Trends in Equipment and Technology in the Wisconsin For-Hire Manure Application Industry, 2001–2023
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Since 2001, the University of Wisconsin (UW-Extension, 2001–2017; UW–Madison Division of Extension, 2018–2023) has created a public directory of Wisconsin’s for-hire manure application industry each year. This directory includes basic information on the type of manure transportation and application equipment used, and a long-term review of this data that provides insights into the industry’s equipment trends. As of December 2023, there are more than 240 for-hire manure application businesses based in Wisconsin, handling more than 6 billion gallons of liquid dairy manure annually.

The data gathered for the annual directory is used by Extension educators to shape the manure applicator training offered each spring. Trends in equipment type, use, and size impact the safety, application skills, and public relations components of each year’s training.

Data Collection and Methods: Starting in late summer or fall each year, Extension educators have reached out to known for-hire manure applicators serving Wisconsin by a variety of means, including in person, US mail, phone, text message, email, or social media messaging, offering to include their businesses in the annual directory and/or update existing information. Manure applicators voluntarily provide information about their manure application, transportation, or storage agitation businesses, including the type and size of equipment they operate, headquarters city, and the trade area served. Additional applicators discovered through field observation, social media, referral, or agency spill records are included in the annual outreach. If a business chooses not to be included in the public directory, they are asked to voluntarily provide the same equipment information, and their data is included in the data summary. This directory is then posted online by a number of UW–Madison Extension county offices and distributed to agricultural conservation agencies within Wisconsin.

In addition to the questions used for the annual inventory, varying additional ones were asked in 2001, 2006, and 2011 to estimate the total gallons (or tons) of manure the industry has applied in the state, the percentage of manure applied each month, and/or the primary concerns the business owners had concerning regulations. This data was collected separately to protect confidentiality. As not all participants were able or willing to provide volume information, the final numbers were an estimate based on the numbers provided.

Numbers and Results: As of December 2023, there are over 240 for-hire manure application/transportation/agitation businesses (hereafter referred to as “applicators”) based in Wisconsin, handling an estimated 7 billion gallons of liquid dairy manure annually. The number of for-hire applicators has grown by more than 50% since 2017, when 161 businesses served Wisconsin livestock producers. This increase followed the prior 6-year period, which saw the total number of for-hire businesses grow by ~13% (~20) over 6 years. Total manure volume hauled by the for-hire manure application industry was estimated from the collected data at 3 billion gallons annually in 2001, 4 billion in 2006, 6 billion in 2011, and estimated to be approximately 7 billion in 2021.

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The growth in the for-hire manure application industry occurred in parallel with a similar growth in the number of for-hire custom forage harvesters in the state, but at the same time as a stagnation in the total number of dairy cows in Wisconsin. There was a 68% drop in the number of dairy farms but a dramatic rise in the number of cows per dairy farm.

Data provided in the annual Wisconsin Agricultural Statistics summary profile of Wisconsin documents the annual changes in farm and livestock numbers. The 2001 data showed 18,693 dairy herds\(^2\) in the state, dropping 68% to 6,033 herds\(^3\) in 2023. The average dairy herd increased from 69 milking cows/farm (1,292,000 total in the state)\(^4\) in 2001 to 211 milking cows/farm in 2022 (1,272,000—a decrease of only 20,000 milking cows, or 1.5%)\(^5\). Farms over 1,000 animal units (1,000,000 pounds) of live weight (for dairy and beef) are regulated by the Wisconsin DNR (Department of Natural Resources) and operate under a WPDES-CAFO (Wisconsin Pollutant Discharge Elimination System Concentrated Animal Feeding Operation) permit. Wisconsin DNR data indicates there were 87 permitted CAFOs in 2000 and 335 in 2023. Approximately 90% of CAFOs are dairy farms. CAFO statistics, available from the DNR’s website, showed that, in 2024, 45% of the state’s dairy cattle (and extrapolating, 45% of the manure volume) is generated by the 5% of the state’s dairy farms that are CAFOs (560,000\(^6\) of Wisconsin’s 1,272,000 milking cows).

Based on these numbers, growth in both the for-hire manure and custom forage harvesting industry is driven not by an increase in the number of farms or dairy cattle, but the change in dairy farm size and livestock farms choosing to focus on dairy management and contracting for manure and forage harvesting services.

While hard numbers do not exist, there is a strong indication that the gallons of manure being generated per cow has increased in the last 15–20 years. Regulatory changes that require addressing precipitation that falls within livestock production areas/feed storage areas has resulted in some livestock producers adding this nutrient-laden water to their manure systems. Informal discussions with for-hire manure applicators and county/state level regulators confirm a sense that volumes per animal unit are increasing.

The majority of the manure transportation and application equipment in Wisconsin is focused around liquid manure, but solid manure application equipment is growing, as shown in the data that follows.

**Application Equipment – Trucks and Tankers**

In 2023, Wisconsin-based applicators operated 669 semis with tankers, 149 straight trucks, and 226 tractor-pulled tankers for manure application, transfer, or both. This represents a 45% increase in semis since 2017, a 28% drop in straight trucks, and a 3% decrease in tractor-pulled tankers. An additional 74 tankers without semis were owned by the industry in 2023 and used in partnership with independent owner/operators who float between applicator and forage harvesting businesses on an as-needed basis to assist—a category that did not exist in 2017. As shown in Figure 1, the number of semis used for manure movement has been growing for more than 2 decades, while the number of farm tractor-pulled (tractor tanker) manure tankers has remained steady and the number of straight trucks has been trending downward in the past few years.

\(^2\) NASS 2001 Wisconsin Ag Statistics, referencing Wisconsin Dept of Food Safety total licensed dairy herds as of 4/1/2001, page 55

\(^3\) NASS 2023 Wisconsin Ag Statistics, referencing Wisconsin Dept of Food and Recreational Safety total licensed dairy herds as of 4/1/2023, page 37

\(^4\) NASS 2002 Wisconsin Ag Statistics, pages 53-54

\(^5\) NASS 2023, Wisconsin Ag Statistics, pages 34–35

\(^6\) Data pulled 3/28/24 from Wisconsin DNR CAFO site. Using guidance from the Wisconsin DNR, the total animal units were adjusted (90% of the animal units are milking animals) and divided by 1.4 (one 1,400 milking head = 1.4 animal units), resulting in 599,628 milking head: [https://apps.dnr.wi.gov/swampereporting/CAFO/Index](https://apps.dnr.wi.gov/swampereporting/CAFO/Index)

\(^7\) Tyler Dix, Wisconsin Dept of Natural Resources, personal communication, 4/3/2024
Reasons for the long-term increase in semis used for manure transport include increasing farm size (larger livestock farms have more cattle, generate more manure/wastewater, and utilize a larger land base for application, increasing both the volume to be transported and the transportation distance), regulatory changes and implementation of nutrient management plans that have reduced the rate per acre (meaning more acres are needed for the same volume of manure), changes to state road weight limits\(^8\) for agricultural equipment and greater enforcement of weight limit laws\(^9\), and the fact that the higher speeds of semis compared to tractor-pulled equipment has increased efficiency. Semis also carry significantly more volume per trip than straight trucks. Weight limit enforcement is also a common reason cited by manure applicators when they remove tractor-pulled tankers from their annual directory listing. Informal discussions with both custom forage harvesters and manure applicators indicate that the number of semis would be higher if sufficient CDL drivers were available to the industry, which has led to the previously noted owner/operator entry into the industry.

![Figure 1](image.png)

**Figure 1:** Over the road liquid manure equipment in use by the for-hire manure application industry in Wisconsin. Note than in 2022, the Semi category was split to more accurately capture the number of semis and tankers operated by the industry and the number of additional tankers available for owner/operators to use.

Another key reason behind the increased use of semis for longer-distance manure hauling is the refinement of rapid transfer technology. Prior to 2010, most manure hauled in semis was either directly land applied (tracking mud onto the road and creating significant compaction issues in the field) or transferred into repurposed portable oilfield frac tanks via hose/pump or an 8- to 12-inch valve. Since 2018, the number of Wisconsin businesses using roadside dumpsters (gravity-fed transfer systems that connect to a pump and field dragline irrigation system) paired with rapid transfer (16- to 20-inch single or double valves for quicker emptying) has grown 70% from 41 to 70. As shown in Figure 2, manure applicators are rapidly replacing older technology (frac tanks, which usually required manual hose connection between the frac tank and semi tanker) with dumpsters.

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\(^8\) Wisconsin State Statute 340, Wisconsin Act 377, Implements of Husbandry, 2014

\(^9\) Personal communication, Board of Directors, Professional Nutrient Applicators Association of Wisconsin (2/19/2024); Kewaunee County, Wisconsin, Sheriff Matt Joski (3/7/2024)
Figure 2: Number of frac tanks and dumpsters in use by Wisconsin's for-hire manure applicators, showing the industry switching from frac tanks to dumpsters (2018–2023).

Image 1: Typical roadside dumpster, showing a semi with manure tanker gravity flowing manure (via two 12-inch valves/pipes into the manure dumpster). An attached pump is connected to the in-field dragline hose application system, and the manure applied to the field by tractor-pulled dragline. Photo credit: Kevin Erb, UW–Madison Division of Extension.
Application Equipment – Manure Hose/Draglines

One of the more efficient methods of moving manure is pumping the liquid through a flexible, portable hose (mainline) to the field edge, and then using a more durable drag-type hose to land apply to the specific field. Benefits include greatly reduced compaction and road traffic (no manure equipment repeatedly entering and exiting the field tracking mud and manure onto the pavement) and greater fuel efficiency. This method, pumping manure directly from the farm’s manure storage to adjacent fields, has been in use since the late 1980s. As farms have grown and are using fields farther away from the livestock site for both forage production and manure application, hose systems have now been paired with semis and frac tanks or dumpsters, allowing manure to be moved longer distances using over the road equipment. The total number of hose systems used by the industry in Wisconsin grew from 25 in 2003 to 49 in 2013 and 91 in 2023—a 264% increase in 20 years.

In the mid-1990s, manure applicators were happy to move 600–800 gallons per minute through a 6-inch line. A greater understanding how to minimize friction loss in hoses, system pressures, and pump spacing has changed how the industry operates hose systems. Between 2010 and 2017, per-minute rates in 6-inch manure lines increased from approximately 1,000 gallons per minute to 1,500 gallons per minute in 6-inch hose systems. Moreover, some applicators report pushing more than 2,000 gallons per minute under ideal conditions.

This focus on efficiency and reducing friction losses has led to a dramatic increase in the miles of 8- and 10-inch dragline throughout the state. As noted in Figure 3, mileage of 8-inch dragline has increased from 54 miles in 2014 to 120 miles in 2017 and 240 in 2023, while mileage for 10-inch dragline went from zero in 2015 to 9 miles in 2016 before quadrupling to 36.5 miles by the end of 2017 and stood at 100.25 miles in 2023. Six-inch line, which remained steady from 2014 to 2016, dropped 10% to 142 miles by 2017 and is down 74% since 2014 to 40.25 miles. Individual farmers who have purchased their own hose system report significant fuel savings using a 12-inch hose compared to a 10-inch, but the for-hire application industry has yet to adopt these larger sizes. As shown in Figure 4, growth in total miles of hose has leveled off in recent years.

![Figure 3: Miles of mainline manure hose by size in use by Wisconsin’s for-hire manure applicators (2014–2023)](image)

The move to larger draglines means that more manure per minute is being applied, requiring more semis per mile of distance from the farm to maintain a constant supply for the application equipment.
Interestingly, while the mileage of draglines operated by Wisconsin applicators has increased from 211 in 2014 to 364 miles in 2020, the growth rate leveled off and has only grown 4.5% to 381 miles between 2020 and 2023. The number of businesses using draglines increased from 58 to 84 between 2011 and 2020 and increased to 91 in 2023.

**Liquid Agitation Equipment – Boats**

In the early 2000s, the industry began exploring using floating agitation (floating dredges initially, quickly evolving to floating high-volume agitation pumps). These floating agitators mix manure solids and create a more uniform manure and nutrient consistency. In 2013, there were 29 agitation boats operating in the state, 87 at the end of 2017, and over 120 in 2023, as shown in Figure 5.

Boat adoption has been driven by efficiency and sand bedding (the density of sand means it settles out and is hard to maintain in suspension during pumping). A single boat can replace four or more tractor-based agitators. Options such as remote control allow operators to agitate the center of a lagoon or move to where solids have accumulated. During the data collection in 2017, two applicators reported that their break-even usage to justify purchase (>-$200,000) was 80 hours per year when they factored in labor, fuel, equipment, and wear and tear. Many farmers and applicators have also chosen to rent rather than purchase agitation boats, and more than a dozen rental units are now available in the state, as well as a few businesses whose only service is providing an agitation boat and a trained, professional operator.

Four Wisconsin-based companies were manufacturing agitation boats in 2013; however, all have since ceased production. A number of applicators are building boats for their own use, however.
Figure 5: Adoption numbers of innovative technologies, including agitation boats, GPS as-applied mapping, and low-disturbance manure injectors on hose systems, by Wisconsin’s for-hire manure applicators.

GPS As-Applied Mapping on Dragline Systems and Tractor-Pulled Manure Tankers

GPS (Global Positioning System) as-applied mapping on manure draglines has increased over the last 12 years, from 14% of dragline systems in 2011 to 77% in 2023. This technology does not increase efficiency, but does provide documentation of where, when, and at what rate manure is being applied. Fewer than 10% of tractor-pulled manure tankers utilize GPS as-applied mapping technology, as implementation requires the additional expense of a flow meter and a pumping system (instead of gravity flow) for application of manure. Only 2% of tractor-pulled tankers have integrated GPS as-applied mapping and the ability to vary rates as manure is applied (VRT). The rate is varied either by changing the flow rate (with addition of a bypass returning part of the flow to the tank) or changing tractor speed. Varying the manure rate on a dragline system is usually accomplished by adjusting the tractor speed, as rapid changes in flow rate can result in dangerous pressure changes within the hose and increased risk of hose rupture.

Nutrient Sensors

The adoption of automated nutrient sensors (devices that use light wavelength technology to estimate in real time the concentrations of nitrogen, phosphorus, potassium, and dry matter) has lagged expectations in Wisconsin for several reasons. In 2019 (the first year of adoption), two dragline systems used nutrient sensors, and in 2023, the number had only increased to six (6.5% of dragline systems). A number of businesses that utilized the systems on draglines moved the sensor to their business’s forage harvesting equipment, as the same technology can be used to estimate forage nutritional value. Reasons given during informal discussions with Wisconsin manure applicators include farmers being willing to pay for the additional cost on forage harvesting equipment, but not on manure equipment, and the uncertainty of what would happen if the regulatorily required lab tests showed a lower nutrient concentration, meaning that the farm was out of compliance (due to overapplication) if they relied on the nutrient sensor to make the rate decision.
Fewer than 1% of tractor tankers utilize a nutrient sensor. As noted earlier in the section on GPS as-applied mapping, add-ons require additional technology, and the nutrient sensor requires the equipment to be set up for using GPS as-applied mapping.

**Low-Disturbance Toolbars**

Due to the increase in farmers implementing conservation management practices and manure application into growing cover crops becoming more common, manure applicators began adopting low-disturbance manure injection toolbars. These devices place manure beneath the soil surface while minimizing soil disturbance. In Wisconsin, the use of low-disturbance manure injectors on hose systems tripled from 6 in 2017 to 18 in 2019 but has leveled off and stands at 23 in 2023. Growth has been limited due to the fact that the equipment applies lower rates per acre than other manure injection equipment, and the window of application is shorter, making it less desirable (less acres to spread the cost over) than other toolbars.

**Application Equipment – Solid Manure Spreaders**

Virtually all newer dairy facilities handle their dairy manure as a liquid. Raw manure averages about 12% solids, and this is near the threshold for pumpable manure. Outdoor storage can net an additional 10+ inches of rainfall to the manure storage annually, reducing the solids content. State regulations on CAFOs require capture and/or treatment of precipitation (rain/snowmelt) that falls in livestock production areas and feed storage areas, and many farms have chosen to divert some or all of this runoff to the manure storage, further diluting the manure. As a result, few dairy farms with newer facilities generated significant amounts of solid manure, other than calf and youngstock areas.

The implementation of manure treatment systems (anaerobic digesters, other treatment systems) has led to an increase in the use of technologies that separate a portion of the solids from the liquid manure on dairy farms, and the for-hire manure application industry has responded by adding equipment to handle this manure source. As shown in Figure 6, there have been three times in the past 20 years that saw larger increases in truck-mounted and tractor-pulled spreaders. Each of these (2007–2009, 2010–2011, and 2019–2023) happened just after farms took advantage of incentive programs (utility industry or government) to install anaerobic digesters for electrical generation (2007–2009, 2010–2011) or during/after the installation of systems that focus on methane destruction/conversion of methane to a form that can be injected into the natural gas pipeline system (2019–2023).

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10 Lorimor, et al, MWPS-18, Manure Characteristics, Manure Management Systems Series, MidWest Plan Service, Iowa State University, Ames, IA, 2000, Table 6
Figure 6: Solid manure spreaders (both tractor pulled and truck mounted) in use by Wisconsin’s for-hire manure application industry 2003-2023.

Summary: Economics Drive Manure Technology Decisions

Overall, economics are the driving factor behind the majority of the technological decisions that Wisconsin’s manure applicators are making. Technologies that save costs (fuel) or labor are more rapidly adopted than those that improve nutrient management implementation. The reason for these changes include:

- Qualified labor shortages (CDL drivers) and overall labor supply issues have induced the industry to switch to using more owner/operators for semis and larger hoses for manure movement.
- Larger dairy farms require a larger land base for forage production and manure application, resulting in manure being transported longer distances. Increased distances have resulted in—
  - The adoption of rapid transfer semis for manure transportation and dumpster transfer systems.
  - Larger hoses for manure movement (lower cost due to less friction loss and the ability to move larger volumes in the same amount of time).
- Agitation boats (which use up to 75% less fuel and are better able to agitate solids in the center of larger manure storage structures) were rapidly adopted despite the upfront cost.
- GPS mapping technology adoption rate was high despite the potential cost, as one of the main additional expenses (GPS receiver and associated in-tractor display technology) became standard equipment on farm tractors, greatly reducing the upfront cost, and almost all Wisconsin manure applicators with draglines already had flow meters, as they use them for billing purposes.
Technologies that do not save cost, carry associated risk, have less farmer demand, and/or are only useful on a portion of a farmer’s land were adopted at a slower rate. These include nutrient sensors and low-distrubance manure injection toolbars.

Wisconsin’s for-hire manure application industry continues to invest significant financial resources into equipment and technology to help meet both the seasonal and regulatory aspects of implementing nutrient management plans. The move toward larger draglines and implementation of GPS-based tracking technologies are expected to continue over the next few years. The industry does not appear to be anticipating or experiencing a movement toward managing all dairy manure as a solid instead of a liquid, based on equipment investments being made.

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