cu ft per cow per day x 7.49 gal per cu. ft. x 365 days per year) +(No. cows serviced per day x 15 gpm per cow x 365 days per year)) / 250 gal per min x 1 hr per 60 min x motor Hp x electric cost in $ per kW-hr. Uses a 7.5 Hp electrical motor.

Labor (converted to an annual value) = 4 hours to replace motor every 7 years and 10 minutes a month for general service.

Component 9: LMS Influent Pump

Initial Capital Investment = Manufacturer's suggested retail price = $4,850

Installation Cost = $500

Annual Preventative Maintenance = $50 for non-specific repairs (float switch, motor starter, connection plumbing, etc.)

Repairs Over Useful Life = $658 for pump rebuild kit every 5 years, $750 for motor replacement every 7 years and $50 annually for general repairs

Annual Electric Cost = ((No. cows serviced per day x 2.25 cu ft per cow per day x 7.49 gal per cu. ft. x 365 days per year) +(No. cows serviced per day x 15 gpm per cow x 365 days per year)) / 250 gal per min x 1 hr per 60 min x motor Hp x electric cost in $ per kW-hr. Uses a 10 Hp electrical motor.

Labor (converted to an annual value) = 8 hours to rebuild pump every 5 years, 4 hours to replace motor every 7 years and 10 minutes a month for general service.

Component No. 10: NC Liquid Manure Separator

Initial Capital Investment = Manufacturer's suggested retail price = $29,435

Installation Cost = $2,500

Annual Preventative Maintenance = $50 for non-specific repairs (float switch, motor starter, connection plumbing, etc.)

Repairs Over Useful Life = $12 ea. for 4 bearings every 5 years, and $20 ea. for 12 brushes every 2 years

Annual Electric Cost = ((No. cows serviced per day x 2.25 cu ft. per cow per day x 7.49 gal per cu. ft. x 365 days per year) + (No. cows serviced per day x 15 gpm per cow x 365 days per year)) / 250 gal/min x 1 hr per 60 min x motor Hp of separator x electrical cost in $ per kW-hr. Uses a 1.5 Hp electrical motor.

Labor (converted to an annual value) = 8 hours to replace bearings every 5 years and 4 hours to replace brushes every 2 years.

Component 11: LMS Solids Effluent Stacking Auger

Initial Capital Investment = Manufacturer's suggested retail price = $6,490

Installation Cost = $500

Annual Preventative Maintenance = $50 for non-specific repairs (switch, motor starter, etc.)

Repairs Over Useful Life = $100 ea. for 7 replacement bearing every 10 years, $200 for motor replacement every 7 years and $50 annually for general repairs

Annual Electric Cost = ((No. cows serviced per day x 2.25 cu ft per cow per day x 7.49 gal per cu. ft. x 365 days per year) +(No. cows serviced per day x 15 gpm per cow x 365 days per year)) / 250 gal per min x 1 hr per 60 min x motor Hp x electric cost in $ per kW-hr. Uses a 5 Hp electric motor.

Labor (converted to an annual value) = 8 hours to replace bearings every 10 years, 4 hours to replace motor every 7 years and 10 minutes a month for general service.

Component 12: LMS Solids Stacking Pad

Initial cost based on estimated price from building project (0.5' x 36' x 60' concrete pad) = $8,000

Component 13: LMS Settling Tanks (2)

Initial cost based on estimated price from building project = $40,000

Component 14: Liquid Storage Pond

Initial Cost = $1.5 per cu. yd. capacity cost for 1) 180 days of processed manure storage (based on 2.25 cu. ft. per cow per day), 2) 5,000 gallons per day of milking center wastewater 3) 18" of rainwater accumulation over a surface area of 3 acres, and 4) 12" of freeboard over a surface area of 3 acres

Annual Maintenance Cost = $500 for mowing banks

Annual Labor = 12 episodes of mowing banks at 2 hours per mowing

Component 15: Aeration Pumps (3)

Initial Capital Investment = Manufacturer's suggested retail price = $6,200 each

Installation Cost = $400 each

Annual Preventative Maintenance = $50 for to grease and non specific repairs (switch, motor starter, etc.)

Repairs Over Useful Life = $600 ea. to rebuild every 5 years, $50 annually for general repairs

Annual Electric Cost = pumps operate 24 hours per day, 240 365 days per year. Motor Hp x electric cost in $ per kW-hr.

Labor (converted to an annual value) = 8 hours to rebuild each pump every 5 years, 1 hour to grease each pump 4x per year.

APPENDIX B

Sample Economic Analysis for Waste Treatment System that Incorporates Mechanical Separation of Bedding Sand from Scraped Sand-Laden Dairy Manure

Enter Ave. No. Cows Serviced Here:	500	
Enter Ave. Electrical Cost Here:	0.1	$/kW-hr.

Total Annual Est. Cost for Ave. No. of Cows Serviced Daily	$48,549.40

Initial Investments, Fixed, and Operating Cost Calculation by Component

Component No. 1 Building and Interior Concrete

a.	Initial Capital Investment	$69,120.00
b.	Installation Cost (includes elec. & plumb. service)	$1,000.00
c.	Useful Life, Years	20
d.	Salvage Value	$0.00
e.	Interest on Investment	0.05
f.	Average Investment (a+b+d)/2	$35,060.00
g.	Annual Interest Charge (e x f)	$1,753.00
h.	Annual Depreciation, linear	$3,506.00
I.	Annual Preventative Maitenance	$50.00
j.	Annual Repairs Over Useful Life	$200.00
k.	Annual Electrical Cost	$1,159.98
l.	Annual Labor Hours	8.0
m.	Labor Rate, all costs	16
n.	Annual Labor Costs (l x m)	$128.00
	Total Annual Cost for Component: (g+h+I+j+k+n):	$6,796.98