Meadow Brook

WATERSHED DESCRIPTION

This **TMDL** applies to a 5.94 mile section of Meadow Brook, located in the Town of China, Maine. The impaired segment of Meadow Brook begins in the northern portion of the watershed in a forest, and flows south crossing Southern Oaks Drive and Dirigo Road, where the stream begins to flow westward. The stream crosses Tobey Road several times and turns south along power lines in a predominantly wooded area. Meadow Brook exits the watershed just west of Dirigo Road at the confluence of the West Branch of the Sheepscot River. The Meadow Brook watershed covers an area of 5 square miles.

- Runoff from agricultural land located throughout the southern and central portion of watershed is likely the largest source of **nonpoint source (NPS) pollution** to Meadow Brook. Runoff from cultivated lands, active hay lands, and pasture can transport nitrogen and phosphorus to the nearest section of the stream.
- The Meadow Brook watershed is predominately non-developed (95.9%). Forested areas (82.2%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (5.3%) may also help filter nutrients.
- Non-forested areas within the watershed are predominantly agricultural (8.25%) and are located throughout the southern and central portion of the watershed.
- Developed areas (4.1%) with impervious surfaces in close proximity to the steam may impact water quality.
- Meadow Brook is on Maine's 303(d) list of Impaired Streams (Maine DEP, 2013).

Definitions

- ***Total Maximum Daily Load (TMDL)*** *represents the total amount of pollutants that a waterbody can receive and still meet water quality standards.*
- **Nonpoint Source Pollution** *refers to pollution that comes from many diffuse sources across the landscape, and is typically transported by rain or snowmelt runoff.*

Waterbody Facts

Segment ID: ME0105000305_528R05

Town: China, ME

County: Kennebec

Impaired Segment Length: 5.94 miles

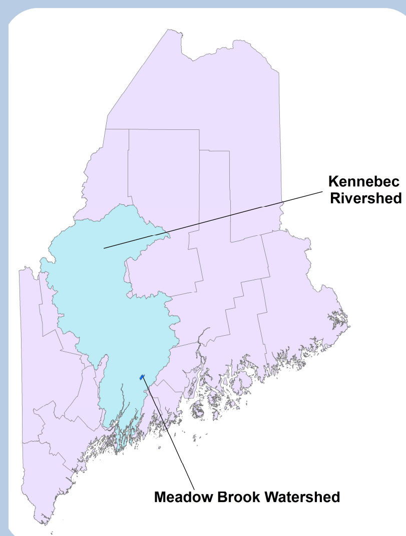
Classification: Class B

Direct Watershed: 5 mi^2 (3,197 acres)

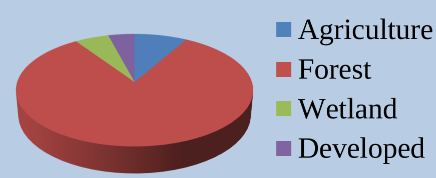
Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 8.25%

Major Drainage Basin: Kennebec River



Watershed Land Uses



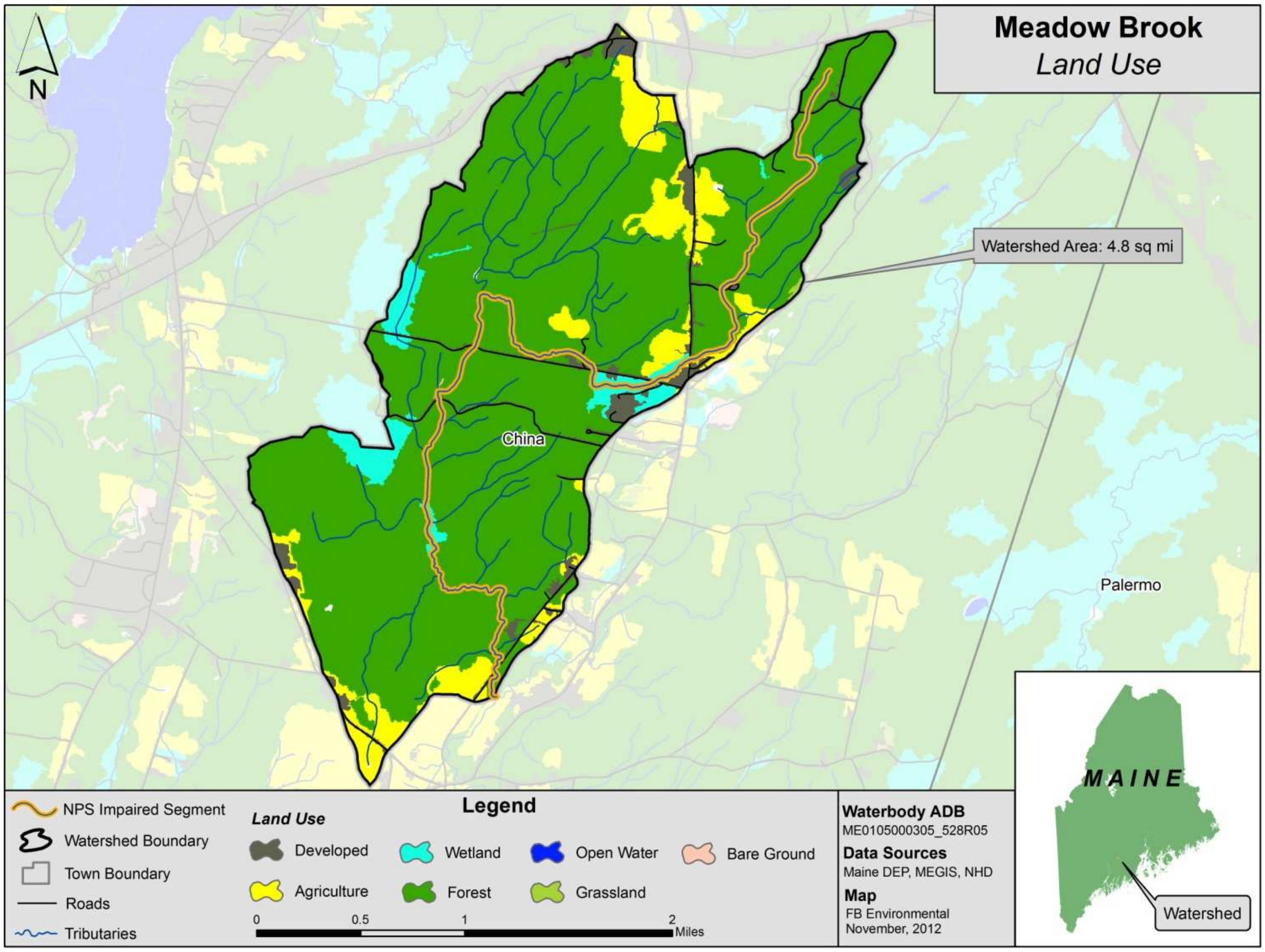


Figure 1: Land Use in the Meadow Brook Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Meadow Brook, a Class B freshwater stream, has been assessed by Maine DEP as not meeting water quality standards for the designated use of aquatic life, and placed on the 303(d) list of impaired waters under the Clean Water Act. The Clean Water Act requires that all 303(d)-listed waters undergo a TMDL assessment that describes the impairments and establishes a target to guide the measures needed to restore water quality. The goal is for all waterbodies to comply with state water quality standards.

__Meadow Brook__ at Station MEBK001-F
Photo: FB Environmental

Agricultural land in the Meadow Brook watershed makes up about 8% of the total area. This is roughly double the area of developed land at about 4%. 20% of the impaired stream segment length passes through agricultural land (Figure 1). Agriculture, especially along Dirigo Road and at Oliver Farm where livestock have direct access to the stream, is therefore likely to be the largest contributor of sediment and nutrient enrichment to the stream. The close proximity of many agricultural lands to the stream further increases the likelihood that nutrients from disturbed soils, manure, and fertilizers will reach the stream.

WATER QUALITY DATA ANALYSIS

Maine DEP uses a variety of data types to measure the ability of a stream to adequately support aquatic life, including; dissolved oxygen, benthic macroinvertebrates, and periphyton (algae). The aquatic life impairment in Meadow Brook is based on historic dissolved oxygen data. Additionally, dissolved oxygen data collected at station MEBK001-F in 2005-2008 and 2010, and station KSRWBMD32 in 2007 corroborates the impairment.

TMDL ASSESSMENT APPROACH: NUTRIENT MODELING OF IMPAIRED AND ATTAINMENT STREAMS

NPS pollution is difficult to measure directly, because it comes from many diffuse sources spread across the landscape. For this reason, a nutrient loading model, MapShed, was used to estimate the sources of pollution based on well-established hydrological equations; detailed maps of soil, land use, and slope; many years of daily weather data; and direct observations of agriculture and other land uses within the watershed.

The nutrient loading estimates for the impaired stream were compared to similar estimates for five non-impaired (attainment) streams of similar watershed land uses across the state. The TMDL for the impaired stream was set as the mean nutrient loading estimate of these attainment stream watersheds, and units of mass per unit watershed area per year (kg/ha/year) were used. The difference in loading estimates between the impaired and attainment watersheds represents the percent reduction in nutrient loading required under this TMDL. The attainment streams and their nutrient and sediment loading estimates and TMDL are presented below in Table 1.

Table 1: Numeric Targets for Pollutant Loading Based on MapShed Model Outputs for Attainment Streams

Attainment Streams	Town	TP load (kg/ha/yr)	TN load (kg/ha/yr)	Sediment load (1000 kg/ha/yr)
Martin Stream	Fairfield	0.14	3.4	0.008
Footman Brook	Exeter	0.33	6.4	0.058
Upper Kenduskeag Stream	Corinth	0.29	5.6	0.047
Upper Pleasant River	Gray	0.22	4.6	0.016
Moose Brook	Houlton	0.25	5.9	0.022
Total Maximum Daily Load		**0.24**	**5.2**	**0.030**

RAPID WATERSHED ASSESSMENT

Habitat Assessment

A Habitat Assessment survey was conducted on both the impaired and attainment stream. The assessment approach is based on the *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (Barbour et al., 1999), which integrates various parameters relating to the structure of physical habitat. The habitat assessments include a general description of the site and physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on Rapid Bioassessment protocols for low gradient streams, Meadow Brook received a score of 142 out of a total 200 for quality of habitat. Higher scores indicate better habitat. The range of habitat assessment scores for attainment streams was 155 to 179.

Habitat assessments were conducted on a relatively short sample reach (about 100-200 meters for a typical small stream) near the most downstream Maine DEP sample station in the watershed. For both impaired and attainment streams, the assessment location was usually near a road crossing for ease of access. In the Meadow Brook watershed, the downstream sample station was located in a forested portion of the stream near the graze lands of a nearby dairy farm at station MEBK001-F.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Meadow Brook. Though these scores show that habitat is clearly an issue in the impairment of Meadow Brook, it is important to look for other potential sources within the watershed leading to impairment. Consideration should be given to major "hot spots" in the Meadow Brook watershed as potential sources of NPS pollution contributing to the water quality impairment.

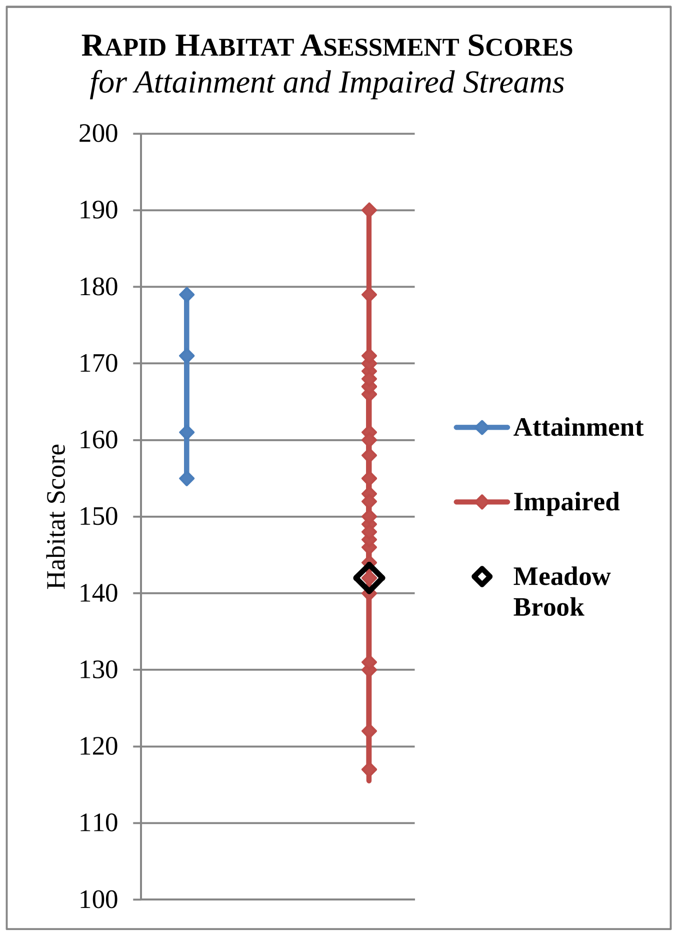


Figure 2: Habitat Assessment Scores

Pollution Source Identification

Pollution source identification assessments were conducted for both Meadow Brook (impaired) and the attainment streams. The source identification work is based on an abbreviated version of the Center for Watershed Protection's Unified Subwatershed and Site Reconnaissance method (Wright, et al., 2005). The abbreviated method includes both a desktop and field component. The desktop assessment consists of generating and reviewing maps of the watershed boundary, roads, land use and satellite imagery, and then identifying potential NPS pollution locations, such as road crossings, agricultural fields, and large areas of bare soil. When available, multiple sources of satellite imagery were reviewed. Occasionally, the high resolution of the imagery allowed for observations of livestock, row crops, eroding stream banks, sediment laden water, junkyards, and other potential NPS concerns that could affect stream quality. As many potential pollution sources as possible were visited, assessed and documented in the field. Field visits were limited to NPS sites that were visible from roads or a short walk from a roadway. Neighborhoods were assessed for NPS pollution at the whole neighborhood level including streets and storm drains (where applicable). The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed. The assessment does not include a scoring component, but does include a detailed summary of findings and a map indicating documented NPS sites throughout the watershed.

The watershed source assessment for Meadow Brook was completed on July 19, 2012. In-field observations of erosion, lack of vegetated stream buffer, extensive impervious surfaces, high-density neighborhoods and agricultural activities were documented throughout the watershed (Table 2, Figure 3).

Table 2: Pollution Source ID Assessment for the Meadow Brook Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
1	Free Man Road	Agriculture	• 1 horse observed in pasture. • Limestone pile identified from roadway. • Tributaries to Meadow Brook flow nearby.
3	Between Tobey Road and Dirigo Road	Agriculture	• Large cornfields observed particularly close to Meadow Brook. • May impact stream.
4	Dirigo Road (north of Apple Tree Lane)	Agriculture	• Potential livestock though none observed. Large barn and fenced in pastures.
6	Dirigo Road (north of Tobey Road)	Road Crossing	• A small wetland has formed from possible culvert impoundment. • A fence protects culvert from debris.
7	Tobey Road	Road Crossing	• Perched and undersized culverts observed at both crossings result in impoundment of stream. • Wetland areas have resulted and may have some temperature issues. • Debris build-up at crossing #8.
8	Tobey Road	Road Crossing	
11	Weeks Mills Road	Agriculture	• Inactive and active hay fields. • May have impact on tributary to Meadow Brook upstream of sampling location.
12	DEP Sample Station MEBK001-F	Agriculture	• Sample reach location. • Severe bank erosion on both banks of reach. • Strong manure smell and manure identified on bank and in stream. • 40-50 cattle estimated at Oliver Farm have direct access to stream in the northern corner of the farms fields. • A covered manure pile is located next to the barn.
14	Dirigo Road	Agriculture	• Windy Ridge Deer Farm property. • 3 horses and 10 cows observed grazing. • Based on website: this farm is a deer breeder for antler production and hunting stock. They are also a large producer of hay in the area. It is unknown how many deer are located here as none were observed.

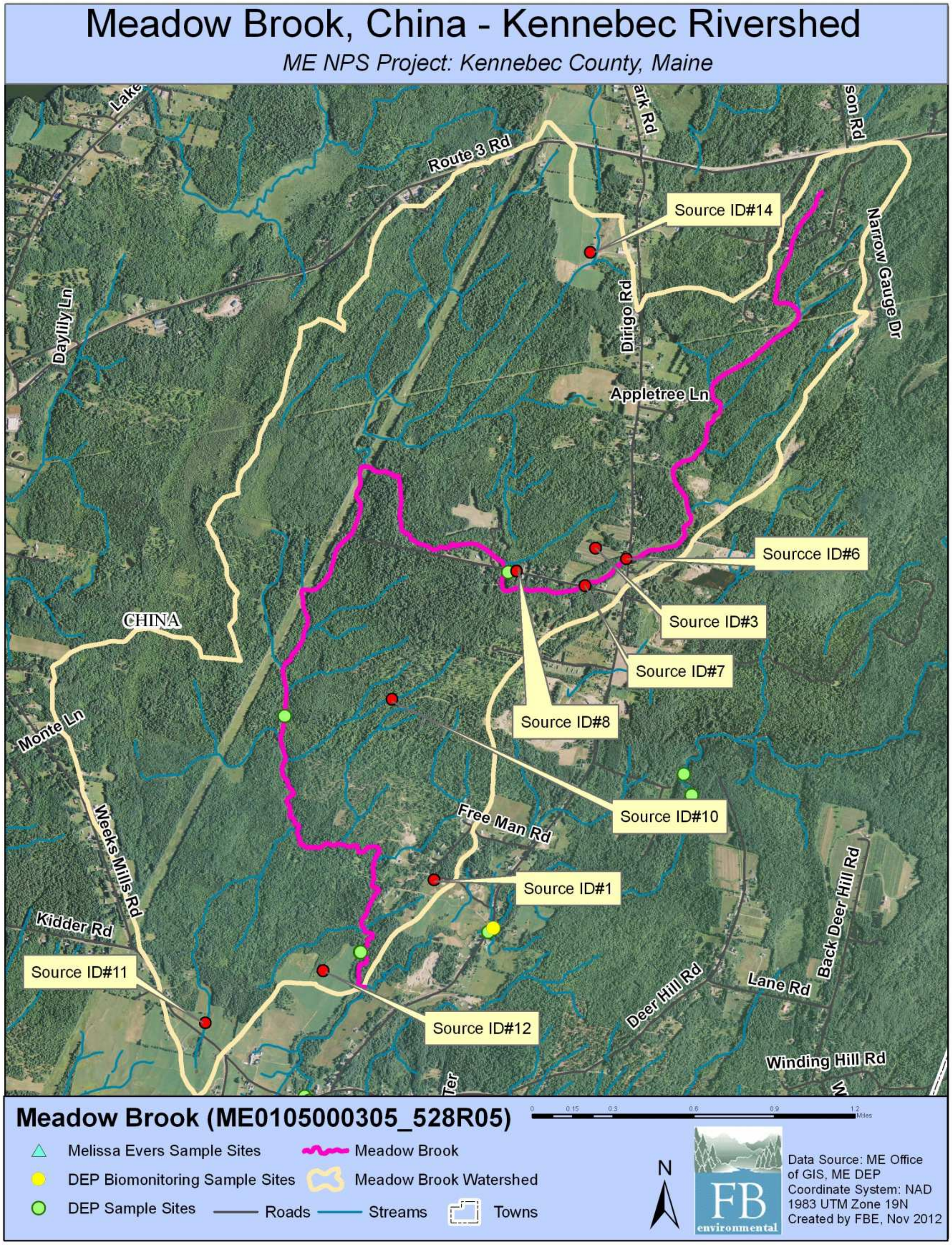


Figure 3: Aerial Photo of Source ID Locations in the Meadow Brook Watershed

NUTRIENT LOADING – MAPSHED ANALYSIS

The MapShed model was used to estimate stream loading of sediment, total nitrogen and total phosphorus in Meadow Brook (impaired), plus five attainment watersheds throughout the state. The model estimated nutrient loads over a 15-year period (1990-2004), which was determined by the available weather data provided within MapShed. This extended period captures a wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time.

Many quality assured and regionally calibrated input parameters are provided with MapShed. Additional input parameters were manually entered into the model based on desktop research and field observations, as described in the sections on Habitat Assessment and Pollution Source Identification. These manually adjusted parameters included estimates of livestock animal units, agricultural stream miles with intact vegetative buffer, Best Management Practices (BMPs), and estimated wetland retention and/or drainage areas.

Livestock Estimates

Livestock waste contains nutrients which can cause water quality impairment. The nutrient loading model considers numbers and types of animals. Table 3 (right) provides estimates of livestock (numbers of animals) in the watershed, based on direct observations made in the watershed, plus other publicly available data..

Table 3: Livestock Estimates in the Meadow Brook Watershed

Type	Meadow Brook
Dairy Cows	50
Beef Cows	10
Broilers	
Layers	10
Hogs/Swine	
Sheep	
Horses	5
Turkeys	
Other	
Total	**75**

The Meadow Brook watershed is predominantly forested, with substantial mixed agricultural land uses as well. Corn and hay fields were observed throughout agricultural areas along with large grazing areas for a livestock. Oliver Farm, a dairy farm off of Dirigo Road, is home to about 50 cows. The cows here have direct access to Meadow Brook. Upstream from sampling station MEBK001-F, at the northern corner of Oliver Farm’s pastures, the brook is experiencing severe bank erosion, sedimentation, and nutrient loading. Manure was observed in Meadow Brook and on its banks. The stream banks have been heavily trodden by cattle, and hoof prints were observed in and around the brook.

Another farm was observed to the west of Dirigo Road in the northern portion of the watershed. Three horses and 10 beef cows were documented on this farm. Two more horses were observed in pasture off of Free Man Road, and some laying hens were observed around a chicken coup on a residential property.

Vegetated Stream Buffer in Agricultural Areas

Vegetated stream buffers are areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands which provide nutrient loading attenuation (Evans & Corradini, 2012). MapShed considers natural vegetated stream buffers within agricultural areas as providing nutrient load attenuation. The width of buffer strips is not defined within the MapShed manual, and was considered to be 75 feet for this analysis. Geographic Information System (GIS) analysis of recent aerial photos along with field reconnaissance observations were used to estimate the number of agricultural stream miles with and without vegetative buffers, and these estimates were directly entered into the model.

Table 4: Summary of Vegetated Buffers in Agricultural Areas

Meadow Brook
• 8.0 stream miles in watershed (includes ephemeral streams) • 1.2 stream miles in agricultural areas • 33% of agricultural stream miles have a vegetated buffer

Meadow Brook is a 5.9 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including tributaries) within the watershed was calculated as 8.0 miles. Of this total, 1.2 stream miles are located within agricultural areas; of this length, 0.4 miles (33%) show a 75-foot or greater vegetated buffer (Table 4, Fig. 4). By contrast, agricultural stream miles (as modeled) with a 75-foot vegetated buffer in the attainment stream watersheds ranged from 34% to 92%, with an average of 61%.

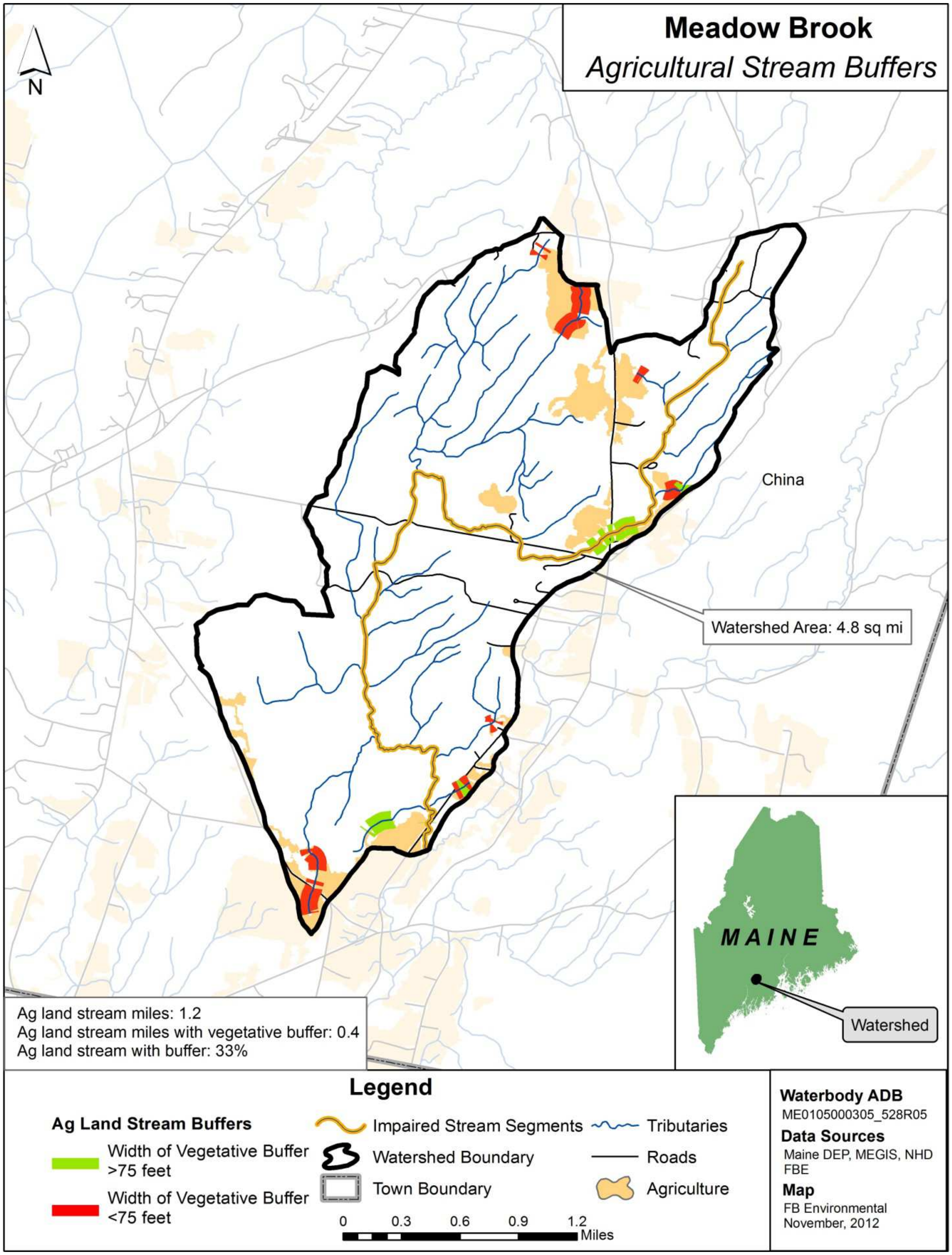


Figure 4: Agricultural Stream Buffer in the Meadow Brook Watershed

Best Management Practices (BMPs)

For this modeling effort, four commonly used BMPs were entered based on literature values. These estimates were applied equally to impaired and attainment stream watersheds. More localized data on agricultural practices would improve this component of the model.

- *Cover Crops:* Cover crops are the use of annual or perennial crops to protect soil from erosion during time periods between harvesting and planting of the primary crop. The percent of agricultural acres cover crops used within the model is estimated at 4%. This figure is based on information from the 2007 USDA Census stating that 4.1% of cropland acres is left idle or used for cover crops or soil improvement activity, and not pastured or grazed (USDA, 2007b).
- *Conservation Tillage:* Conservation tillage is any kind of system that leaves at least 30% of the soil surface covered with crop residue after planting. This reduces soil erosion and runoff and is one of the most commonly used BMPs. This BMP was assumed to occur in 42% of agricultural land. This figure is based on a number given by the Conservation Tillage Information Center's 2008 Crop Residue Management Survey stating that 41.5% of U.S. acres are currently in conservation tillage (CTIC, 2000).
- *Strip Cropping / Contour Farming:* This BMP involves tilling, planting and harvesting perpendicular to the gradient of a hill or slope using high levels of plant residue to reduce soil erosion from runoff. This BMP was assumed to occur in 38% of agricultural lands, based on a study done at the University of Maryland (Lichtenberg, 1996).
- *Grazing Land Management:* This BMP consists of ensuring adequate vegetation cover on grazed lands to prevent soil erosion from overgrazing or other forms of over-use. This usually employs a rotational grazing system where hays or legumes are planted for feed and livestock is rotated through several fenced pastures. In this TMDL, a figure of 75% of hay and pasture land is assumed to utilize grazing land management. This figure is based on a study by Farm Environmental Management Systems of farming operations in Canada (Rothwell, 2005).

Pollutant Load Attenuation by Lakes, Ponds and Wetlands

Depositional environments such as ponds and wetlands can attenuate watershed sediment loading. This information is entered into the nutrient loading model by a simple percentage of watershed area draining to a pond or a wetland. The Meadow Brook watershed is 5% wetland, and overall 5% of the watershed drains to wetlands. Percent of watershed draining to a wetland in the attainment watersheds ranged from 15% to 60%, with an average of 35%.

NUTRIENT MODELING RESULTS

The MapShed model simulates surface runoff using daily weather inputs of rainfall and temperature. Erosion and sediment yields are estimated using monthly erosion calculations and land use/soil composition values for each source area. Below, selected results from the watershed loading model are presented. The TMDL itself is expressed in units of kilograms per hectare per year. The additional results shown below assist in better understanding the likely sources of pollution. The model results for Meadow Brook indicate a reduction of phosphorus is needed to improve water quality. Below, loading for sediment, nitrogen and phosphorus are discussed individually.

Sediment

Sediment loading in the Meadow Brook watershed is mainly derived from development (50%) (Table 5 and Figure 5). Combined agricultural sources account for 44% of the total sediment load. Note that total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Meadow Brook* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Loads by Source

Meadow Brook	Sediment (1000kg/year)	Sediment (%)
Source Load		
Hay/Pasture	0.71	11%
Crop land	2.20	33%
Forest	0.44	7%
Wetland	0	0%
Disturbed Land	0	0%
Low Density Mixed	0.66	10%
Medium Density Mixed	0	0%
High Density Mixed	2.72	40%
Low Density Residential	0	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	0	0%
Septic Systems	0	0%
Source Load Total:	**6.73**	**100%**
Pathway Load		
Stream Banks	3.24	-
Subsurface / Groundwater	0	-
Total Watershed Mass Load:	**9.97**	

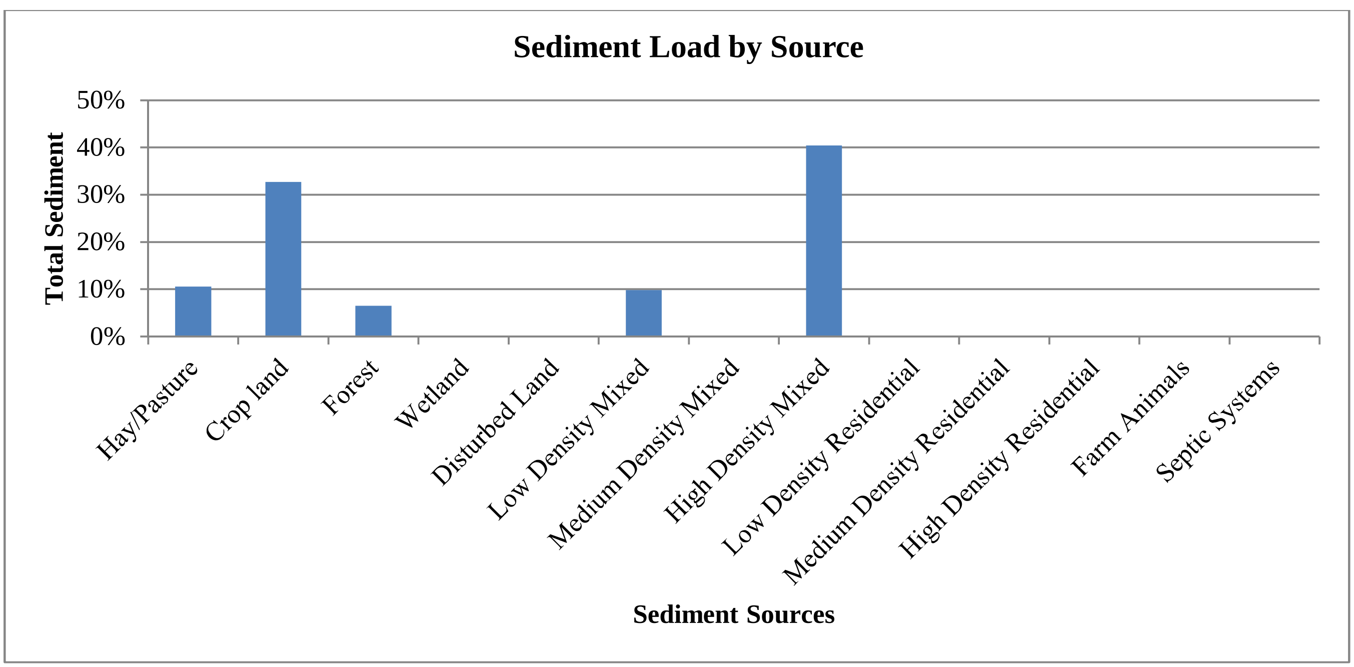


Figure 5: Total Sediment Loads by Source in the Meadow Brook Watershed

Total Nitrogen

Nitrogen loading in the Meadow Brook watershed is primarily attributed to farm animals, with combined agricultural sources accounting for almost 70% of the total nitrogen load. Table 6 and Figure 6 show estimated total nitrogen load in terms of mass and percent of total, and by source in Meadow Brook. Note that total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Meadow Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Loads by Source

Meadow Brook	Total N (kg/year)	Total N (%)
Source Load		
Hay/Pasture	44.3	3%
Crop land	149.7	11%
Forest	180.6	13%
Wetland	22.5	2%
Disturbed Land	0	0%
Low Density Mixed	18.8	1%
Medium Density Mixed	0	0%
High Density Mixed	109.7	8%
Low Density Residential	0	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	735.2	55%
Septic Systems	80.8	6%
Source Load Total:	**1341.5**	**100%**
Pathway Load		
Stream Banks	2.0	-
Subsurface / Groundwater	4834.5	-
Total Watershed Mass Load:	**6178.0**	

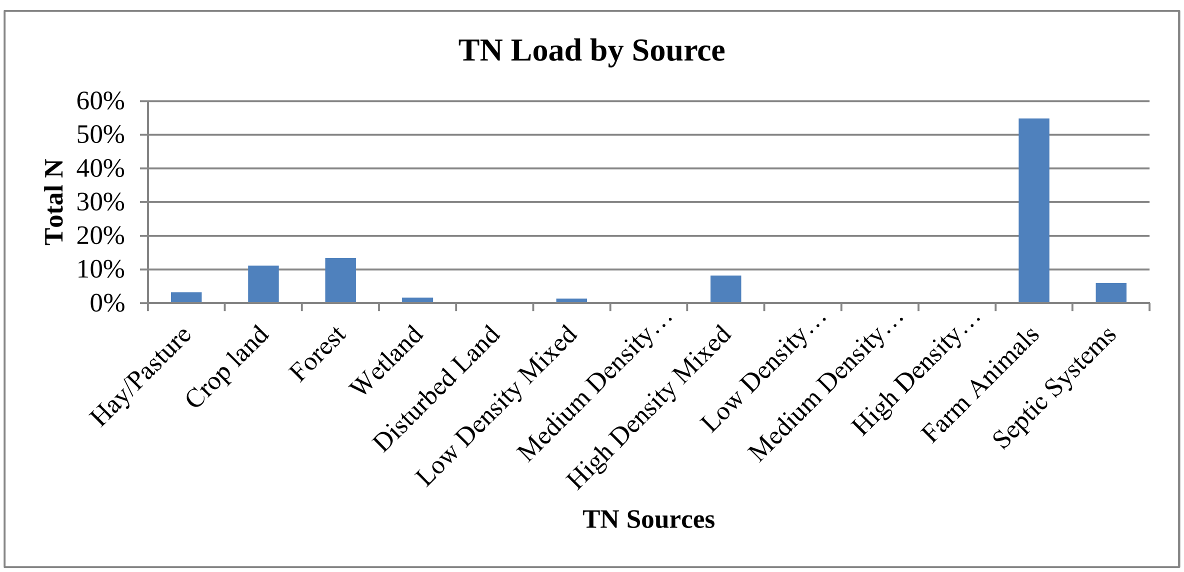


Figure 6: Total Nitrogen Loads by Source in the Meadow Brook Watershed

Total Phosphorus

Phosphorus loading in the Meadow Brook watershed is primarily attributed to farm animals, with combined agricultural sources accounting for 83% of the total phosphorus load. Phosphorus loads are presented in Table 6 and Figure 7. Note that total loads by mass cannot be directly compared between watersheds due to differences in watershed area. See section *TMDL: Target Nutrient Levels for Meadow Brook* below for loading estimates that have been normalized by watershed area.

Table 6: Total Phosphorus Loads by Source

Meadow Brook	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	16.4	8%
Crop land	14.6	7%
Forest	9.7	5%
Wetland	1.2	1%
Disturbed Land	0	0%
Low Density Mixed	2.1	1%
Medium Density Mixed	0	0%
High Density Mixed	11.4	5%
Low Density Residential	0	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	145.3	68%
Septic Systems	12.4	6%
Source Load Total:	**213.0**	**100%**
Pathway Load		
Stream Banks	1.0	-
Subsurface / Groundwater	142.9	-
Total Watershed Mass Load:	**356.9**	

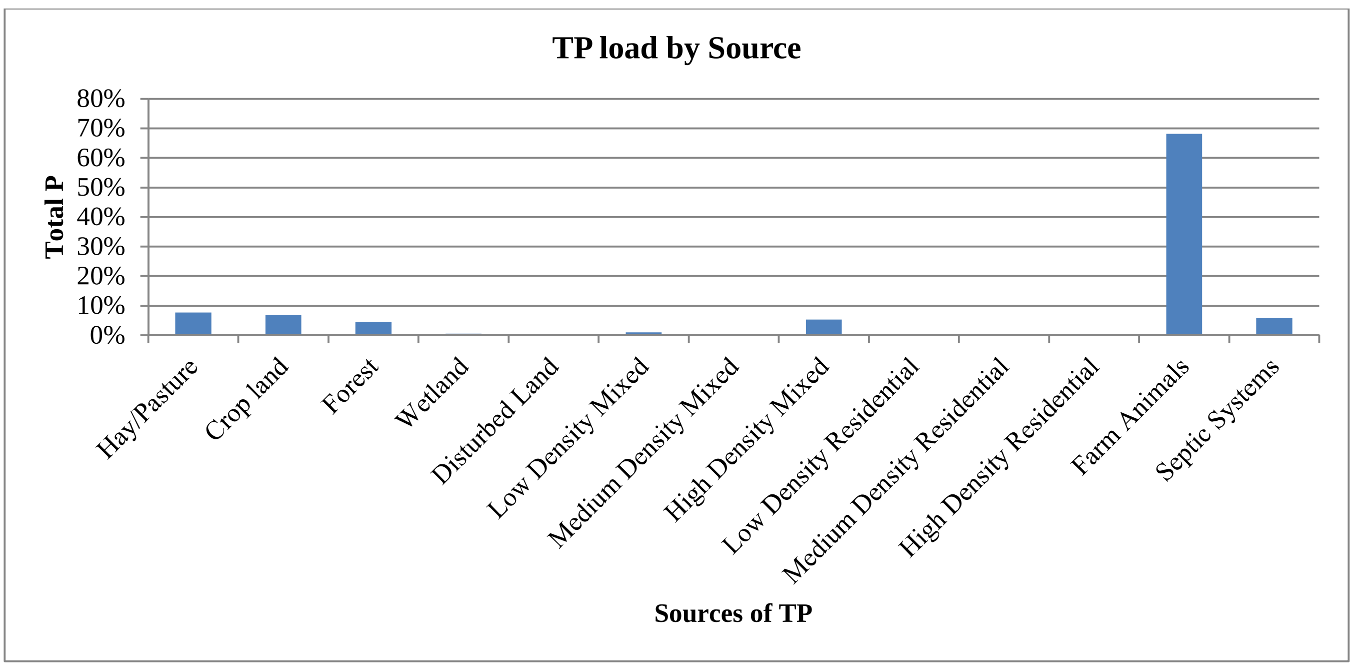


Figure 7: Total Phosphorus Loads by Source in the Meadow Brook Watershed

TMDL: TARGET NUTRIENT LEVELS FOR MEADOW BROOK

The existing loads for sediments and nutrients in the impaired segment of Meadow Brook are listed in Table 8, along with the TMDL numeric target which was calculated from the average loading estimates of five attainment watersheds throughout the state. Table 9 presents a more detailed view of the modeling results and calculations used in Table 8 to define TMDL reductions, and compares the existing sediment and nutrient loads in Meadow Brook to TMDL endpoints derived from the attainment waterbodies. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads.

Table 8: TMDL Targets Compared to Meadow Brook Pollutant Loading

TMDL POLLUTANT LOADS Annual Loads per Unit Area	**Estimated Loads Meadow Brook**	**Total Maximum Daily Load Numeric Target**	**TMDL % REDUCTIONS Meadow Brook**
Sediment Load *(1000 kg/ha/year)*	**0.008**	**0.030**	**No Reduction Needed**
Nitrogen Load *(kg/ha/year)*	**5.01**	**5.2**	**No Reduction Needed**
Phosphorus Load *(kg/ha/year)*	**0.29**	**0.24**	**16%**

Future Loading

The prescribed reduction in pollutants discussed in this TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities have the potential to increase runoff and associated pollutant loads to Meadow Brook. To ensure that the TMDL targets are attained, future agriculture or development activities in the watershed will need to meet the TMDL targets. Future growth from population increases is a moderate threat in the Meadow Brook watershed because Kennebec County has increasing population trends, with a 3.3% increase between 2000 and 2008 (USM MSAC, 2009). The growth in agricultural lands is also increasing, with a 13% increase in the total number of farms in Kennebec County between 2002 and 2007. However, a decrease of 4% was seen in the land (acres) in farms between 2002 and 2007, and a 15% decrease occurred in the average farm size in this time period as well (USDA, 2007a). Future activities and BMPs that achieve TMDL reductions are addressed below.

Next Steps

The use of agricultural and developed area BMPs can reduce sources of polluted runoff in Meadow Brook. It is recommended that municipal officials, landowners, and conservation stakeholders in China work together to develop a watershed management plan to:

- Encourage greater citizen involvement through the development of a watershed coalition to ensure the long term protection of Meadow Brook;
- Address existing nonpoint source problems in the Meadow Brook watershed by instituting BMPs where necessary; and

- Prevent future degradation of Meadow Brook through the development and/or strengthening of a local Nutrient Management Ordinance.

Table 9: Modeling Results Calculations for Derived Numeric Targets and Reduction Loads for Meadow Brook

Meadow Brook				
	Area ha	**Sediment 1000kg/yr**	**TN kg/yr**	**TP kg/yr**
Land Uses				
Hay/Pasture	69	0.7	44.3	16.4
Crop land	35	2.2	149.7	14.6
Forest	1032	0.4	180.6	9.7
Wetland	46	0.0	22.5	1.2
Disturbed Land	0	0.0	0.0	0.0
Low Density Mixed	26	0.7	18.8	2.1
High Density Mixed	25	2.7	109.7	11.4
Other Sources				
Farm Animals			735.2	145.3
Septic Systems			80.7	12.4
Pathway Loads				
Stream Banks		3.2	2.0	1.0
Groundwater			4834.5	143.0
Total Annual Load		10 x 1000 kg	6178 kg	357 kg
Total Area	1234 ha			
Total Maximum Daily Load		**0.008 1000kg/ha/year**	**5.01 kg/ha/year**	**0.29 kg/ha/year**

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