

## **Appendix 1. Methods and Calculations for Estimates of Livestock and Poultry in the Maumee Watershed in Ohio and the Relative Proportion of Manure Phosphorus Generated Annually to Crop Demand**

Manure phosphorus inputs for the Maumee watershed in Ohio were calculated from animal population inventories of the United States Department of Agriculture Census of Agriculture and permitted capacities from the Ohio Department of Agriculture Division of Livestock Environmental Permitting (ODA DLEP).

The procedures used for this analysis include:

- Section A1.1 - Prorating county level animal population numbers from the Census of Agriculture to estimate the animals within the Maumee Watershed
- Section A1.2 - When the population was not disclosed by the Census of Agriculture, then permitted capacities from the Ohio Department of Agriculture Division of Livestock Environmental Permitting were used,
- Section A1.3 - Calculating the phosphorus content of the animal manure using two recent, local datasets of manure analysis compiled by the Ohio Department of Agriculture, and
- Section A1.4 - Estimating annual crop removal using average crop nutrient removal, yield goals, and relative crop planting distribution.

Similar methods have been used by Environmental Working Group (EWG, 2019), Ruddy et al. (2006), Mueller and Gronberg (2013), and Goolsby et al. (1999).

### ***A1.1 Prorating County Level Data from the Census of Agriculture***

#### *Census of Agriculture*

The United States Department of Agriculture published the Census of Agriculture every five years (USDA, 2017). The most recent report, at the time of this analysis, was conducted in 2017 and published in 2019.

#### *Discussion of Livestock by Type*

This analysis used three categories of livestock and poultry from the Census of Agriculture:

1. Cattle and calves, which is divided into three subgroups: 1) beef cows, 2) milk cows, and 3) other cattle (which includes heifers that had not calved, steers, calves, and bulls).
2. Hogs and pigs
3. Poultry, which is divided into five subgroups: 1) layers, 2) pullets for laying flock replacement, 3) broilers and other meat-type chickens, 4) turkeys, and 5) ducks, geese, and other miscellaneous poultry.

Most livestock in the region falls into these three categories. Therefore, other livestock types, such as sheep and horses, were not included. Similarly, the poultry subgroup of ducks, geese, and other miscellaneous poultry was not considered, as this population is comparatively very low. It is safe to

assume that the relatively small numbers of these other livestock and poultry types in the region would not substantially alter the estimate of manure phosphorus produced.

#### Areal Proration

The Census of Agriculture publishes results by county. To estimate the animals within the Maumee Watershed the population was prorated by area. **Table A1.1** below shows the percentages used for the calculations.

**Table A1.1 Areas of Ohio Counties within the Maumee Watershed used to prorate animal numbers from the Census of Agriculture**

County Name	Area (acres)	Area of County in Maumee Watershed (acres)	Percent of County in Maumee Watershed Rounded
Allen	258835.2	258323.6	100
Auglaize	256800	196779.8	77
Defiance	263142.4	263142.4	100
Fulton	260339.2	260339.2	100
Hancock	340064	250521.9	74
Hardin	300985.6	105822	35
Henry	266560	266560	100
Lucas	217894.4	177339	81
Mercer	296492.8	127877.8	43
Paulding	266406.4	266406.4	100
Putnam	309676.8	309676.8	100
Seneca	352377.6	5759.9	2
Shelby	261932.8	15972.3	6
Van Wert	262457.6	262457.6	100
Williams	269913.6	269913.6	100
Wood	395084.8	114908.5	29
Wyandot	259590.4	27368.9	11

## ***A1.2 Permitted Capacities from the Ohio Department of Agriculture Division of Livestock Environmental Permitting***

### Census of Agriculture Data Suppression

Not all animal numbers are published in the Census of Agriculture. If publishing data would identify an individual operation (for example, if there is only one producer of a particular species in a county), the Census does not publish the information. In such cases, the data are suppressed and shown as “(D),” meaning “withheld to avoid disclosing data for individual operations.” Data suppression can cause a substantial number of animals to be unreported, particularly laying hens and pullets.

#### DLEP Permit Numbers

Table A1.2 shows the animal agriculture facilities permitted by ODA DLEP as of June 2022 with their permitted capacity. In cases where the Census suppressed data, then ODA DLEP information was used to fill in the gap. All permitted facilities are required to have a permitted capacity. These capacities were used in cases where it was known that animal agriculture existed within a county, but the animal population was suppressed by the Census. These facilities are not always populated to their full capacity, therefore using the capacity may lead to an overestimate of animals.

**Table A1.2 Confined Animal Feeding Facilities permitted by ODA DLEP in the Maumee in Ohio with permitted capacity. June 2022**

Facility Name	Watershed	Animal 1 Species	Animal 1 Count	Animal 2 Species	Animal 2 Count
Bridgewater Dairy, LLC	04100003	Dairy	3,900		
Del-Rod Farms, LLC	04100003	Swine - over 55 lbs	5,000		
Grand Republic	04100003	Swine - over 55 lbs	7,350		
Heritage Family Farms, LLC	04100003	Swine - over 55 lbs	6,000		
Bowersock Pork	04100004	Swine - over 55 lbs	4,800	Beef	20
Heartland Dairy Holdings, LLC	04100004	Dairy	2,100		
KFS Farms, LLC	04100004	Swine - over 55 lbs	7,680	Beef	820
Liberty Egg Farms, Ltd.	04100004	Chickens-Layers	207,360		
Luginbill Swine Farm	04100004	Swine - over 55 lbs	7,200		
MVP Dairy	04100004	Dairy	4,500		
Pine Valley Ranch, LLC	04100004	Chickens-Layers	2,264,000		
R & S Farms Ag, LLC	04100004	Chickens-Layers	105,000		
Wilker Eggs and Grain Farm LLC	04100004	Chickens-Layers	317,151		
Wilker Family Farms	04100004	Chicken-Pullets	210,000		
Flat Land Dairy	04100005	Dairy	3,144		
Fox Tail	04100005	Swine - over 55 lbs	3,675		
Hicksville Farm	04100005	Beef	3,020		
Hillandale Farms	04100005	Chickens-Layers	4,011,864		
Pheasant Run	04100005	Swine - over 55 lbs	7,350		
Vissers Dairy	04100005	Dairy	1,600		
West Side Dairy	04100005	Dairy	1,400		
Bernath Farms 1 and 2	04100006	Swine - over 55 lbs	5,000		
Brown Swine Farm	04100006	Swine - over 55 lbs	4,800		
Crites Farms	04100006	Swine - over 55 lbs	4,800	Sheep	100
De Vries Dairy Ltd. North	04100006	Dairy	2,400		
Goebel Pork, LLC	04100006	Swine - over 55 lbs	4,550		
Nofziger Livestock	04100006	Swine - over 55 lbs	10,000		
PGC Chesterfield Hogs	04100006	Swine - over 55 lbs	4,800		
Planson Pork LLC	04100006	Swine - over 55 lbs	4,800		
VanderMade Dairy LLC	04100006	Dairy	1,800	Dairy	180
Zeedyk Swine Farm	04100006	Swine - over 55 lbs	6,000		
Bob Sinn Swine	04100007	Swine - over 55 lbs	9,600		
Bruce Rosswurm Swine Farm	04100007	Swine - over 55 lbs	9,600		
Canal Farm	04100007	Swine - over 55 lbs	3,582		
Convoy Dairy, LLC	04100007	Dairy	2,033	Slaughter-Feeder-Heifer	240
Creek View Farm	04100007	Swine - over 55 lbs	4,800		
Deer Run Farm	04100007	Swine - over 55 lbs	3,500		
Feather Ridge Farm	04100007	Chickens-Layers	183,288		
Gina Dairy LLC	04100007	Dairy	1,300	Slaughter-Feeder-Heifer	200
Happy Yolks, LLC	04100007	Chickens-Layers	404,616		
Harting Livestock LLC	04100007	Swine - over 55 lbs	14,000	Chickens-Layers	44,000

Facility Name	Watershed	Animal 1 Species	Animal 1 Count	Animal 2 Species	Animal 2 Count
Hefner's Dola Swine Farm	04100007	Swine - over 55 lbs	4,200		
Hillside Acres	04100007	Swine - over 55 lbs	13,600		
Jeff and Alan Ricker Swine	04100007	Swine - over 55 lbs	4,900	Turkey	36,000
Lamar Swine Farms LLC	04100007	Swine - over 55 lbs	9,600		
Miller City Dairy	04100007	Dairy	1,250	Slaughter-Feeder-Heifer	116
Oak Forest	04100007	Turkey	74,000		
Paulding Dairy	04100007	Dairy	5,501		
Pessefall Farms, LLC	04100007	Swine - over 55 lbs	5,200		
Profit Family Pork	04100007	Swine - over 55 lbs	9,600		
Riverbend Sow Complex	04100007	Swine - over 55 lbs	3,500		
RMK Farming, LLC	04100007	Swine - over 55 lbs	4,800		
Rose Grove Farm	04100007	Swine - over 55 lbs	3,611		
Schweinefarmen, LLC	04100007	Swine - over 55 lbs	4,800		
Sugar Lane Dairy, LLC	04100007	Dairy	3,820		
Sun Mountain Dairy LLC	04100007	Dairy	3,200	Slaughter-Feeder-Heifer	700
The Brick Farm Swine, LLC	04100007	Swine - over 55 lbs	6,000		
Tim Sinn Family Hog Farm	04100007	Swine - over 55 lbs	4,800		
Triple R Farms, Inc.	04100007	Swine - over 55 lbs	7,200		
Triple V Pork LLC	04100007	Swine - over 55 lbs	5,450		
Van Erk Dairy	04100007	Dairy	2,000		
Vandenhengel Pork, LLC	04100007	Swine - over 55 lbs	7,350		
White Oak Farm	04100007	Swine - over 55 lbs	2,776		
Wildcat Dairy	04100007	Dairy	1,102		
Willow Tree Swine, LLC	04100007	Swine - over 55 lbs	9,600		
Continental Dairy, LLC	04100008	Dairy	2,250		
Highslip Pork	04100008	Swine - over 55 lbs	4,200		
Vrieco Farms Ltd	04100008	Dairy	825		
Fenstermaker Farms, Inc.	04100009	Swine - over 55 lbs	6,780	Swine - under 55 lbs	2,400
Hertzfeld Poultry Farms, Inc.	04100009	Chickens-Layers	1,256,191		
KMLS Farms LLC	04100009	Swine - over 55 lbs	5,234	Swine - under 55 lbs	200
BB Land, LLC	04100010	Dairy	5,000		
Boyer Farms	04100010	Swine - over 55 lbs	4,800		
Reyskens Dairy LLC	04100010	Dairy	2,000		
Roger and Lori Rader Farms	04100010	Swine - over 55 lbs	4,000		

#### Animal Units

The term animal unit is a unit of measurement used to standardize animals by size. For any animal feeding operation, animal units were calculated by adding the following numbers: the number of beef cows and other cattle multiplied by 1.0, plus the number of milk cows multiplied by 1.4, plus the number of swine weighing over 55 pounds multiplied by 0.4, plus the number of turkeys of seven pounds or more by 0.018, plus the number of broiler or layer chickens over three pounds multiplied by 0.01.

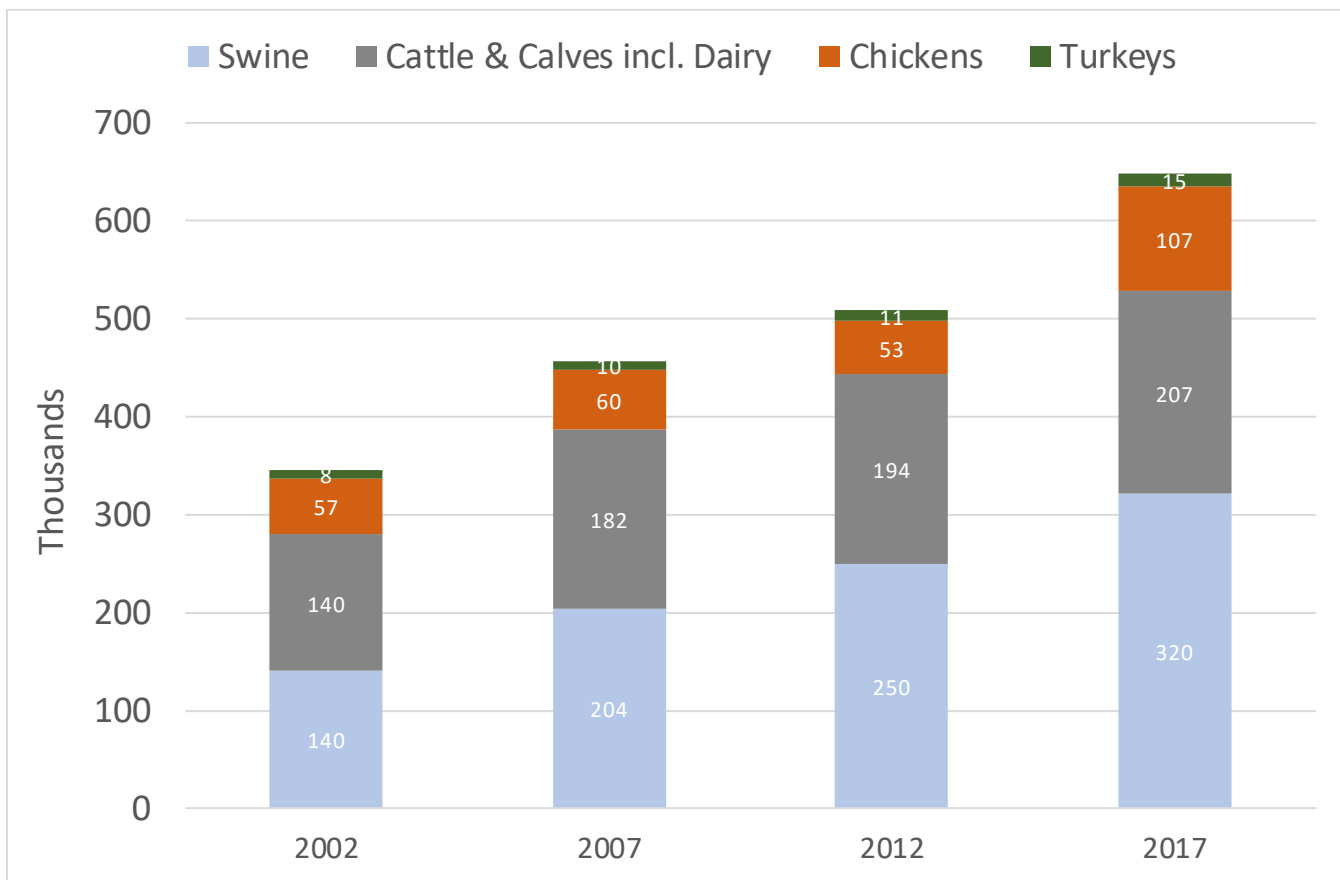
The Census does not provide the distribution animal maturity or size within a county. For this analysis, it was assumed that all livestock reported in the Census of Agriculture and in ODA DLEP permits were mature. For

example, if 100,000 swine were reported in a county, then ODA assumed all 100,000 were over 55 pounds, used the 0.4 animal unit conversion, and arrived at total of 40,000 animal units.

This assumption likely overestimates the amount of animal units, as surely some animals are not mature. (In this example, breeding sows and swine under 55 pounds). A similar assumption was made for poultry. For example, all turkeys reported by the Census were assumed to be seven pounds or more. Again, this assumption likely overestimates animal units, and some turkeys are less than seven pounds and would have a lower animal unit conversion factor.

#### Animal Unit Results

Figure A1.1 shows the resulting estimate of animal units in the Maumee watershed in Ohio over the past four Censuses of Agriculture. In this Figure, animal types reported in the Census are consolidated into four general categories: Swine, Cattle and calves including dairy, Chickens, and Turkeys.



**Figure A1.1** Estimate of animal units in the Maumee watershed in Ohio 2002-2017, using a combination of Census of Agriculture and ODA DLEP permitting data.

### A1.3 Manure Phosphorus Generated

The livestock population can be multiplied by an estimate of manure phosphorus produced by each animal to arrive at an estimate of the total manure phosphorus produced in the watershed. Of course, the estimate of manure phosphorus produced by each animal greatly influences the calculation. Past estimates of this nature have used “book values” such as the Mid-West Plan Service 2004 publication Livestock Waste Facilities Handbook (MWPS-18, 1993) or Ruddy et al. (2006). Manure nutrient content has changed over the past twenty years as livestock feed

management evolved. Therefore, ODA used an average of two recent datasets of manure analysis to determine the estimate of manure phosphorus produced by each animal.

Permitted facilities are required to submit manure nutrient analysis and the amount of manure produced as a condition of a Permit to Operate issued by ODA DLEP. The most recent manure analyses for permitted operations in the Maumee watershed in Ohio were compiled and averaged in 2021.

The Grand Lake St. Marys watershed is presently designated as a Watershed in Distress under Ohio Administrative Code 901:13-1-20. Non-permitted facilities in this watershed, which is adjacent to the Maumee watershed, are required to submit manure nutrient analysis and the volume of manure produced as part of a nutrient management plan. The most recent manure analyses for these non-permitted operations were compiled and averaged in 2021.

**Table A1.3 shows a comparison of manure phosphorus produced per animal used in ODA’s analysis.**

**Table A1.3. Comparison of manure phosphorus concentration estimates.**

<b>Estimated Phosphorus in Manure (Metric Tons P animal<sup>-1</sup> yr<sup>-1</sup>)</b>			
	<b>Ruddy (2006)</b>	<b>MWPS (2004)</b>	<b>ODA Average (2021)</b>
Dairy Cow	0.01169	0.03219	0.02121
Beef Cattle	0.01863	0.00723	0.00819
Finishing Hogs	0.00438	0.00362	0.00137
Layers	0.00022	0.00006	0.00018
Pullets and broilers	0.00011	0.00010	0.00004
Tom turkeys	0.00073	0.00054	0.00045

#### Lifecycle/days

Past estimates of manure phosphorus have considered the life cycle of the animal, specifically how many days the animal is in captivity. For example, Gronberg and Arnold (2017) used the equation:

Phosphorus in manure of an animal category = Census population of an animal category × phosphorus (kilograms per animal per day) × life cycle (days).

However, the Census does not provide information on the lifespan of reported animals. Therefore, periods of animal confinement were not considered for this estimate. It was assumed that all animals reported in the Census population and in ODA DLEP permits were confined for 365 days per year. This simplification likely leads to an overestimate of manure phosphorus produced, possibly greatest in animal species that typically have confinement periods of less than one year, such as slaughter cattle and turkeys.

#### Phosphorus Generated by Species

ODA used the average manure nutrient values of these two recent datasets and multiplied by the population estimates from 2002 and 2017. The calculations described above find approximately 5,200 metric tons of manure phosphorus were produced in the Maumee watershed in Ohio in 2017.

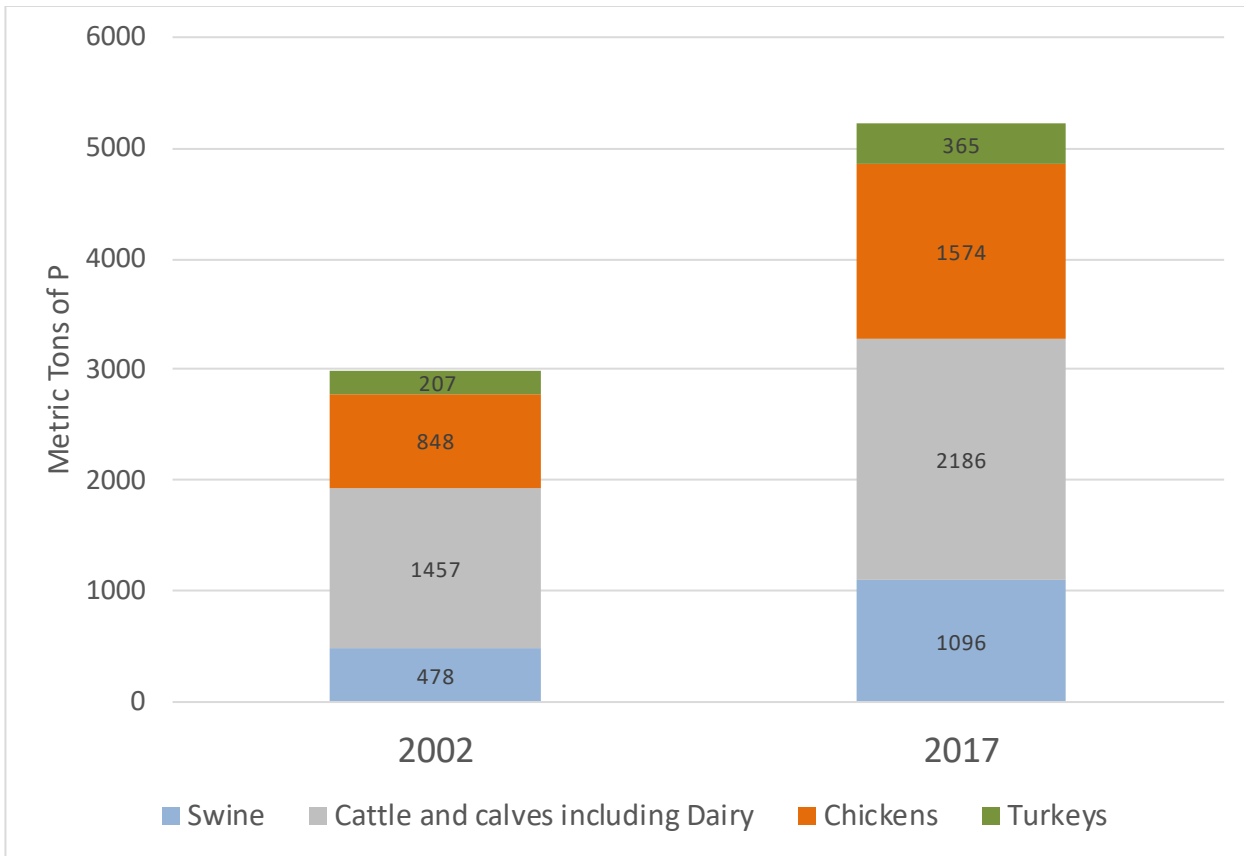


Figure 2 ODA calculated metric tons of phosphorous produced in Ohio's portion of the Maumee watershed by livestock species in 2002 and 2017.

#### A1.4 Estimate of Crop Removal / Fertilizer Need

Annual crop removal of phosphorus from the Maumee can also be estimated using the crop removal rates found in the most recent Tri-State Recommendations (Culman et al., 2020) multiplied by an assumed crop yield. For this estimate, it was assumed that the average yields were 180 bushel an acre for corn and 50 bushels an acre for soybeans. It is assumed that the 2.3 million acres of cropland in the Maumee watershed in Ohio were planted in an even 50/50 split of corn and soybeans (although cropping patterns do vary from year to year). Under these assumptions, crop removal is in approximately 23,500 metric tons of phosphorus per year.

$$\begin{aligned} \text{Assumed average corn yield goal (180 bu.ac)} \times 0.35 \text{ lbs P2O5 lbs. per bushel} \\ = 63 \text{ lbs. P2O5 removed per acre of corn} \end{aligned}$$

$$\begin{aligned} \text{Assumed average soybean yield goal (50 bu.ac)} \times 0.8 \text{ lbs P2O5 lbs. per bushel} \\ = 40 \text{ lbs. P2O5 removed per acre of soybean} \end{aligned}$$

$$\text{Assumed 50:50 corn: soybean split in crop acreage} \therefore 51.5 \text{ lbs. P2O5 removed from average acre}$$

$$51.5 \text{ lbs P2O5} \div 2.29 \text{ (to account for mass of phosphorus in P2O5)} = 22.5 \text{ lbs P removed per acre per year}$$



$$22.5 \text{ lbs P} * 2.3 \text{ million cropland acres in Ohio in Maumee watershed} \\ = 51,750,000 \text{ lbs P removed from Ohio Maumee watershed per year}$$

$$51,750,000 \text{ lbs P removed from Ohio Maumee watershed per year} \\ \div 2,205 \text{ lbs per metric ton (unit conversion)} \\ = 23,469 \text{ metric tons P removed from Ohio Maumee watershed per year}$$

#### Manure's Contribution to Crop Need

Combining the estimates of crop removal and manure phosphorus produces results in the final estimate: that manure phosphorus produced supplies approximately 22% of the crop need in the Maumee watershed in Ohio.

$$\frac{5,200 \text{ metric tons manure produced per year}}{23,469 \text{ metric tons P removed per year}} = 22.2\%$$

Conservative assumptions are noted throughout this appendix that mention a likely overestimate of the amount of manure produced in the Maumee watershed.

#### **A1.5 Works Cited**

Works cited are included in Appendix 5.