Total Maximum Daily Load (TMDL) Report

Dudley Brook
Aroostook County, Maine

Prepared for:

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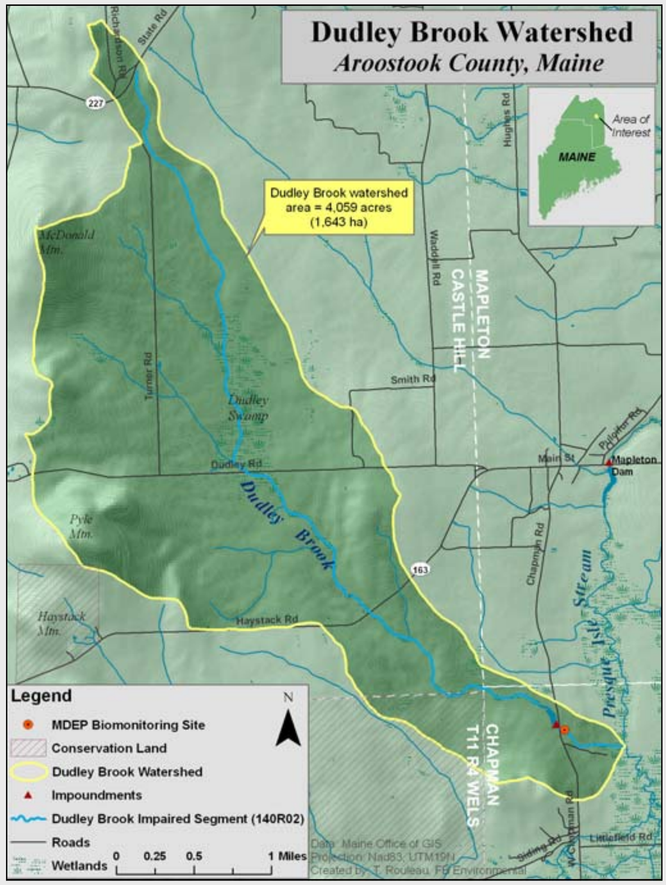
Dudley Brook above impoundment near West Chapman Road, 2008.

Dudley Brook TMDL Summary Fact Sheet

Description of the Watershed

The Dudley Brook watershed is part of the larger Aroostook River watershed (HUC 0101004) in Maine and New Brunswick. It's headwaters begin in the Town of Castle Hill, Maine. The stream flows southeast through Castle Hill before terminating at its confluence with Presque Isle Stream just east of West Chapman Road in Chapman. Dudley Brook, designated a Class A stream, is approximately 6.4 miles in length and has a drainage area of 4,059 acres (1,643 ha). The entire length of Dudley Brook is classified as impaired according to Maine's 2008 305 (b) list of waters that do not meet State water quality standards (Maine DEP 2008).



Land use in the Dudley Brook watershed is a mix of forested areas and agriculture with sparse residential development along roadways. The northern half of the watershed is predominantly forested, and the southern half is dominated by agricultural fields. The area topography is defined by gently rolling hills and lowlands with elevations ranging from 500 feet to 1,280 feet.

Why do a 'TMDL' on Dudley Brook?

Dudley Brook is impaired due in large part to nutrients and sediments transported by **nonpoint source (NPS)** runoff resulting from anthropogenic activities within the watershed. All land disturbances have the potential to contribute runoff, but the degree of disturbance associated with agricultural land is likely the greatest contributor of silt and nutrient enrichment to the stream. Streams such as Dudley Brook that do not meet Maine's water quality standards are called impaired and placed on the **303(d) list**. Dudley Brook violates Maine's standards for aquatic life. The Clean Water Act requires that all 303(d) listed waters undergo a **TMDL** assessment that describes the impairments and identifies the measures needed to restore water quality. The goal is for all waterbodies to comply with each state's water quality standards.

Sampling Results & Pollutant Sources

The Dudley Brook TMDL is based on sampling data collected in 1994 and 1999 which includes monitoring of the macroinvertebrate community and water chemistry. Sampling results were compared to Maine's statutory Class A water quality standards and the stream was listed due to non-attainment of aquatic life criteria.

Dudley Brook (Spring 2008): *Bare soil on agricultural fields contributes sediment and nutrients to Dudley Brook.*

Macroinvertebrate populations indicate a combination of intricate environmental factors. Aquatic life impairment is likely due to sedimentation and runoff containing a variety of pollutants associated with agricultural stormwater runoff. Agricultural land encompasses the second-largest land area in the Dudley Brook watershed (after forested land), making it potentially a large contributor of silt and nutrient enrichment to the stream, particularly in the lower reaches of the watershed.

A watershed model, Generalized Watershed Loading Functions (GWLF), was used to simulate the nonpoint source loading of the pollutants of concern, i.e. nitrogen, phosphorus and sediment, to Dudley Brook. Maine does not have numeric water quality standards for nutrients or sediment, so numeric endpoints were developed by comparing Dudley Brook to unimpaired (attainment) watersheds with similar land use characteristics. It is assumed that the GWLF model results for these streams will provide reasonable targets to achieve attainment in Dudley Brook.

Required TMDL Elements and GWLF Modeling Results

The GWLF model results indicate that reductions of nutrients and sediments are needed to improve the water quality of Dudley Brook. Cropland is the largest source of sediment to Dudley Brook, accounting for an estimated 95% of the total sediment load within the watershed. Cropland is also the dominant source of phosphorus in the watershed, while nitrogen loading is attributed to both groundwater and cropland.

Estimated Reductions Needed by Pollutant Type for Dudley Brook

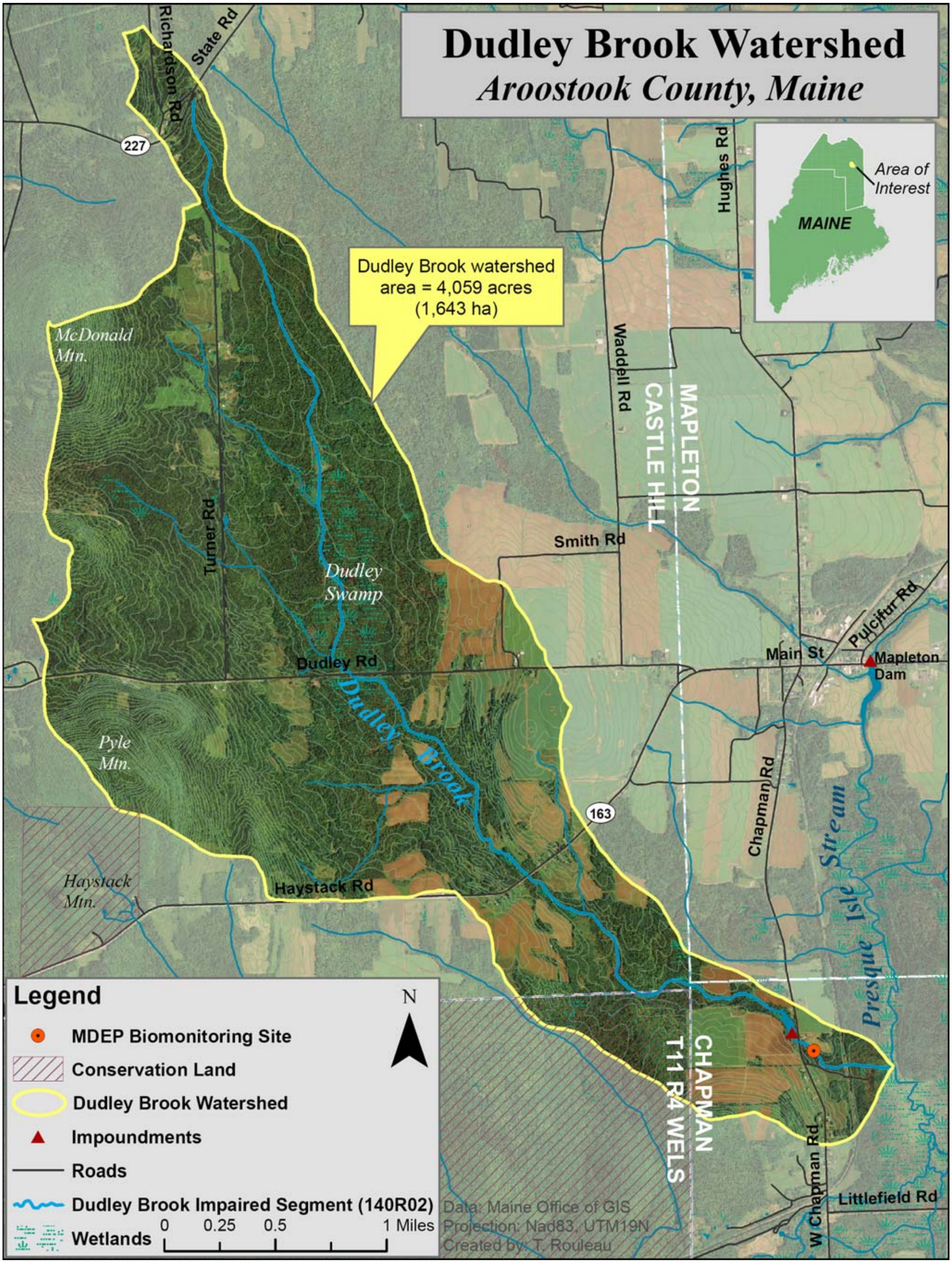
TMDL Pollutant Loads *(unit area loads)*	**Dudley Brook TMDL % Reductions**
Phosphorus Load (kg/ha/year)	25%
Nitrogen Load (kg/ha/year)	30%
Sediment Load (t/ha/year)	50%

The Dudley Brook TMDL report contains elements required by the Clean Water Act. The ultimate goal of the TMDL process is to attain water quality standards in Dudley Brook. The target goals above provide technical guidance to initiate a strategy for **BMP** implementation. Reversing long term degradation from anthropogenic activities in the watershed over many decades will require careful planning and effort that includes local stewardship, instream restoration and attention to cumulative impacts. A watershed survey should be conducted to identify all potential nutrient/ sediment sources with a major emphasis on implementing Best Management Practices on agricultural land.

Definitions

- **303d List** *identifies water quality limited waters within the state, the causes and sources of nonattainment standards, and a timetable for the development of TMDLs.*
- **TMDL** *is an acronym for* ***Total Maximum Daily Load****, representing the total amount of a pollutant that a waterbody can receive annually and still meet water quality standards.*
- **Nonpoint Source (NPS) Pollution** *comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into waterbodies.*
- **BMPs or Best Management Practices** *are engineered solutions or techniques designed to reduce the impacts of developed impervious cover, pollutants, and the altered flow associated with stormwater runoff.*

Figure 1. Map of the Dudley Brook Watershed showing the impaired stream segment (140R02), which flows into Presque Isle Stream in Chapman.



1. DESCRIPTION OF WATERBODY, POLLUTANT OF CONCERN, POLLUTANT SOURCES AND PRIORITY RANKING

Description of Waterbody and Watershed

Dudley Brook (HUC 8 01010004) originates south of Route 277 in the Town of Castle Hill in Aroostook County, Maine (Figure 1). The 6.4-mile stream flows south through Dudley Swamp, and then southeasterly until it crosses the Chapman town line, before eventually meeting up with Presque Isle Stream east of Chapman Road. Just west of Chapman Road, there is a small dam on the stream, creating a 3-acre (1.2 hectare) impoundment. Dudley Brook drains approximately 4,059 acres (1,643 hectares) in the Towns of Castle Hill (90%), Chapman (7%), Mapleton (<1%), and the unorganized territory of T11 R4 WELS (3%). Three unnamed tributaries flow into Dudley Brook from the west.

Dudley Brook flows over a small dam just west of Chapman Road.

Land use in the watershed is a mix of forested and agricultural land with sparse residential development along roadways. The northern half of the watershed is generally forested, and the southern half is dominated by agricultural fields. Potatoes are the most prominent crop in the region. Watershed elevations range from approximately 500 feet to 1,280 feet, with the highest points being Pyle Mountain (~1,280 feet) and McDonald Mountain (~1,130 feet) on the western side of the watershed. Soils in the watershed are generally mapped as Aurelie-Daigle-Perham-Burnham. These loamy soils, with common surface stones, are formed in till derived mainly from slate, phyllite, and metasandstone (Ferwerda et al. 1997).

Agricultural fields are located primarily in the southern half of the Dudley Brook watershed.

Impaired Stream Segment

The entire length (6.41 miles) of Dudley Brook, classified as a Class A stream, was included in Maine's 2008 305(b) list (Maine DEP 2008) of waters that do not meet State water quality standards (Table 1). The listing was based on stream assessment and sampling results from the Biological Monitoring Program of the Maine Department of Environmental Protection (Maine DEP) conducted in 1994 and 1999. At the time of monitoring, due to aquatic life violations, Dudley Brook only met classifications for Class C streams.

Table 1. The status of impairment for Dudley Brook and the TMDL development priority as documented on the 2008 303(d) List.

ASSESSMENT UNIT ID	SEGMENT NAME	CAUSE	SEGMENT SIZE	SEGMENT CLASS	TMDL PRIORITY
ME0101000412 _140R02	Dudley Brook (Chapman)	Benthic-Macroinvertebrate Bioassessments	6.41 miles	Class A	2008

Descriptive Land Use Information

Analysis using 2004 land cover data from Maine DEP (MELCD) shows that land uses in the Dudley Brook watershed are dominated by forest land (69%) and cultivated land (18%) (Figure 2). The remaining 13% of the Dudley Brook watershed is comprised of wetland (6%), hay/pasture land (5%), low intensity development (2% - low density residential development with impervious surfaces from 21 to 49%), high intensity development (<1% - with impervious surfaces from 50 to 100%), and non-vegetated/disturbed land (<1%).

The northern portion of the watershed is predominantly forested, with some hay/pasture land, and low density residential development along Dudley Road and Turner Road (Figure 3). The southern portion of the watershed is primarily cultivated land, with smaller areas of hay/ pasture land, and low density residential development along Haystack Road, West Chapman Road, and Dudley Road.

Agricultural land occupies 23% of the Dudley Brook watershed, which includes cultivated land and hay/pasture.

Figure 2. Land uses in the Dudley Brook watershed.

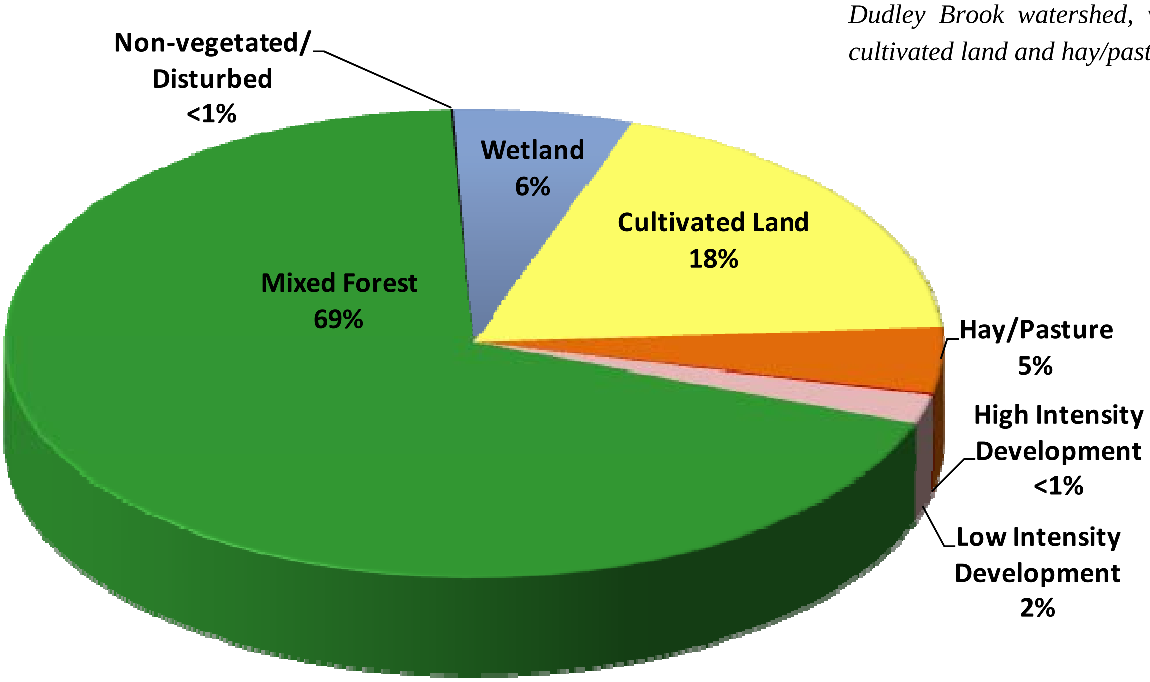
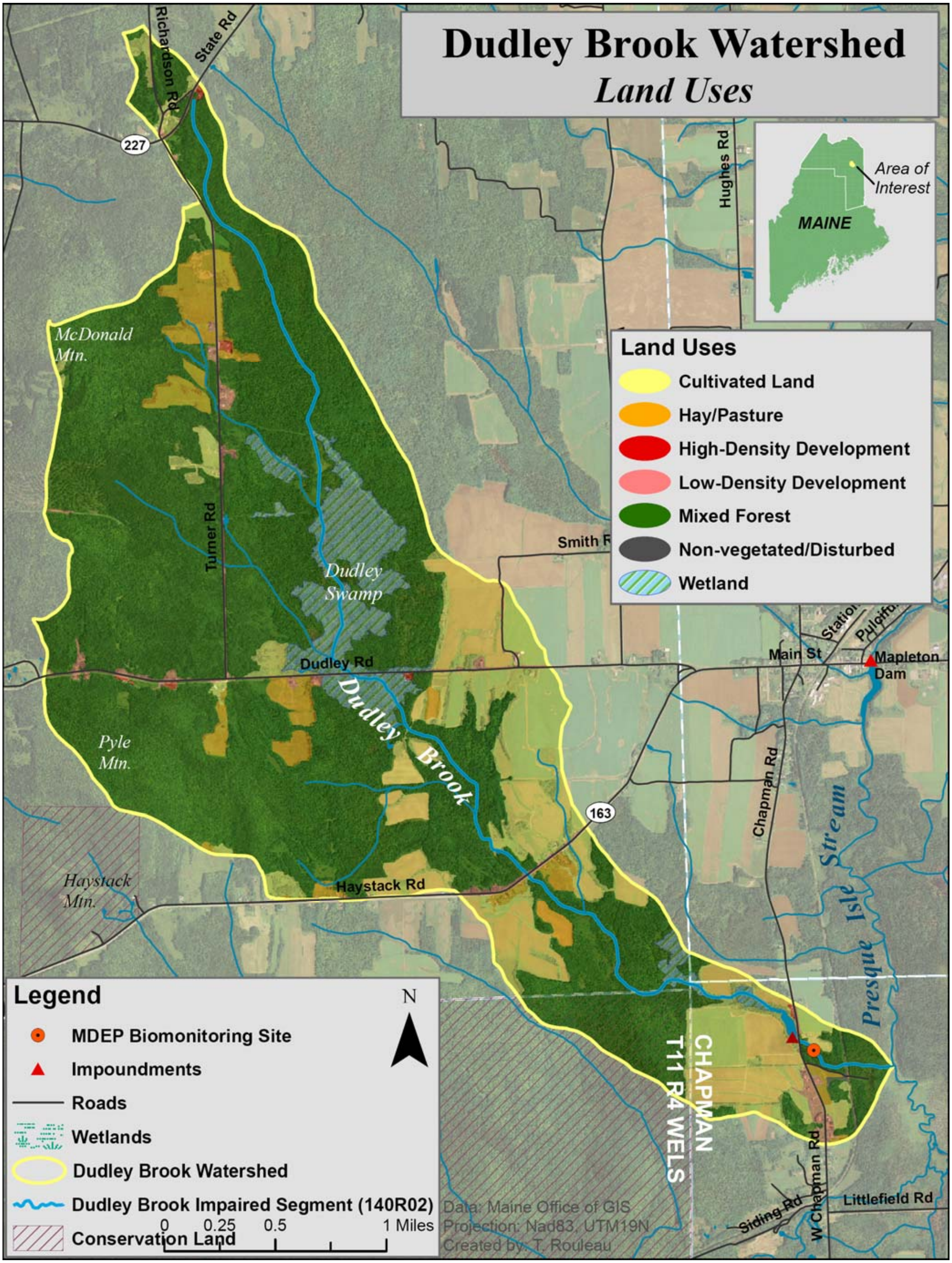


Figure 3. Dudley Brook Watershed Land Use Map.



Pollutant Sources, Description of Impairments & Sampling Results

Dudley Brook is impaired by nonpoint source runoff primarily from anthropogenic activities within the watershed. All land disturbances have the potential to contribute runoff, but the degree of disturbance associated with agricultural land is likely the greatest contributor of silt and nutrient enrichment to the stream. The close proximity of these land uses to the stream in the lower portions of the watershed increases the likelihood that the disturbed and bare soil will reach the stream.

Maine DEP biologists sampled Dudley Brook for aquatic life or macroinvertebrate populations in 1994 and 1999. Although Dudley Brook is a statutory Class A stream under Maine's Water Classification system, sampling results (in Table 2 below) indicate that aquatic life did not meet the Class A criteria and instead attained the lower Class C criteria (Hoppe 2008, Tsomides 1999). Macroinvertebrate populations indicate a combination of intricate environmental factors, and no single factor is commonly the cause of macroinvertebrate impairments under the influence of nonpoint source stressors. Nutrient enrichment, and general degradation of the stream habitat due to sedimentation and physical alterations are essential contributors to the observed impairments.

Table 2. Maine DEP biomonitoring sampling results for Dudley Brook below West Chapman Road.

SAMPLING STATION	SAMPLING DESCRIPTION AND LOCATION	STATUTORY CLASS	SAMPLING RESULTS	DATE SAMPLED
Dudley Brook (S-215)	Below West Chapman Road	Class A	Class C	1994
Dudley Brook (S-215)	Below West Chapman Road	Class A	Class C	1999

Pollutants of Concern

This TMDL addresses instream constituents for Dudley Brook that are the primary contributors to the habitat degradation that is the likely cause of aquatic life violations. Elevated nutrient loading and accumulation contributes to excess algae growth, which consumes oxygen during respiration and depresses dissolved oxygen (DO) levels. Phosphorus and nitrogen are the major limiting nutrients for algae growth and are pollutants of concern in Dudley Brook.

Excess sediment contributions to the stream are symptomatic of habitat degradation and reduced suitability for a wide spectrum of aquatic life. Over time, sedimentation alters habitat by filling in pools, embedding substrate in riffles and contributing nutrients. These factors then alter habitat suitability, which in turn shifts the composition of organisms adapted to living in the stream. While sediment is not the only factor affecting habitat in the dynamic stream environment, it is a significant contributor and provides a reasonable surrogate for aquatic habitat degradation in this TMDL.

A watershed model, GWLF (Appendix 1), was used to simulate the nonpoint source loading of the pollutants of concern, i.e. nitrogen, phosphorus and sediment. Maine does not have numeric water quality standards for nutrients or sediment so numeric endpoints were developed by comparing Dudley Brook to unimpaired (attainment) watersheds, with similar land use characteristics.

Priority Ranking and Listing History

The large numbers of streams listed for nonpoint source pollution on the 303(d) list requires Maine to set priority rankings based on a variety of factors. Factors include the severity of degradation, the duration of the impairment, and the opportunities for remediation. Maine has set priority rankings for 303(d) listed streams by TMDL completion date, and has designated Dudley Brook for completion in 2008.

Dudley Brook near West Chapman Road, 2008.

Atmospheric Deposition

Atmospheric deposition of nutrients that fall within a watershed will reach a stream through runoff from land deposited material, and direct contact with rain and dry airborne material that settles on the stream surface. It is assumed that the soil buffers and adsorbs most atmospherically deposited nutrients before they reach the stream through the runoff processes.

Natural Background Levels

As is true of all watersheds with a history of human habitation, the Dudley Brook watershed is not pristine and nonpoint source loading has resulted from human related activities. Natural environmental background levels for Dudley Brook were not separated from the total nonpoint source load because of the limited and general nature of available information. Without more detailed site-specific information on nonpoint source loading, it is very difficult to separate natural background from the total nonpoint source load (USEPA 1999).

2. DESCRIPTION OF THE APPLICABLE WATER QUALITY STANDARDS AND NUMERIC WATER QUALITY TARGET

Maine State Water Quality Standard

Dudley Brook is classified as a Class A stream under Maine’s Water Classification Program. Water quality standards and water quality classification of all surface waters of the State of Maine have been established by the Maine Legislature (Title 38 MRSA 464-467). By definition, discharges to Class A waters shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the resident biological community.

Designated Uses and Antidegradation Policy

Dudley Brook is listed as Class A water and does not attain classification due to aquatic life impairments. Class A waters and their designated uses are defined under Maine’s Water Quality Classification Program, Maine Revised Statutes, Title 38, Article 4-A. Class A waters are generally designated for: drinking water after disinfection; fishing; agriculture; recreation in and on the water; industrial cooling water supply; hydroelectric power generation; navigation; water supply; and habitat for fish and aquatic life. Additionally, “The habitat shall be characterized as natural." Maine's anti-degradation policy requires that "existing in-stream water uses and the level of water quality necessary to sustain those uses, must be maintained and protected." MEDEP must consider aquatic life, wildlife, recreational use and social significance when determining 'existing uses'.

Numeric Water Quality Target

Numeric nutrient and sediment targets for Dudley Brook were established by comparing the Dudley Brook watershed to attainment watersheds in the same geographical region. In order to produce realistic targets, the attainment watersheds need to share similar landscape, development and agricultural patterns. No statutory Class A stream could be found that meet these criteria, but two nearby watersheds that attain Class A standards were selected. Moose Brook and B Stream are designated as statutory Class B streams, but have been documented to attain Class A standards for aquatic life and dissolved oxygen (Table 3). Since these streams attain Class A, it is assumed that the AVGWLF model results for these streams will provide reasonable targets to achieve attainment in Dudley Brook. Details of stream characteristics and model comparison can be found in the 'Modeling Report to Support TMDL Development for Dudley Brook' (Appendix 1).

A comparative attainment approach requires identical modeling procedures be applied to all watersheds, which is documented in Appendix 1. Numeric endpoints are derived from modeling results for total phosphorus, total nitrogen and sediment in Moose Brook and B Stream (Table 4). An average of the unit area loads was chosen for the numeric target needed to obtain designated uses.

Table 3. Maine DEP Biomonitoring Sampling Results for Moose Brook and B Streams in Aroostook County.

STREAM	STATION, TOWN	DATE SAMPLED	SAMPLING PARAMETER	ANALYSIS/ RESULTS	CLASS ATTAINMENT
B Stream	464, Houlton & 465, Hammond	1999	Macroinvertebrate Pro-tocols	Model	A
B Stream	464, Houlton & 465, Hammond	2000	Macroinvertebrate Pro-tocols	Model	A
B Stream	464, Houlton	2004	Dissolved Oxygen	>7 pmm	A
Moose Brook	466, Houlton & 467, Ludlow	1999	Macroinvertebrate Pro-tocols	Model	A
Moose Brook	466, Houlton & 467, Ludlow	2000	Macroinvertebrate Pro-tocols	Model	A
Moose Brook	466, Houlton	2005	Dissolved Oxygen	>7 pmm	A
Moose Brook	467, Ludlow	2004	Dissolved Oxygen	>7 pmm	A

Source: Maine DEP Biomonitoring Database, 2008)

Table 4. Numeric loading endpoints for pollutants of concern, based on GWLF modeling results (Appendix 1).*

POLLUTANTS	REFERENCE WATERBODIES		NUMERIC TARGET
Annual Unit ** Area Loads	Moose Brook	B Stream	Average for Waterbodies
Phosphorus Load (kg/ha/year)	0.24	0.17	0.21
Nitrogen Load (kg/ha/year)	5.8	3.8	4.8
Sediment Load (t/ha/year)	0.03	0.01	0.02

***** *The TMDL loads can be expressed as a daily maximum load by dividing the annual averages above by 365.*

****** *1 kg/ha/year = 0.892 lbs/acre/year, and 1 t/ha/year = 809.37 lbs/acre/year*

3. LOADING CAPACITY - LINKING WATER QUALITY AND POLLUTANT SOURCES

Loading Capacity & Linking Pollutant Loading to a Numeric Target

The loading capacity is the mass of constituent pollutants that Dudley Brook can receive over time and still meet numerical water quality targets. Loading capacity is expressed as an annual load and a daily load to normalize the spatial and temporal variation associated with instream nonpoint source pollutant concentrations. The loading capacity is based on a comparative attainment approach to set the allotment for existing and future nonpoint sources that will ensure support for existing and designated uses. The GWLF model output (Appendix 1) expresses pollutants in terms of landuse-based loads which have been broken down into a unit area basis for comparative purposes. Table 4 lists the loading targets or assimilative capacity for comparisons between the attainment watersheds and Dudley Brook in subsequent TMDL analysis.

Supporting Documentation - TMDL Approach

The TMDL approach includes measuring various environmental parameters and developing a water quality model to estimate pollutant loadings and reductions that will ensure attainment of Maine's water quality standards. The Dudley Brook TMDL analysis uses the GWLF model to estimate pollutant loadings (Appendix 1). GWLF is an established midrange modeling tool that uses landuse runoff coefficients, universal soil loss equations and rainfall inputs to compute flow and pollutant loads. The model was run for all watersheds under consideration (impaired and attainment) for a 15-year period to capture a wide range of hydrologic conditions to account for variations in nutrient and sediment loading over time. To estimate the TMDL reductions needed to attain water quality standards, the GWLF model results are used to calculate the existing load in Dudley Brook and the attainment watersheds. The difference between the impaired and attainment watershed is the reduction needed to achieve water quality criteria for all nonpoint source pollutants of concern.

Strengths and Limitations

The TMDL uses a GWLF model analysis (Appendix 1) of existing and target loads to compute reductions needed to achieve water quality standards.

Model Strengths:

- GWLF is an established midrange model that is commonly accepted to calculate pollutant loads in river and stream TMDLs.
- The GWLF model was created using regional input data to reflect local conditions to the greatest extent possible.
- The model makes best use of available landuse data to estimate nonpoint source loads.
- The model was run for a 15-year period to account for a wide range hydrologic conditions among years.
- An attainment approach is a reasonable mechanism to establish criteria for pollutants of concern, where no regulatory numeric criteria exists.

Model Limitations:

- The GWLF model is a screening-level model that provides a general estimate of watershed nutrient-loading conditions.
- This GWLF model has not been calibrated to observations of nutrients, sediment, or streamflow volumes in the Dudley Brook or attainment watersheds.
- No effort has been made to account for changes to the conditions of the watershed that have occurred since the development of the data used to create model inputs.
- The GWLF model does not account for forested riparian buffers.

Critical assumptions used in the GWLF modeling report:

- Meteorological data were assumed to be representative of the watersheds, although the stations are located outside of the watershed.
- Septic system failure rates are assumed to be similar to failure rates for rural communities in upstate New York in 1990.
- Values for parameters reported in the Northeast GWLF report (Penn. State 2007) are assumed to be representative of conditions in the Aroostook County watersheds.
- Forest land in the model is considered naturally forested, and does not account for forestry operations.

Dudley Brook watershed, 2008.

Critical Conditions

The loading capacity for Dudley Brook is set to protect water quality and support uses during critical conditions, defined as environmental conditions that induce a stress response in aquatic life. Environmentally stressful conditions may occur throughout the year and depend on the biological requirements of the life stage of resident aquatic organisms. Traditionally, summer low flow periods are considered critical for aquatic organisms due the combination of low velocity, high temperatures and low dissolved oxygen. Critical condition is complex in flowing water and a major consideration in using an average annual load approach for nonpoint source TMDLs.

TMDL Loading Calculations

The estimated annual loads for nutrients and sediments in Dudley Brook are listed in Figures 4 and 5 (next page). Appendix 1, the 'Modeling Report to Support TMDL Development for Dudley Brook' describes the GWLF modeling results and calculations used in Figures 4 and 5 to define TMDL reductions. An annual time frame provides a mechanism to address the daily and seasonal variability associated with nonpoint source loads. As previously mentioned, it was not possible to separate natural background from nonpoint pollution sources in this watershed because of the limited and general nature of the available information.

Figures 4 and 5 also compare the estimated nutrient and sediment loads in Dudley Brook to the TMDL endpoints derived from attainment streams (Table 4). Figures 4 and 5 graphically compare the modeling results between the watersheds and estimates of the reductions needed to achieve compliance with Maine's Class A water quality standards in the impaired stream. The percent reductions will be applied to load and waste load allocations.

Future Loading

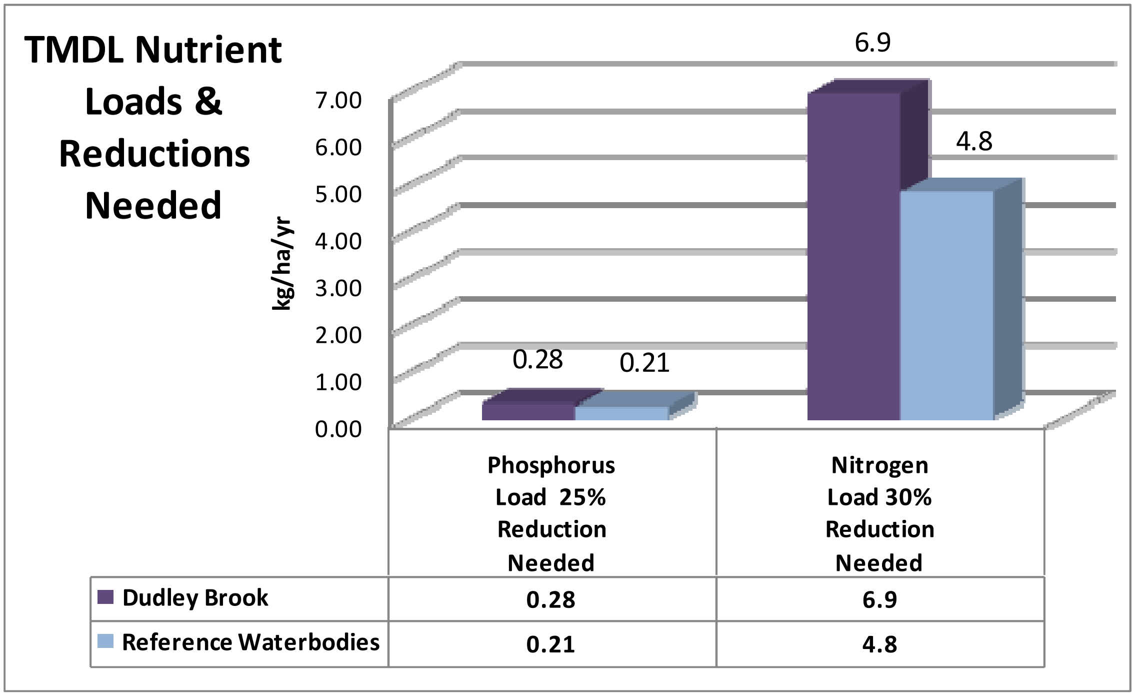
The prescribed reduction in pollutants discussed in the TMDL reflects reduction from estimated existing conditions. Expansion of agricultural and development activities have the potential to increase runoff and associated pollutants. To ensure that the TMDL targets are attained, future agriculture or development activities will need to meet the TMDL targets. Future growth from population increases is a minimal threat in the Dudley watershed because Aroostook County has declining population trends, with a 15% drop between 1990 and 2000, and a 2.3% from 2000 to 2007. The growth in agricultural lands is mixed, with a steady decline in the total acres

Table 5. Load Allocations and Waste Load Allocations for pollutants in the Dudley Brook TMDL.

TMDL= LA + WLA	***Nutrients***		***Sediment***
	Phosphorus Load (kg/ha/year)	Nitrogen Load (kg/ha/year)	Sediment Load (t/ha/year)
Load Allocations (LA)	0.21	4.8	0.02
Waste Load Allocations (WLA)	0	0	0
Loading Capacity (TMDL)	0.21	4.8	0.02

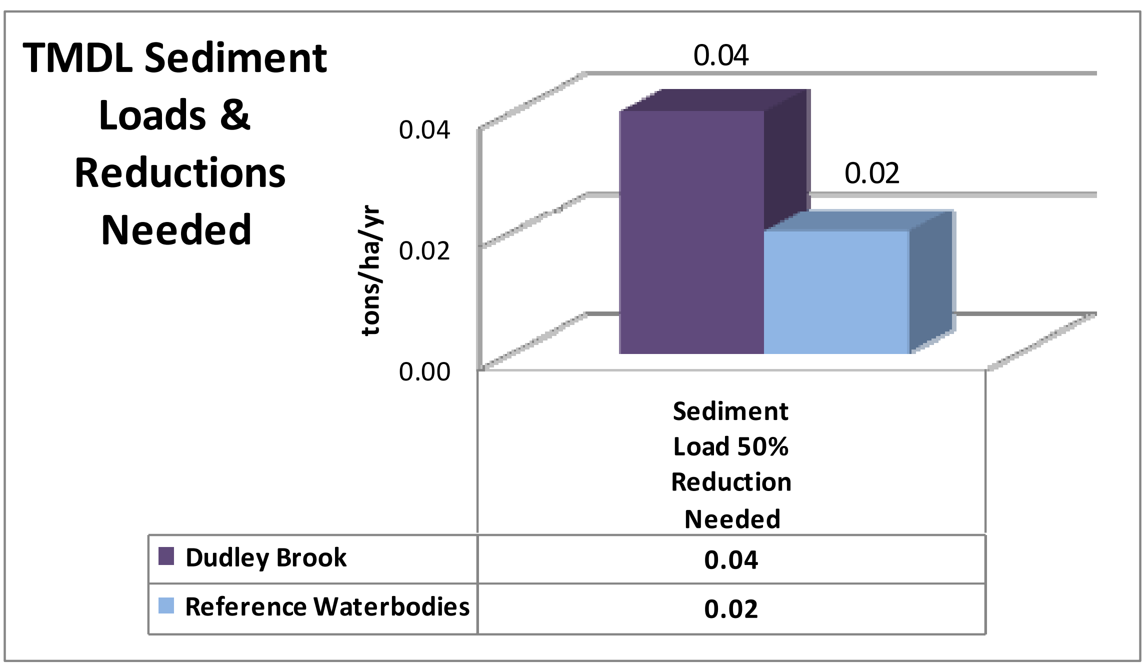
** 1 kg/ha/year = 0.892 lbs/acre/year, and 1 t/ha/year= 809.37 lbs/acre/year*

Figure 4. Nutrient load estimates compared between the Dudley Brook and attainment watersheds, and reductions needed to achieve compliance with Maine's Class A water quality standards in the impaired stream segment.



** 1 kg/ha/year = 0.892 lbs/acre/year*

Figure 5. Sediment load estimates compared between the Dudley Brook and attainment watersheds, and reductions needed to achieve compliance with Maine's Class A water quality standards in the impaired stream segment.



** 1 ton/ha/year = 809.37 lbs/acre/year* farmed from 1974 to 1997, and a smaller increase from 1997 to 2002 (NMDC 2007). Future activities and BMPs that achieve TMDL reductions are addressed in the updated Watershed Management Plan (prepared by watershed stakeholders with support from Maine DEP).

4. LOAD ALLOCATIONS (LA's)

The load allocation (LA) for each of the candidate pollutants in Dudley Brook are listed in Table 5. On an annual basis, the LA represents the stream's assimilative capacity allocated to only nonpoint sources of nutrients and sediments. All pollutant sources in these calculations are assigned LAs, representing nonpoint sources from anthropogenic activities including roadways and agricultural inputs for which there are no associated discharge or general permits. The reported LA's represent the entire length of Dudley Brook.

5. WASTE LOAD ALLOCATIONS (WLA's)

No portion of the Dudley Brook watershed is designated as an urban area and would not be subject to coverage under Maine's general permit for municipal separate stormwater sewer systems (MS4s). Stormwater associated with construction site activities over one acre would be subject to the MEPDES stormwater permit program, although those activities are expected to be short term and infrequent. Therefore, the waste load allocation is defined as 0 for all pollutants of concern.

6. MARGIN OF SAFETY (MOS)

A margin of safety was incorporated into the Dudley Brook TMDL through the selection of the numeric water quality target, based on watersheds (Moose Brook and B Stream) that attain Class A. AVGWLF calculates pollutant loads with minimal losses to the absorptive capacity of landscape conditions and BMPs that reduce the runoff the stream receives. The modeling process did not include riparian buffers and agricultural BMPs in the Dudley watershed that effectively reduce loading. A landuse runoff model, like AVGWLF, does not account for instream processes that attenuate nutrients and settle sediments during transit, which also reduces the pollutant load that moves through the system. These factors provide a MOS to account for uncertainty and reasonably insure that water quality standards will be attained in Dudley Brook.

Monitoring the water quality of Dudley Brook is essential to determine the affect of watershed improvements over time.

7. SEASONAL VARIATION

Seasonal variation is considered in the allowable annual loads of nutrients and sediment which protect macroinvertebrates and other aquatic life under the influence of seasonal fluctuations in environmental conditions such as flow, rainfall and runoff. All unregulated streams in Maine experience seasonal fluctuations in flow, which influences the instream concentration of nutrients and sediment. Typically, high flows occur during spring and fall and low flows occur during the summer and winter. Snow and rainfall runoff may contribute variable amounts of nutrients and sediment, while large volumes of runoff may also dilute instream nutrients and sediment concentrations, depending on the source.

8. MONITORING PLAN (EPA approval request for past TMDLs)

Addressing water quality impairments in Dudley Brook will require the identification and assessment of individual NPS pollution sites in the watershed. Once sites are identified, and BMPs have been applied, assessments should include stream monitoring to develop standards for post and pre-application comparisons. Water quality monitoring should be conducted to gauge effectiveness of any BMPs or engineered design solutions, as recommended in the 'Implementation Plans' section. As restoration plans proceed, Maine DEP will check on the progress towards attainment of Maine's Class A water quality standards with both water chemistry and biological monitoring evaluations. Also, Maine DEP's Biomonitoring Unit will check on water quality status or improvement in the future under the existing rotating basin sampling schedule. Since the last date of biological monitoring was nearly 10 years ago (1999), it is important to monitor the aquatic life in Dudley Brook in the immediate future.

A stakeholder group, which met for the first time in October 2008, suggested the following water quality monitoring recommendations: 1) sample in more than one location along the stream in order to isolate specific areas that need improvement; 2) conduct annual sampling for dissolved oxygen and temperature; 3) sample above and below the impoundment on West Chapman Rd.; 4) investigate a volunteer stormwater monitoring program organized by the Central Aroostook SWCD.

9. IMPLEMENTATION PLAN and REASONABLE ASSURANCES

The goal of this TMDL assessment of Dudley Brook is to use a midrange water quality model, GWLF (Appendix 1), to define pollutant loads and set water quality targets that will assure compliance with Maine's water quality standards. The nutrient and sediment reductions listed in the TMDL Allocations, Table 4, represent averages over the year (given the seasonal variation of runoff and ambient conditions), and demonstrate the need to reduce nutrient and sediment loads as the key to water quality restoration. The load reductions provide a guide for restoration plans and engineered solutions that will lower the content of nutrient and sediment in the runoff reaching the stream.

Recommendations

Watershed inventory and watershed planning are important first steps toward reducing sediment and nutrient inputs in Dudley Brook. Yet restoring a sustainable and functional aquatic community requires more than just planning and assessment. Reversing long term degradation from anthropogenic inputs will require planning and effort that include local stewardship, instream restoration and attention to cumulative impacts. An effective restoration approach should look to all potential nutrient/sediment sources including the impact of agricultural land, impervious surfaces such as roads and eroding road ditches, i and residential and commercial development.

Restoration of Dudley Brook requires the participation of the human inhabitants of the watershed. One key to success for long term restoration is having residents that care about the stream and are actively involved in the restoration process, or an active watershed organization. The initial Dudley Brook stakeholder meeting in October 2008 provides evidence that local residents are interested in restoring the water quality of Dudley Brook. Ideas developed at the stakeholder meeting are listed below, and will be included in a Watershed-Based Management Plan that can be used to guide future watershed efforts.

Recommendation Synopsis

- Establish a viable watershed organization
- Develop and implement a successful watershed management plan
- Collect recent water quality data, including water chemistry and biological information
- Conduct watershed and stream surveys to identify and address nutrient sources, sediment inputs, and areas lacking riparian buffers (hot spots analysis, forest land, agricultural land, roads, culverts and ditches)
- Identify and assess existing agricultural BMPs
- Encourage cropland owners to develop Conservation Plans through NRCS
- Assess tributaries of Dudley Brook, especially within agricultural land
- Maintain and reestablish shaded riparian zones along Dudley Brook and its tributaries using both trees and shrubs
- Assess the effects that Kilcollins Irrigation Pond has on water quality, and assess annual irrigation/ withdrawals from the pond
- Assess impact of beaver dams on stream flow
- Explore Grass Roots community participation, including school groups for collecting information about Dudley Brook (visual assessments, pictures, water quality, etc.)
- Identify and contact major agricultural and forest landowners/operators to participate in watershed efforts and stakeholder group

10. PUBLIC PARTICIPATION

Public participation in the Dudley Brook TMDL development is ensured through several avenues. Paper and electronic forms of the *Dudley Brook TMDL Draft Report* were made available for public review between September 26th and October 31, 2008. A public review draft was distributed by U.S. mail to interested stakeholders without electronic means of communication, and electronically on September 26, 2008 to the following individuals who expressed a specific interest, or helped develop the draft of the Dudley Brook TMDL report:

Maine DEP CMRO (Melissa Evers, Dave Courtemanch, Leon Tsomides); Maine DEP NMRO (Kathy Hoppe, Nick Archer, Bill Sheehan, Sean Bernard); Central Aroostook SWCD (Linda Alverson); USDA/NRCS (Skip Babineau and Joe Weber); Maine Potato Board (Tim Hobbs). Town of Castle Hill and Chapman (John Edgecomb, Martin Puckett, Willie Winslow, Leah Buck, Tim Scott); Cavendish Farms (Sue Moraeu); interested landowners (Lucy and Bev Lovely, Annette Roope, Carol & Willy Soucy, Dana Spooner, Laurie Ireland, Donald Turner Jr., George & Carol Bilge).

FB Environmental staff presented information about the TMDL at a joint TMDL and watershed planning meeting in Presque Isle on October 30, 2008. The Town of Chapman/Castle Hill/Mapleton provided FB

Environmental with a list of watershed landowners. Each landowner was contacted by phone and/or mail regarding the TMDL meeting. The report was posted on the FB Environmental Internet Web site and two notices were placed in the Star Herald on October 8th and October 29th, 2008.

Results of the TMDL were presented at a follow-up watershed planning meeting on June 17, 2009. The meeting included a field tour of the watershed and an evening presentation which reviewed results from the TMDL and strategies for implementing the TMDL using the Watershed-based Management Plan. All watershed landowners, land managers, and town selectmen and planners were contacted by phone and e-mail, and postcards were sent by mail. A press release was sent to the Star Herald on June 8, 2009.

PUBLIC DOCUMENT READY FOR REVIEW- DUDLEY BROOK

The Maine Department of Environmental Protection has prepared a Total Maximum Daily Load (TMDL) report for impaired water quality in Dudley Brook in Maple Hill and Chapman. The stream runs along the foot of McDonald and Pyle Mountains in Maple Hill, joining Presque Isle Stream in Chapman. This report estimates nonpoint source loadings of nutrients and sediments and the reductions needed to restore Dudley Brook to meet Maine's Water Quality Criteria.

A Public Review draft of the report may be viewed at the Maine DEP Offices in Augusta (Ray Building, Hospital St., Rt. 9) or on-line at: http://www.state.me.us/dep/blwq/comment.htm.

Send all written comments – by October 24, 2008, to Melissa Evers, Stream TMDL's, Maine DEP, State House Station #17, Augusta, ME 04333 or email: melissa.evers@maine.gov.

No written Public Comments were received.

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APPENDIX 1

Dudley Brook

Total Maximum Daily Load (TMDL)

FIGURES

TABLES

Appendix 1:
Modeling Report to Support
Total Maximum Daily Load (TMDL) Development for Dudley Brook

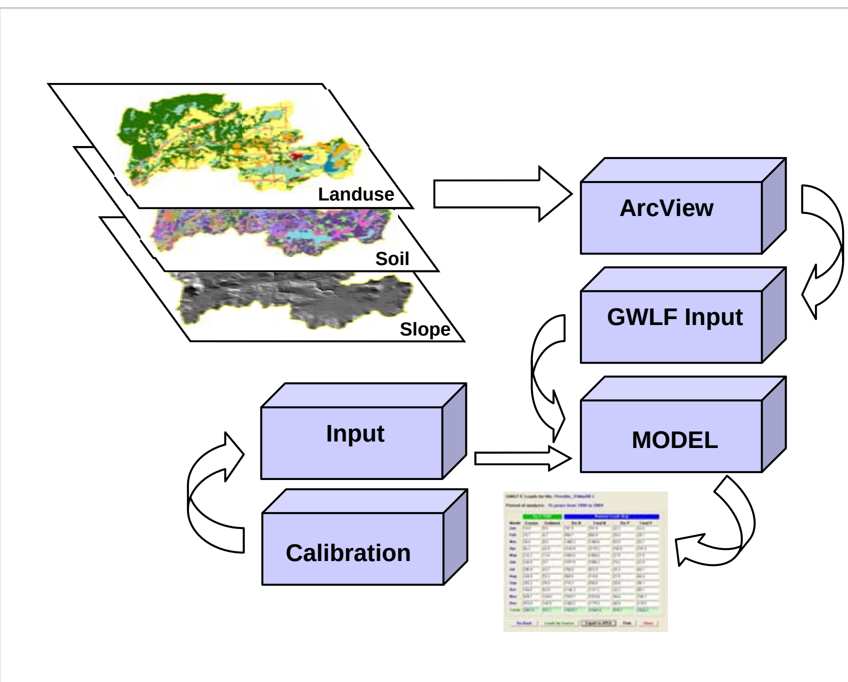
1. Model Description

As a component of the Dudley Brook TMDL, landuses for the watershed were modeled using Northeast AVGWLF (Generalized Watershed Loading Function with an ArcView (AV) geographic information systems (GIS) interface). The Arcview interface facilitates the development of model input data for GWLF, the core watershed simulation model, which uses hydrology, land cover, soils, topography, weather, pollutant discharges, and other critical environmental characteristics to model sediment and nutrient (N and P) transport within a watershed.

The AVGWLF model is an aggregate distributed/lumped parameter watershed model. For surface loading, it is distributed in that it allows multiple land use/cover scenarios. However, loads originating from the watershed are lumped and spatial routing of nutrient and sediment loads is not available. For example, all farmland is lumped together and defined by one set of parameter values, and all forested land is lumped together and defined by a different set of parameter values. Other factors that affect the nutrient balance of a watershed such as groundwater, point-sources, and septic systems are also lumped together and each is treated as one unique source.

GWLF uses existing conventions and data to model surface runoff and soil erosion. The Soil Conservation Service Curve Number (SCS-CN) coupled with daily precipitation and temperature from the National Climatic Data Center (NCDC) is used to model surface runoff and streamflow. Evapotranspiration is estimated using daily weather data and a cover factor dependent on land use/cover type. The Universal Soil Loss Equation

Figure 1.1. *AVGWLF model structure.*



With the ArcView interface, GIS data sets are loaded and the user is prompted to provide information related to “non-spatial” model parameters (e.g., beginning and end of the growing season; and the months during which manure is spread on agricultural land). This information is subsequently used to automatically derive values for required model input parameters, which are then written to the transport and nutrient input files needed to execute the GWLF model. Also accessed through the interface are Excel files that contain temperature and precipitation information used to create the necessary weather input file for a given watershed simulation. Both the transport and nutrient. input files can be edited via the use of an edit screen, and watershed-specific information such as livestock numbers and existing BMPs can be incorporated.

(USLE) is used to model monthly erosion and sediment loss. Nutrients (nitrogen and phosphorus) are modeled using export coefficients for both the dissolved and solid phases from each type of land use. (Evans et al. 2002, 2008)

The general modeling approach for this TMDL was as follows: 1) derive input data for GWLF for use in the impaired watershed, 2) simulate nutrient and sediment loads within the impaired watershed, and 3) compare simulated loads within the impaired watershed against loads simulated within the watersheds of two nearby unimpaired attainment streams (Moose Brook and B Stream) that exhibit similar landscape, development and agricultural patterns. A TMDL target for the impaired watershed was established by comparing model results to the average annual nutrient and sediment loads estimated for the attainment watersheds.

The model evaluation was screening level, as model predictions represent rough estimates based on empirical data and are not calibrated to site specific data. Therefore, model predictions provide planning level estimates rather than exact predictions of loads entering streams. Specification of key model parameters is described in Section 3.

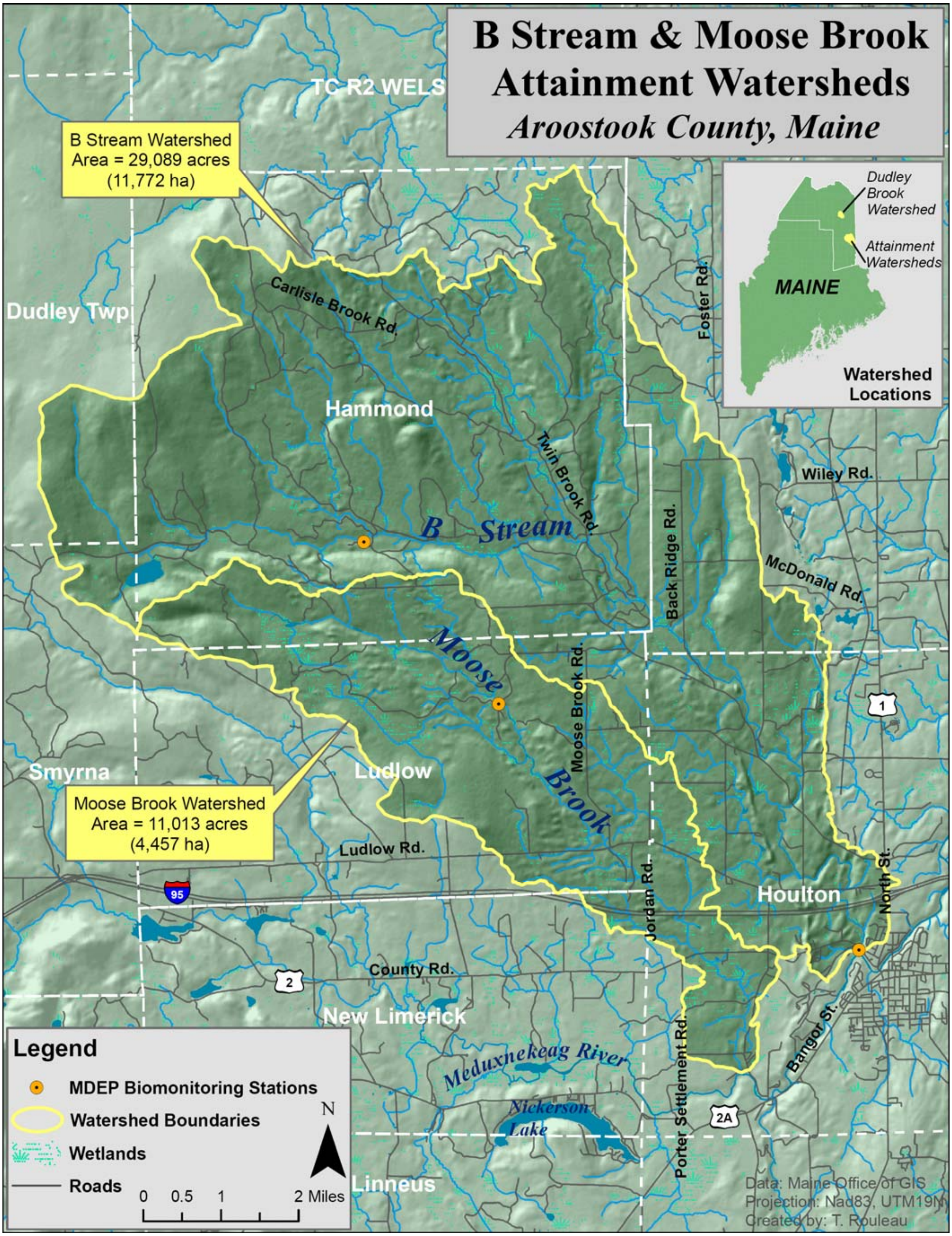
2. Approach and Background

An attainment watershed approach was used to establish numeric endpoints for nitrogen and phosphorus non point source loadings. The approach was based on selecting two non-impaired watersheds that share similar land use and soil characteristics with the impaired watershed. Stream conditions in the attainment watersheds were assumed to be representative of the conditions needed for the impaired stream to obtain its designated uses. The numeric endpoint can be derived from the most representative attainment watershed or from the average of both attainment watersheds.

Table 2.1. *Watershed descriptions for B Stream, Moose Brook, and Dudley Brook.*

Watershed	Description
B Stream *(Attainment Stream)*	The B Stream watershed is part of the Big Presque Isle and Meduxnekeag Stream watershed (HUC 0101005) in Maine and New Brunswick. It's headwaters begin in the Town of Hammond, Maine. flows southeast through Littleton and Houlton before terminating at its confluence with Meduxnekeag Stream just south of U.S. Route 2 in Houlton. B Stream is approximately 17 miles in length and has a drainage area of 29,089 acres (11,772 ha).
Moose Brook *(Attainment Stream)*	The Moose Brook watershed is part of the Big Presque Isle and Meduxnekeag Stream watershed (HUC 0101005) in Maine and New Brunswick. It's headwaters begin in the Town of Hammond, Maine. It flows southeast through Ludlow and Houlton before terminating at its confluence with Meduxnekeag Stream just south of U.S. Route 2A in Houlton. Moose Brook is approximately 11 miles in length and has a drainage area of 11,013 acres (4,457 ha).
Dudley Brook *(Impaired Stream)*	The Dudley Brook watershed is part of the Aroostook River watershed (HUC 0101004) in Maine and New Brunswick. It's headwaters begin in the Town of Castle Hill, Maine. It flows southeast through Castle Hill before terminating at its confluence with Presque Isle Stream just east of West Chapman Road in Chapman. Dudley Brook is approximately 6.4 miles in length and has a drainage area of 4,059 acres (1,643 ha).

Figure 2.1. *B Stream and Moose Brook watershed map.*



Two unimpaired attainment watersheds (B Stream and Moose Brook) were identified based on watershed size, land cover, and recommendations from Maine DEP. These watersheds were selected because they had similar land use/land cover (primarily forested and agricultural) and bio-monitoring data indicated they support healthy benthic communities. A brief description of the impaired watershed and two attainment watersheds is provided in Table 2.1.

3. MODEL INPUTS

3.1 GIS Data

The modeling approach for the Dudley Brook watershed relied on the use of GIS shapefiles and grids developed for use with Northeast AVGWLF in New York and New England. Watershed boundary shapefiles and land use/ cover data were obtained from the Maine Office of GIS (MEGIS) and all other GIS data was obtained from the New England Interstate Water Pollution Control Commission (NEIWPCC) website (Table 3.1). The GIS land use layer used for this analysis was created at the request of the Maine DEP Bureau of Land and Water Quality (BLWQ). The data is primarily derived from Landsat Thematic Mapping imagery from the years 1999-2001, and was further refined using panchromatic imagery from the spring and summer months of 2004. Land cover data for the watersheds was further edited and verified using 2006 National Agriculture Imagery Program (NAIP) aerial orthoimagery, and land use classes were recoded for use in AVGWLF. All GIS data were projected as follows:

- Projection: Custom GEOGCS, GCS_North_American_1983
- Datum: North_American_1983
- Unit: meters

Table 3.1. *GIS data used in the Dudley Brook AVGLWF application.*

File Names	Description	Required
Shape Files		
Weather stations	Weather station locations (points)	Y
Basins	Watershed boundary (polygons)	Y
Streams	Map of stream network (lines)	Y
Roads	Road map (lines)	N
Counties	County boundaries - for USLE data (polygons)	N
Septic Systems	Septic system numbers and types (polygons)	N
Animal density	Animal density (in AEUs per acres) (polygons)	N
Soils	Contains various soil-related data (polygons)	Y
Physiographic provinces	Contains hydrologic parameter data (polygons)	N
Grid Files		
Land use/cover	Map of land use/land cover (16 classes)	Y
Elevation	Elevation grid	Y
Groundwater-N	Background estimate of N in mg/l	N
Soil-P	Estimate of P in mg/kg (total or soil test P)	N

3.2 Input Files

As described earlier, the AVGWLF interface is used to create input files for the GWLF model. For execution, the GWLF model requires three separate input files containing transport parameters, nutrient parameters, and weather related data. The following sections summarize the model input parameters and the sources of data used for each file for the Dudley Brook and attainment watershed applications.

3.2.1 Weather

The weather file contains daily precipitation and temperature values. This data is available from the NCDC for a number of weather stations in Maine. For GWLF modeling of Dudley Brook, data from Presque Isle (Station 6937) was used. For the attainment watersheds, B Stream and Moose Brook, weather data from Houlton (Station 3944) was used. Both weather stations have a record of concurrent precipitation and temperature data from 1990 to 2004. All model simulations were conducted over this 15-year period.

3.2.2 Transport

The transport file contains information about the physical properties of the watershed including landuse and soils, as well as information about the effects of the hydrologic cycle on the movement of water and sediment through the watershed.

AVGWLF model inputs for transport parameters are described in Table 3.2 and watershed-specific transport parameters generated for each watershed are shown in subsequent tables below. These parameters include global transport parameters, seasonal transport parameters, and source area transport parameters. **Global parameters** apply to all source areas in the watershed and include the unsaturated water capacity, saturated storage capacity, initial snow amount, seepage coefficient, recession coefficient, and SDR. The unsaturated water capacity is a function of the maximum watershed rooting depth and the soil available water storage capacity. The seepage coefficient is a function of the loss of water to the deep aquifer. The recession coefficient is a function of the basin's hydrologic response to a precipitation event. The SDR specifies the percentage of eroded sediment

Table 3.2. *AVGWLF Transport file parameters.*

Parameter	Source	Value
Basin size	GIS/derived from basin boundaries	watershed-specific
Land use/cover distribution	GIS/derived from land cover map	watershed-specific
Curve numbers (CN) by source area	GIS/derived from land cover and soil maps	watershed-specific
USLE (KLSCP) factors by source area	GIS/derived from soil, DEM, and land cover	watershed-specific
ET cover coefficients	GIS/derived from land cover	watershed-specific
Erosivity coefficients	GIS/ derived from physiography map	watershed-specific
Daylight hrs. by month	Computed automatically	based on latitude
Growing season months	Input by user	assumed May-September
Initial saturated storage	Default value	0 cm
Initial unsaturated storage	Default value	10 cm
Recession coefficient	Default value	0.03
Seepage coefficient	Default value	0
Initial snow amount	Default value	0 cm
Sediment delivery ratio	GIS/based on basin size	watershed-specific
Soil water (available water capacity)	GIS/derived from soil map	watershed-specific

delivered to surface water, and is a function of watershed area. These parameters were set to suggested default values for the Northeast AVGWLF model (Penn State 2007).

Source area transport parameters describe the spatial variation in hydrology, erosion, and nutrient loading in the watershed and include landuse areas, curve numbers, and Universal Soil Loss (USLE) parameters K, LS, C, and P. Land use areas were derived directly using the landuse GIS layer. The curve number (CN) parameter determines the amount of precipitation that infiltrates into the ground or enters surface water as runoff. Based on specified combinations of landuse and hydrologic soil type, CN is estimated directly using landuse and soil GIS layers. The USLE equation parameters, derived from the NRCS Natural Resources Inventory Database (NRI), determine soil erodibility.

Table 3.3. *Dudley Brook (Impaired Stream) Source Area Transport Parameters.*

Landuse	Area (hectares)	Percentage of Watershed	CN	K·LS·C·P
Hay/Pasture	88	5	75	0.0011
Cropland	302	18	82	0.0130
Mixed Forest	1125	69	73	0.0001
Wetland	103	6	87	0.0001
Non-vegetated/Disturbed[1]	1	<1	0	0
Low Intensity Development	20	1	83	0.0014
High Intensity Development	2	<1	93	0.0012
Total	***1,641***	***100***		

[1]Includes transitional land, gravel pits, and mines.

Table 3.4. *B Stream (Attainment Stream) Source Area Transport Parameters.*

Landuse	Area (hectares)	Percentage of Watershed	CN	K·LS·C·P
Hay/Pasture	239	2	75	0.0011
Cropland	807	7	82	0.0099
Mixed Forest	9,503	81	73	0.0043
Wetland	892	8	87	0.00004
Non-vegetated/Disturbed[1]	53	0	0	0
Low Intensity Development	230	2	83	0.0011
High Intensity Development	48	0	90	0.0010
Total	***11,772***	***100***		

Table 3.5. *Moose Brook (Attainment Stream) Source Area Transport Parameters.*

Landuse	Area (hectares)	Percentage of Watershed	CN	K·LS·C·P
Hay/Pasture	88	2	75	0.0009
Cropland	754	17	82	0.0105
Mixed Forest	2,820	63	73	0.0001
Wetland	703	16	87	0.00004
Non-vegetated/Disturbed[1]	5	<1	0	0
Low Intensity Development	82	2	83	0.0010
High Intensity Development	5	<1	90	0.0010
Total	***4,457***	***100***		

[1]Includes transitional land, gravel pits, and mines.

Model inputs for the **seasonal transport parameters** account for seasonal variability in hydrology, erosion, and sedimentation. The monthly evapotranspiration cover coefficient, day length, and erosivity coefficient are estimated automatically within the model based on regional literature values (Haith et al. 1992).

Table 3.6. *Dudley Brook (Impaired watershed) Seasonal Transport Parameters.*

Month	Evapotranspiration Cover Coefficient	Daylight (hours)	Growing Season (0=no, 1=yes)	Erosivity Coefficient
January	0.6	8.7	0	0.07
February	0.65	9.9	0	0.07
March	0.68	11.7	0	0.07
April	0.7	13.5	0	0.13
May	0.87	15	1	0.13
June	0.97	15.7	1	0.13
July	1.03	15.3	1	0.13
August	1.06	14.1	1	0.13
September	1.08	12.3	1	0.13
October	0.93	10.5	0	0.07
November	0.84	9	0	0.07
December	0.79	8.3	0	0.07

Table 3.7. *B Stream and Moose Brook (Attainment watersheds) Seasonal Transport Parameters.*

	B Stream	Moose Broook			
Month	Evapotranspiration Cover Coefficient	Evapotranspiration Cover Coefficient	Daylight (hours)	Growing Season (0=no, 1=yes)	Erosivity Coefficient
January	0.63	0.65	9.2	0	0.07
February	0.68	0.70	10.3	0	0.07
March	0.71	0.73	11.7	0	0.07
April	0.72	0.75	13.3	0	0.13
May	0.88	0.91	14.5	1	0.13
June	0.97	1.00	15.1	1	0.13
July	1.02	1.05	14.8	1	0.13
August	1.05	1.08	13.7	1	0.13
September	1.07	1.10	12.3	1	0.13
October	0.93	0.96	10.7	0	0.07
November	0.85	0.88	9.5	0	0.07
December	0.81	0.84	8.9	0	0.07

3.2.3 Nutrients

The nutrient file specifies loading parameters for phosphorus and nitrogen in runoff and sediment. Dissolved nutrients, associated with overland runoff, point sources and subsurface discharges to the stream, are obtained by multiplying runoff volumes by average dissolved concentrations for both nitrogen and phosphorus. Sediment nutrients originate from point sources, soil erosion, and wash-off of material from impervious areas. AVGWLF model inputs for nutrient parameters are described in Table 3.8 below, and watershed-specific nutrient parameters generated for each watershed are shown in subsequent tables. Typical concentrations of nutrients in runoff are reported in the GWLF User's Manual and have been used in the Aroostook County AVGWLF model application.

The nutrient file also contains parameters that define septic system loads such as the number of people who are serviced, the state of failure of the systems, per capita nutrient contributions, and the uptake of nutrients by plants during the growing season. Estimates of the septic systems in the watershed (Table 3.10) were generated based on 1990 Census data contained in the census GIS layer.

Table 3.8. *AVGWLF Nutrient file parameters.*

Parameter	Source	Value
Dissolved N in runoff by land cover type	Default values/adjusted using AEU density	watershed-specific
Dissolved P in runoff by land cover type	Default values/adjusted using AEU density	watershed-specific
N/P concentrations in manure runoff	Default values/adjusted using AEU density	watershed-specific
Background N/P concentrations in GW	GIS/derived from groundwater N map	watershed-specific
Background P concentrations in soil	GIS/derived from soil P loading map	watershed-specific
Background N concentrations in soil	Based on map in GWLF Manual	3000 mg/kg
Months of manure spreading	Input by user	assumed June-September
Population on septic systems	GIS/derived from census tract map	watershed-specific
Per capita septic system loads (N/P)	Default values	12 g N/day, 2.5 g P/day

Table 3.9. *Nutrient Concentrations for watershed land uses.*

Rural Landuse	Dissolved Nitrogen (mg/L)	Dissolved Phosphorus (mg/L)
Hay/Pasture	2.9	0.294
Cropland	2.9	0.294
Forest	0.19	0.006
Wetland	0.19	0.006
Non-vegetated/Disturbed[1]	2.9	0.2
Manure	2.44	0.38
Urban Landuse Accumulation	**Nitrogen (kg/ha/day)**	**Phosphorus (kg/ha/day)**
Low Intensity Development	0.012	0.002
High Intensity Development	0.101	0.011

[1]Includes transitional land, gravel pits, and mines.

Table 3.10. *Dudley Brook, B Stream, and Moose Brook watershed septic status.*

Watershed	Population on Septic	Normal Systems	Ponding Systems	Short Circuit Systems
Dudley Brook *(Impaired Stream)*	49	48	0	1
B Stream *(Reference Stream)*	419	384	0	35
Moose Brook *(Reference Stream)*	164	149	0	15

3.3 Additional Model Inputs

3.3.1 Farm Animals

Data on animal populations can be entered in GWLF via two mechanisms: 1) via direct typing of values into the appropriate cells, or 2) via use of GIS layer that contains farm animal density information. For the Northeast AVGWLF, county-level GIS data on animal populations and weights were developed using data from the National Agricultural Statistics Service. In this data layer, animal density is expressed in terms of animal equivalent units (AEUs) per acre, where one AEU is equal to 1000 pounds of animal weight. This GIS layer was used to determine animal densities in Dudley Brook, and the attainment stream watersheds.

In each case, it is assumed that there are typical production rates associated with different animal types that can be used to estimate the total amounts of nitrogen and phosphorus generated by the animal populations within a given watershed on a yearly basis. It is also assumed that there are different loss rates associated with each nutrient and transport mechanism that can be used to estimate the nitrogen and phosphorus loads delivered to surface water bodies each year as well.

3.3.2 Lakes, Ponds, and Wetlands

For each of the watersheds, the pollutant-attenuating effects of lakes, ponds and wetlands were accounted for. This was achieved by estimating the total land area drained by lakes and wetlands, based on percentage of area upslope of each wetland or lake. For sediment and nutrient retention within these areas, the retention coefficients used were as follows: nitrogen (0.12), phosphorus (0.25), and sediment (0.90) (Penn State 2007). This goal of this simple methodology is to account for losses that occur as a result of wetlands and lakes in each watershed, not to simulate the complex processes that influence the transport of nutrients and sediment in watersheds where these features exist. In cases where such processes and losses are significant, not accounting for them could potentially result in overestimation of nutrient and sediment loads. The estimated percentage of land area drained by lakes, ponds, and wetlands in the watersheds are as follows: Moose Brook (20%), B Stream (10%), Dudley Brook (5%).

4. RESULTS

The impaired watershed (Dudley Brook) and attainment watersheds (B Stream and Moose Brook) models were run for a 15-year period (1990 to 2004). It is assumed that this period will capture sufficient hydrologic and weather conditions to account for typical variations in nutrient loading conditions. The 15-year means for total nitrogen, and total phosphorus, and sediment loads by land use were estimated for each watershed (Tables 4.1, 4.2 and 4.3). Estimated reductions for Dudley Brook are presented in Table 4.4 (p. 30).

Watershed Nitrogen, Phosphorus, and Sediment Loads by Source:

Table 4.1. *Watershed Nitrogen loads by source for Dudley Brook and attainment streams.*

Source	Total N (kg/yr)	Total N (%)	Total N (kg/yr)	Total N (%)	Total N (kg/yr)	Total N (%)
Hay/Pasture	295	3%	857	2%	312	1%
Cropland	1839	16%	4985	11%	4645	18%
Forest	218	2%	1954	4%	577	2%
Wetland	54	0%	501	1%	391	2%
Bare Land	0	0%	0	0%	0	0%
Groundwater	8880	79%	36752	81%	19644	77%
Septic Systems	8	0%	176	<1%	73	<1%
Total	***11,295***	***100%***	***45,225***	***100%***	***25,642***	***100%***
Unit Area Load (kg/ha/yr)	*6.9*		*3.8*		*5.8*	

Table 4.2. *Watershed Phosphorus loads by source for Dudley Brook and attainment streams.*

	Dudley Brook		B Stream		Moose Brook	
Source	Total P (kg/yr)	Total P (%)	Total P (kg/yr)	Total P (%)	Total P (kg/yr)	Total P (%)
Hay/Pasture	33	7%	91	5%	33	3%
Cropland	234	51%	564	28%	532	49%
Forest	8	2%	64	3%	20	2%
Wetland	2	0%	16	1%	12	1%
Bare Land	0	0%	0	0%	0	0%
Groundwater	183	40%	1251	62%	482	44%
Septic Systems	1	0%	29	1%	12	1%
Total	***461***	***100%***	***2,015***	***100%***	***1,091***	***100%***
Unit Area Load (kg/ha/yr)	*0.28*		*0.17*		*0.24*	

Table 4.3. *Watershed Sediment loads by source for Dudley Brook and attainment streams.*

	Dudley Brook		B Stream		Moose Brook	
Source	Sediment (t/yr)	Sediment (%)	Sediment (t/yr)	Sediment (%)	Sediment (t/yr)	Sediment (%)
Hay/Pasture	2	3%	3	3%	1	1%
Cropland	68	95%	88	92%	104	92%
Forest	2	2%	5	5%	3	3%
Wetland	0	<1%	0	0%	1	<1%
Bare Land			0	0%	4	4%
Total	***72***	***100%***	***96***	***100%***	***113***	***100%***
Unit Area Load (kg/ha/yr)	*0.04*		*0.01*		*0.03*	

Figure 4.1. *Dudley Brook Nitrogen loads by source.*

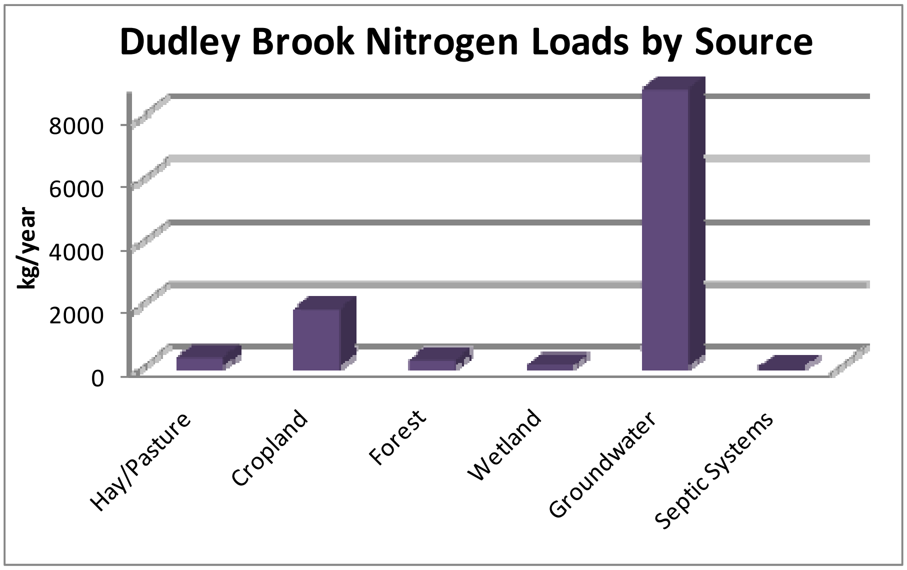


Figure 4.2. *Dudley Brook Phosphorus loads by source.*

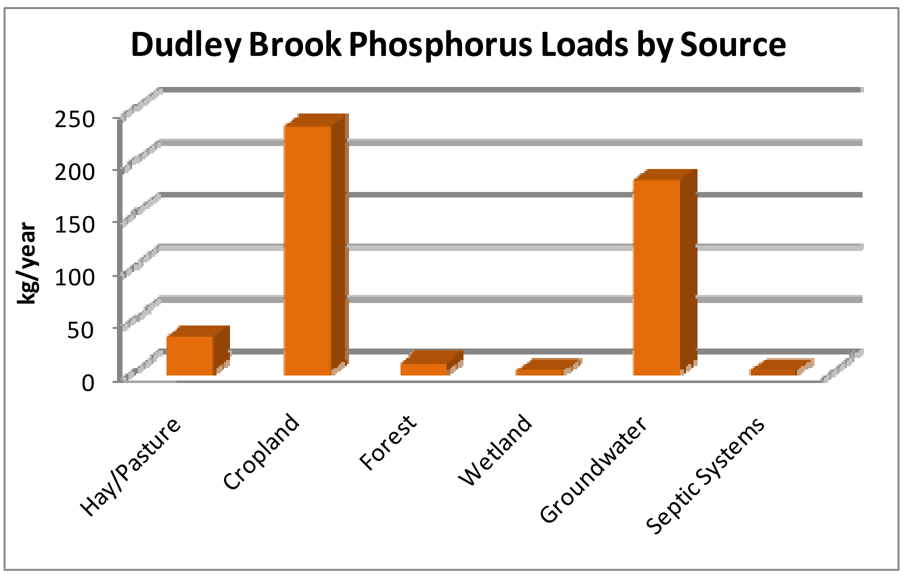


Table 4.4. *Estimated Load Reductions needed for Dudley Brook*.*

	Estimated Loads	Numeric target	TMDL
Annual Unit Area Loads**	**Dudley Brook**	**Reference Waterbodies**[1]	**% Reductions Needed**
Phosphorus (kg/ha/yr)	0.28	0.21	25%
Nitrogen (kg/ha/yr)	6.9	4.8	30%
Sediment (t/ha/yr)	0.04	0.02	50%

[1]Average of unit area loads for B Stream and Moose Brook.

*[**Load Reduction Calculation:** % Reduction Needed = ((Estimated Load - Target Load)/Estimated Load) x 100]

** 1 kg/ha/year = 0.892 lbs/acre/year, and 1 t/ha/year = 809.37 lbs/acre/year

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