MILTON THREE PONDS
LAKE LOADING RESPONSE MODEL

Prepared by **FB Environmental Associates**

September 2025

PREPARED FOR:
Strafford Regional Planning Commission
Three Ponds Protective Association
New Hampshire Department of Environmental Services
Maine Department of Environmental Protection

TABLE OF CONTENTS

INTRODUCTION

The purpose of this report is to provide results from the Lake Loading Response Model (LLRM) developed for Milton Three Ponds (Northeast Pond, Townhouse Pond, and Milton (Depot) Pond). Each pond was modeled separately. The LLRM is an Excel-based model that uses environmental data to develop a water and phosphorus loading budget for lakes and their tributaries[1]. Water and phosphorus loads (in the form of mass and concentration) are traced from various sources in the watershed through tributary basins and into the lake. The model incorporates data about watershed and sub-watershed boundaries, land cover, point sources (if applicable), septic systems, waterfowl, rainfall, volume and surface area, and internal phosphorus loading. These data are combined with coefficients, attenuation factors, and equations from scientific literature on lakes, rivers, and nutrient cycles. The following describes the process by which critical model inputs were determined using available resources and GIS modeling and presents annual average predictions[2] of total phosphorus, chlorophyll-a, Secchi disk transparency, and algal bloom probability. The model can be used to identify current and future pollutant sources, estimate pollutant limits and water quality goals, and guide watershed improvement projects.

WATERSHED AND SUB-WATERSHED DELINEATIONS

Watershed and tributary drainage area (sub-watershed) boundaries are needed to determine both the amount of water flowing into a surface waterbody and the area of different land cover types contributing to nutrient loading. FB Environmental Associates (FBE) extracted the watershed boundary from the USGS National Watershed Boundary Dataset (WBD); the Milton Three Ponds watershed covers four HUC12 watershed areas (Headwaters Salmon Falls River HUC12-010600030503; Headwaters Branch River HUC12-010600030501; Branch River HUC12-010600030502; and Upper Salmon Falls River HUC12-010600030504) for the direct Milton Three Ponds watershed, which includes Northeast Pond, Townhouse Pond, and Milton (Depot) Pond as primary waterbodies of interest for modeling (Figure 1). Other waterbodies in the watershed include Kingswood Lake, Great East Lake, Horn Pond, Wilson Lake, and Lovell Lake. The latter four lakes are part of the Acton Wakefield Watersheds Alliance (AWWA) who completed a watershed management plan for the area in 2010 (AWWA & FBE, 2010).

FBE completed desktop aerial delineation of sub-watersheds for the Milton Three Ponds watershed using USGS 1/3 arc-second digital elevation models (DEMs) as an input to a spatial workflow using the ESRI ArcGIS Pro Spatial Analyst Hydrology toolbox. FBE then used ESRI World Topo Map with 20-foot contours to manually confirm the modeled sub-watershed boundary delineations. FBE confirmed sub-watershed boundaries in-person on 4/15/2025 (Figure 2).
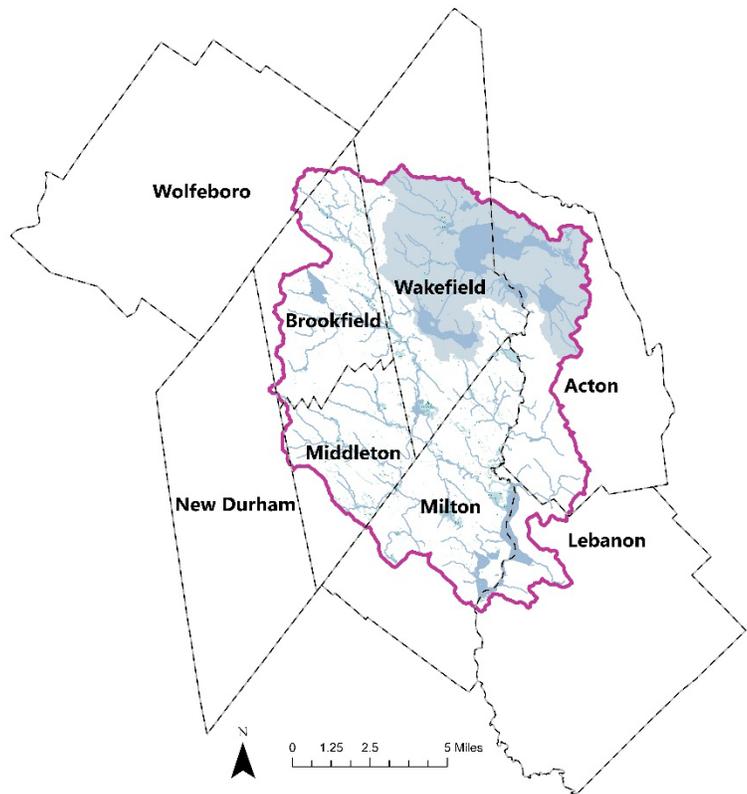
FIGURE 1. Boundaries for the Milton Three Ponds watershed (purple line). Shaded parts of the watershed are part of the Acton Wakefield Watersheds Alliance (AWWA).

---

[1] AECOM (2009). LLRM Lake Loading Response Model Users Guide and Quality Assurance Project Plan. AECOM, Willington, CT.
[2] The model cannot simulate short-term weather or loading events.
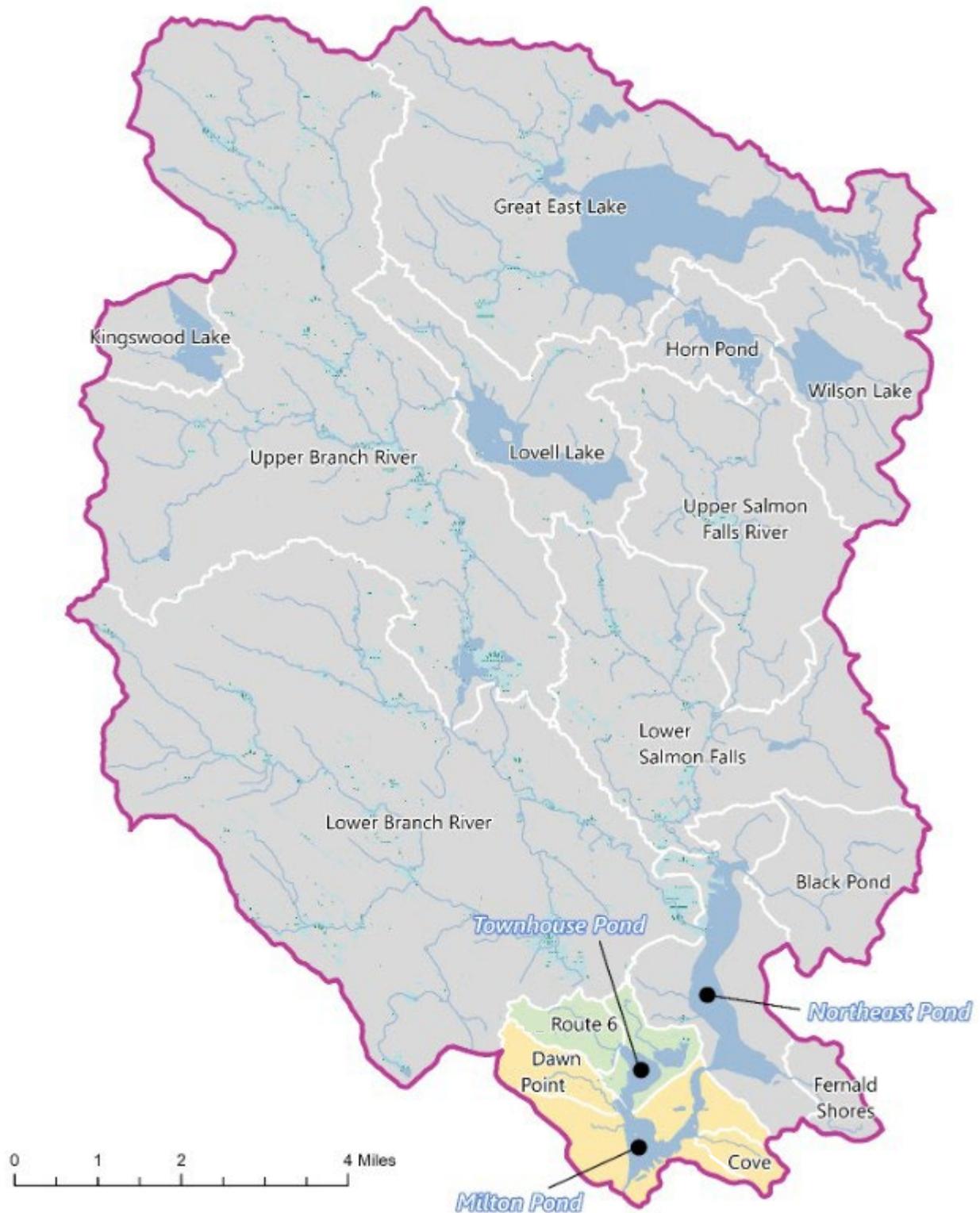
FIGURE 2. Final sub-watershed boundaries for the Milton Three Ponds watershed. Separate models were run for each of the three ponds, including Northeast Pond (gray), Townhouse Pond (green), and Milton (Depot) Pond (yellow). The Northeast Pond and Townhouse Pond models were inputs to the Milton Pond model; Milton Pond backflushing influence was also included as an input to Townhouse Pond. Refer to the Calibration section for routing. Direct shoreline sub-watersheds to the three ponds are not labeled in the map.

LAND COVER FILE CREATION

Land cover determines the movement of water and phosphorus from the watershed to surface waterbodies via surface runoff and baseflow (groundwater). A significant amount of time went into reviewing and refining the land cover data by FBE. The entire watershed was initially assigned the "Forest 1: Upland" LLRM category as a default. Then, FBE overlayed wetlands from the National Wetlands Inventory (NWI), waterbodies from the National Hydrography Dataset (NHD), roads from the New Hampshire Department of Transportation (NHDOT) and Maine Department of Transportation (MEDOT), and building footprints from the publicly available Microsoft building footprints layer. All data were acquired from New Hampshire's data clearinghouse, NH GRANIT or the Maine GeoLibrary. Streams from the NHD and roads from NHDOT and MEDOT were given 15-foot and 30-foot buffers, respectively. Next, rectangular grids (or quads) were created to break up the watershed into more manageable portions for review. ESRI World imagery dated 5/26/2023 and 10/28/2022 and Google Earth imagery dated 10/31/23 and 5/4/2018 were reviewed for delineating agriculture, residential or commercial development, cleared land, and additional roads. Changes were made using the Editor tools for editing polygon vertices and splitting polygons. Each new polygon was relabeled in the attribute table with the appropriate LLRM land cover category.

A few assumptions or actions were made during this process:

- Agricultural fields (whether row crops or hayfields) that were clearly not pasture were assigned to "Agric 2: Row Crop/Hayfield"; it was difficult to discern whether a field was used as a cover crop and so no cover crops were assigned in the watershed. FBE further refined land cover by distinguishing among hayfields ("Agric 2: Row Crop/Hayfield"), meadows that were scrub-shrub, non-wetland areas ("Open 2: Meadow"), or extensive lawns or athletic fields or cemeteries ("Urban 5: Open Space"). Residential lawns were included in "Urban 1: Low Density Residential."

- Recently logged areas ("Other 1: Logging") were differentiated from upland forest areas ("Forest 1: Upland").

- Palustrine wetland areas from the NWI were added as "Forest 2: Wetlands."

- Open water areas and streams from the NHD were added as "Open 1: Water."

- Roads from the NHDOT roads layer were differentiated between "Urban 3: Roads" or "Other 2: Unpaved Roads."

- Major bare soil areas that were not associated with new residential home construction were labeled as "Open 3: Excavation."

Agricultural and developed lands were checked carefully since modeling coefficients (i.e., phosphorus export) are generally higher for those land cover types. Aerials were checked thoroughly for each major agricultural or developed area to distinguish between hayfields, grazing/pasture, lawns, and meadows. The resulting land cover file is a more accurate representation of current land cover within the watershed compared to coarse-scale data such as the National Oceanographic and Atmospheric Administration's (NOAA) Office of Coastal Management Coastal Analysis Change Program 2015/2016 land cover data file (refer to Figure 3 for zoomed-in comparison between NOAA's and FBE's land cover file).

Within the LLRM, export coefficients are assigned to each land cover type to represent typical concentrations of phosphorus in runoff and baseflow from those land cover types (Attachment 1). Unmanaged forested land, for example, tends to deliver very little phosphorus downstream when it rains, while low to high density urban development export significantly more phosphorus due to impervious surfaces, fertilizer use, soil erosion, car and factory exhaust, pet waste, and many other sources. Smaller amounts of phosphorus are also exported to lakes and streams via groundwater under baseflow conditions. This nutrient load is delivered with groundwater to the lake directly or to tributary streams; however, much of the phosphorus is adsorbed onto soil particles as water infiltrates to the ground. Attachment 1 presents the runoff and baseflow phosphorus export coefficients for each land cover type used in the model, along with the total land cover area by land cover type for each sub-watershed. These coefficients were based on values from Tarpey (2013), Johnes (1996), USEPA (2017), King et al. (2007), Hutchinson Environmental Sciences Ltd (2014), and Schloss et al. (2000), among others.

Figure 4 shows a breakdown of land cover by major category for the Milton Three Ponds watershed (not including lake areas), as well as total phosphorus load by major land cover category for the watershed. Developed areas cover 7% of the watershed and contribute 60% of the total phosphorus watershed load to the three ponds.
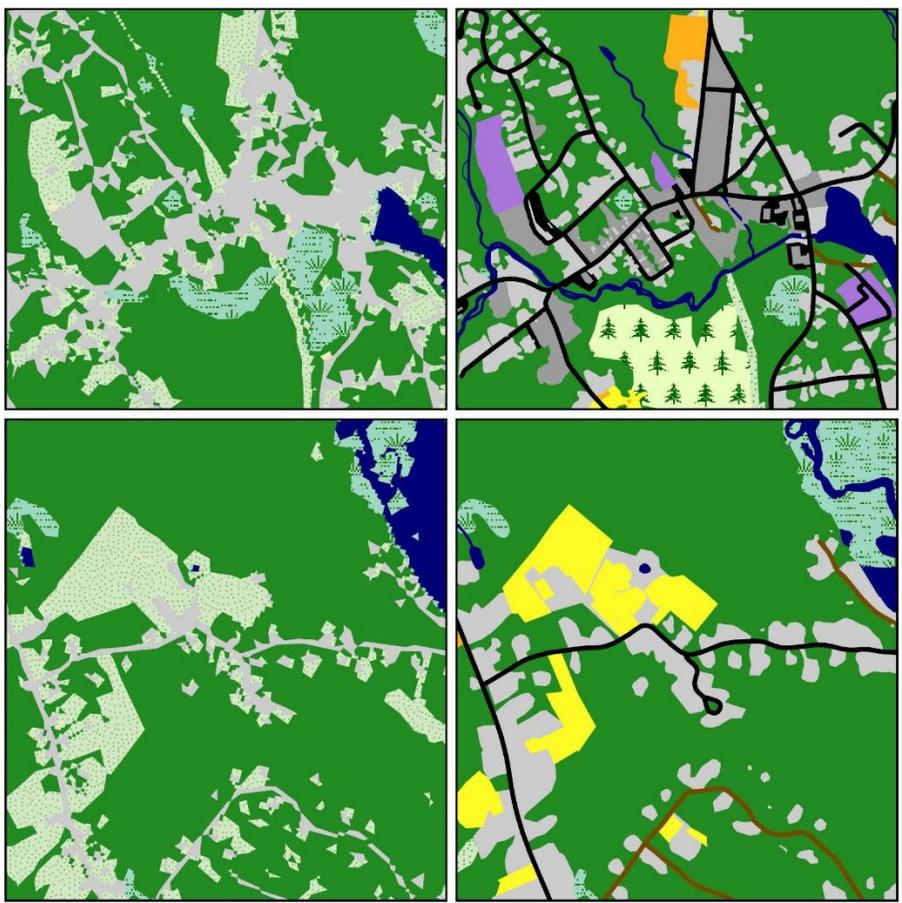
FIGURE 3. Examples of land cover file comparisons between NOAA's Office of Coastal Management Coastal Analysis Change Program 2015/2016 land cover and FBE's modified land cover file for the Milton Three Ponds watershed.
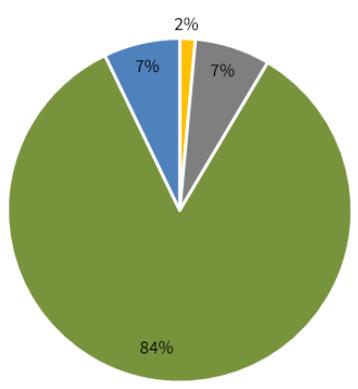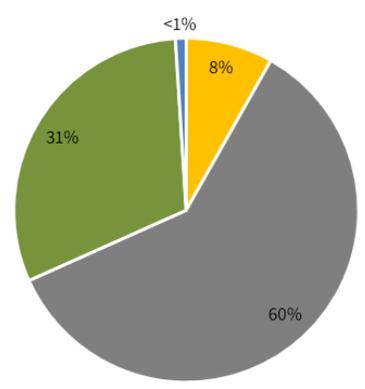
FIGURE 4. Milton Three Ponds (including Northeast Pond, Townhouse Pond, and Milton Pond watersheds) land cover area by major category (agriculture, developed, forest, and water/wetlands) and total phosphorus (TP) watershed load by major

land cover type. This shows that developed areas cover 7% of the watershed and contribute 60% of the TP watershed load to Milton Three Ponds. The water/wetlands category does not include the lake areas.

OTHER MAJOR LLRM INPUTS

The following presents a brief outline of other variable sources and assumptions input into the model. Refer to Limitations to the Model for further discussion.

- **Monthly precipitation data** were obtained from NOAA NCEI for the Rochester Skyhaven Airport (NH) (USW00054791), Rochester (NH) (USC00277253), and Acton 2.7 NW (ME) (US1MEYK0048) weather stations. The average annual precipitation totals from 2015-2024 were input as 39.5 in or 1.0 m.
- **Direct atmospheric deposition** phosphorus export coefficient was assumed to be 0.11 kg/ha/yr from Schloss et al. (2013) and represents a largely undeveloped watershed.
- **Lake volume and area estimates** were obtained from the NHFGD via NH GRANIT's "Bathymetry Lakes Polygons" spatial file. These estimates were compared to the most recent NHDES Lake Trophic Survey Reports for each pond; these reports only accounted for the portions of the ponds in New Hampshire and thus only represented half of the lake area for each pond.
- **Townhouse Pond and Milton Pond were assumed to act as a well-mixed system with substantial backflow from Milton Pond into Townhouse Pond.** The Townhouse Pond model calibrated well assuming at least 30% up to 100% of the water passing through Milton Pond backflows into Townhouse Pond. A hydrodynamic study of the pond system would be needed for a more accurate estimate of water exchange.
- **Point sources** from upstream models were input to downstream models. The three ponds were each modeled separately, with Northeast Pond and Townhouse Pond being routed directly into Milton Pond as a point source. The outputs of water load corrected for pan evaporation and predicted annual average in-lake phosphorus concentrations from Northeast Pond was entered as an input to Milton Pond. Because Townhouse Pond was modeled with substantial backflow from Milton Pond, the total water and phosphorus loads (excluding backflow) from Townhouse Pond were entered as a direct input Milton Pond, rather than using the predicted in-lake total phosphorus concentration from the model.
- **Septic system data** were estimated from a residential survey. The Strafford Regional Planning Commission (SRPC) sent a septic system questionnaire to all parcels with buildings within 250 feet of the three ponds' shorelines. The questionnaire included pertinent information such as the age of the septic system, occupancy, and seasonal or year-round use. Due to a moderate response rate, these data were extrapolated to all parcels with buildings in the 250-foot shoreland zone. From this information, the number of "old" (>25 years) and "young" (<25 years) shoreline septic systems was determined. Systems were split into four occupancy categories representing varied levels of seasonal and year-round use. The total number of systems in each occupancy and age category was multiplied by the average household size (the average number of occupants across survey responses for each category) to determine the number of persons on septic systems around the lake and ultimately the associated water and total phosphorus load from shoreline septic systems.
- **Water quality data** were gathered from the NHDES Environmental Monitoring Database (EMD) and University of New Hampshire Lakes Lay Monitoring Program (LLMP). Data were screened for relevant site locations and water quality parameters (Secchi disk transparency, chlorophyll-a, total phosphorus, dissolved oxygen, and temperature). The model was calibrated, as appropriate, using tributary and pond samples taken between 2015-2024. Sites were only included if they were lake samples or a close match to the outlet of a sub-watershed used in the model. Data were summarized to obtain median and mean water quality summaries for total phosphorus, chlorophyll-a, and Secchi Disk Transparency and aggregated for multiple lake sites, if relevant.
- **Waterfowl counts** for the three ponds were based on a standard estimate of 0.3 birds per hectare of lake surface area. This default value is based on best professional experience with modeling other similar lakes in the area. Waterfowl can be a direct source of nutrients to lakes; however, if they are eating from the lake and their waste returns to the lake, the net change may be less than might otherwise be assumed; even so, the phosphorus excreted may be in a form that can be readily used by algae and plants.
- **Internal loading estimates** were determined by calculating the total mass of phosphorus in the water column for each sample event with epilimnion (surface) and hypolimnion (bottom) grab samples, averaging by month, and extracting the difference between late summer and early summer as the contribution of phosphorus from sediments

in each pond annually. Annual estimates of internal phosphorus loading were averaged for the most recent 10 years. The internal load estimate in any given year was highly variable given its high flushing rate and warrants continued monitoring.

CALIBRATION

Calibration is the process by which model results are brought into agreement with observed data and is an essential part of environmental modeling. Usually, calibration focuses on the input data with the greatest uncertainty. Changes are made within a plausible range of values, and an effort is made to find a realistic explanation among environmental conditions for these changes. Few tributary phosphorus concentration data were available for the modeling period for the three ponds (2015-2024, typically two samples per year with one in spring and one in fall) and thus were only used as guideposts; enhanced tributary monitoring efforts may be used to improve model calibration in the future. Observed in-lake phosphorus concentrations were given primacy during the calibration process, such that the ability of the model to accurately simulate annual average in-lake phosphorus concentration was used as a leading indicator of acceptable model performance. Continued water quality sampling in the watershed can be designed to reduce the uncertainty encountered in modeling and help assess assumptions made during calibration.

The following key calibration input parameter values and modeling assumptions were made:

- Default **water and phosphorus attenuation factors** were first used before each sub-watershed's attenuation factors and were adjusted to account for landscape features that would increase or decrease attenuation (Table 1). Water can be lost through evapotranspiration, groundwater, and wetlands, while phosphorus can be removed by infiltration or uptake processes. We generally expect at least a 5% loss (95% passed through, default) in water and a 10% loss (90% passed through, default) in phosphorus for each sub-watershed. Larger water losses (<95% passed through) can be expected with lower gradient or wetland-dominated sub-watersheds. Additional infiltration, filtration, detention, and uptake of phosphorus will lower the phosphorus attenuation value, such as for sub-watersheds dominated by moderate/small ponds or wetlands (75%-85% passed through) or channel processes that favor uptake (85% passed through), depending on the gradient. Headwater systems are assumed to have a greater attenuation than higher order streams since the flow of water is lower, giving more opportunity for infiltration, adsorption, and uptake.
- The average of multiple **empirical formulas** for predicting annual in-lake phosphorus concentration was used according to the most appropriate formulas for each pond; the same four models were used for all three ponds: Larsen-Mercier (1976), Jones-Bachmann (1976), Reckhow General (1977), and Nürnberg (1998).

TABLE 1. Reasoning for water and phosphorus attenuation factors used by model and sub-watershed.

Sub-Watershed	Water Atten. Factor	Phos. Atten. Factor	Reasoning (water; phosphorus (P))
Northeast Pond			
Fernald Shores	0.95	0.90	Default water and P attenuation factor.
Black Pond	0.80	0.75	Attenuation by small pond and stream.
Great East Lake	1.00	1.00	Attenuation from this sub-watershed is considered in a downstream sub-watershed (Horn Pond).
Horn Pond	0.80	0.40	Attenuation by headwater lake (including Great East Lake and Wilson Lake).
Kingswood Lake	0.90	0.40	Attenuation by headwater lake.
Lovell Lake	0.90	0.40	Attenuation by headwater lake.
Lower Branch River	0.85	0.65	Attenuation by wetlands/large river/large tributary network.
Lower Salmon Falls River	0.90	0.75	Attenuation by wetlands/large river.
Northeast Pond Direct Drainage	0.95	0.90	Default water and P attenuation factor.
Upper Branch River	1.00	1.00	Attenuation from this sub-watershed is considered in a downstream sub-watershed (Lower Branch River).
Upper Salmon Falls River	1.00	1.00	Attenuation from this sub-watershed is considered in a downstream sub-watershed (Lower SF River).
Wilson Lake	1.00	1.00	Attenuation from this sub-watershed is considered in a downstream sub-watershed (Horn Pond).
Townhouse Pond			
12 Route 6 River	0.95	0.90	Default water and P attenuation factor.
Townhouse Pond Direct Drainage	0.95	0.90	Default water and P attenuation factor.
Milton Pond			
Milton Pond Direct	0.95	0.90	Default water and P attenuation factor.
10 Dawn Point	0.95	0.90	Default water and P attenuation factor.
7 Cove	0.95	0.90	Default water and P attenuation factor.

LIMITATIONS TO THE MODEL

There were several limitations to the model; literature values and best professional judgement were used in place of measured data, wherever appropriate. Acknowledging and understanding model limitations is critical to interpreting model results and applying any derived conclusions to management decisions. The model should be viewed as one of many tools available for lake management. Because the LLRM incorporates specific waterbody information and is flexible in applying new data inputs, it is a powerful tool that predicts annual average in-lake total phosphorus concentrations with a good degree of confidence; however, model confidence can be increased with more data. The following lists limitations to the model:

- **The model represents a static snapshot in time based on the best information available at the time of model execution.** Factors that influence water quality are dynamic and constantly evolving; thus, the model should be regularly updated when significant changes occur within the watershed and as new water quality and physical data are collected. In this respect, the model should only be considered up-to-date on the date of its release. Model results represent annual averages and are best used for planning level purposes and should only be used with full recognition of the model limitations and assumptions.

- **Limited water quality data were available for calibration and internal loading estimates.** Limited tributary data were available. Monthly total phosphorus and flow data at the outlet(s) and tributaries would be needed to effectively calibrate the sub-watershed predictions to known observations. Ample data were available for assessing the in-lake total phosphorus concentration and internal phosphorus load, though additional data in the shoulder months (spring and early fall) and at more discrete depths (or a composite sample down to 10 meters) would be useful to further refine estimates for model calibration.

- **Septic system loading was estimated based on default literature values and regional statistics.** Default literature values for daily water usage, phosphorus concentration output per person, and system phosphorus attenuation factors were used and may not reflect local watershed conditions. Regional statistics on usage (duration and number of occupants) or best professional judgement were also used when information on septic systems was unavailable.

- **Waterfowl counts were based on default estimates and limited observation data.** In the future, a large bird (e.g., geese, ducks, etc.) census throughout the year would help improve the model loading estimates.

- **Land cover export coefficients were estimates.** Literature values and best professional judgement were used in evaluating and selecting appropriate land cover export coefficients. While these coefficients may be accurate on a larger scale, they are likely not representative on a site-by-site basis. Refer to documentation within the model spreadsheet for specific citations.

- **Upstream waterbodies (AWWA lakes) were not modeled.** Modeling upstream waterbodies may refine predictions for the downstream ponds by accounting for attenuation/settling processes that were roughly estimated through attenuation factors for these models. The lakes upstream of the three ponds were modeled as part of the 2010 Salmon Falls Headwater Lakes Watershed Management Plan (AWWA & FBE, 2010), though these models are out of date and may not reflect current conditions in the watershed. The attenuation factor for Horn Pond was adjusted so that the water and phosphorus load output fell within range of the 2010 modeled loads.

- **Sub-watersheds encompass large areas of land and may not explicitly highlight smaller sub-areas with high phosphorus export.** Phosphorus load in the model is aggregated over large sub-watershed areas, which can include both densely developed areas and undeveloped land. This aggregation may give the false impression that the entire sub-watershed exports an equally distributed portion of the phosphorus load. The developed portions of these sub-watersheds (e.g., downtown Wakefield in the Upper Branch River sub-watershed) may require substantial phosphorus control in the future, while the undeveloped portions of these sub-watersheds may not.

- **Backflow from Milton Pond into Townhouse Pond was approximated based on best professional judgement.** The assumption that at least 30% up to 100% of the water in Milton Pond backflows into Townhouse Pond generalizes the temporal and spatial variability of total phosphorus concentrations in the ponds, especially as it relates to extreme weather observed in recent years (e.g., warmer temperatures, larger storm events, more prolonged drought periods) and cyanobacteria blooms that can be blown to or migrate between ponds via water currents.

RESULTS

CURRENT LOAD ESTIMATION

Overall, model predictions for Northeast Pond, Townhouse Pond, and Milton Pond were in good agreement with observed data for total phosphorus (1%, 2%, and 4%, respectively), chlorophyll-a (11%, 30%, and 2%, respectively), and Secchi disk transparency (19%, 6%, and 7%, respectively) (Table 2). It is important to note that the LLRM does not explicitly account for all the biogeochemical processes occurring within a waterbody that contribute to overall water quality and is less accurate at predicting chlorophyll-a and Secchi disk transparency. For example, chlorophyll-a is estimated strictly from nutrient loading, but other factors strongly affect algae growth, including transport of phosphorus from the sediment-water interface to the water column by cyanobacteria, low light from suspended sediment, grazing by zooplankton, presence of heterotrophic algae, and flushing effects from high flows. There were insufficient data available to evaluate the influence of these other factors on observed chlorophyll-a concentrations and Secchi disk transparency readings. The model predicts 15 cyanobacteria bloom days for Northeast Pond, 6 for Townhouse Pond, and 11 for Milton Pond (Table 2), which aligns with the number of bloom warnings and alerts were issued by NHDES in recent years. Bloom warnings/alerts spanned 9 days (*Dolichospermum*) in 2023 and 7 days (*Dolichospermum*) in 2024 in Northeast Pond.

Watershed runoff combined with baseflow (96%) was the largest phosphorus loading contribution across all sources to Milton Pond, which is the final receiving waterbody in the Milton Three Ponds watershed (Table 3; Figure 5). The watershed load (96%) to Milton Pond includes the loads from Northeast Pond (84%), Townhouse Pond (6%), and the direct land area to Milton Pond (7%) (Table 3; Figure 5). Atmospheric deposition (1%), internal loading (<1%), waterfowl (<1%), and septic systems (2%) were relatively minor sources to Milton Pond but may be seasonally important during low flow summer conditions. For Townhouse Pond, 93% of the total phosphorus load is a result of backflow from Milton Pond. Without this backflow flushing, the predicted in-lake total phosphorus concentration in Townhouse Pond would be double and water quality conditions likely much worse.

Development in the watershed is most concentrated along the shorelines of the three ponds, as well as within multiple downtown areas in the upper watershed, including downtown Wakefield (Upper Branch River), Milton Mills (Lower Salmon Falls River), downtown Milton and Route 125 (Milton & Townhouse Pond direct sub-watersheds), and downtown Union (Upper
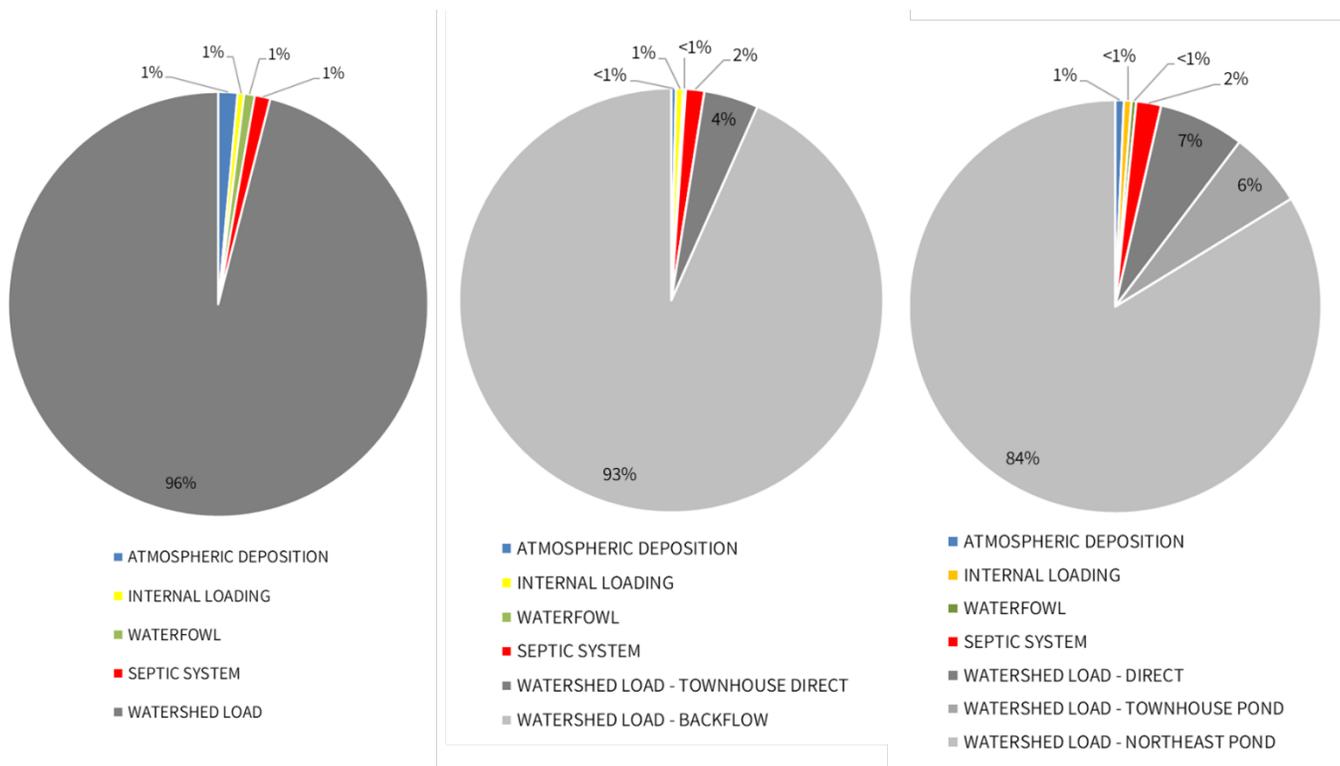

FIGURE 5. Summary of total phosphorus loading by major source for Northeast Pond (left), Townhouse Pond (middle), and Milton Pond (right). Refer to Table 3 for a breakdown.

and Lower Branch River). Development is also dense around the shoreline where septic systems or holding tanks are located within a short distance to the water, leaving little horizontal (and sometimes vertical) space for proper filtration of wastewater effluent. Improper maintenance or siting of these systems can cause failures, which leach untreated, nutrient-rich wastewater effluent to the lake. The entirety of the shoreline of the three ponds, except for a small portion of the Milton Pond shoreline in downtown Milton, is serviced by septic systems. Sewer can also represent a potential vulnerability if the sewer systems are old or damaged and leaking wastewater into groundwater near the ponds. Note that the septic system load estimate is only for those systems directly along the shoreline and potentially short-circuiting minimally treated effluent to the ponds. The load from septic systems throughout the rest of the watershed is inherent to the coefficients used to generate the watershed load.

Normalizing for the size of a sub-watershed (i.e., accounting for its annual discharge and direct drainage area) better highlights sub-watersheds with elevated pollutant exports relative to their drainage area. Sub-watersheds with moderate-to-high phosphorus mass exported by area (>0.20 kg/ha/yr) generally had more development (i.e., highly developed urban areas along the three ponds' shorelines and the Upper Salmon Falls sub-watershed; Table 4, Figure 6). Drainage areas directly adjacent to waterbodies have direct connection to lakes and are usually targeted for development, thus increasing the possibility for phosphorus export. Other high loading areas (such as downtown areas in the Upper Branch River, Lower Branch River, and Lower Salmon Falls River sub-watersheds) were embedded in large, mostly undeveloped watersheds which led to generally lower total phosphorus loads when compared to the sub-watershed area.

PRE-DEVELOPMENT LOAD ESTIMATION

Once the model is calibrated for current in-lake phosphorus concentration, we can then manipulate land cover and other factor loadings to estimate pre-development loading scenarios (e.g., what in-lake phosphorus concentration was prior to human development or the best possible water quality for the ponds). Refer to Attachment 2 for details on methodology. Pre-development loading estimation showed that total phosphorus loading to Milton Pond (representative of the total loads to all three ponds) increased by 234%, from 554 kg/yr prior to European settlement to 1,853 kg/yr under current conditions (Table 3). These additional phosphorus sources are coming from development in the watershed (especially from the direct shoreline of the three ponds and the multiple downtown areas), septic systems, atmospheric dust, and internal loading (Tables 3, 4). Water quality prior to settlement was predicted to be excellent with extremely low phosphorus and chlorophyll-a concentrations and high water clarity (Table 2).

FUTURE LOAD ESTIMATION

We can also manipulate land cover and other factors to estimate future loading scenarios (e.g., what in-lake phosphorus concentration might be at full build-out under current zoning or the worst possible water quality for the ponds). Refer to Attachment 3 and the 2025 Milton Three Ponds Buildout Report (SRPC, 2025) for details on methodology. Note: the future scenario did not assume a 10% increase in precipitation over the next century (NOAA Technical Report NESDIS 142-1, 2013), which would have resulted in a lower predicted in-lake phosphorus concentration; this is because the model does not consider the rate and distribution of the projected increase in precipitation. Climate change models predict more intense and less frequent rain events that may exacerbate erosion of phosphorus-laden sediment to surface waters and therefore could increase in-lake phosphorus concentration (despite dilution and flushing impacts that the model assumes).

Future loading estimation showed that total phosphorus loading to Milton Pond (representative of total phosphorus loading to all three ponds) may increase by 76%, from 1,853 kg/yr under current conditions to 3,267 kg/yr at full build-out (2216) under current zoning (Table 3). Additional phosphorus will be generated from more development in the watershed (especially in undeveloped headwater areas), greater atmospheric dust, more septic systems, and enhanced internal loading (Tables 3, 4). The Milton Pond model predicted higher (worse) phosphorus (19.3 µg/L), higher (worse) chlorophyll-a (7.2 µg/L) with 118 bloom days, and lower (worse) water clarity (2.4 m) compared to current conditions for Milton Pond (Table 2). Predicted future water quality was similarly poor for Northeast Pond and Townhouse Pond.

TABLE 2. In-lake water quality predictions for the Milton Three Ponds. TP = total phosphorus. Chl-a = chlorophyll-a. SDT = Secchi disk transparency. Bloom Days represent average annual probability of chlorophyll-a exceeding 8 µg/L.

Model Scenario	Median TP (µg/L)	Predicted Median TP (µg/L)	Mean Chl-a (µg/L)	Predicted Mean Chl-a (µg/L)	Mean SDT (m)	Predicted Mean SDT (m)	Bloom Days
Northeast Pond							
Pre-Development	--	3.7	--	0.7	--	8.4	0
Current (2025)	11.5	11.6	3.4	3.8	2.9	3.5	15
Future (2216)	--	21.1	--	8.0	--	2.2	148
Townhouse Pond							
Pre-Development	--	3.3	--	0.6	--	9.3	0
Current (2025)	9.8	9.9	4.2	3.1	3.7	4.0	6
Future (2216)	--	17.4	--	6.3	--	2.6	86
Milton Pond							
Pre-Development	--	3.3	--	0.6	--	9.3	0
Current (2025)	10.5	10.9	3.6	3.5	3.5	3.7	11
Future (2216)	--	19.3	--	7.2	--	2.4	118

TABLE 3. Total phosphorus (TP) and water loading summary by model and source for Northeast, Townhouse, and Milton Ponds. Italicized sources sum to the watershed load.

SOURCE	PRE-DEVELOPMENT			CURRENT (2024)			FUTURE (2216)		
	TP (KG/YR)	%	WATER (CU.M/YR)	TP (KG/YR)	%	WATER (CU.M/YR)	TP (KG/YR)	%	WATER (CU.M/YR)
NORTHEAST POND									
ATMOSPHERIC	18.8	3%	2,695,429	29.6	1%	2,695,429	67.2	2%	2,695,429
INTERNAL	0.0	0%	0	10.3	1%	0	18.7	1%	0
WATERFOWL	16.1	2%	0	16.1	1%	0	16.1	<1%	0
SEPTIC SYSTEM	0.0	0%	0	24.2	1%	23,382	28.3	1%	28,492
WATERSHED LOAD	605.8	95%	132,849,312	1,925.3	96%	132,428,792	3,509.1	96%	131,872,342
TOTAL LOAD TO POND	**640.7**	**100%**	**135,544,741**	**2,005.5**	**100%**	**135,147,603**	**3,639.4**	**100%**	**134,596,263**
TOWNHOUSE POND									
ATMOSPHERIC	3.7	1%	528,589	5.8	<1%	528,589	13.2	<1%	528,589
INTERNAL	0.0	0%	0	9.1	1%	0	13.0	<1%	0
WATERFOWL	3.2	1%	0	3.2	<1%	0	3.2	<1%	0
SEPTIC SYSTEM	0.0	0%	0	23.4	1%	22,407	23.4	1%	22,407
WATERSHED LOAD	535.8	99%	143,947,890	1,614.2	98%	143,929,319	2,841.1	99%	143,917,241
Direct Land Use Load	*11.2*	*2%*	*2,153,437*	*68.7*	*4%*	*2,134,865*	*104.5*	*4%*	*2,122,787*
Backflow from Milton Pond	*524.6*	*97%*	*141,794,454*	*1,545.6*	*93%*	*141,794,454*	*2,736.6*	*95%*	*141,794,454*
TOTAL LOAD TO POND	**542.7**	**100%**	**144,476,480**	**1,655.8**	**100%**	**144,480,315**	**2,893.9**	**100%**	**144,468,237**
MILTON POND									
ATMOSPHERIC	8.0	2%	1,150,405	12.6	1%	1,150,405	28.7	1%	1,150,405
INTERNAL	0.0	0%	0	10.9	1%	0	19.2	1%	0
WATERFOWL	6.9	1%	0	6.9	<1%	0	6.9	<1%	0
SEPTIC SYSTEM	0.0	0%	0	36.1	2%	34,502	37.9	1%	36,760
WATERSHED LOAD	539.2	97%	141,048,119	1,786.3	96%	140,609,547	3174.2	97%	140,007,886
Direct Land Use Load	*24.8*	*4%*	*4,476,014*	*124.4*	*7%*	*4,430,745*	*206.2*	*6%*	*4,392,502*
Townhouse Pond	*18.0*	*3%*	*2,410,738*	*110.2*	*6%*	*2,414,573*	*157.3*	*5%*	*2,402,496*
Northeast Pond	*496.4*	*90%*	*134,161,366*	*1,551.7*	*84%*	*133,764,228*	*2810.8*	*86%*	*133,212,888*
TOTAL LOAD TO POND	**554.1**	**100%**	**142,198,524**	**1,852.8**	**100%**	**141,794,454**	**3,266.9**	**100%**	**141,195,051**

TABLE 4. Summary of land area, water flow, and total phosphorus (TP) concentration and loading by model and sub-watershed for Milton Three Ponds. Land area does not include the area of the lakes.

Sub-Watershed	Land Area (ha)	Pre-Development Watershed Loads				Current (2024) Watershed Loads					Future (2216) Watershed Loads			
		Water Flow (m³/year)	Calc. P Conc. (mg/L)	P mass (kg/year)	P mass by area (kg/ha/year)	Water Flow (m³/year)	Calc. P Conc. (mg/L)	Measured P Conc. (mg/L)	P mass (kg/year)	P mass by area (kg/ha/year)	Water Flow (m³/year)	Calc. P Conc. (mg/L)	P mass (kg/year)	P mass by area (kg/ha/year)
Northeast Pond														
Fernald Shores	202.2	1,145,935	0.005	6.1	0.03	1,141,560	0.013	0.017	14.5	0.07	1,130,067	0.047	52.6	0.26
Black Pond	746.1	3,392,568	0.005	16.8	0.02	3,380,058	0.014	--	45.7	0.06	3,368,160	0.025	84.7	0.11
Great East Lake	4,098.6	23,268,445	0.005	127.9	0.03	23,177,449	0.021	--	476.6	0.12	23,074,884	0.036	835.2	0.20
Horn Pond*	461.9	2,093,847	0.003	5.6	0.01	2,083,487	0.010	--	20.0	0.04	2,074,672	0.017	35.5	0.08
Kingswood Lake	444.8	2,264,714	0.002	5.2	0.01	2,260,282	0.006	--	13.0	0.03	2,257,300	0.008	17.7	0.04
Lovell Lake	1,235.1	6,338,373	0.002	15.5	0.01	6,291,568	0.011	--	67.7	0.05	6,234,282	0.025	156.7	0.13
Lower Branch River*	6,628.7	32,282,644	0.005	146.5	0.02	32,220,891	0.012	0.013	385.1	0.06	32,132,873	0.020	629.2	0.09
Lower Salmon Falls River*	2,332.6	9,774,112	0.004	41.7	0.02	9,714,141	0.014	0.010	134.8	0.06	9,672,814	0.025	238.5	0.10
Northeast Pond Direct	848.6	4,788,698	0.005	25.0	0.03	4,777,837	0.019	--	88.5	0.10	4,741,454	0.044	209.0	0.25
Upper Branch River*	6,258.1	38,844,430	0.007	256.5	0.04	38,686,236	0.022	0.011	847.9	0.14	38,553,377	0.038	1,464.7	0.23
Upper Salmon Falls River*	1,850.0	17,577,242	0.010	170.2	0.09	17,578,911	0.033	--	574.4	0.31	17,496,067	0.062	1,089.9	0.59
Wilson Lake	999.8	5,744,327	0.006	33.9	0.03	5,730,714	0.019	--	109.6	0.11	5,685,095	0.047	269.1	0.27
Townhouse Pond														
12 Route 6 River	196.5	1,114,232	0.005	5.9	0.03	1,110,944	0.011	0.013	12.6	0.06	1,104,147	0.030	32.8	0.17
Townhouse Pond Direct	188.7	1,039,204	0.005	5.3	0.03	1,023,921	0.055	--	56.0	0.30	1,018,641	0.070	71.7	0.38
Milton Pond														
10 Dawn Point	208.9	1,187,631	0.005	6.4	0.03	1,178,518	0.024	0.018	28.1	0.13	1,169,269	0.041	47.9	0.23
7 Cove	111.7	634,094	0.006	4.0	0.04	632,268	0.017	0.010	10.9	0.10	627,555	0.033	21.0	0.19
Milton Pond Direct	466.7	2,654,289	0.005	14.4	0.03	2,619,958	0.033	--	85.4	0.18	2,595,678	0.053	137.3	0.29

Table shows water and P loads for the direct sub-watershed area only.
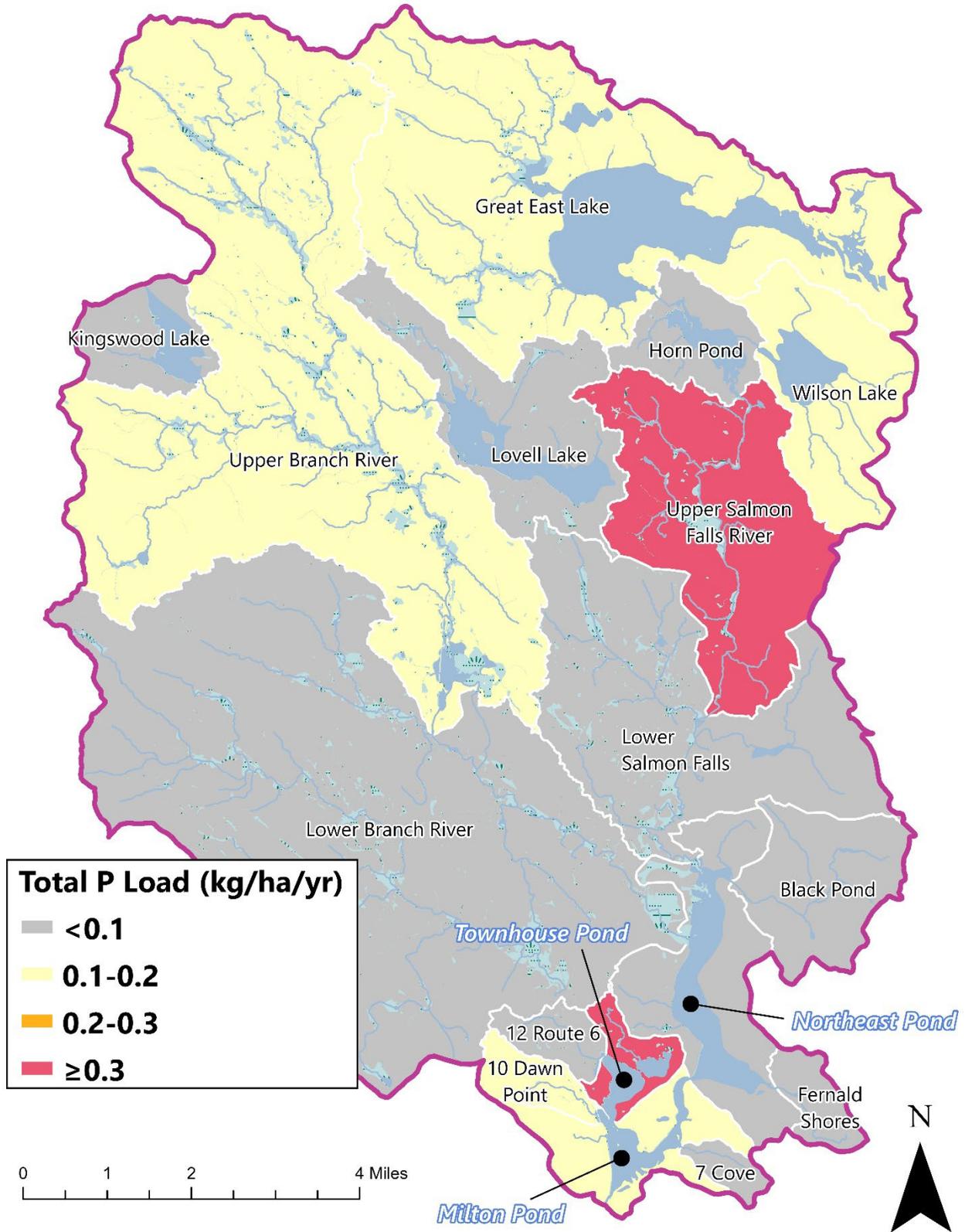
FIGURE 6. Map of current total phosphorus load per unit area (kg/ha/yr) for each sub-watershed in the Milton Three Ponds watershed. Higher phosphorus loads per unit area are concentrated around the Townhouse Pond direct shoreline and in the Upper Salmon Falls River.

CONCLUSION

The modeling showed that the water quality of Northeast Pond, Townhouse Pond, and Milton Pond is threatened by current development activities in the watershed and will degrade further with continued unmitigated development in the future. The three ponds are known to have historically good water quality with infrequent cyanobacteria blooms, comprised of *Dolichospermum*, which are nitrogen-fixers that can regulate their buoyancy in the water column and are potentially toxic.

Cyanobacteria blooms in recent years (2016, 2023, 2024) have caused alarm in the region about the three ponds' water quality. These blooms are often fueled by excess phosphorus loading to waterbodies. Modeled results for Milton Three Ponds suggest that most of the phosphorus loading to the ponds comes from external sources (96%). Watershed protection efforts may focus on high-loading sub-watersheds, including the direct watersheds of the three ponds, Upper Salmon Falls River, Upper Branch River, and the shorelines of headwater lakes. Many urbanized downtown areas exist throughout the watershed and are included in larger sub-watersheds that also include large swaths of undeveloped land. Actions that both serve to mitigate pollution from existing impervious areas and protect undisturbed land are likely necessary to protect the three ponds.

For all modeled waterbodies, the model predicts more prevalent blooms in the future (up to 148 bloom days). Any new increases in phosphorus to a lake can disrupt the ecological balance in favor of increased algal growth, resulting in degraded water clarity. The impact from new buildings and septic systems can be greatly reduced by implementing low impact development (LID) techniques and ensuring that all new septic systems are well separated from surface waters both horizontally and vertically (above seasonal high groundwater in suitable soil). A substantial increase in phosphorus loading is predicted to occur due to the development of undeveloped headwater areas, such as the AWWA lakes sub-watersheds and the Upper Salmon Falls River and Upper Branch River. Future loading may be prevented through land conservation efforts or land use planning that seeks to protect undisturbed natural areas whilst promoting LID in areas with existing infrastructure to support the growing population. The watershed management plan for Milton Three Ponds will highlight the following actions to improve and protect water quality in the watershed: 1) maximize land conservation of intact forestland, 2) consider zoning ordinance amendments that encourage LID techniques and protect natural resources, and 3) improve and maintain stormwater control practices throughout the watershed.

REFERENCES

Acton Wakefield Watersheds Alliance (AWWA) & FB Environmental Associates (FBE). 2010. Salmon Falls Headwater Lakes Watershed Management Plan. March 2010.

Strafford Regional Planning Commission (SRPC). 2025. Milton Three Ponds Buildout. August 2025.

ATTACHMENT 1: LAND COVER

Land cover water (precip) and phosphorus (P) export coefficients and land cover areas for sub-watersheds of each modeled waterbody in the Milton Three Ponds watershed. Excludes lake surface area.

	RUNOFF EXPORT COEFF.		BASEFLOW EXPORT COEFF.		Milton Pond			
	Precip	P Export	Precip	P Export	10 Dawn Point	7 Cove	Milton Pond Direct	
LAND COVER	(Fraction)	(kg/ha/yr)	(Fraction)	(kg/ha/yr)	AREA (HA)	AREA (HA)	AREA (HA)	TOTAL AREA (HA)
Urban 1 (Low Density Res.)	0.30	0.79	0.25	0.010	16.42	2.82	38.93	58.17
Urban 2 (Medium Density Res./Comm.)	0.50	0.82	0.05	0.010	5.62	3.10	23.27	31.98
Urban 3 (Roads)	0.50	1.16	0.05	0.010			17.45	17.45
Urban 4 (Industrial)	0.50	1.42	0.05	0.010				0.00
Urban 5 (Open Space/Mowed)	0.30	0.51	0.25	0.010	1.43		0.60	2.02
Agric 2 (Row Crop/Hayfield/Orchard)	0.30	0.37	0.30	0.010	2.57	0.96	5.53	9.06
Agric 3 (Grazing)	0.30	1.50	0.30	0.010				0.00
Forest 1 (Upland)	0.20	0.03	0.40	0.004	0.27	95.94	361.01	457.22
Forest 2 (Wetland)	0.05	0.003	0.40	0.004	172.49	1.34	2.84	176.67
Open 1 (Emergent Wetland/Lake)	0.05	0.01	0.40	0.004	3.67	1.38	5.49	10.53
Open 2 (Meadow)	0.30	0.20	0.30	0.004	0.69	4.06	1.74	6.49
Open 3 (Excavation)	0.80	0.80	0.10	0.010				0.00
Other 1 (Logging)	0.30	0.06	0.30	0.004	1.42		1.73	3.15
Other 2 (Unpaved Road)	0.60	0.83	0.05	0.010	4.32	2.08	8.13	14.54
					208.89	**111.68**	**466.73**	**787.30**

	Northeast Pond												
	Fernald Shores	Black Pond	Great East Lake	Horn Pond	Kingswood Lake	Lovell Lake	Lower Branch River	Lower Salmon Falls River	Northeast Pond Direct	Upper Branch River	Upper Salmon Falls River	Wilson Lake	TOTAL AREA (HA)
LAND COVER	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	
Urban 1 (Low Density Res.)	6.68	28.90	257.90	24.94	14.97	97.51	222.27	123.40	37.29	268.52	77.72	53.78	1,213.88
Urban 2 (Medium Density Res.)	3.07	6.36	55.13	6.94	1.49	23.68	38.71	29.09	9.30	91.90	15.72	12.70	294.08
Urban 3 (Roads)						0.86	72.69	4.52	3.37	23.08	1.45		105.96
Urban 4 (Industrial)									18.32				18.32
Urban 5 (Open Space/Mowed)			18.34	2.79		0.98	9.14	5.47	0.34	9.55	0.14	6.00	52.75
Agric 2 (Row Crop/Hayfield/Orch)	0.71	15.42	20.80	2.13	1.35	32.29	43.14	90.32	19.70	63.27	13.41	11.44	313.99
Agric 3 (Grazing)		0.38	1.84			0.64	3.69	6.92	1.25	17.48	1.29	1.16	34.64
Forest 1 (Upland)	184.59	519.50	2,620.76	307.42	298.65	787.85	5,277.75	1,764.08	709.99	5,026.08	1,475.94	700.00	19,672.62
Forest 2 (Wetland)	2.47	152.83	72.54	8.57	0.11	13.40	179.28	218.43	36.20	231.93	148.20	42.57	1106.53
Open 1 (Emergent Wetland/Lake)	3.74	10.67	843.15	97.90	105.33	242.23	161.89	48.41	5.00	168.77	45.94	135.43	1,868.46
Open 2 (Meadow)	0.33	8.00	43.32	2.37	0.53	11.53	74.17	31.99	0.29	57.75	20.22	22.23	272.72
Open 3 (Excavation)			13.17				21.93		0.57	10.33	21.34	6.17	73.50
Other 1 (Logging)			80.86		15.78	4.92	474.01	0.90	1.24	215.83	7.23		800.78
Other 2 (Unpaved Road)	0.56	4.05	70.75	8.82	6.63	19.24	50.01	9.10	24.06	55.30	21.40	8.32	278.25
	202.16	**746.12**	**4,098.55**	**461.89**	**444.84**	**1,235.12**	**6,628.67**	**2,332.62**	**848.59**	**6,258.11**	**1,850.01**	**999.80**	**26,106.49**

LAND COVER	Townhouse Pond		TOTAL AREA (HA)
	12 Route 6 River AREA (HA)	Townhouse Pond Direct AREA (HA)	
Urban 1 (Low Density Res.)	0.82	28.10	28.92
Urban 2 (Medium Density Res./Comm.)	12.68	9.16	21.84
Urban 3 (High Density Res./Comm./Roads)	3.53	18.49	22.02
Urban 4 (Industrial)			0.00
Urban 5 (Open Space/Mowed)		1.80	1.80
Agric 2 (Row Crop/Hayfield/Orchard)	2.85	4.37	7.22
Agric 3 (Grazing)		0.17	0.17
Forest 1 (Upland)	180.79	90.54	271.34
Forest 2 (Wetland)	1.62	4.08	5.69
Open 1 (Emergent Wetland/Lake)	4.16	23.00	27.16
Open 2 (Meadow)			0.00
Open 3 (Excavation)		3.29	3.29
Other 1 (Logging)			0.00
Other 2 (Unpaved Road)	0.09	5.68	5.77
	206.54	**188.69**	**395.23**

ATTACHMENT 2: Estimating Pre-Development Phosphorus Load

1. Converted all human land cover to forest (Forest 1) and updated model.
2. Removed all septic inputs (set population to zero).
3. Removed internal loading, if applicable, assuming internal loading was the result of excess nutrient loading from human activities in the watershed.
4. Reduced atmospheric loading coefficient to 0.07 kg/ha/yr.
5. Reduced point sources (other lakes) to reflect pre-development phosphorus loads from upstream lakes/ponds, if applicable, according to their LLRM outputs.
6. Roughly matched outflow TP to predicted in-lake TP.
7. Kept all else the same, assuming waterfowl counts and precipitation input did not change (though they likely did).

ATTACHMENT 3: Estimating Future Phosphorus Load at Full Build-Out

1. Estimated number of new buildings at full buildout by sub-watershed. CommunityViz software uses model inputs such as population growth rates, zoning, wetlands, conservation lands, and other constraints to construction, and generates a projected number of new buildings in the future. The new building count was generated for each sub-watershed at full buildout. Refer to the 2025 Milton Three Ponds Buildout Report (SRPC, 2025).
2. Calculated developed land coverage after full buildout projection. Each new building was assumed to generate new developed land uses, including buildings, roads, etc. Specifically, the calculated areas of Urban 1-5, Open 3, and Other 2 per new building (based on current land cover areas and number of existing buildings) were multiplied by the number of new buildings in each sub-watershed.
3. Incorporated land use changes to LLRM for P loading predictions. Added the new developed land use figures to the LLRM. Within each sub-watershed, existing undeveloped land uses (Forest 1) were replaced with areas equal to added developed land.
4. Incorporated septic system loading to LLRM for P loading predictions. The number of new buildings within 250 ft of water was estimated from the CommunityViz output shapefile of projected new buildings. Projected buildings within 250 ft of lake or pond shorelines were joined with the NHDES Water and Sewer Line parcel; projected buildings in the area served by sewer were removed.
5. Increased atmospheric loading coefficient to 0.25 kg/ha/yr.
6. Calculated potential increase in internal loading. Assumed a similar magnitude increase in future loading from internal loading sources as compared to the increase in future total load to Milton Three Ponds.
7. Roughly matched outflow TP to predicted in-lake TP.
8. Kept all else the same.