TMDL Summary — Appendix 6-15

Mulligan Stream

Watershed Description

This **TMDL** applies to a 4.8 mile section of Mulligan Stream, located in the Towns of St. Albans, Corinna and Newport, Maine. The impaired segment of Mulligan Stream begins at the outlet of the Mulligan Stream impoundment in a predominantly forested area and flows northeast crossing Williams Road. At the crossing of the power lines, Mulligan Stream turns to flow south in forested land, crossing Nokomis Road, Newport Road (Route 7), and the Newport/Dover-Foxcroft Rail Trail before flowing into Sebasticook Lake. The Mulligan Stream watershed covers an area of 21 square miles. The majority of the watershed is located within the Towns of St. Albans, Corinna and Palmyra, however, a small portion of the watershed lies within the surrounding Town of Newport.

- Runoff from a dairy farm on Corinna Road and agricultural land located throughout the watershed is likely the largest source of **nonpoint source (NPS) pollution** to Mulligan Stream. Runoff from cultivated lands, active hay lands, and pasture can transport nitrogen and phosphorus to the nearest section of the stream.
- The Mulligan Stream watershed is predominately non-developed (94.4%). Forested areas (63.7%) within the watershed absorb and filter pollutants helping protect both water quality in the stream and stream channel stability. Wetlands (8%) may also help filter nutrients.
- Non-forested areas within the watershed are predominantly agricultural (22.7%) and are located throughout the watershed.
- Developed areas (5.6%) with impervious surfaces in close proximity to the steam may impact water quality.
- Mulligan Stream 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: ME0103000308_325R03

Town: St. Albans, Corinna and Newport, ME

County: Somerset

Impaired Segment Length: 4.8 miles

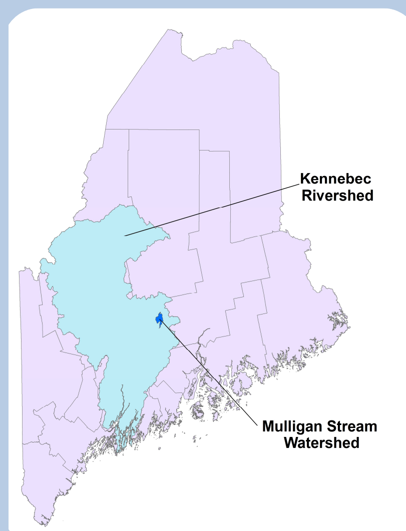
Classification: Class B

Direct Watershed: 20.84 mi^2 (13,338 acres)

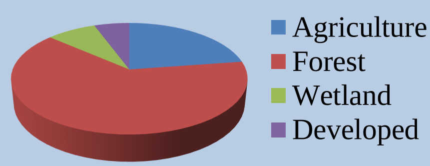
Impairment Listing Cause: Dissolved Oxygen

Watershed Agricultural Land Use: 22.67%

Major Drainage Basin: Kennebec River



Watershed Land Uses



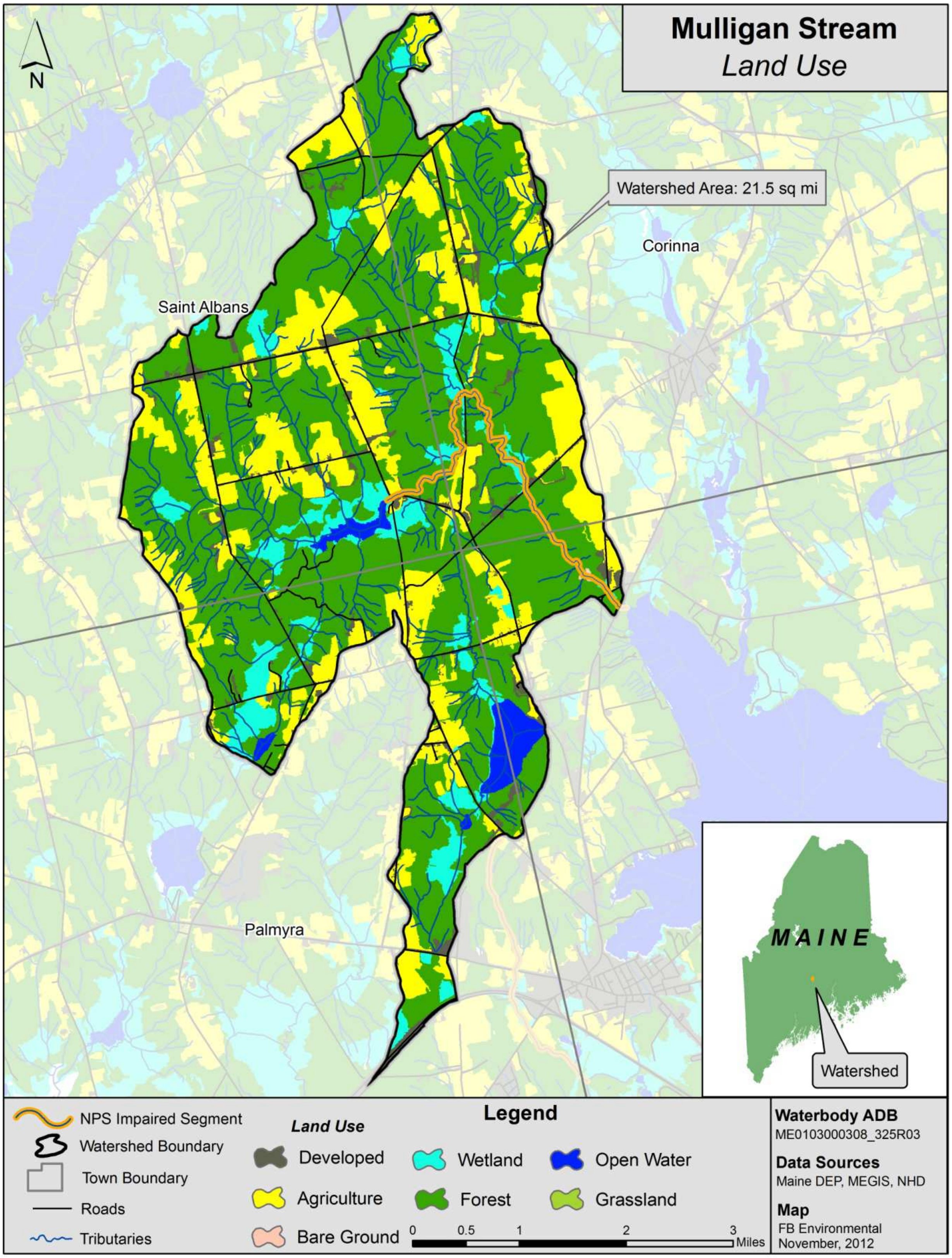


Figure 1: Land Use in the Mulligan Stream Watershed

WHY IS A TMDL ASSESSMENT NEEDED?

Mulligan Stream, 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.

Mulligan Stream *downstream of the Nokomis Road crossing. Photo: FB Environmental*

Agricultural land in the Mulligan Stream watershed makes up about 23% of the total land area within the watershed. This is about four times larger than the area of developed land making up about 6% of the watershed (Figure 1). The Mulligan Stream watershed is heavily forested with forested lands making up almost 64% of the watershed area. However, agriculture is likely to be the largest contributor of sediment and nutrient enrichment to the stream, especially from a large dairy farm on Corinna Road and agricultural fields where the use of liquid manure was observed. 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. However, since the headwaters of Mulligan Stream flow from an impoundment, Mulligan Stream may also exhibit naturally low dissolved oxygen concentrations.

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 Mulligan Stream is based on historic dissolved oxygen.

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 streams. 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, physical characterization and visual assessment of in-stream and riparian habitat quality.

Based on Rapid Bioassessment protocols for low gradient streams, Mulligan Stream 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 Mulligan Stream watershed, the downstream sample station was located in a forested portion of the stream with a thick buffer with agricultural fields located nearby. A large wetland complex is located just upstream of the Nokomis Road crossing. The impaired segment of Mulligan Stream does not flow adjacent to agricultural areas. However, its many tributaries and associated ephemeral waterways do. Tributaries to Mulligan Stream are potentially affected a great deal more by agriculture than the main impaired segment.

Figure 2 (right) shows the range of habitat assessment scores for all attainment and impaired streams, as well as for Mulligan Stream. Though these scores show that habitat is clearly an issue in the impairment of Mulligan Stream, 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 Mulligan Stream watershed as potential sources of NPS pollution contributing to the water quality impairment.

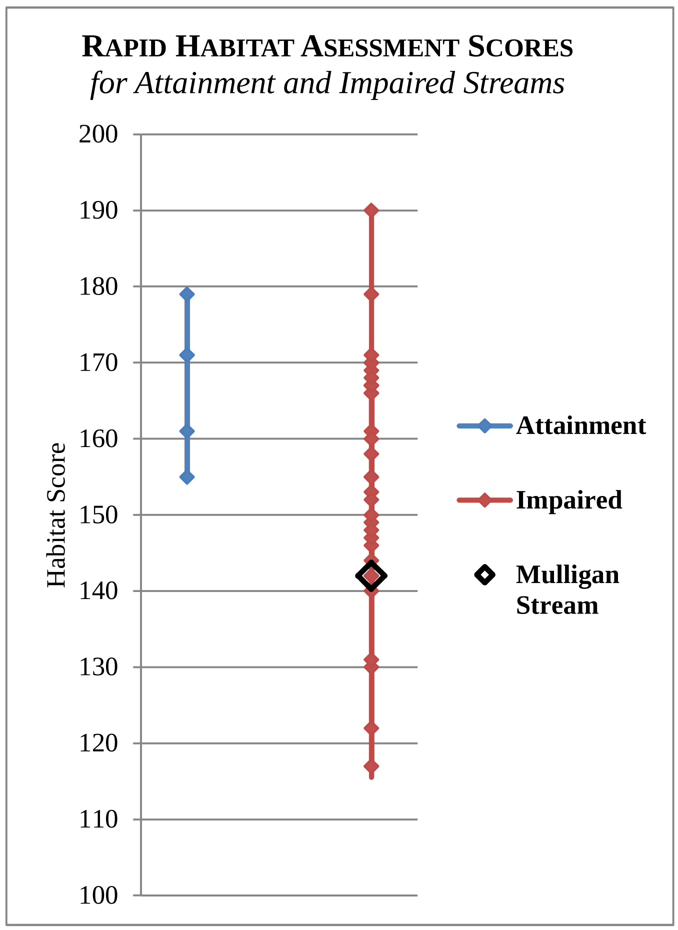


Figure 2: Habitat Assessment Scores

Pollution Source Identification

Pollution source identification assessments were conducted for both Mulligan Stream (impaired) and all 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 watershed source assessment for Mulligan Stream was completed on July 2, 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 Mulligan Stream Watershed

Potential Source			Notes
ID#	**Location**	**Type**	
1	Nokomis Road	Sample Reach & Wetland	• Sample reach located downstream of Nokomis Road crossing. • Wetland area on the upstream side of crossing. • Obvious source of low dissolved oxygen.
4	Old County Road	Agriculture	• Large active agricultural fields adjacent to Mulligan Stream.
7	Origin of Mulligan Stream	Wetland	• Wetland complex at origin of Mulligan Stream. • Western watershed drains into wetland before Mulligan Stream. • Large retention potential for nutrients and sediment, however may be a source of low dissolved oxygen in Mulligan Stream.
8	Pleasant Vale Road	Agriculture	• Active agricultural fields along Pleasant Vale Road. • Multiple tributaries to Mulligan Stream flow adjacent to fields.
12	Nokomis Road	Agriculture	• Potato and corn crops. • Observed liquid manure truck actively spraying fields. • Hay fields to the north west.
13	Packard Road	Agriculture	• Horse farm and active hay fields.
14	Corinna Road	Agriculture	• Dairy farm; estimated 50 cows.
15	Nokomis Road	Agriculture	• Alpaca farm; estimated 6 alpacas.

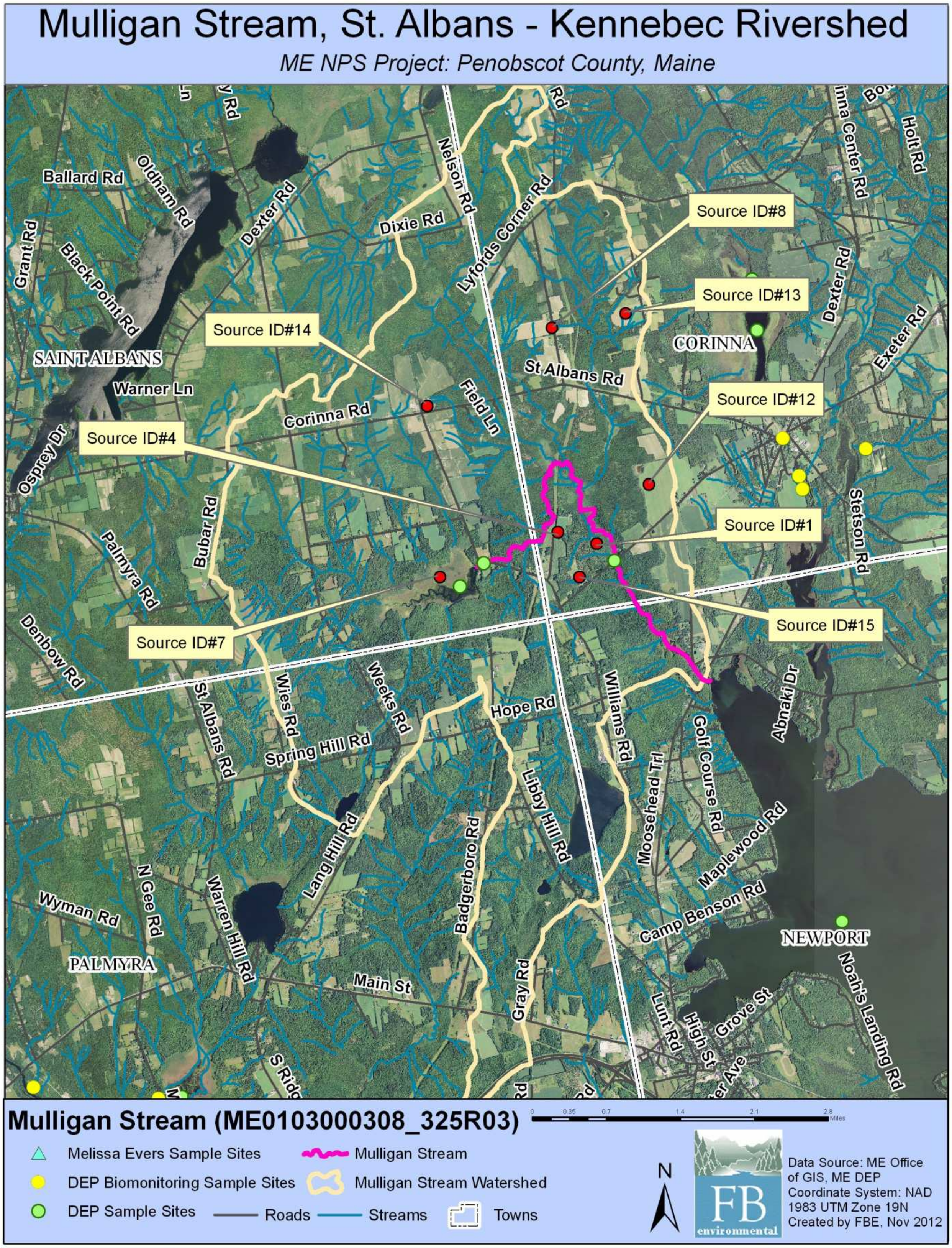


Figure 3: Aerial Photo of Source ID Locations in the Mulligan Stream Watershed

NUTRIENT LOADING – MAPSHED ANALYSIS

The MapShed model was used to estimate stream loading of sediment, total nitrogen and total phosphorus in Mulligan Stream (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 Mulligan Stream Watershed

Type	Mulligan Stream
Dairy Cows	50
Beef Cows	
Broilers	
Layers	
Hogs/Swine	
Sheep	
Horses	5
Turkeys	
Other	6 (alpacas)
Total	**61**

The Mulligan Stream watershed is predominantly forested, with substantial mixed agricultural land uses as well. Large areas of potato, corn and hay fields were documented throughout the watershed, as well as a large dairy farm on Corinna Road. An estimated 50 cows are located on the property. Large agricultural fields surround this property north and south of Corinna Road, and multiple tributaries flow nearby to the south east to Mulligan Stream. Five horses were also documented in various locations throughout the watershed along with a small hobby farm with about 6 alpacas located on Nokomis Road in Corinna. No livestock was observed near Mulligan Stream.

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

Mulligan Stream
• 44.1 stream miles in watershed (includes ephemeral streams) • 0.88 stream miles in agricultural areas • **27%** of agricultural stream miles have a vegetated buffer

Mulligan Stream is a 4.8 mile-long impaired segment as listed by Maine DEP. As modeled, the total stream miles (including non-listed tributaries) within the watershed was calculated as 44.1 miles. Of this total, 0.88 stream miles are located within agricultural areas; of this length, 0.24 miles (27%) 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%.

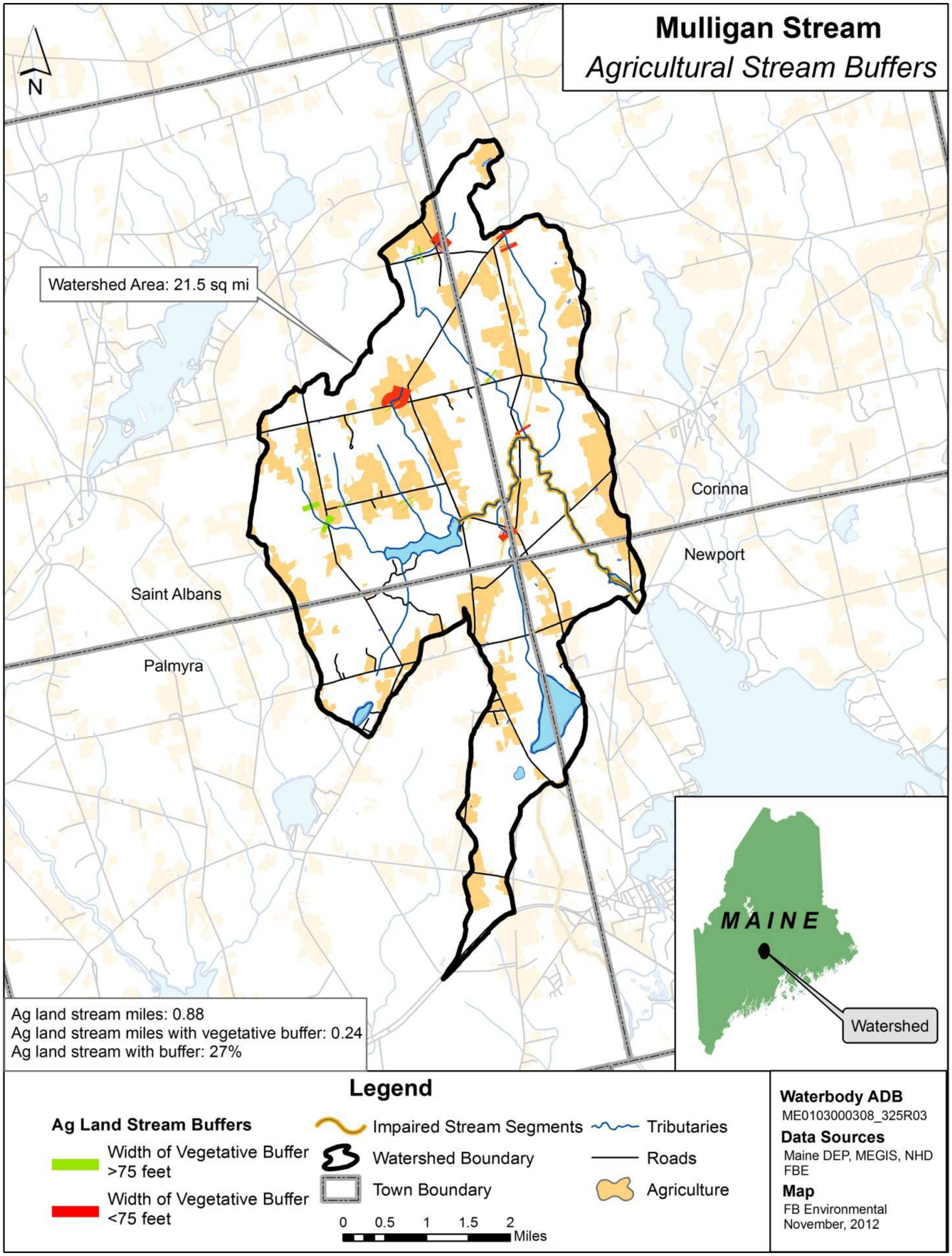


Figure 4: Agricultural Stream Buffer in the Mulligan Stream Watershed

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 an 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 Mulligan Stream watershed is 8% wetland, and overall 27% 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 Mulligan Stream indicate that significant reductions of sediment and nutrients are needed to improve water quality. Below, loading for sediment, nitrogen and phosphorus are discussed individually.

Sediment

Sediment loading in the Mulligan Stream watershed is mainly derived from crop land with combined agricultural sources making up 78% of the total sediment load (Table 5 and Figure 5). High density mixed development also contributes a significant portion of the load at 16%, respectively. 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 Mulligan Stream* below for loading estimates that have been normalized by watershed area.

Table 5: Total Sediment Loads by Source

Mulligan Stream	Sediment (1000kg/year)	Sediment (%)
Source Load		
Hay/Pasture	8.04	5%
Crop land	119.65	73%
Forest	7.51	5%
Wetland	0.29	0%
Disturbed Land	0	0%
Low Density Mixed	0.86	1%
Medium Density Mixed	0	0%
High Density Mixed	26.92	16%
Low Density Residential	0.16	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	0	0%
Septic Systems	0	0%
Source Load Total:	**163.43**	**100%**
Pathway Load		
Stream Banks	43.38	-
Subsurface / Groundwater	0	-
Total Watershed Mass Load:	**206.81**	

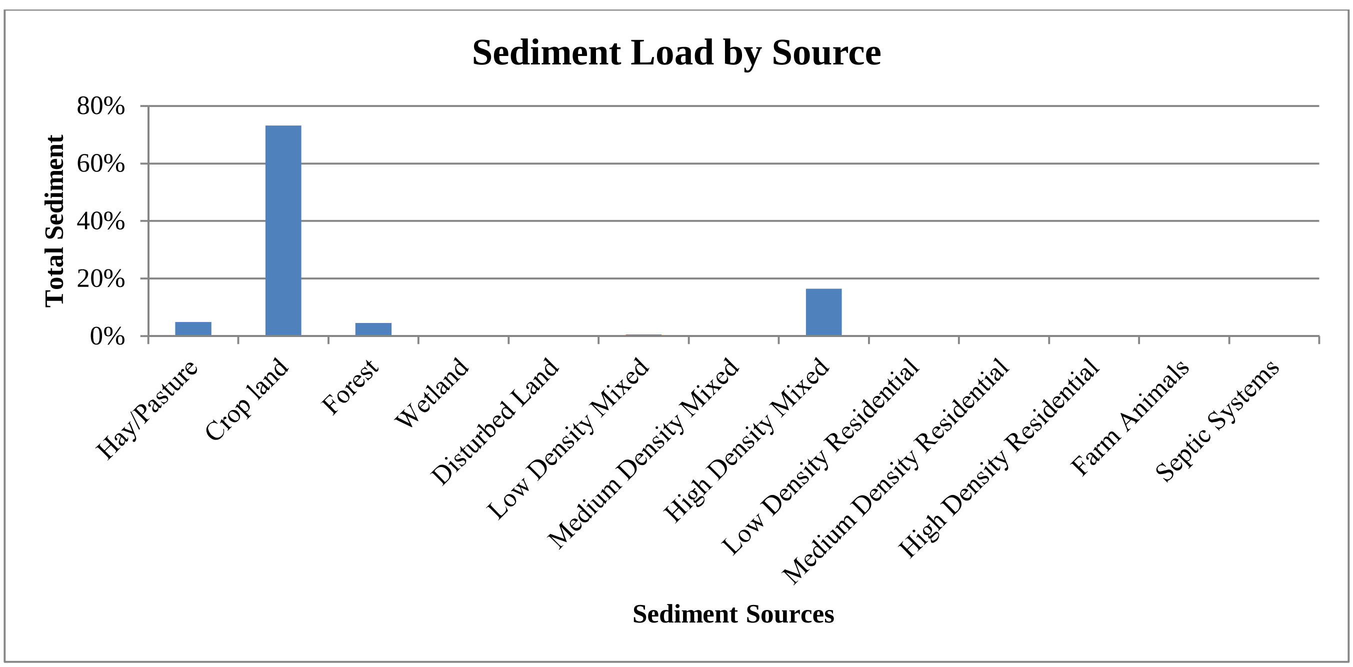


Figure 5: Total Sediment Loads by Source in the Mulligan Stream Watershed

Total Nitrogen

Nitrogen loading in Mulligan Stream is primarily attributed to crop land with combined agricultural sources making up just under 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 Mulligan Stream. 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 Mulligan Stream* below for loading estimates that have been normalized by watershed area.

Table 6: Total Nitrogen Loads by Source

Mulligan Stream	**Total N (kg/year)**	**Total N (%)**
Source Load		
Hay/Pasture	711.4	6%
Crop land	6898.9	58%
Forest	1645.4	14%
Wetland	384.1	3%
Disturbed Land	0	0%
Low Density Mixed	27.4	0%
Medium Density Mixed	0	0%
High Density Mixed	1307.2	11%
Low Density Residential	5.0	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	521.2	4%
Septic Systems	340.6	3%
Source Load Total:	**11841.1**	**100%**
Pathway Load		
Stream Banks	33.9	-
Subsurface / Groundwater	31770.1	-
Total Watershed Mass Load:	**43645.0**	

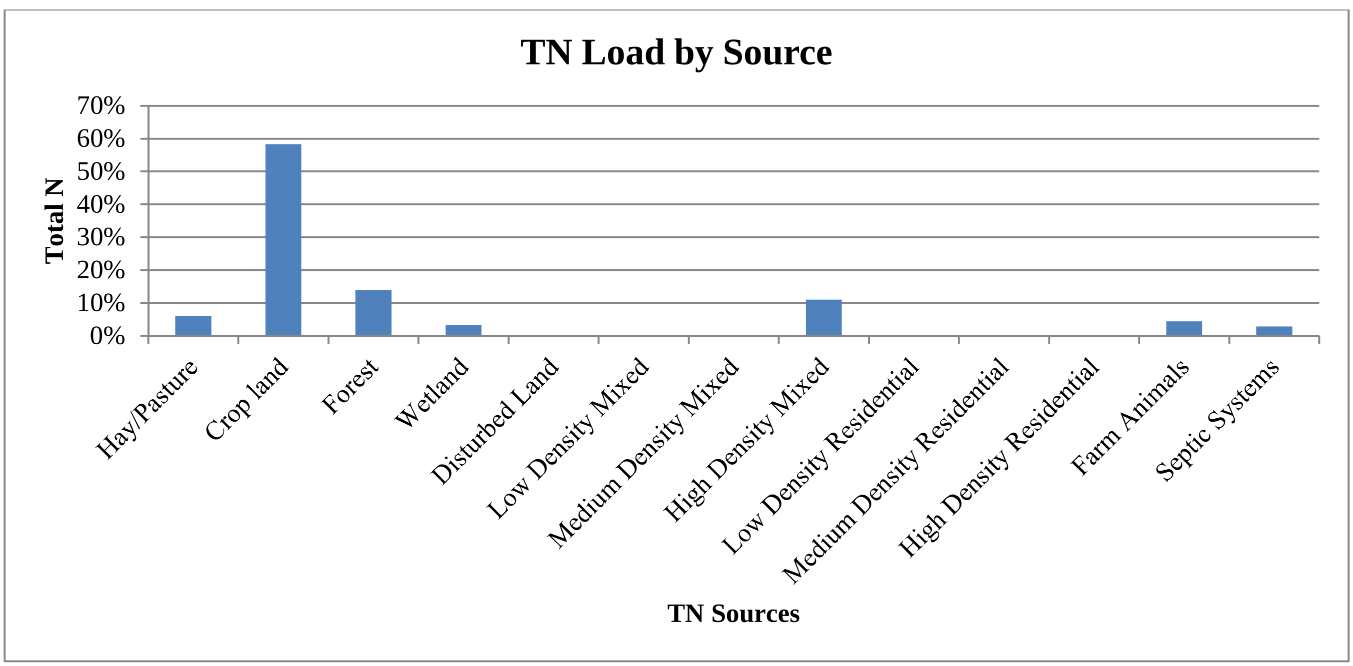


Figure 6: Total Nitrogen Loads by Source in the Mulligan Stream Watershed

Total Phosphorus

Phosphorus loading in the Mulligan Stream watershed is primarily attributed to crop land and hay/pasture. Combined agricultural sources make up 81% of the total load. Phosphorus loads are presented in Table 7 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 Mulligan Stream* below for loading estimates that have been normalized by watershed area.

Table 7: Total Phosphorus Loads by Source

Mulligan Stream	Total P (kg/year)	Total P (%)
Source Load		
Hay/Pasture	283.0	21%
Crop land	748.4	54%
Forest	89.0	6%
Wetland	19.5	1%
Disturbed Land	0	0%
Low Density Mixed	3.0	0%
Medium Density Mixed	0	0%
High Density Mixed	130.7	9%
Low Density Residential	0.5	0%
Medium Density Residential	0	0%
High Density Residential	0	0%
Farm Animals	99.9	7%
Septic Systems	2.3	0%
Source Load Total:	**1376.2**	**100%**
Pathway Load		
Stream Banks	12.9	-
Subsurface / Groundwater	642.8	-
Total Watershed Mass Load:	**2031.9**	

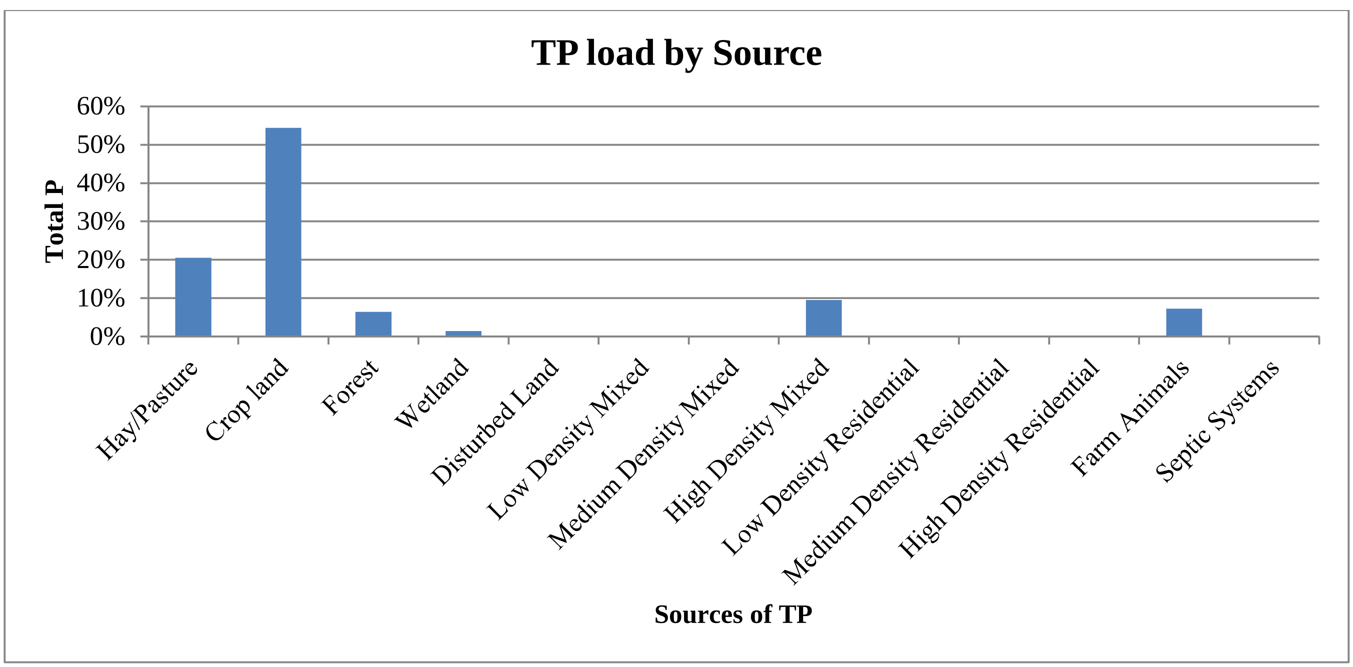


Figure 7: Total Phosphorus Loads by Source in the Mulligan Stream Watershed

TMDL: TARGET NUTRIENT LEVELS FOR MULLIGAN STREAM

The existing loads for sediments and nutrients in the impaired segment of Mulligan Stream 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 Mulligan Stream 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 Mulligan Stream Pollutant Loading

TMDL POLLUTANT LOADS Annual Loads per Unit Area	**Estimated Loads Mulligan Stream**	**Total Maximum Daily Load Numeric Target**	**TMDL % REDUCTIONS Mulligan Stream**
Sediment Load *(1000 kg/ha/year)*	**0.038**	**0.030**	**20%**
Nitrogen Load *(kg/ha/year)*	**7.94**	**5.2**	**35%**
Phosphorus Load *(kg/ha/year)*	**0.37**	**0.24**	**34%**

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 Mulligan Stream. 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 Mulligan Stream watershed because Somerset County has increasing population trends, with a 1% increase between 2000 and 2008 (USM MSAC, 2009). The growth in agricultural lands are also increasing, with a 12% increase in the total number of farms in Somerset County between 2002 and 2007, and a 1% increase in the land (acres) in farms between 2002 and 2007. However, a 10% decrease occurred in the average farm size in this time period (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 Mulligan Stream. It is recommended that municipal officials, landowners, and conservation stakeholders in St. Albans, Corinna and Newport 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 Mulligan Stream;
- Address existing nonpoint source problems in the Mulligan Stream watershed by instituting BMPs where necessary; and
- Prevent future degradation of Mulligan Stream 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 Mulligan Stream

Mulligan Stream				
	Area ha	**Sediment 1000kg/yr**	**TN kg/yr**	**TP kg/yr**
Land Uses				
Hay/Pasture	455	8.1	711.4	283.0
Crop land	797	119.7	6898.9	748.4
Forest	3492	7.5	1645.4	89.0
Wetland	428	0.3	384.1	19.5
Disturbed Land	0	0.0	0.0	0.0
Low Density Mixed	33	0.9	27.4	3.0
High Density Mixed	288	26.9	1307.2	130.7
Low Density Residential	6	0.2	5.0	0.5
Other Sources				
Farm Animals			521.2	99.9
Septic Systems			340.6	2.3
Pathway Loads				
Stream Banks		43.4	33.9	12.9
Groundwater			31770.1	642.8
Total Annual Load		207 x 1000 kg	43645 kg	2032 kg
Total Area	5499 ha			
Total Maximum Daily Load		**0.038 1000kg/ha/year**	**7.94 kg/ha/year**	**0.37 kg/ha/year**

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