Appendix F

Northeast Lakeshore TMDL

Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids

Agricultural Practice Summary Report

Agricultural Practice Summary

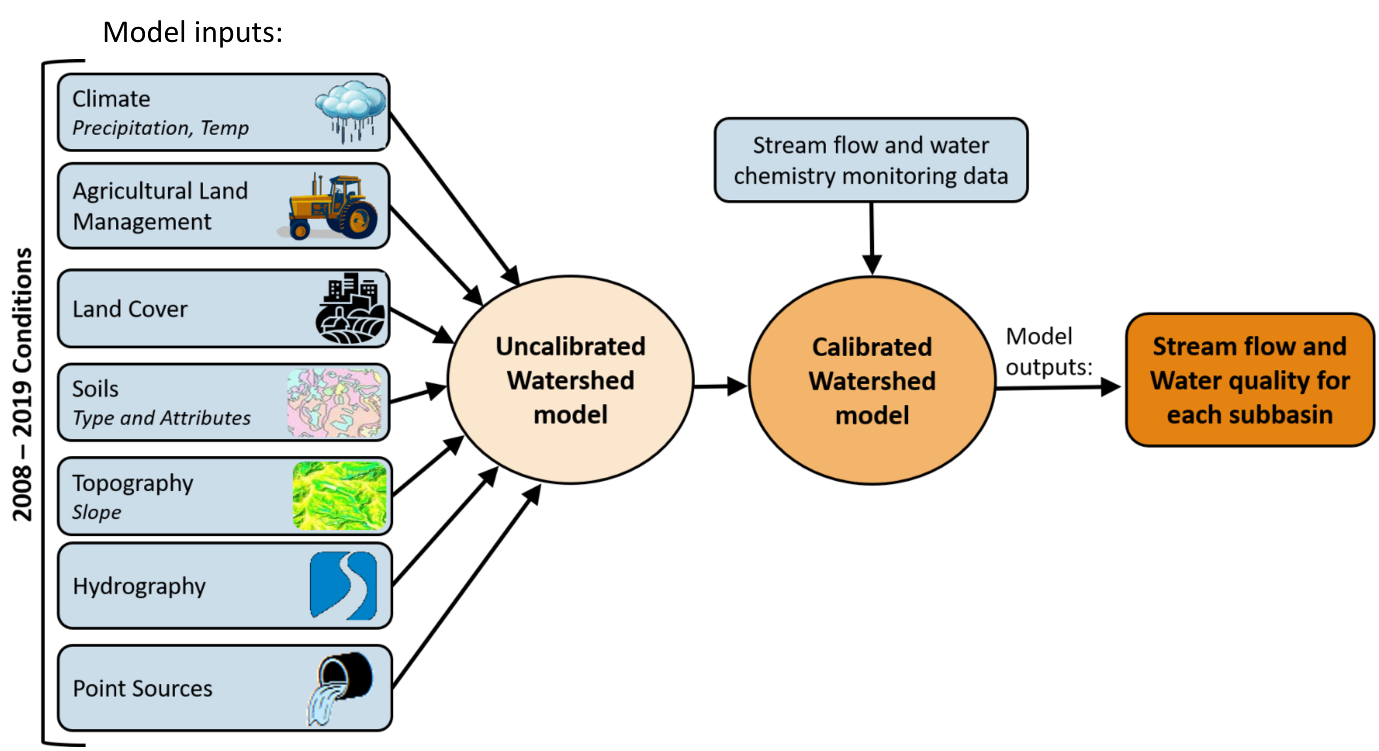
Prepared by the Wisconsin Department of Natural Resources and The CADMUS Group, LLC
September 18, 2020

OVERVIEW

This document summarizes the results of an agricultural land cover and land management survey administered by the Wisconsin Department of Natural Resources and completed by Land and Water Conservation Departments or Soil and Water Conservation Departments (LWCDs) within the eight Northeast Lakeshore TMDL counties. The following information will be incorporated into a Soil and Water Assessment Tool (SWAT) model of the NE Lakeshore basin, which will be used to evaluate phosphorus and sediment loading in support of TMDL development. The SWAT model inputs and settings for agricultural areas proposed here may be adjusted through calibration procedures based on feedback from agricultural practitioners and watershed managers in the study area.

Agricultural land cover and land management data are two of the many important inputs to a SWAT model. Other important model inputs, shown in Figure 1, include data about precipitation, temperature, soil, slope, and point source locations and discharge characterizations. Water quality monitoring data is then used to calibrate the model before the outputs of stream flow and stream loads are estimated.

Figure 1. Diagram of the primary model inputs and output from the SWAT watershed model.



The Wiscland 2.0 (Wiscland) land cover dataset was used to initially define the type and extent of different crop rotation types for the SWAT model. However, the dataset includes only general land cover categories such as dairy, cash grain, and potato/vegetable rotations. To augment the Wiscland dataset, LWCDs from the eight counties in the NE Lakeshore basin were surveyed for information on typical agricultural practices. LWCDs were asked to provide information on agronomic practices in their county at both the countywide scale and by twelve-digit hydrologic unit code (HUC12), which are watersheds with an average size of 20,000 acres. Questions covered the following topics:

- The extent of dairy, cash grain, potato/vegetable, and hay farmland
- The type and sequence of crops planted in a dairy rotation
- Tillage timing and intensity
- Chemical fertilizer application timing and application rates
- Animal manure spreading frequency, timing, form (solid or liquid), spreading rates, and whether manure spreading is followed by incorporation into the soil
- Planting, harvest, and hay cutting dates
- Crop yields
- Livestock grazing
- Irrigation and tile drainage
- Soil phosphorus content

The agricultural survey results were used to define 17 agricultural classes within the SWAT model for the NE Lakeshore basin. Each agriculture class is associated with a distinct set of agronomic operations, including crops planted, fertilizer and manure applications, and tillage. The approach of using land cover datasets to map crop types, and local knowledge from county LWCDs to determine agronomic practices associated with each crop type, is consistent with methods described by Kirsch et al. (2002), Larose et al. (2007), and Heathman et al. (2008).

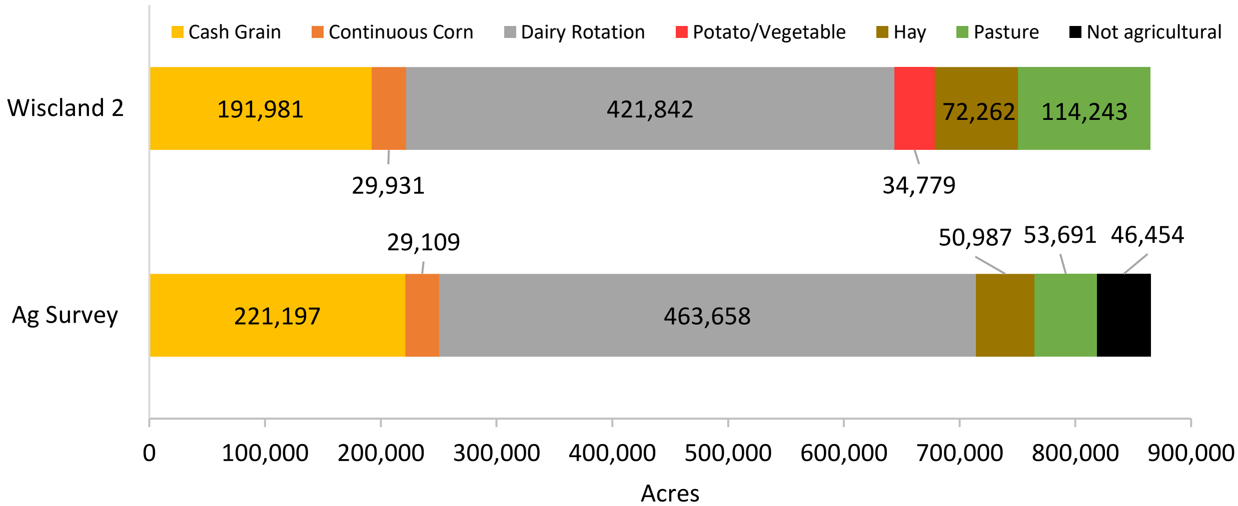
The agricultural classes selected for SWAT modeling are representative of typical agronomic behaviors in the study area while capturing variation in factors that have the greatest impact on runoff volumes, soil erosion, and phosphorus loading. The selected classes are not an exact reflection of each farm in the study area as the ability to simulate additional agricultural classes is limited by model processing times and data storage requirements. However, the selected classes do balance variability in agronomic practices with limitations imposed by the scale of the watershed modeling effort.

Despite the necessary aggregation of the agricultural survey results for development of the SWAT watershed model, a separate dataset will also be produced from the agricultural survey results that preserves the detailed agricultural data provided by county LWCDs at the HUC12 scale. This detailed dataset will be used to translate watershed scale nonpoint source TMDL reductions into unique field-scale TP and TSS targets using Wisconsin's nutrient planning software, SnapPlus (Soil Nutrient Application Planner). These targets translate results of the SWAT watershed model into field-scale model outputs that are better understood by the agricultural community and serve as a tool for producers to evaluate management options to implement on their own fields in order to meet the nonpoint source reduction goals of the NE Lakeshore TMDL.

CROP SEQUENCES AND EXTENT

Six general crop rotation types are represented in the Wiscland dataset in the NE Lakeshore basin: dairy, cash grain (i.e., corn and soybean), continuous corn, potato/vegetable, pasture, and hay. The agricultural survey provided to county LWCDs included questions to verify the presence and extent of these six rotation types (Figure 2). Overall, county survey results showed that the Wiscland dataset accurately represents the acres of dairy, cash grain, continuous corn, and continuous hay, but over represents the amount of potato/vegetable and pasture acres (Figure 2). The survey also included questions to determine the most appropriate crop sequences to apply in dairy rotations. For example, a dairy rotation in the study area might consist of three years of corn silage followed by three or more years of alfalfa. Below is a summary of the county LWCD's responses regarding the extent of the six general crop rotations represented in Wiscland dataset and the typical crops in a dairy rotation.

Figure 2. Summary of the acres in the NE Lakeshore TMDL area by crop rotation.



Values in the Wiscland 2 row represent crop rotation acres reported directly from the Wiscland 2 dataset.

Values in the Ag survey row represent adjusted crop rotation acres based on review of the Wiscland 2 dataset by County Land and Water Departments.

Dairy – A total of 23 unique dairy crop sequences were reported from the county agricultural surveys, with an average rotation length of seven years (Table 1). Across all counties, dairy rotations were predominately comprised of two to four years of corn silage followed by three to four years of alfalfa. Corn grain was reported to be a part of dairy rotations by four of the eight counties. Additionally, winter wheat, oats, and peas were identified as transitional crops between corn and alfalfa in some counties. Less common was the inclusion of one year of soybeans. When present, soybeans were either planted between the corn years (i.e., corn-soybean-corn) or following the corn years (i.e., corn-corn-soybean) and often followed by winter wheat.

Table 1. Summary of the dairy crop rotations provided by County Land and Water Departments in the NE Lakeshore TMDL agricultural questionnaire survey.

County	Area (ac)	Rotation Year 1	2	3	4	5	6	7	8
Manitowoc	132,039	Cs	Cs	Cg	Cs	A	A	A	
Kewaunee	82,799	Cs	Cs	o/a	A	A	A		
Sheboygan	72,515	Cs	S	Cs	S	A	A	A	
Calumet	41,823	Cs	Cs	Cs	A	A	A	A	
Brown	22,447	Cs	Cs	Cs	Cs	A	A	A	A
Brown	16,346	Cs	Cg	S	Ww	Cs	A	A	A
Door	14,849	Cs	Ww/o	A	A	A	A		
Fond du Lac	12,604	Cs	Cs	p/o	A	A	A		
Sheboygan	8,685	Cs	Ww	A	A	A			
Sheboygan	8,410	Cs	A	A	A				
Fond du Lac	7,878	Cg	Cs	Cg	Cs	o/a	A	A	A
Ozaukee	7,431	Cs	Cs	S	Ww	p/o	A	A	A
Fond du Lac	6,069	Cs	S	Cs	A	A	A	A	
Fond du Lac	5,752	Cs	S	Cs	Ww	A	A	A	A
Calumet	5,228	Cs	Cs	Cg	A	A	A	A	
Ozaukee	3,287	Cs	Cs	Cs/a	A	A	A	A	Cg
Door	3,273	Cs	Cs	Ww/o	A	A	A	A	
Fond du Lac	3,236	Cs/cc	Cs/cc	o/a	A	A	A		
Calumet	2,613	Cs	Cs	S	A	A	A	A	
Calumet	2,613	Cs	Cs	Ww	A	A	A	A	
Ozaukee	2,515	Cs/cc	Cs/cc	S	Ww	p/o	A	A	A
Ozaukee	1,629	Cs/cc	Cs/cc	Ww	S	A	A	A	Cg
Door	1,490	Cs	Cs	A	A	A	A		

A	Alfalfa
Cg	Corn grain
Cs	Corn silage
Cs/cc	Corn silage w/ cover crop
Cs/a	Corn silage w/ alfalfa
o/a	Oats/alfalfa
p/o	Peas/oats
S	Soybean
Ww	Winter wheat
Ww/o	Winter wheat w/ oat

County survey results were used to define three dairy crop sequences for use in the SWAT model (Table 2). Although 23 different sequences were reported, the number of rotations modeled in SWAT had to be reduced due to model processing and storage requirements. The use of three dairy sequences will ultimately result in faster model run-times, allowing for more thorough model calibration to the water quality data. The modeled dairy rotations were chosen with the goal of representing the dominant crops and trends among the 23 reported sequences. The crop sequences were fit to a six-year rotation timeline in order to allow for two full rotations to occur within the model period of twelve years (2008 to 2019).

When assigning land areas (acres) to each of the SWAT dairy sequences in the model, the county-reported sequences and corresponding land areas (table 1) will be translated to the SWAT dairy sequence that is the best match (table 2). Additionally, to account for the fact that all farms would not realistically start a given dairy sequence in the same calendar year, the dairy sequences assigned to dairy areas will be staggered equally within the NE Lakeshore area so that 50% of the dairy areas will start their sequence on year 1 (corn silage) while the other 50% of the dairy areas will start their sequence on year 4 (winter wheat or alfalfa). This offsetting approach will double the number of dairy classes that are simulated in the SWAT model.

Table 2. Agricultural crop sequences selected for SWAT modeling based on county survey results.

Class Name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
*Dairy Sequence 1	CS	CS	CS	ALF	ALF	ALF
*Dairy Sequence 2	CS	CS	CG	ALF	ALF	ALF
*Dairy Sequence 3	CS	CS	SOY	WW	ALF	ALF
*Cash Grain Sequence	CG	SOY	CG	SOY	CG	SOY
Continuous Corn Sequence	CG	CG	CG	CG	CG	CG
Continuous Hay Sequence	ALF	ALF	ALF	ALF	ALF	ALF

CG = corn grain, CS = corn silage, ALF = alfalfa, SOY = soybean, WW = winter wheat
*Sequence will be equally offset amongst assigned dairy areas to start on either “year 1” or “year 4”

Cash Grain and Continuous Corn – County agricultural survey results verified that cash grain and continuous corn rotations occupied significant cropland in the NEL basin. The cash grain rotation will be represented in the SWAT model with an alternating sequence of corn grain and soybeans (Table 2). Continuous corn will be represented by corn grain plantings in all years of the rotation (Table 2).

Potato/Vegetable - Results of the county agricultural survey indicated that the area mapped as potato/vegetable in Wiscland is significantly overrepresented in the NEL basin (Figure 2). Based on county survey responses, fields mapped as potato/vegetable are best represented by dairy rotations in the SWAT model.

Hay – Although less extensive than other rotations, continuous hay fields were reported to occur in the NEL basin. Areas designated as hay in Wiscland will be represented in the SWAT model as alfalfa in all years of the rotation (Table 2).

Pasture – County agricultural survey results indicated that areas identified as pasture in Wiscland are most often not used for livestock grazing and are more commonly non-agricultural rural lands such as open grasslands, roadside ditches, etc. Therefore, grazed pasture will not be included in the SWAT model. Areas identified as pasture in Wiscland will instead be modeled with continuous growth of a perennial grass such as Kentucky bluegrass.

PLANT AND HARVEST DATES

Planting dates were not typically reported for individual crops in survey; however, across all crops, the average planting date was May 21. Unlike planting dates, harvest dates were reported for individual crops in survey responses. The average harvest date for corn grain was October 13th. As expected, the average harvest date for corn silage was earlier, approximately three weeks prior to corn grain (September 20th). The average harvest date for soybeans fell near the corn harvest dates on October 7th. Only Fond du Lac County provided harvest dates for winter wheat, which averaged July 26th. These planting and harvest dates will be applied in the SWAT model.

HAY CUTTINGS

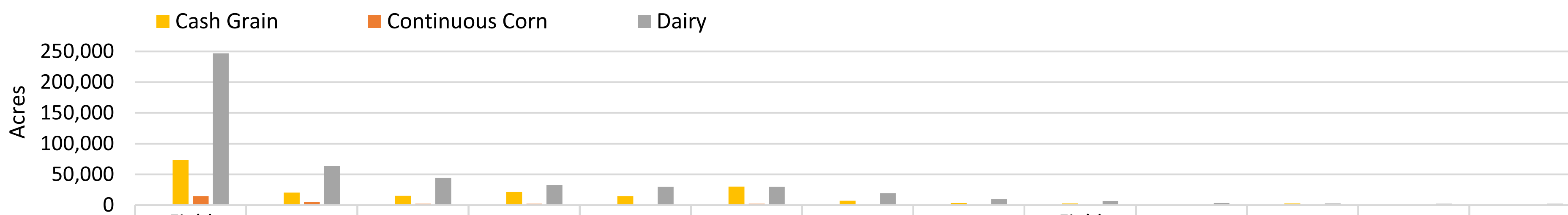
The number of hay cuttings reported in survey responses ranged from three to five per year. The average number of cuttings across all counties was just over four cuttings per year. In the SWAT model, alfalfa cuttings within the dairy and continuous hay rotations will occur at four evenly spaced times per throughout the growing season.

TILLAGE

Survey results described 13 different tillage practices used in the NEL basin (Figure 3). However, certain practices were much more commonly reported to be used over larger areas. For SWAT modeling, four tillage practice categories will be represented. These tillage categories are listed in Table 3.

In the fall, the most commonly reported tillage types were chisel plow, moldboard plow, disk plow, and vertical till. In the spring, the use of field cultivators was most common with some vertical till. Chisel plow is a less intensive tillage practice when compared with moldboard plow and disk plow. However, SWAT tillage parameters (depth and mixing efficiency) for moldboard plow and disk plow are similar so they are represented signally as disk plow. Note that tillage does not apply to back-to-back years of alfalfa or winter wheat in the dairy rotation. Back-to-back years or alfalfa or winter wheat and alfalfa will be cut and allowed to regrow in the subsequent year without tillage.

Figure 3. Acres of crop rotation area (cash grain, continuous corn, and dairy) in the NE Lakeshore basin receiving the tillage strategies provided by the county agricultural survey.



Spring tillage:	Field Cultivator, Twice	Field Cultivator	Field Cultivator	Vertical Till	Field Cultivator	No-till	None	Field Cultivator	Field Cultivator, Twice	None	Vertical Till	None	Field Cultivator
Fall tillage:	Chisel Plow	Moldboard Plow	Vertical Till	None	Chisel Plow	No-till	Field Cultivator	Disk & Chisel Plow	Moldboard Plow	Alfalfa to Alfalfa No Till	Vertical Till	Fall Chisel Plow	None
Number of counties	8	8	7	7	1	8	7	7	1	1	1	1	1
Cash Grain (ac)	73,363	20,359	15,198	21,111	14,827	30,190	6,950	3,445	2,591	899	2,595	449	1,123
Continuous Corn (ac)	14,525	4,797	2,190	2,233	912	2,054	644	327	937	171	365	86	214
Dairy (ac)	246,965	63,649	43,999	32,611	29,579	29,448	19,627	9,625	6,733	3,670	2,535	2,202	2,202

Table 3. Agricultural tillage categories selected for SWAT modeling based on county survey results

ID	Fall	Spring
Till 1	Chisel Plow	Cultivator, 2X
Till 2	Disk Plow	Cultivator
Till 3	None	Vertical Till
Till 4 (Cash Grain only)	Chisel Plow (Corn), No Till (Soybean)	Cultivator (Corn), No Till (Soybean)

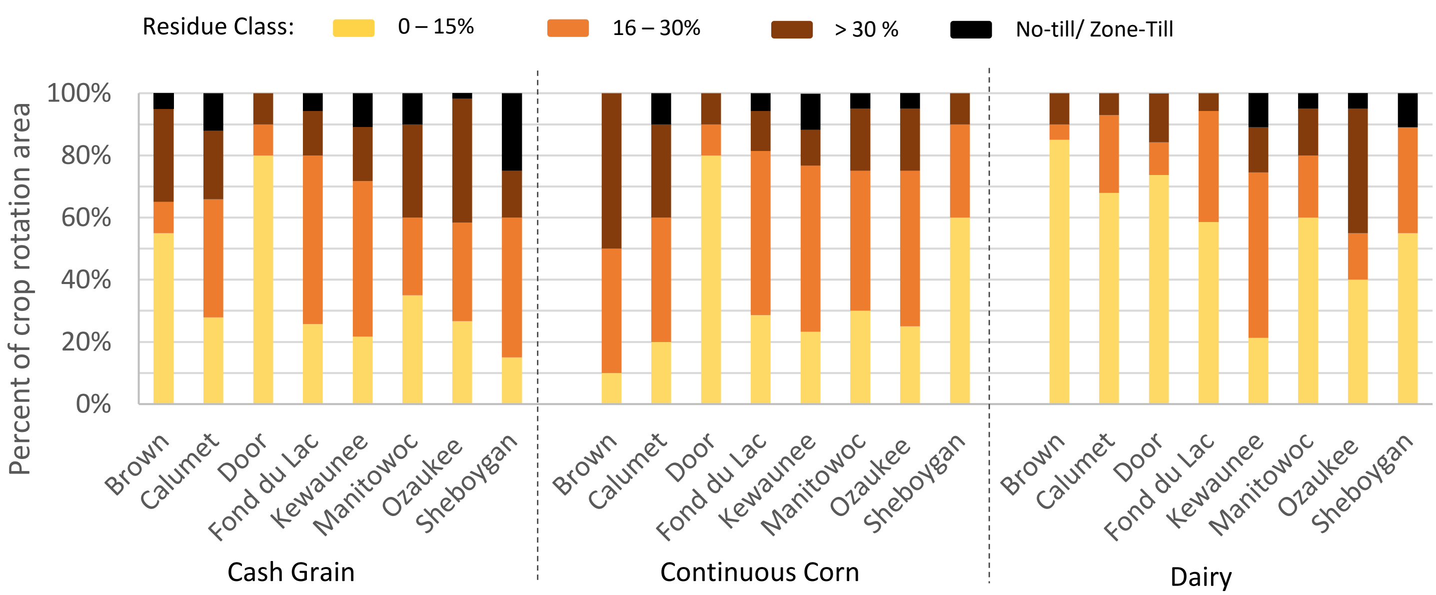
NO-TILL

Survey responses showed that true no-till farming (i.e. no tillage operations during all years of a rotation cycle) is rarely practiced in the study area. However, while not part of a formal no-till system, some individual crop years are not subject to tillage operations. In addition to perennial alfalfa and winter wheat growth described above, soybeans were cited as a crop that is not tilled on some farms. To represent this practice in the SWAT model, an additional tillage category is defined where tillage does not occur when transitioning from soybean to corn grain (Table 3; category 4). In these years, corn will be planted directly into soybean stubble and will be allocated land area within the model according to values reported in survey responses.

CROP RESIDUE

In addition to tillage instruments, county LWCDs provided estimates of the prevalence of various levels of crop residue remaining on the surface following tillage (e.g., 16% to 30% of residue remaining) (Figure 4). This information will be used to calibrate tillage parameters in the SWAT model. Initial tillage parameters for mixing efficiency and depth will be set to default SWAT values for the instruments listed in Table 3. During model calibration, the simulated crop residue levels following tillage will be compared to survey results and tillage parameters will be adjusted as needed.

Figure 4. Average percent occurrence of a crop residue class by crop rotation and county.



CHEMICAL FERTILIZER

Table 4 lists average application rates of phosphate (as P2O5) in chemical fertilizer from county surveys. Figure 5 illustrates the variability in survey results for chemical fertilizer by county and crop sequence. Survey results regarding the timing of chemical fertilizer application by crop type are listed in Table 5.

Table 4. Average phosphate (as P2O5) chemical fertilizer application rates from county surveys.

Rotation	P2O5 (pounds/acre/year)
Cash Grain	48
Continuous Corn	46
Dairy	26

Figure 5. Average chemical phosphate (as P2O5) applications by county and crop sequence.

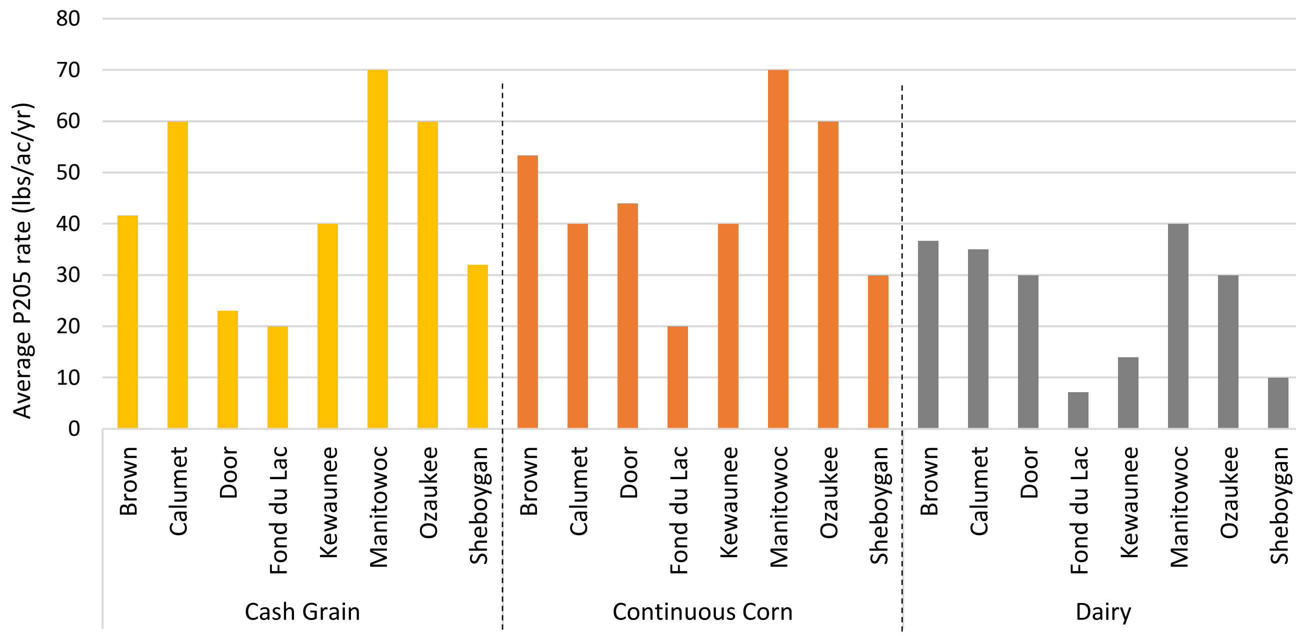


Table 5. Chemical phosphate (as P2O5) fertilizer application timing.

Crop Type	Pre-Planting	At-Planting	During Growing Season
Corn Grain or Soybean	X	X	X
Corn Silage	X	X	X
Alfalfa or Winter Wheat (Dairy Rotation only)		X	X

For SWAT modeling, chemical phosphate fertilizer will be applied according to the average application rates in Table 4 and timing in Table 5. Annual application rates will be divided into two equal parts for alfalfa and three equal parts for corn. Note that alfalfa grown in the continuous hay rotation will not receive chemical fertilizer applications.

CROP YIELDS

Crop yields reported in county surveys will be used in conjunction with values from the USDA National Agricultural Statistics Service (NASS) to calibrate crop production in the SWAT model. Calibration of crop yields will be completed by adjusting plant growth parameters in the model.

MANURE: Agriculture survey

County Land and Water Departments provided average manure spreading rates per HUC12 watershed. The average annual spreading rate of daily haul (solid) manure within the NEL basin was 12 tons per acre per year and ranged from 2 to 25 tons per acre per year among HUC12 watersheds. The average annual spreading rate of stored (liquid) manure was 13,000 gallons per acre per year and ranged from 10,000 to 17,000 gal per acre per year among HUC12 watersheds. The survey also indicated that on average, 15% of dairy fields within the NEL basin receive solid manure from daily haul farms and 85% of dairy fields receive liquid manure from farms with manure storage. Because most farms in the NEL basin use manure storage (liquid manure), all manure spreading in SWAT will be modeled as storage farms with liquid manure. To simulate this in the SWAT model, stored liquid manure will be applied as a spring and fall application and will be immediately followed by a tillage operation to simulate the soil disturbance that occurs during injection and/or incorporation.

MANURE: WDNR manure analysis

A supplemental effort to estimate manure spreading rates and its associated phosphorus was also completed by the Wisconsin Department of Natural Resources (WDNR). This effort is referred to as the 'WDNR manure analysis'. The WDNR manure analysis provided estimates of the amount of manure and the associated phosphorus that was applied for each SWAT model subbasin. The agriculture industry (or sector) typically utilizes the terms phosphorus, phosphate, and P2O5 interchangeably. As such, for consistency, the manure phosphorus results from the WDNR manure analysis are expressed as phosphate and will hereafter be referred to as P2O5. A brief summary of the WDNR manure analysis method, results, and validation approach is below. Refer to the WDNR manure analysis documentation for full details on the methods, results, and validation of this analysis.

Method Overview

Step 1: Calculate the amount of manure and associated P2O5 spread per subbasin

The primary objective of the WDNR manure analysis was to calculate the mass of manure and associated P2O5 applied per subbasin per year. In brief, these values were estimated using cattle numbers from two sources 1) the countywide cattle numbers reported in the 2017 Cattle Census from the National Agricultural Statistics Service and 2) cattle numbers reported in CAFO's 2018 Annual Reports. Next, yearly manure and associated P2O5 production amounts were calculated for seven various cattle types (calves, small heifers & small steers, large heifers, large beef, dairy cow, beef cow, and bull) using liquid manure rates and P2O5 concentrations consistent with SnapPlus. Lastly, the liquid manure and P2O5 amounts were divided amongst subbasins based on number of acres assumed to be receiving manure in each subbasin. The countywide non-CAFO manure and associated P2O5 contributions were divided amongst subbasins based on the acres of non-CAFO dairy fields in the subbasin, as derived by Wiscland 2. The CAFO manure and associated P2O5 contributions were divided amongst subbasins based on the acreage and locations of fields reported in their Nutrient Management Plans. The result of step 1 provided estimates of total manure amount (gallons) and associated P2O5 mass (pounds) spread per subbasin per year.

Step 2: Calculate spreading rates of manure and associated P2O5 per subbasin

For SWAT watershed modeling, manure and associated P2O5 spreading rates were calculated by applying the manure and P2O5 amounts per subbasin (as described above) to Wiscland2 dairy fields during the non-alfalfa and non-winter wheat years of the modeled dairy rotations. This resulted in approximately 50% of Wiscland dairy fields receiving manure and associated P2O5 applications in a given year (table 2). Yearly manure and associated P2O5 spreading rates will be equally divided between a spring and fall application.

It is recognized that not all cattle manure is captured and applied to the non-alfalfa and non-winter wheat years in a dairy rotation, for example, manure is sometimes applied to cash grain fields or alfalfa crops grown on dairy fields. However, these are difficult situations to account for. Thus, for SWAT modeling, manure and associated P2O5 was only applied to the non-alfalfa and non-winter wheat crops in the dairy rotation, as these crops in a dairy rotation comprise the largest and most consistent land cover receiving manure in the NE Lakeshore basin. Overall, the *amount* of manure and associated P2O5 per subbasin is a more important model parameter than the *rate* of manure P2O5 per subbasin. With this in mind, the WDNR approached the manure spreading analysis with the goal of estimating the amount, rather than rate, of manure and associated P2O5 applied per subbasin per year.

Results for the SWAT model

The subbasin P2O5 spreading rates for SWAT in figure 10 represent the rates proposed for input to the NE Lakeshore TMDL SWAT model. In the majority of subbasins, the yearly SWAT P2O5 spreading rates ranged from 70 to 150 lb of P2O5 per acre per year, with a NEL basin average of 107 lb of P2O5 per acre per year (figure 10). Four percent of subbasins had a SWAT P2O5 spreading rate between 161 to 270 lb per year. Thirteen small subbasins (less than 750 ac) received no manure P2O5 because they did not contain any Wiscland dairy areas.

Validation of the WDNR manure analysis

WDNR verified the results of the manure analysis using two different approaches. The first approach involved a comparison of the subbasin manure spreading rates (calculated with the WDNR manure analysis) to the HUC12 manure spreading rates reported by LWCDs. The second approach involved a comparison of manure and associated P2O5 spreading at CAFO facilities (calculated with the WDNR manure analysis) to similar values reported directly by CAFO facilities in their Nutrient Management Plans.

Comparison of WDNR manure spreading rates to county reported manure spreading rates

The county average SWAT subbasin manure spreading rates estimated with the WDNR method were within 12% of those reported by the county LWCDs, on average (figure 7). The county LWCDs reported average HUC12 manure spreading rates ranging from 10,000 to 17,000 gal/ac/day (figure 8), while the majority of SWAT subbasin spreading rates ranged between 9,000 to 20,000 gal/ac/day (figure 9). Three percent of subbasins had SWAT spreading rates between 20,000 and 25,000. Thirteen small subbasins (less than 750 ac) received no manure because they did not contain any Wiscland dairy areas. Overall, the average SWAT manure spreading rates calculated by the WDNR showed consistent trends with values reported in the county agricultural surveys. Note that counties with higher SWAT rates than reported by the county LWCDs can be attributed to an assumption in the WDNR manure analysis that all manure is captured and applied to non-alfalfa and non-winter wheat years of a dairy rotation.

Comparison of WDNR estimated CAFO spreading rates to CAFO reported spreading rates

While the main objective of the WDNR analysis was to estimate the mass of manure and associated P2O5 per subbasin per year, the WDNR analysis also provided estimates of liquid manure and associated P2O5 spread per CAFO facility. CAFO manure and associated P2O5 spreading values calculated with the WDNR manure analysis were compared to the actual manure and associated P2O5 spreading values reported by WDPES permitted CAFOs in their Nutrient Management Plans and Annual Reports. This comparison provided a second method to validate results of the WDNR manure analysis.

The WDNR analysis provided yearly manure production at 106 CAFOs in the NE Lakeshore TMDL counties, which were then compared to the yearly manure spreading amounts reported by CAFOs in their 2018 Annual Reports. Comparisons showed that the average yearly manure production volume and manure spreading rates calculated by the WDNR were within 11% of the average values reported by CAFO facilities. Additionally, annual P2O5 production amounts and spreading rates were gathered from the Nutrient Management Plans of 39 CAFOs in the NE Lakeshore TMDL area and compared with the P2O5 amounts and rates calculated by the WDNR. Comparisons showed that the average yearly P2O5 production amounts and spreading rates from the WDNR analysis were less than 14% different than the average P2O5 amounts and rates reported by CAFOs in their Nutrient Management Plans. Overall, the CAFO manure and associated P2O5 values estimated by the WDNR were consistent with the values reported by CAFOs. See the WDNR manure analysis documentation for additional methods and results of these comparisons.

Figure 7. Average HUC12 manure spreading rates reported by County Land and Water Departments compared with average SWAT subbasin manure spreading rates estimated from the WDNR manure analysis. Error bars represent plus or minus one standard deviation. WDNR SWAT manure analysis rates assume manure is spread on 50% of the Wiscland 2 dairy acres. See the WDNR manure analysis documentation for additional details.

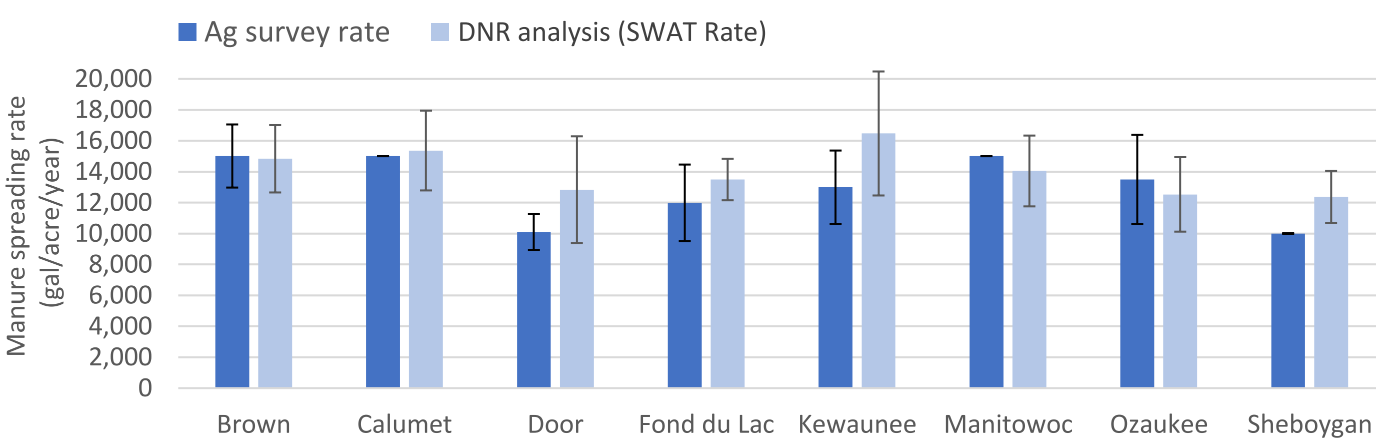


Figure 8. *Data source: County Agriculture Surveys completed by County Land and Water Departments.* Average liquid manure spreading rates (gallons per acre per year) by HUC12.

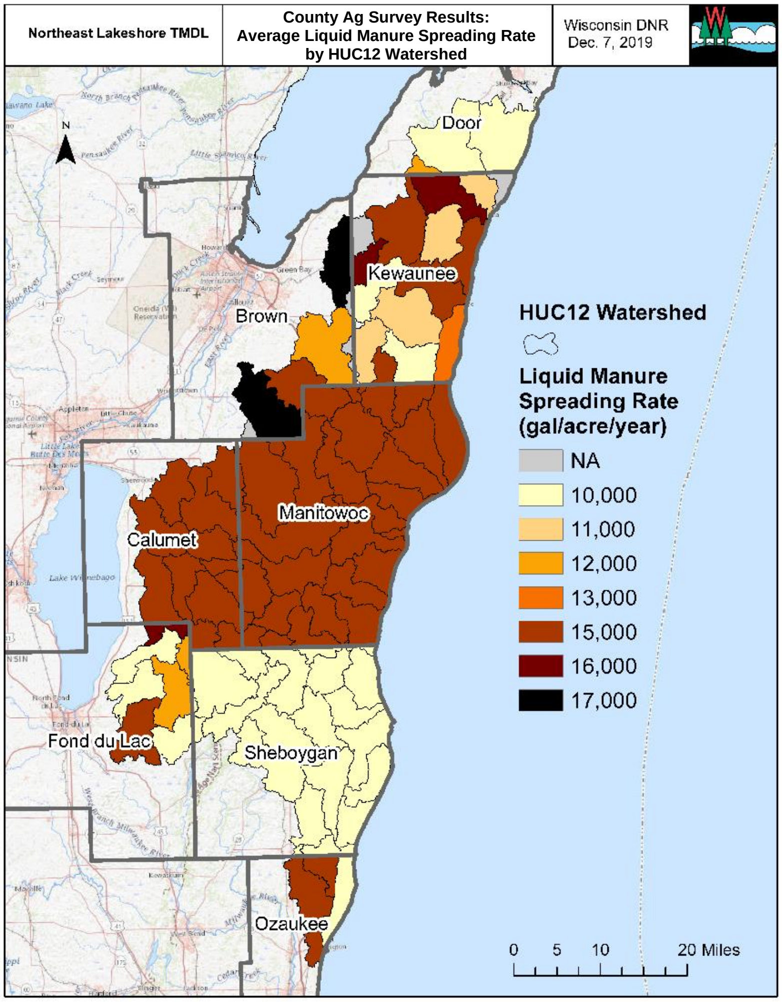


Figure 9. *Data source: WDNR manure spreading analysis.* Average SWAT liquid manure spreading rates (gallons per acre per year) by TMDL subbasin. See the [WDNR manure analysis]() documentation for additional details.

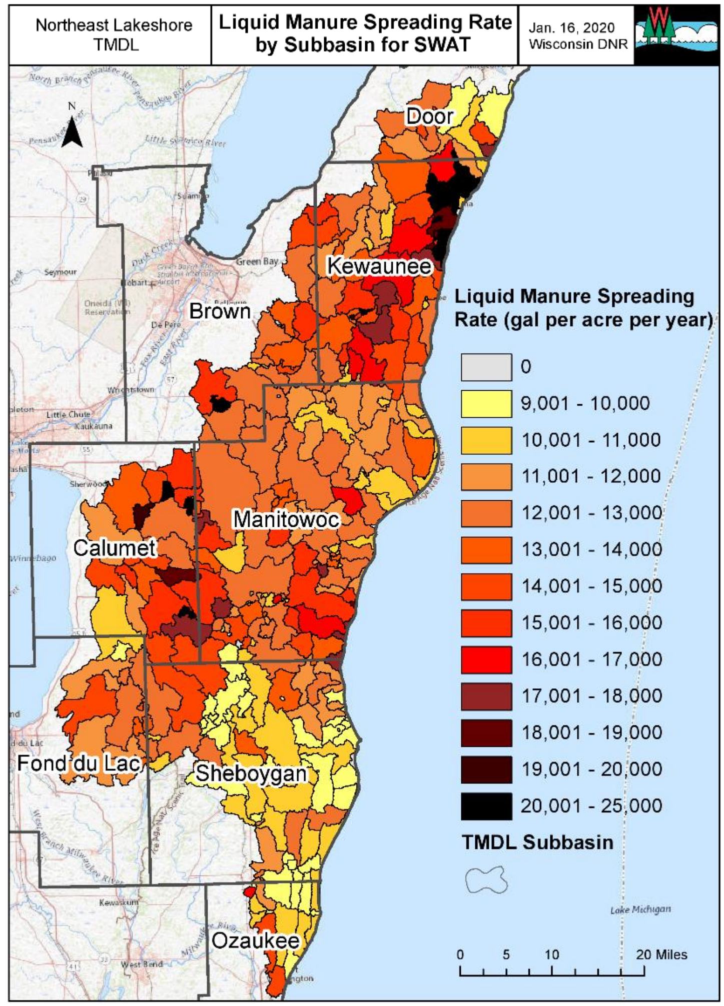
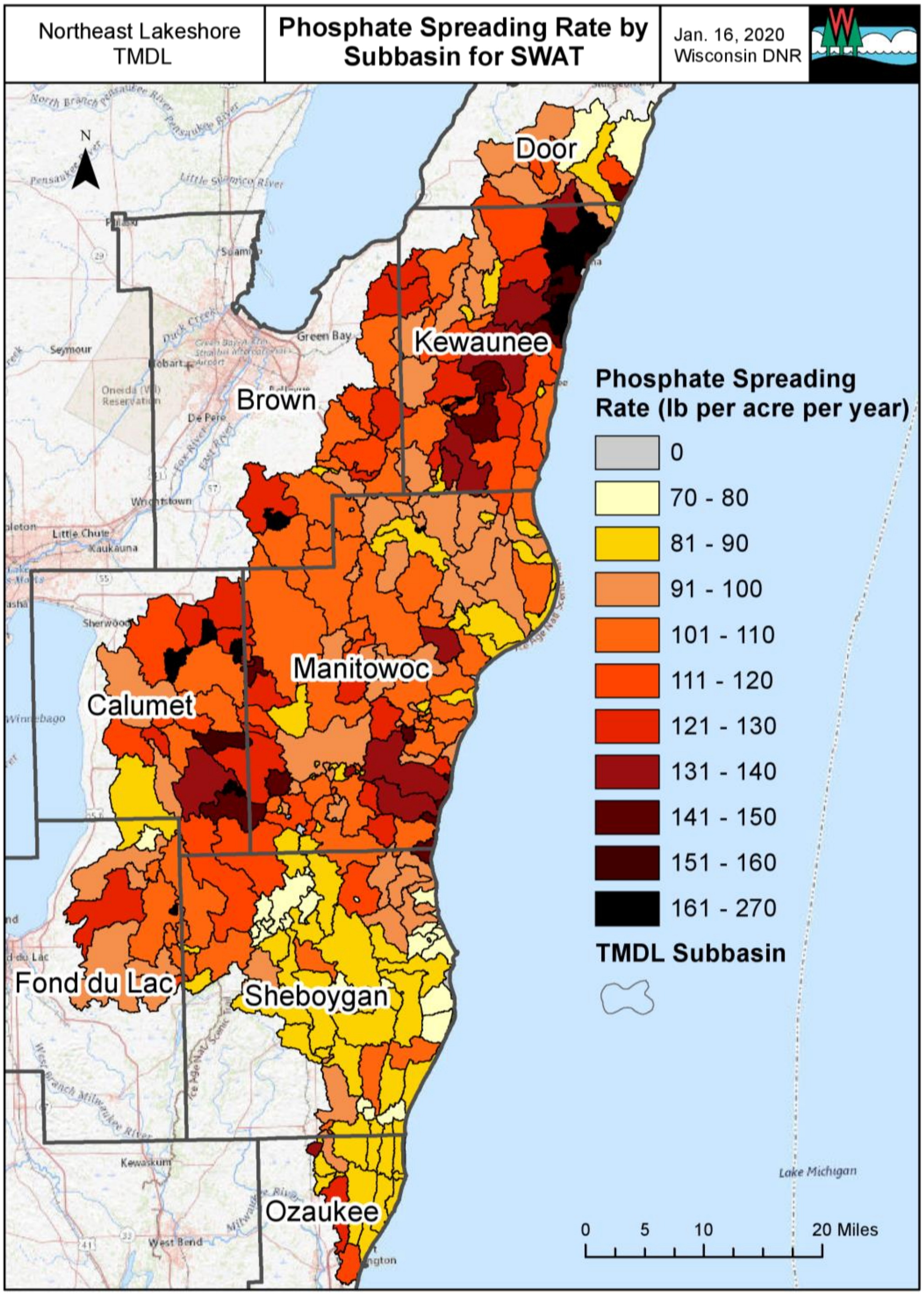


Figure 10. *Data source: WDNR manure spreading analysis.* Average annual SWAT manure phosphate spreading rates (lb P2O5 per receiving acre per year) by TMDL subbasin. During SWAT modeling, manure phosphate spreading rates will be reduced by 50% to account for the distribution of manure from both a spring and fall application. See the [WDNR manure analysis]() documentation for additional details.



SOIL PHOSPHORUS

Like manure spreading, estimates of soil P levels were available from both the county surveys and a supplemental analysis by WDNR to summarize soil P concentrations from CAFO Nutrient Management Plans. CAFO Nutrient Management Plans provide a soil P value for each field in the plan. The WDNR collected soil P data for all 69 CAFOs with production areas in the NE Lakeshore TMDL area, which resulted in over 8,000 soil P samples. Approximately 2,000 of the soil P samples were located to the specific field where the sample was taken. The remaining soil P values were spatially joined to a subbasin based on the following attributes: soil type, facility, and county. Average soil P values from county surveys are consistent with those generated by the WDNR's review of CAFO Nutrient Management Plans and the University of Wisconsin–Madison (UW) county average soil P values from 2010 – 2014 (figure 11). However, the WDNR values provide a better understanding of spatial variability within SWAT model subbasins (figure 12). Therefore, the SWAT model will use values derived from WDNR review of Nutrient Management Plans. Instead of assigning a single average soil P value per model, county, or subbasin, results from the WDNR's soil P analysis will be used to assign each agricultural land unit in the model a unique soil P concentration based on the mean soil P value in the agricultural land unit.

Figure 11. Mean and median soil phosphorus concentrations (ppm) according to 1) county survey results, 2) WDNR analysis of CAFO Nutrient Management Plans, and 3) UW countywide averages. Error bars on median values represent the first and third quartiles. Median values are not shown for the county agricultural surveys because median soil P values were not specifically requested in the surveys. Note that soil P samples from the CAFO Nutrient Management Plans and the UW countywide averages showed a right-skewed distribution; therefore, the typical soil P value from these data sources is best represented by the median, rather than the mean.

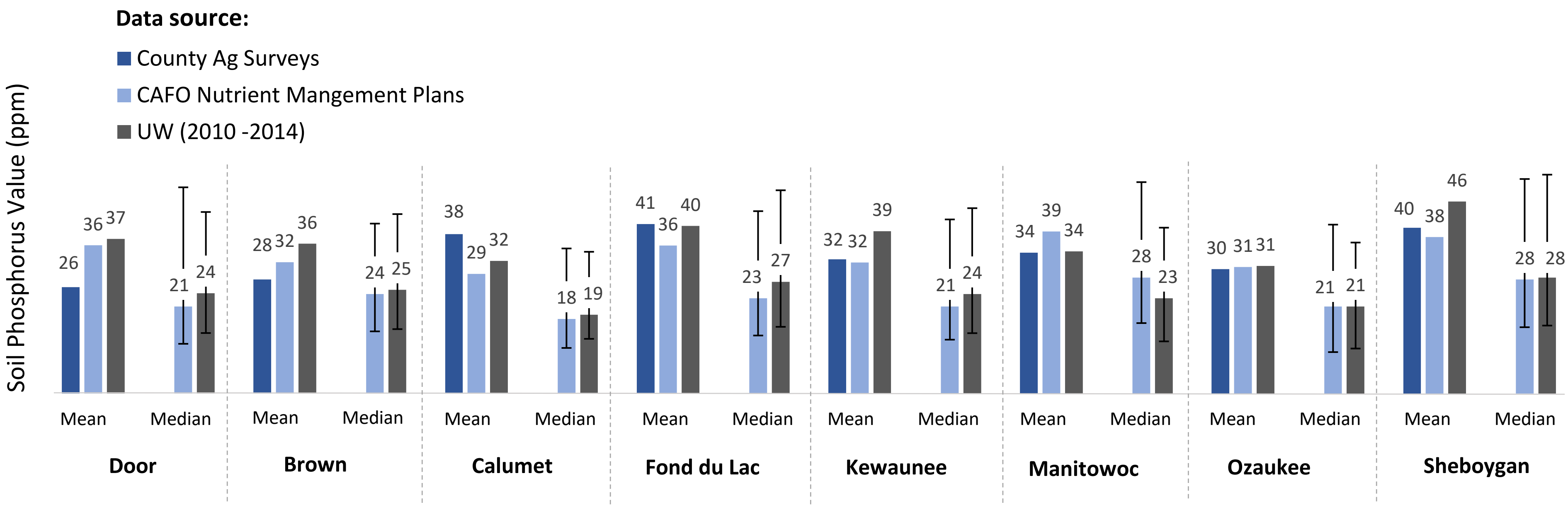
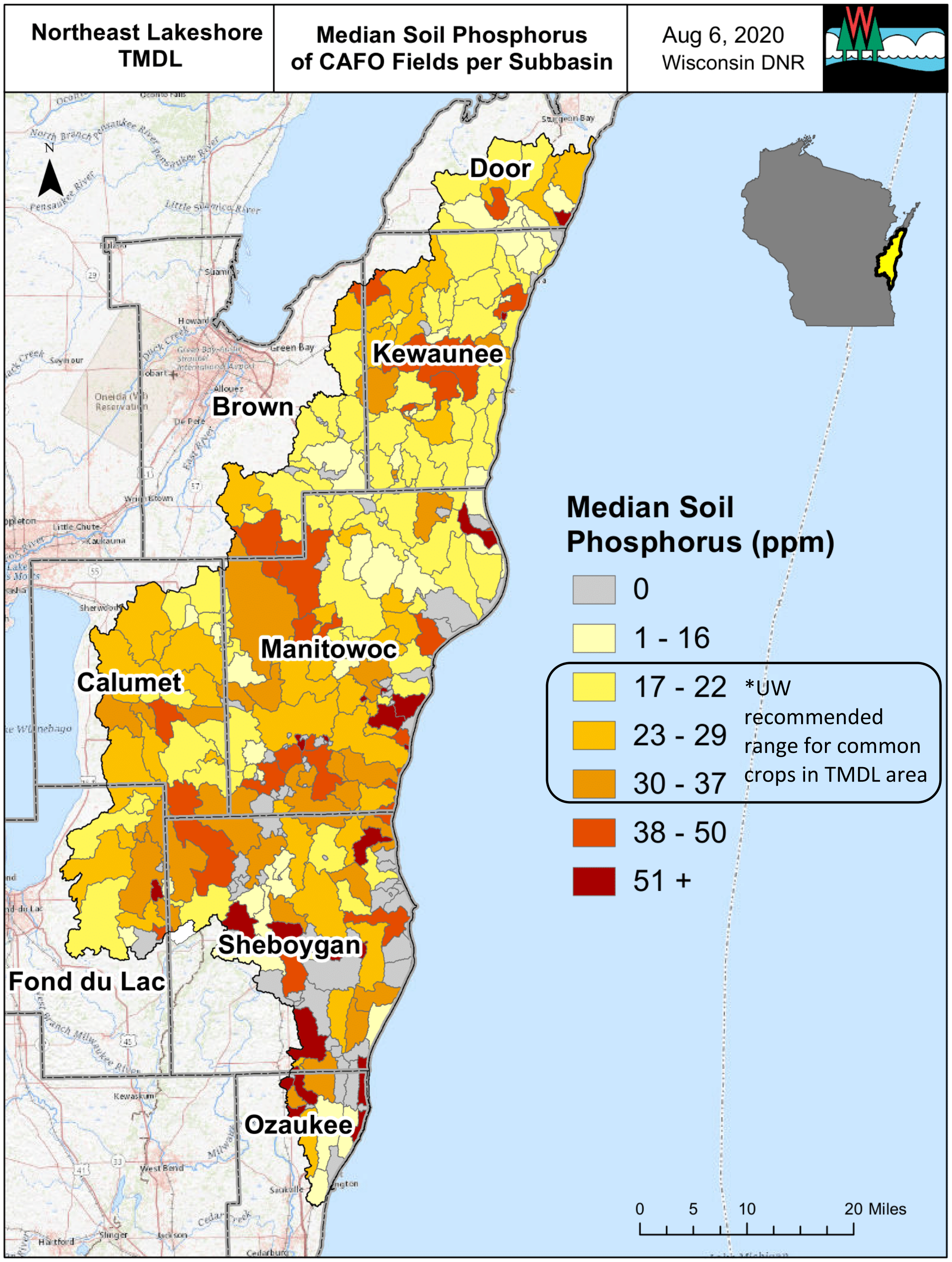


Figure 12. Median soil P values (ppm) per subbasin. Values were derived from the WDNR's review of soil P values from the 69 CAFOs with production areas in the NE Lakeshore TMDL study area. Note that soil P samples from the CAFO Nutrient Management Plans showed a right-skewed distribution; therefore, the typical soil P value of a subbasin is best represented by the median, rather than the mean.



* According to Table 7.1 in UW Extension document A2809: Nutrient application guidelines for filed, vegetable and fruit crops in WI

LIVESTOCK GRAZING

As discussed in the Crop Sequences and Extent section of this document, results of the county surveys suggest that livestock grazing is not significant in the study area. Livestock grazing will not be represented in the SWAT model.

IRRIGATION & TILE DRAINAGE

County survey results indicate that irrigation is not prevalent in the study area. Therefore, irrigation will not be simulated in the SWAT model.

Tile drainage was identified as being practiced in six of the eight counties in the NEL basin. Tile drainage will not be explicitly modeled in SWAT due to the lack of detailed data on the sizing, spacing, and depth of tile drain systems. The information generated from county surveys on large tile drained areas in Ozaukee, Sheboygan, and Fond du Lac counties will be considered during model calibration to understand and address discrepancies between observed and simulated data.

SWAT AGRICULTURE CLASSES

Table 6 summarizes the 17 agricultural classes that will be represented in the SWAT model for the NEL basin. These classes will be assigned land areas within the model based on the extent of each crop rotation in the Wiscland land cover dataset and from county survey estimates of the frequency of specific crop sequences and tillage practices.

Table 6. Summary of agriculture classes defined for SWAT modeling.

Name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	**Fall Tillage	**Spring Tillage	Chemical P2O5 (lb/ac/year)	***Manure
*Dairy Sequence 1 - Till 1	CS	CS	CS	ALF	ALF	ALF	Chisel Plow	Cultivator, 2X	26	Liquid
*Dairy Sequence 1 - Till 2	CS	CS	CS	ALF	ALF	ALF	Disk Plow	Cultivator	26	Liquid
*Dairy Sequence 1 - Till 3	CS	CS	CS	ALF	ALF	ALF	None	Vertical Till	26	Liquid
*Dairy Sequence 2 - Till 1	CS	CS	CG	ALF	ALF	ALF	Chisel Plow	Cultivator, 2X	26	Liquid
*Dairy Sequence 2 - Till 2	CS	CS	CG	ALF	ALF	ALF	Disk Plow	Cultivator	26	Liquid
*Dairy Sequence 2 - Till 3	CS	CS	CG	ALF	ALF	ALF	None	Vertical Till	26	Liquid
*Dairy Sequence 3 - Till 1	CS	CS	SOY	WW	ALF	ALF	Chisel Plow	Cultivator, 2X	26	Liquid
*Dairy Sequence 3 - Till 2	CS	CS	SOY	WW	ALF	ALF	Disk Plow	Cultivator	26	Liquid
*Dairy Sequence 3 - Till 3	CS	CS	SOY	WW	ALF	ALF	None	Vertical Till	26	Liquid
*Cash Grain Sequence - Till 1	CG	SOY	CG	SOY	CG	SOY	Chisel Plow	Cultivator, 2X	48	None
*Cash Grain Sequence - Till 2	CG	SOY	CG	SOY	CG	SOY	Disk Plow	Cultivator	48	None
*Cash Grain Sequence - Till 3	CG	SOY	CG	SOY	CG	SOY	None	Vertical Till	48	None
*Cash Grain Sequence - Till 4	CG	SOY	CG	SOY	CG	SOY	Chisel Plow (Corn), No Till (Soybean)	Cultivator (Corn), No Till (Soybean)	48	None
Continuous Corn Sequence - Till 1	CG	CG	CG	CG	CG	CG	Chisel Plow	Cultivator, 2X	46	None
Continuous Corn Sequence - Till 2	CG	CG	CG	CG	CG	CG	Disk Plow	Cultivator	46	None
Continuous Corn Sequence - Till 3	CG	CG	CG	CG	CG	CG	None	Vertical Till	46	None
Continuous Hay	ALF	ALF	ALF	ALF	ALF	ALF	None	None	None	None

CG = corn grain, CS = corn silage, ALF = alfalfa, SOY = soybean, WW = winter wheat

*Sequence will be equally offset amongst assigned dairy areas to start on either “year 1” or “year 4”

**Tillage will not be applied to the alfalfa or winter wheat years of the dairy sequences

***Liquid manure spreading rates will vary by subbasin according to results of the WDNR manure analysis. Manure will not be applied during alfalfa or winter wheat years.

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