Water Quality Management Plan

Pond Brook Tributary, Lewis Creek Watershed
Monkton & Bristol, Addison County, Vermont

May 2013



Prepared under contract to *Prepared by*

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This study was made possible through an Ecosystem Restoration Program grant received from the State of Vermont Department of Environmental Conservation, Watershed Management Division. The grant was administered by the Lewis Creek Association. Technical assistance was provided by the VT Department of Environmental Conservation, Mapping, Assessment & Planning Program and the River Management Program. John McNerny, pilot, provided flight services for aerial assessment of the watershed in the Spring of 2011 and 2012. Steve Parren granted permission for a temporary flow gaging station on his property. The project was guided by a Steering Committee of watershed stakeholders:

Project Steering Committee

Marty Illick	Lewis Creek Association, Addison County River Watch Collaborative
Steve Parren	Monkton citizen
Sam Burr	Last Resort Farm
Neil Kamman	VTDEC Mapping, Assessment & Planning Program
Ethan Swift	VTDEC Mapping, Assessment & Planning Program
Shannon Pytlik	VTDEC River Management Program
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Michelle Smith	VACD/VTAA – South Lake Champlain CREP Planner (Rutland / Addison)
Nate Sands	VT Agency of Agriculture, MFO Coordinator
Pam Stefanik	Otter Creek Natural Resources Conservation District
Jeff Carter	UVM Agricultural Extension Service (Middlebury)
April Moulaert	Waterscapes, LLC (representing Ducks Unlimited)
Kristen Underwood	South Mountain Research & Consulting

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Abbreviations:

ANAC – Agricultural and Natural Areas Committee (Monkton)
ARS – Agricultural Resource Specialist
BMP – Best Management Practice
CLU – Common Land Unit
CREP – Conservation Reserve Enhancement Program
CRP – Conservation Reserve Program
EQIP - Environmental Quality Incentives Program
ERP – Ecosystem Restoration Program
LCA – Lewis Creek Association
LFO – Large Farm Operation
MFO – Medium Farm Operation
NRCD – Natural Resources Conservation District
NRCS – Natural Resources Conservation Service
OCNRCD – Otter Creek Natural Resources Conservation District
SFO – Small Farm Operation
USDA – US Department of Agriculture
UVM – University of Vermont
VACD – Vermont Association of Conservation Districts
VLT - Vermont Land Trust
VRC – Vermont River Conservancy
VTAA – Vermont Agency of Agriculture
VTANR – Vermont Agency of Natural Resources
WRP – Wetland Reserve Program

EXECUTIVE SUMMARY

A Water Quality Management Plan has been prepared for the Pond Brook tributary of the Lewis Creek watershed based on assessments completed in 2012. Pond Brook is the third major tributary to Lewis Creek and drains 18.3 square miles of land in the towns of Bristol, Monkton, and Hinesburg. Land use within the watershed is estimated as 49% forested, 28% agricultural, and 4% urbanized (developed, transportation, utilities), with the remaining 19% comprised of lakes, ponds, and wetlands.

Pond Brook has been identified as a major sediment and phosphorus loader to the Lewis Creek watershed based on Spring / Summer water quality monitoring from 2004 to present. One station on the Pond Brook (LCT3D.5 at the Silver Street crossing) has been regularly monitored by the Addison County Riverwatch Collaborative for turbidity, nutrients, and E.coli.

E.coli is frequently above the State water quality standard. Total phosphorus concentrations have consistently been above levels which would suggest nutrient enrichment. Turbidity levels (suspended sediments) are generally low in Pond Brook, below the State water quality standard, but increase well above the standard during high flows. While these storm-related conditions do not technically constitute a violation of the Vermont water quality standards, it is clear that these events are delivering sediment (and associated nutrients) to receiving waters and Lake Champlain.

The State of Vermont has listed the lower 1.5 miles of the Pond Brook as impaired for contact recreation use due to *E. coli* impacts likely resulting from agricultural runoff. A TMDL for Bacteria-impaired Waters including Pond Brook was issued by the VTDEC in September 2011. Phosphorus, suspended sediments, and *E.coli* are impacting the brook as a result of channel erosion, land erosion, and non-erosion-related nutrient and pathogen loading.

Assessment tasks included: evaluations during high-water events to identify locations of direct stormwater and sediment runoff; flow monitoring in the Pond Brook; and expanded water-quality testing to sub-units of the watershed. Significant mobilization of fine sediments, phosphorus and *E.coli* to the Pond Brook is occurring, related to: (1) fall-tilling, manure applications, and cropping practices in close proximity to unbuffered swales, road ditches and other locations of concentrated runoff to surface waters; (2) occasional inundation of fields beyond minimum buffer widths required by AAPs and LFO/MFO rules; (3) maintenance of drainage ditches in agricultural fields; (4) livestock pastured with direct access to surface waters; and (5) stormwater and sediment runoff from forested and developed lands and road and driveway networks.

Ultimately, best opportunities for controlling the transport and delivery of fine sediments, nutrients and pathogens within the watershed are through: (1) improved management of nutrient and pathogen inputs within the upstream areas of the river network; and (2) interruption of the transport processes of sediments and nutrients at their source.

Guided by a Steering Committee of watershed stakeholders, short-term and long-term actions, projects and strategies have been identified for implementation at the site-level, reach-level and community scale to decrease nutrient, sediment and pathogen loading. Remedies are discussed generally in Section IV. Site-specific projects are identified in the Implementation Table and accompanying Plate 1, presented in Section V.

This plan complements the *Lewis Creek Watershed: River Corridor Conservation & Management Plan,* and will be incorporated in future updates to the Otter Creek Basin Plan authored by the VT Watershed Management Division. Funding was provided by an Ecosystem Restoration Program grant received from the State of Vermont Department of Environmental Conservation, Watershed Management Division.

I. Introduction

This plan presents the results of an assessment completed in the Pond Brook tributary of the Lewis Creek watershed in 2012. Pond Brook has been identified as a major sediment and phosphorus loader to the Lewis Creek watershed based on spring / summer water quality monitoring from 2004 to present (Hoadley, 2011; available at: http://lewiscreek.org/lewis-creek-water-quality). The State of Vermont has listed the lower 1.5 miles of the Pond Brook as impaired for contact recreation use due to *E. coli* impacts likely resulting from agricultural runoff (VTDEC WQD, 2010). A TMDL for Bacteria-impaired Waters including Pond Brook was issued by the VTDEC in September 2011 (VTDEC, 2011). The length of impairment is a function of the limited availability of historic water quality stations maintained along the Pond Brook by the ACRWC (furthest upstream station has been at Silver Street, at approximate river mile 1.5). Overall objectives of this assessment were to:

- Expand water quality testing to upstream sections of the Pond Brook, with a focus on sediment, nutrients, and pathogens;
- Identify locations of direct stormwater and sediment runoff to the Pond Brook network;
- Identify areas of saturation excess overland flow that overlap nutrient, sediment and pathogen source areas (Critical Source Areas);
- Identify sustainable river corridor management strategies through continued outreach to individual landowners and through public meetings;
- Prioritize management strategies that mitigate for hydrologic and sediment regime modifications, and reduce sediment, nutrient and pathogen loading to the Pond Brook, Lewis Creek and ultimately Lake Champlain; and
- Evaluate spatial and seasonal variability in nutrient (phosphorus) and sediment loading at the subwatershed scale through empirical means.

Based on assessment data, and guided by a Steering Committee of watershed stakeholders, short-term and long-term actions projects and strategies have been identified for implementation at the site-level, reach-level and community scale to address excess sediment, nutrients and pathogens.

This summary report has been prepared by South Mountain Research & Consulting (SMRC) based in Bristol, Vermont under contract to the Lewis Creek Association (LCA). Project tasks have been carried out by LCA and SMRC, with technical support from the VTDEC Mapping, Assessment & Planning Program and the River Management Program, as well as volunteer assistance from the Addison County Riverwatch Collaborative. Members of the project Steering Committee are identified in the Acknowledgements section (page ii).

This plan is intended to support an adaptive management approach in the Pond Brook watershed, following the Tactical Basin Planning approach of the VT Watershed Management Division. This plan complements the *Lewis Creek Watershed: River Corridor Conservation & Management Plan* (SMRC, 2010), and will be incorporated in future updates to the Otter Creek Basin Plan authored by the VT Watershed Management Division.

II. Background

A. Geographic Setting

Pond Brook is the third major tributary of Lewis Creek watershed, draining 18.3 square miles of land in the towns of Bristol, Monkton, and Hinesburg. This tributary catchment represents approximately one quarter of the total Lewis Creek watershed, an 81-square-mile basin that spans Addison County (77% by area) and Chittenden County (23%) (Figure 1).

At the headwaters of Pond Brook is Winona Lake, known locally as Bristol Pond. This pond is 248 acres in area and occupies a glacial kettle depression (George Springston, personal communication). It is a natural pond with an artificial earthen dam at the outlet maintained by the Vermont Fish & Wildlife Department. Maximum depth is 9 feet according to an early 1980s bathymetric survey conducted by the state of Vermont (VT Watershed Management Division, 2013).

From Winona Lake, Pond Brook flows from south to north through a wide, low-gradient valley bound on the east by steep, talus slopes of the Hogback Mountain and on the west by Monkton Ridge. The Hogback Mountain separates Pond Brook from the main stem of the Lewis Creek to the east. Monkton Ridge represents the drainage divide between Pond Brook and the headwaters of Little Otter Creek to the west.

Pond Brook joins the Lewis Creek main stem just north of the Monkton/ Hinesburg town line (between Silver Street to the east and Baldwin Road to the west). At its point of confluence, the Pond Brook represents approximately 47% of the upstream watershed of the Lewis Creek (39 sq mi).

Lewis Creek drains directly into Lake Champlain at Hawkins Bay near Long Point and Gardner Island. This location is within the Otter Creek lake segment, as defined within the Vermont Water Quality Standards (Vermont Natural Resources Board, 2008) and by the Lake Champlain Phosphorus Management Task Force (1993). Under the VTDEC basin planning process, the Lewis Creek watershed is considered a part of the Otter Creek Basin, although these river systems drain separately to Lake Champlain; the mouth of the Otter Creek is located 2.7 miles to the southwest of the mouth of Lewis Creek.

B. Regional Geologic Setting

The Lewis Creek watershed spans two geophysical provinces, with its eastern headwaters located in the Northern Green Mountains and the central and western regions located in the broad Champlain Valley province (Stewart, 1973; Capen, 1998). Pond Brook is located in the south-central portion of the Lewis Creek watershed, entirely within the Champlain Valley province.

The Pond Brook tributary watershed is defined by two north-south trending ridge lines composed of elevated slabs of crystalline rock that resulted from low-angle thrusting and folding (Stewart, 1973; Doll, 1961). Hogback Mountain, composed of relatively more erosion-resistant Cheshire Quartzite, forms the eastern boundary of the watershed. Monkton Ridge forms the western boundary and is comprised of locally more erosion-resistant Monkton Quartzite and Winooski Dolostone associated with the Monkton Thrust fault. The broad valley between these two ridgelines is underlain by Dunham dolostone and Cheshire quartzite (Ratcliffe *et al*., 2011; Stewart, 1973; Doll, 1961).

The surficial sediments and soils present in the Pond Brook watershed reflect the glacial and post-glacial lake history of the region. Upland slopes are dominated by shallow- to moderate-thickness glacial till deposits overlying bedrock. These till deposits are a dense mixture of sediment sizes from silts to cobbles and boulders; the till sediments are typically cohesive and of low permeability (Stewart, 1973; Stewart & MacClintock, 1969). In the Pond Brook valley, the landscape is dominated by clay and silt deposits generated during former occupation by Lake Vermont. Peat deposits are mapped adjacent to Winona Lake and separate wetland areas near the central part of the watershed (Calkin, 1965). Smaller areas of glaciofluvial deposits are present along the margins of the valley at the transition point between the ridge lines and the broad Pond Brook valley. Alluvial deposits are limited in extent to the downstream-most reach of the Pond Brook within a mile upstream of the confluence with Lewis Creek (Calkin, 1965).

Soil survey mapping for the Pond Brook subwatershed (USDA, 2006: USDA, 2007) indicates soil type distributions consistent with mapped surficial geology. Figure 2 depicts the generalized soil types, grouped by geologic parent material. The upland, western and eastern margins of the catchment are dominated by soils derived from glacial till. The central portion of the subwatershed is dominated by silt loams which have their origin in silt and clay deposits of freshwater lake environments.

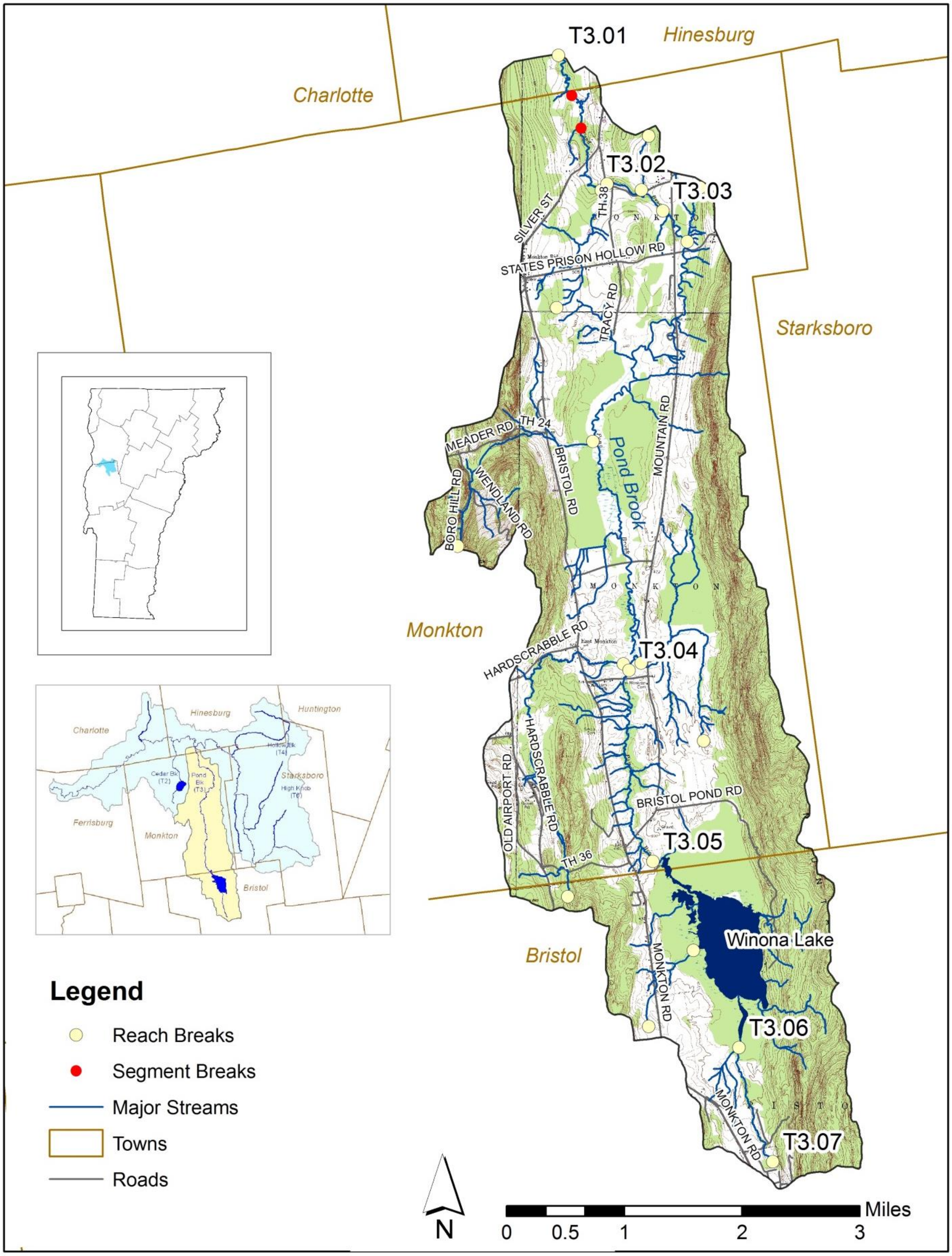


Figure 1. Pond Brook tributary of Lewis Creek watershed, location map.

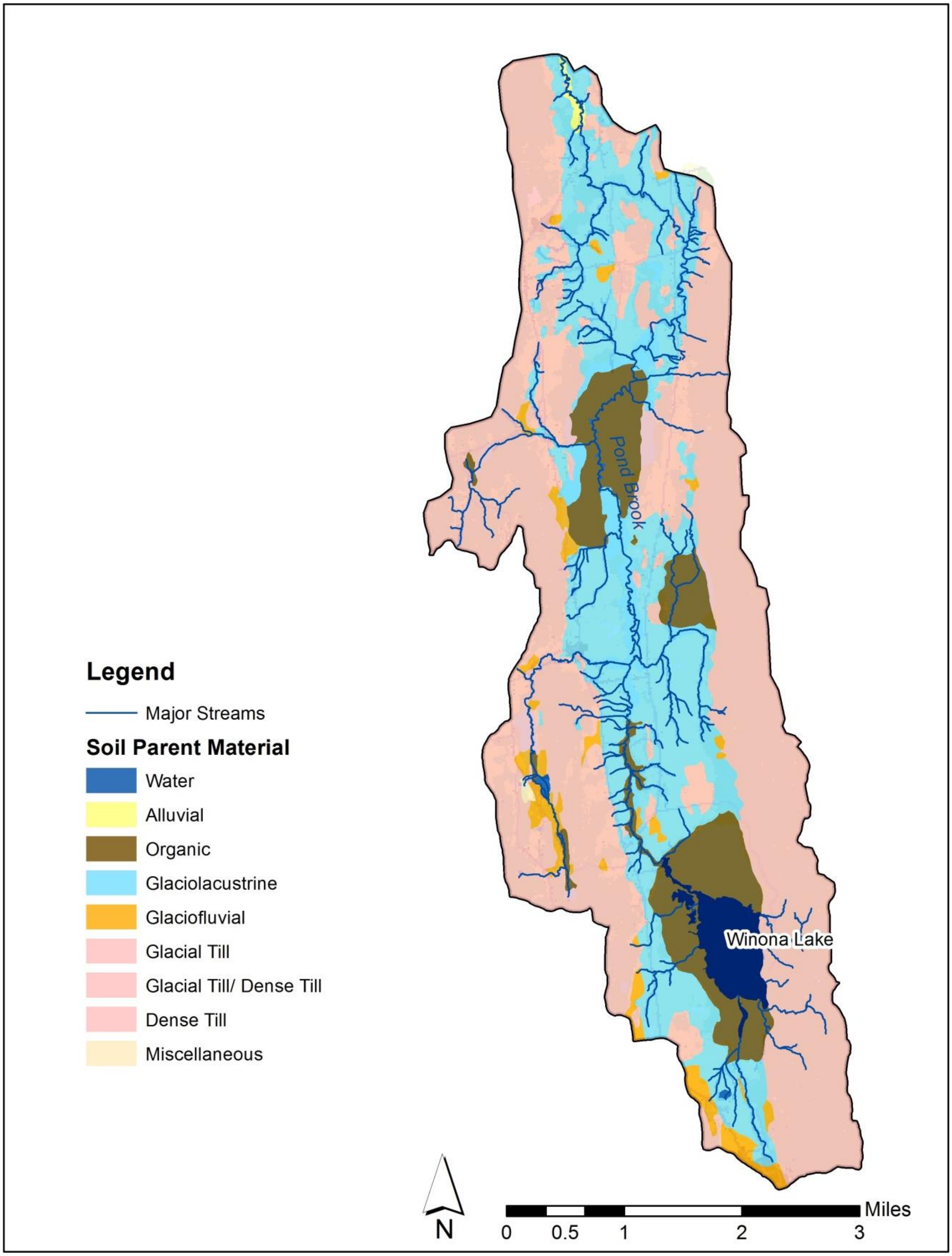


Figure 2. Soil parent material, Pond Brook subwatershed.

C. Geomorphic Setting

Surface waters of the Lewis Creek watershed were delineated into a total of 103 reaches in a previously-completed Phase 1 Stream Geomorphic Assessment (SGA; VTDEC WQD, 2001a; VTDEC WQD, 2003; SMRC, 2004; SMRC, 2007). Geomorphic reaches were defined based on variation in valley confinement, gradient, and sinuosity, as well as tributary influence (see protocols for further background). Seven (7) major tributaries of the Lewis Creek were identified. Each reach was assigned a unique alphanumeric identification. Reaches along the main stem of the Lewis Creek were prefixed with a capital "M". Major tributary reaches were denoted with a capital "T"; minor tributaries with a capital "S". Reach-labeling procedures followed VTANR protocols (VTANR, 2009).

Pond Brook is the third major tributary of Lewis Creek watershed – designated "T3". The Pond Brook main stem was delineated into six reaches (Table 1).

Table 1. Pond Brook reaches

Reach	Length (ft)	Length (mi)	Slope (%)	Drainage Area (sq mi)
T3.01	9,403	1.8	0.67	18.3
T3.02	3,616	0.7	0.88	16.6
T3.03	32,308	6.1	0.20	16.2
T3.04	11,625	2.2	0.06	15.4
T3.05	10,598	2.0	0.13	6.8
T3.06	6,319	1.2	0.71	5.4

Reach T3.06 is a first-order feeder tributary to Winona Lake (Figure 1). Reach T3.05 is essentially Winona Lake itself and the contiguous wetlands. From the southern crossing of Mountain Road downstream to the Church Road, the Pond Brook meanders through a broad valley setting with contiguous wetlands (T3.04). Downstream of the Church Road, Pond Brook enters an expansive valley containing a large wetland complex, which receives contributions from several side streams flowing off the higher elevations from the east and west (T3.03). These two reaches (T3.04 and T3.03) comprising 8.3 miles of the channel could be characterized as a "slow-winder", very low-gradient channel. At the downstream end of reach T3.03 the valley begins to narrow somewhat as the Pond Brook transitions from a wetland-dominated system to a more fluvial system. North and west of Tyler Bridge Road, the valley narrows significantly and the channel gradient increases. These downstream reaches of the Pond Brook exhibit fluvial characteristics and have been evaluated following stream geomorphic assessment protocols published by the VT Agency of Natural Resources. Geomorphic data for T3.01 were summarized in the *River Corridor Conservation & Management Plan* for the Lewis Creek Watershed (SMRC, 2010). Reach T3.02 (behind Last Resort Farm) had been examined in 2001 during the VTANR pilot test for development of the stream geomorphic assessment protocols (VTDEC, 2003); it has been assessed to 2009 SGA protocols during this current project (see Section III.D and Appendix B).

D. Hydrology / Flood History

The presence of Winona Lake and abundant wetlands contiguous to the Pond Brook channel, provide for storage and attenuation of storm flows in this subwatershed of Lewis Creek. These conditions are in contrast to the somewhat flashy nature of the upper watershed above the Pond Brook confluence, where high relief in the eastern portion of the Lewis Creek watershed, as well as the predominance of low-permeability glacial till and bedrock leads to more rapid runoff and greater snowmelt volumes. The flashiness of upper watershed flows is somewhat moderated by lagged flows from the Pond Brook watershed.

The United States Geological Survey (USGS) maintains one active streamflow gaging station on the Lewis Creek (see Figure 3) with real-time data available on the Internet (http://waterdata.usgs.gov/vt/nwis/). Station #04282780 is located near the Route 7 crossing and measures flow from an approximate drainage area of 77.2 square miles (or 95% of the watershed).

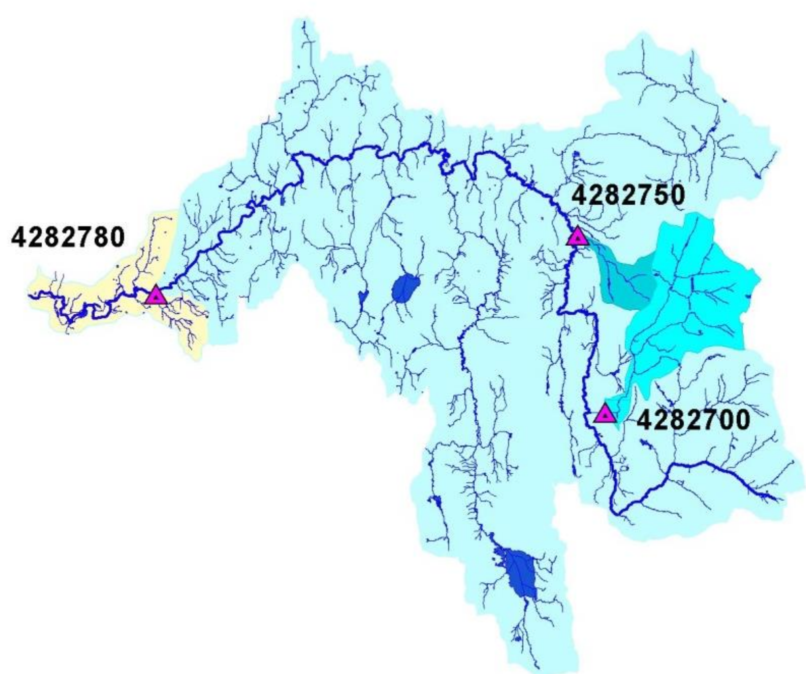


Figure 3. Location of USGS streamflow gaging stations in the Lewis Creek watershed. Station #4282780 is active and reports data online; Stations #4282750 and 4282700 were operated briefly in the 1960s and 1970s.

Station #04282780 has daily flow records dating back to 1990, or approximately 22 years.

Figures D-1 through D-3 in Appendix D present the cumulative annual flow in the Lewis Creek for water years 1991 through 2012. A majority of the total annual streamflow in Lewis Creek occurs from late Winter through late Spring, from ice-out to mid-May in a typical year. This phenomenon is typical for other tributaries in the Lake Champlain basin (Shanley & Denner, 1999), and is due to melting of the snow pack stored in higher elevations, low evapotranspiration rates prior to leafing of deciduous vegetation, saturated or frozen ground, and occurrence of spring rains. These conditions are coincident with wide-spread bare (tilled) soils in the agricultural portions of the watershed.

Based on the recent twenty-two years of record for Lewis Creek, spring thaw (ice-out) typically occurs in February or March. In water year 2012, ice-out in the lower Lewis Creek occurred on or about 4 March 2012. Hodgkins and Dudley (2006) have documented earlier timing of significant Winter/Spring flow events in Northeastern watersheds located north of 44 degrees latitude, attributed primarily to earlier timing of snowmelt.

While up to one half of the total annual flow for the Lewis Creek occurs between ice out and mid-May, individual storm events (typically in the Spring or Fall) can account for between 5 and 15 % of the total annual flow. Often the peak storm in a given water year is coincident with snowmelt in the late Winter or early Spring, but the peak event can also occur during a Summer thunderstorm, or late Fall.

While the primary driver of hydrology is climate (precipitation and snowmelt), hydrology in the Lewis Creek has been influenced by human land use impacts, including ditching of tributaries and wetlands, conversion of wetlands to culvtivated fields (and associated loss of microtopography), installation of subsurface drainage tiles, and hydrologically-connected road ditch networks. Examples of these modifications were documented in various locations in the Pond Brook watershed during windshield assessments.

The Addison County region was affected by major flood events of 1913, 1927, 1936, 1938, 1973 and 1976 (USGS, 1990; VTDEC WQD, 1999). From the available record for the Lewis Creek gage, it is evident that the watershed sustained a significant flood event in April of 2011 (Figure 4). The maximum peak flow recorded was 4,690 cubic feet per second (cfs) on 27 April 2011. Based on USGS regression curves for Vermont streams (Olson, 2002; Table 2), this discharge corresponded to an approximate 100-year flow, or that size of storm with a 1% chance of occurring in any given year. This peak flow in April 2011 resulted from heavy spring rains and snow melt during a wetter-than-normal year. When Tropical Storm Irene hit the state later that year (28-29 August 2011), flows in Lewis Creek were relatively modest, peaking at 2,500 cfs, or approximately equal in magnitude to a 2-year storm (Figure 4; Table 2; USGS, 2012).

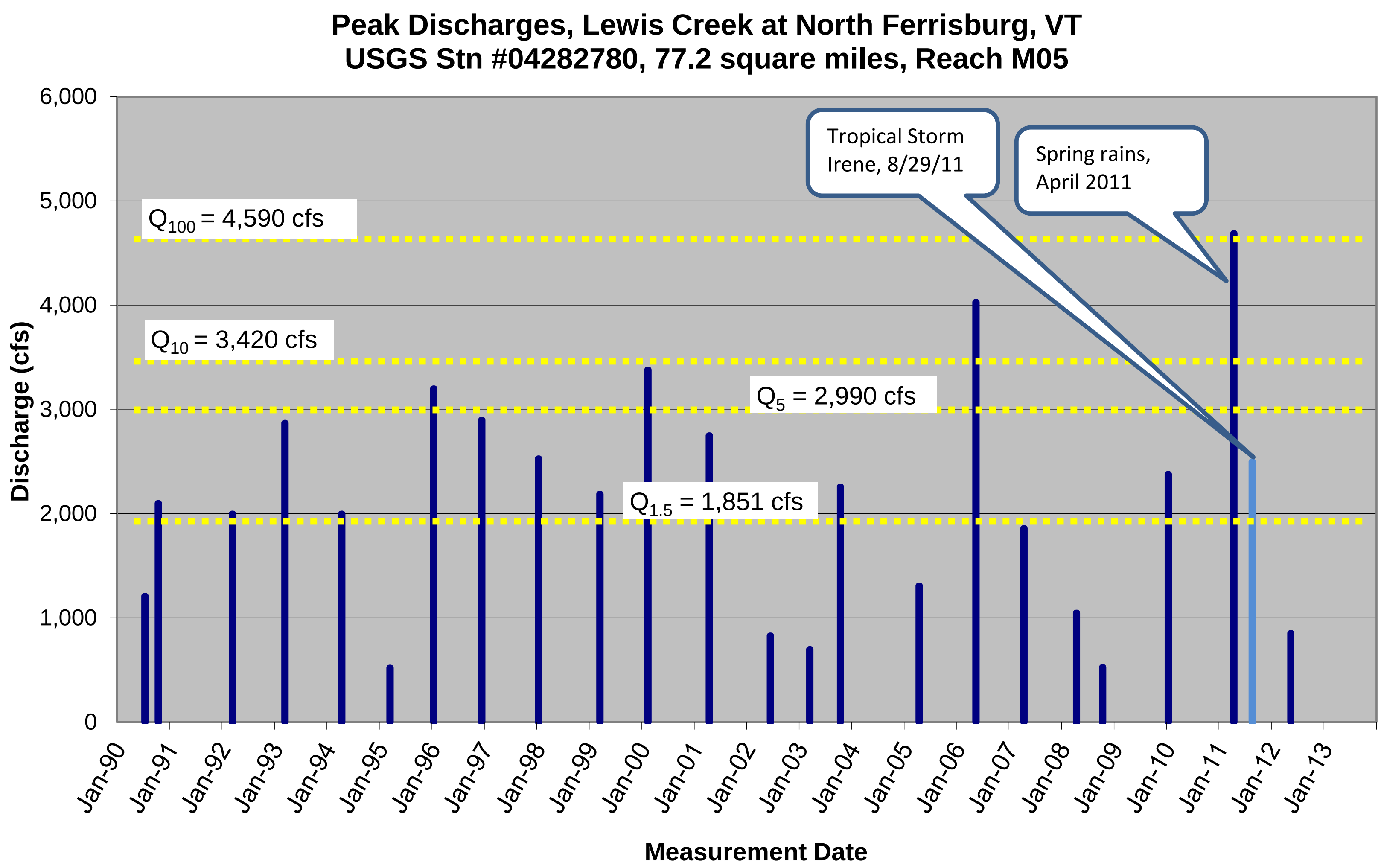


Figure 4. Recorded Peak Flows for Lewis Creek at North Ferrisburgh, VT gage, USGS Stn #04282780 (77.2 square miles) compared to estimated flood peaks after Olson (2002).

Table 2. Estimated flood magnitudes for Lewis Creek.

	USGS Stn #	4282780
	USGS Description	Lewis Creek at North Ferrisburg
	USGS Period of Record	1990 - present
	Upstream Dr. Area, (USGS, 2009) (sq mi)	77.2
	Upstream Dr. Area, (Olson, 2002) (sq mi)	77.4
	Geomorphic Reach	M05
Storm Magnitude	**Data Source**	**Discharge (cfs)**
$Q_{1.5}$	*(VTDEC WQD, 2001b)*	1,851
Q_{2}	*(Olson, 2002)*	2,280
Q_{5}		2,990
Q_{10}		3,420
Q_{50}		4,270
Q_{100}		4,590
Q_{500}		5,290

E. Ecology

The Pond Brook tributary subwatershed is located wholly within the Champlain Valley biogeophysical province (Stewart, 1973; Capen, 1998). Broadly speaking, the natural community assemblages in the watershed consist of Northern Hardwood Forests and Oak-Pine Northern Hardwood

Forests on the uplands

and Forested Wetlands and Open or Shrub Wetlands present in the lowlands (Thompson & Sorenson, 2000). Fragments of intact and modified clayplain forest communities are found in the watershed. Documented roosting habitat for the federally-endangered Indiana Bat is located in the highlands south and west of the watershed (Liz Thompson, personal communication).

As a tributary of the Lewis Creek, Pond Brook is identified as a Class B cold-water stream in the Vermont Water Quality Standards (Vermont Natural Resources Board, 2008). There are no macroinvertebrate testing stations in the Pond Brook and only two fish stations with limited data (Fiske, 2012).

Winona Lake (Bristol Pond) is a mesotrophic/eutrophic water body (Langdon *et al.*, 1998). Fish species include yellow perch, northern pike, largemouth bass, bullhead, panfish, and black crappie (VFW website).

F. Land Use

Land use within the Lewis Creek watershed as a whole is estimated as 61% forested, 26% agricultural fields, and 5% urbanized (developed, transportation, utilities), with the remaining 8% comprised of lakes, ponds, and wetlands (VCGI, 2003; Millette, 1997 – source imagery dated 1991 to 1993) (Table 3).

Table 3. Land cover/ land use in Lewis Creek watershed and Pond Brook.

Watershed	Drainage Area (sq mi)	Developed	Agricultural	Forest / Shrub	Water / Wetland
Lewis Creek (full watershed)	81.1	4.9%	26.0%	60.6%	8.2%
Lewis Creek (upstream of M13)	38.9	4.5%	14.7%	73.9%	6.8%
T3 (Pond Brook) - T3.01	18.3	3.9%	27.7%	48.8%	19.5%
LCT3D.5 (u/s of Silver Street culvert)	17.4	3.7%	26.3%	49.3%	20.7%
LCT3-3.9 (u/s of Mountain Rd culv)	15.2	3.8%	25.6%	49.6%	21.0%
LCT3-8.7 (u/s of Church Rd culvert)	6.8	3.8%	24.5%	49.8%	21.8%
LCT3-10.5 (u/s of Mountain Rd culv)	5.4	3.2%	18.7%	53.2%	24.7%

The Pond Brook tributary watershed has a somewhat higher percentage of agricultural land use coincident with the silt and clay-rich soils of glaciolacustrine origin found in the central valley. Forested land cover dominates the ridgelines that flank the valley to the west and east. Residential and commercial development is relatively sparse; buildings are concentrated along the rural road network (Figure 6). Evidence of a historic mill site was observed along reach T3.02 in the northern end of the catchment. An impoundment was also noted on the historic Burlington, VT topographic quadrangle map (USGS, 1906).

Widespread deforestation of Vermont’s landscape occurred by the early- to mid-1880s to support subsistence and sheep farming and lumber industries. Forest cover in the highlands began to regenerate in the late 1800s and early 1900s, during the industrial age when upland farms and sawmills were commonly abandoned (Thompson & Sorensen, 2000).

Over the last 200 or more years, wetland or hydric soils along the floodplains of Vermont rivers have commonly been converted to agricultural fields. Often, field drainage is improved by channelization of small tributaries or through installation of a network of constructed ditches or underground tiles. Conversion of channel-contiguous wetlands to agricultural uses and associated ditching can increase runoff volumes and velocities in the receiving river channel. In turn, those increased flows can exceed erosion thresholds in the channel bed and banks. This

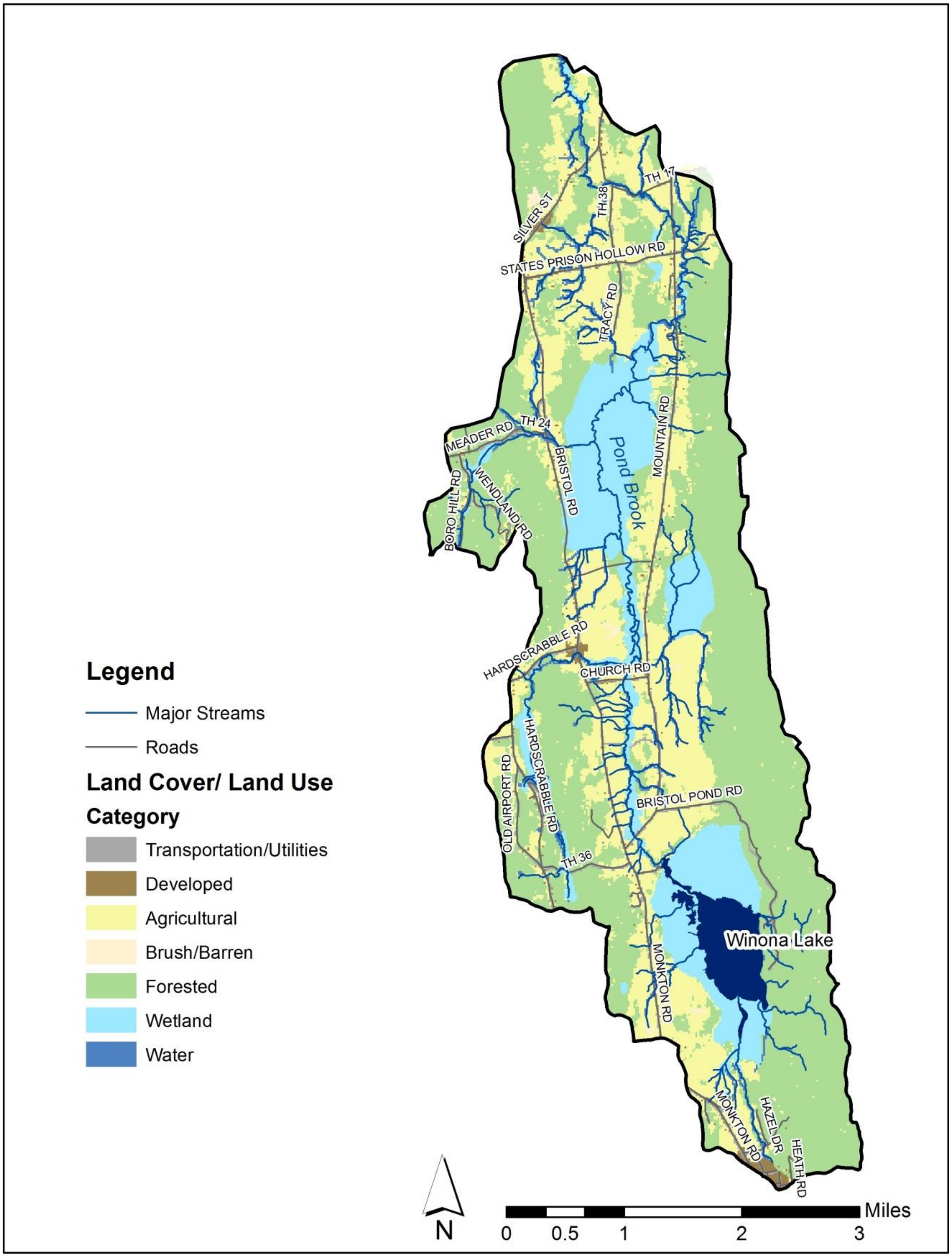


Figure 5. Generalized land cover / land use in the Pond Brook subwatershed. (2006)

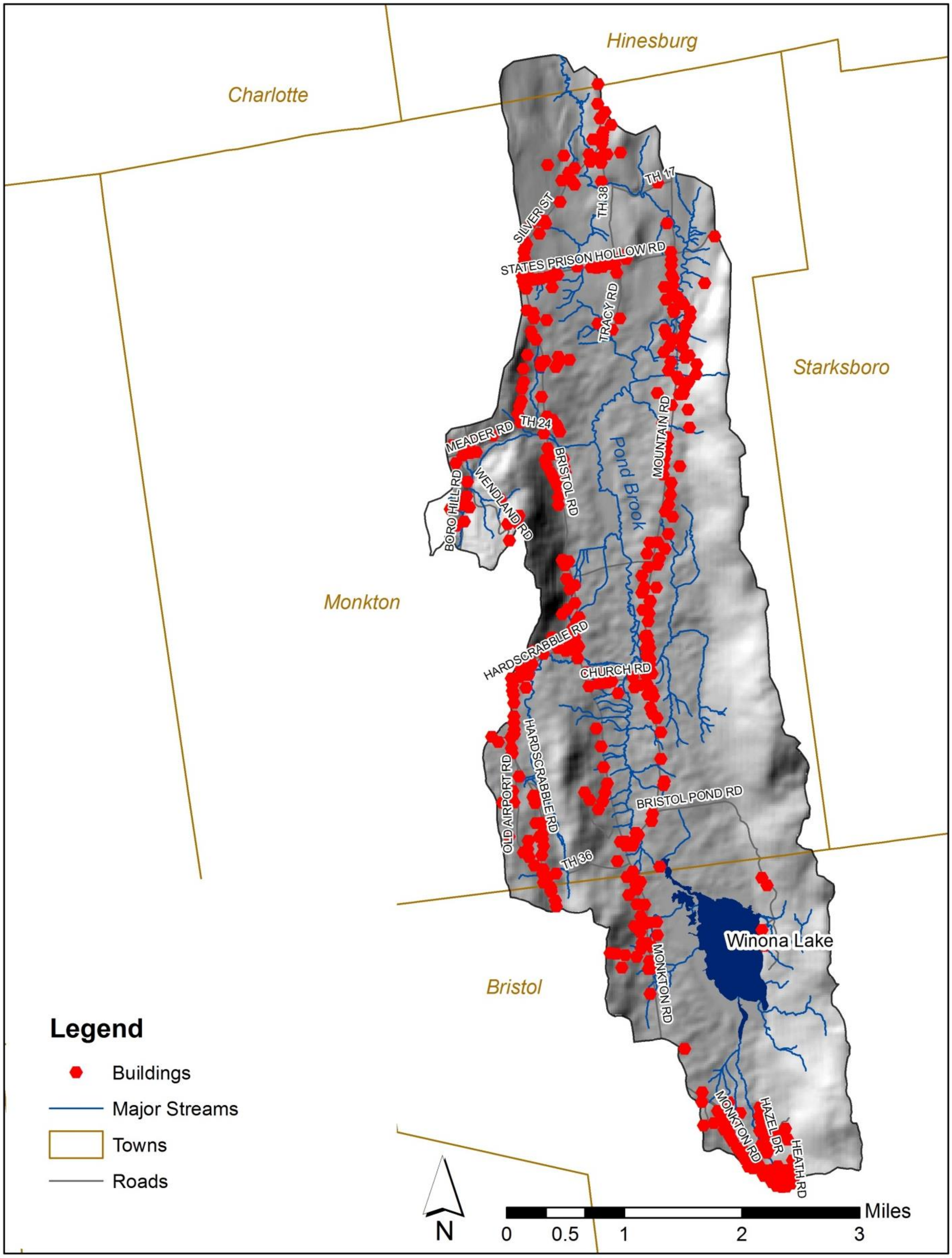


Figure 6. Buildings site locations, Pond Brook subwatershed (2011).

factor, along with periodic ditch maintenance, can result in increased sediment mobilization to the river.

The degree of wetland loss or conversion in a watershed is difficult to estimate with accuracy. However, a qualitative evaluation can be performed by comparing the percentage (by area) of hydric soils across a watershed, to the percentage of mapped wetlands. Significant areas of possible wetland loss were apparent in the Pond Brook subwatershed as well as the Lewis Creek watershed in general (Table 4).

Table 4. Percent by Area of Hydric Soils (USDA) versus mapped wetlands in the Upstream Drainage Area of Pond Brook and Portions of the Lewis Creek watershed.

Stream	Subwatershed	Subwatershed Area (sq mi)	Hydric Soils (% by Area)	VSWI Wetlands (% by Area)	NWI Wetlands (% by Area)
Lewis Creek	Upstream of M01	81.0	19.0	6.7	7.9
Lewis Creek	Upstream of M14	38.2	10.6	2.4	2.6
Pond Brook (T3)	Upstream of confluence w/ Lewis Creek	18.3	33.4	13.7	16.9

NWI = National Wetland Inventory; VSWI = VT Significant Wetlands Inventory

This comparison does not accurately reveal the area of wetlands drained or otherwise converted to agricultural or urbanized use, since NWI or VSWI coverage does not include smaller Class III wetlands which may be present in the watershed. As with any spatial data sets, there are also issues of mapping methods, mapping resolution, scale, accuracy, and currency that would render the two data sets not directly comparable. Nevertheless, this comparison serves as a coarse measure of potential wetland loss in the Pond Brook and Lewis Creek watershed.

G. Water Quality & Stressors

Pond Brook has been identified as a major sediment and phosphorus loader to the Lewis Creek watershed based on Spring / Summer water quality monitoring from 2004 to present (Hoadley, 2011; available at: http://lewiscreek.org/lewis-creek-water-quality). One station on the Pond Brook (LCT3D.5 at the Silver Street crossing) is regularly monitored by the Addison County Riverwatch Collaborative (ACRWC) for turbidity, phosphorus, nitrates, and E.coli. This station complements 18 other monitoring stations in the Lewis Creek watershed that have been monitored since 1992.

E.coli is frequently above the State water quality standard (77 organisms per 100 mL) at the Pond Brook station (ACRWC/SMRC, 2013; Hoadley, 2011).

Turbidity levels (suspended sediments) are generally low in Pond Brook, below the state standard of 10 Nephelometric Turbidity Units (NTUs) for this Class B cold-water stream (Vermont Natural Resources Board, 2008). Turbidity levels occasionally increase well above 10 NTUs during storm events or spring runoff (Hoadley, 2011; ACRWC/SMRC, 2013). While these storm-related conditions do not technically constitute a violation of VWQS, it is clear that these events are delivering sediment (and associated nutrients) to receiving waters and Lake Champlain.

Total phosphorus concentrations have consistently been above levels which would suggest nutrient enrichment near the mouth of Pond Brook (2004-2008; 2010-2012). Total phosphorus concentrations for summer low-flow conditions are compared to proposed instream nutrient criteria (VTDEC WQD, 2009) to identify potential impacts to Aquatic Life Support and Aesthetics uses of these waters. Phosphorus concentrations have been above the recently proposed instream nutrient criteria of 0.044 mg/L for Class B "warm-water medium-gradient" wadeable streams (VTDEC WQD, 2009). There are no significant point sources of phosphorus (such as wastewater treatment plants) within the Pond Brook subwatershed of Lewis Creek (VTANR and NYSDEC, 2002); nonpoint sources account for essentially the total contribution of phosphorus in the catchment.

Based on water quality monitoring results from the ACRWC, the State of Vermont has listed the lower 1.5 miles of the Pond Brook as impaired for contact recreation use due to *E. coli* impacts likely resulting from agricultural runoff (VTDEC WQD, 2010). The length of impairment is a function of the limited availability of historic water quality stations maintained along the Pond Brook by the ACRWC (furthest upstream station has been at Silver Street, at approximate river mile 1.5). A TMDL for Bacteria-impaired Waters including Pond Brook was issued by the VTDEC in September 2011 (VTDEC, 2011).

Winona Lake (Bristol Pond) is also considered a Class B water. The average spring phosphorus concentration is 23 ug/l, based on 14 years of data; the average summer phosphorus concentration is 22 ug/l, based on 1 year of data. The lake is eutrophic in status. (http://www.vtwaterquality.org/cfm/lakerep/lakerep_details.cfm?id=WINONA)

The reader is referred to the *River Corridor Conservation & Management Plan for the Lewis Creek Watershed* (SMRC, 2010) for a discussion of water quality in the overall Lewis Creek watershed which drains to the Otter Creek segment of Lake Champlain (LCBP, 2008).

Phosphorus and suspended sediments are resulting from channel erosion, land erosion, and non-erosion-related nutrient loading. Possible sources include:

Table 5. Identification of Stressors and Pollutants of Concern in the Pond Brook watershed.

Stressor	Pollutant of Concern	Source	Comment
Land Erosion	Sediment, Phosphorus, E.coli	Agricultural Lands	Cultivation of soils, or overgrazing of pastures leaves the land surface vulnerable to erosion from rills and gullies. Impervious surfaces associated with barnyards can lead to increased runoff.
	Sediment, Phosphorus, E.coli	Developed Lands/ Construction Sites	Impervious surfaces result in increased runoff leading to increased flow peaks and magnitudes. Enhanced potential to erode sediments where runoff is concentrated in rills or gullies.
	Sediment, (Phosphorus)	Forested Lands	Accelerated runoff (increased flow peaks and magnitudes) as well as sediment loading can result from poorly-managed networks of logging access roads, skidder trails, and logging landings where these intersect with the stream network.
	Sediment, (Phosphorus)	Road Networks	Substantial volumes of sediment (possibly nutrient-laden) erode from ditches and enter surface waters where road and driveway networks intersect the stream network. These effects are particularly significant during intense rains or flood events.
Channel Erosion	Sediment	Livestock Trampling/ Removal of Vegetative Buffers	Streambank erosion can be accelerated in locations where forested riparian buffers have been removed to facilitate cultivation, pasturing, or development. Direct access to the stream by livestock can contribute to soil loss.
	Sediment	Channel/Floodplain Modifications/ channel evolution	Excess sediment production can result in channel reaches that are undergoing active adjustment in response to a history of manipulation, sediment and/or flow alterations.
	Phosphorus	Streambanks	Eroding streambanks have also been identified as a contributing nonpoint source of phosphorus in rivers and streams of Vermont where there is a legacy of phosphorus in floodplain soils (VTANR, 2001; DeWolfe *et al*., 2004; Langendoen *et al*., 2012) and elsewhere in the nation (Kalma & Ulmer, 2003; Nelson & Booth, 2002).

After: VTDEC, 2012 Surface Water Management Strategy

Table 5 (continued). Identification of Stressors and Pollutants of Concern in the Pond Brook watershed.

Stressor	Pollutant of Concern	Source	Comment
Nutrient Loading (non-erosion related)	Phosphorus, nitrogen	Poorly-managed animal wastes (manure).	Manure application to farm fields can occur at rates which exceed the agronomic needs of the soil, when soils are not regularly tested and nutrient management planning is not practiced.
	Phosphorus, nitrogen	Under-treated domestic waste.	All of the residential / commercial buildings in the Pond Brook watershed are served by on-site septic disposal systems. Aging or non-maintained systems in close proximity to surface waters can be a source of nutrient loading.
	Phosphorus, nitrogen	Over-fertilization of residential lawns/ gardens.	Phosphorus and nitrogen can be applied at rates which exceed the agronomic needs of the soil, when soils are not regularly tested.
	Phosphorus	Internal phosphorus loading.	Release of phosphorus from fine sediments stored in channel-contiguous wetlands during specific biogeochemical conditions (e.g., reducing conditions).
Pathogens	E.coli	Poorly-managed animal wastes (manure).	Manure application to fields in close proximity to surface waters and/or at times closely preceeding intense runoff events can result in direct runoff to the Pond Brook.
	E.coli	Direct pasturing	Livestock with direct access to streams are a source of pathogens in surface water.
	E.coli	Natural Sources	Wildlife including geese & other waterfowl, beavers, deer.

After: VTDEC, 2012 Surface Water Management Strategy

III. Watershed Assessment

In a multi-barrier approach, various assessment tasks were completed on a parallel track in the Pond Brook tributary subwatershed: (a) Identify and convene a project steering committee to guide assessment work; (b) complete an inventory of farms operating in the watershed; (c) evaluate conditions during high-water events and review existing remote sensing data to pinpoint locations of direct stormwater and sediment runoff; (d) fill data gaps including stream geomorphic assessments and bridge & culvert evaluations; (e) monitor flow in the Pond Brook; and (f) expand water-quality testing to sub-units of the watershed. Evaluations were conducted with a goal of identifying specific restoration and conservation projects and practices that decrease nutrient, sediment and pathogen loading and mitigate for the effects of hydrologic and sediment regime modifications (channel erosion), as well as land erosion, non-erosion-related nutrient loading and pathogen introduction.

A. Project Steering Committee & Working Group Meetings

Lewis Creek Association formed a Project Steering Committee to guide assessment work and assist with project identification and prioritization. Members of the project Steering Committee are identified in the Acknowledgements section (page ii), and included a Monkton citizen and farmer, members of the VTDEC Watershed Management Division, VT Agency of Agriculture, VT Association of Conservation Districts, UVM Agricultural Extension Service, Ducks Unlimited. Three Steering Committee meetings were held on 16 February 2012, 30 August 2012, and 26 March 2013. Minutes of these meetings are contained on the Project CD.

Working meetings were also convened with agricultural partners including the UVM Extension Service staff, representatives from the Middlebury field office of the USDA Farm Service Agency, the Otter Creek Natural Resources Conservation District and the Vermont Association of Conservation Districts. A local farmer, Sam Burr (Last Resort Farm) also attended these meetings, which were held on 23 March 2012 and 25 June 2012. Notes from these meetings are contained on the Project CD.

B. Farm Inventory

Based on windshield surveys and a review of public land records, LCA developed an inventory of ten farms operating in the Pond Brook subwatershed (Table 6):

- A conventional cow dairy large farm operation (LFO) based outside the watershed owns and operates fields in the southern half of the watershed;
- Five conventional cow dairy small farm operations (SFO);
- One grass-fed Angus beef farm (SFO);
- Two small ruminant farms (including sheep, alpacas, and llamas);
- One organic vegetable/ berry/hay farm.

Table 6. Farms operating in the Pond Brook watershed.

Farm	Description	Road / Town	Status	Size (approx)
Burr (Last Resort Farm)	Organic fruits & vegetables; hay & pasture	Tyler Bridge Rd & Turkey Ln / Monkton	SFO	208 ac
Cota Brothers Farm	Dairy	States Prison Hollow Rd/ Monkton	SFO	315 ac
Hill (Four Hills Farm)	Dairy	Burpee Rd / Bristol w/ fields owned, operated in Bristol, Monkton (and other areas outside Pond Bk watershed).	LFO	Several 100 acres
Layn Farm	Dairy	Bristol Rd & Mountain Rd & Church Rd / Monkton	SFO	950 ac
Mierop Farm	Dairy	Monkton Rd / Bristol w/ fields owned, operated in Bristol, Monkton	SFO	Several 100 acres
Phillips	Dairy	States Prison Hollow Rd / Monkton	SFO	>500 ac
Regier	Ruminants	Mountain Road	SFO	11.6 ac
Russell, Phil	Beef	Silver St / Monkton w/ fields owned / operated in Monkton, Hinesburg	SFO	190 ac
Source, Michael & Kelly Leary	Ruminants	Mountain Road	SFO	10.4 ac
Tracey	Dairy	States Prison Hollow Rd / Monkton	SFO	195 ac

SFO – Small Farm Operation, LFO – Large Farm Operation, MFO – Medium Farm Operation

LCA shared water quality monitoring results with agricultural partner agencies. A collective strategy for approaching these farm owners/operators was developed, to identify priority projects and practices that will most effectively address resource concerns, as further detailed in Appendix H. These working sessions also led to development of the agriculture-related projects identified on the Implementation Table (Table A) and associated project location map (Plate 1).

C. Remote Sensing / High-water Events

LCA/ ACRWC volunteers and SMRC conducted windshield surveys of the Pond Brook watershed during high-flow conditions. Since the calendar year 2012 was a drier-than-normal year with below-normal snowpack, there were relatively few events that were classified as high-water events (see Section E and Appendix D). Windshield surveys were conducted during four separate storm events in the Pond Brook during sampling: April 23, May 16 & 17, October 20 & 22, and December 18 & 19 (see Section F). Since 2012 was a relatively dry year, this assessment also relied on images obtained during aerial surveys of the watershed conducted in the Spring of 2010.

Flow accumulation maps of the Pond Brook were prepared by Reed Sims of the USDA Natural Resources Conservation Service (NRCS) offices in Colchester, VT - presented in Appendix A. These maps were used during windshield surveys to identify potential locations of stormwater and sediment runoff to the Pond Brook.

D. Geomorphic Assessment/ Bridge & Culvert Assessments

While most of the Pond Brook can be classified as a "slow-winder" wetland-dominated system, the downstream two miles of channel exhibit fluvial characteristics suitable for assessment by VTANR Stream Geomorphic Assessment protocols. Pond Brook reach T3.01 had been previously assessed, as summarized in the *River Corridor Conservation & Management Plan for the Lewis Creek Watershed* (SMRC, 2010). The channel has reasonable access to the floodplain in upper segment C and lower segment A. A previously-channelized segment B has lost some connection to the floodplain (IR=1.4) and is presently dominated by lateral adjustments – undergoing a lateral stream type departure from E to C stream type.

As part of this study, a geomorphic assessment was completed for the next upstream reach, T3.02, in July of 2012. Assessment results are summarized in Appendix B. Reach T3.02 is a relatively short reach of Pond Brook that extends from just downstream of the Tyler Bridge Road culvert crossing to just upstream of the Silver Street culvert crossing (Figure 1). On average, the channel is semi-confined by moderate to high terraces of glaciolacustrine sediments, with a slope generally greater than 25%. These terraces range in height from 9 to more than 25 feet above the channel thalweg (or approximately 4 to more than 11 times the maximum depth of the channel). The overall valley confinement and relatively low gradient (0.9%) suggest a Bc stream type. The channel has good access to its narrow floodplain (IR=1.0).

Stormwater & sediment inputs were evident from five gullies developed in the right-bank valley wall in the downstream half of reach (draining from a hay field up on the high terrace). Deposits of coarse sediment were noted at the confluence of these gullies with Pond Brook.

A total of six public bridge and culvert crossings were encountered on the Pond Brook main stem. Structure reports are contained in Appendix B. The status of each bridge and culvert as either a bankfull or flood-prone-width constrictor is summarized in Table 7. All of the crossings were bankfull-constrictors. A few structures had downstream scour pools, and one of the culverts had some minor, upstream aggradation.

Table 7 presents priority for each of the bridges and culverts to be further evaluated for possible replacement or retrofit to resolve geomorphic incompatibilities and/or improve aquatic organism passage. Priority is suggested without regard to technical feasibility, social feasibility, or cost; rather the priority is based generally on the geomorphic and habitat condition of the given reach or segment, and its relationship to (and potential impact on) the crossing structure. At this time, none of the structures encountered are identified as a high priority for retrofit or replacement.

Overall, these undersized structures were causing minimal localized channel instability, probably due to the generally low gradients (lower scour velocities) and minimal bedload. Consequently, most of the structures are assigned a Low priority for replacement or retrofit. The coarse screening tool embedded in the VTANR online structures database, indicates that aquatic organism passage (AOP) at the Silver Street culvert is reduced and that this structure is largely incompatible with the geomorphic setting due to a large downstream scour pool, shallow in-structure flow depths, and a sharp approach angle that has induced upstream aggradation. Retrofit potential is provisionally rated as medium for organisms that are strong swimmers. This structure is located approximately 1.4 miles upstream from the confluence of Lewis Creek. Retrofit or replacement of this structure would open up medium-gradient, forested riparian habitats for at least an additional mile upstream of this structure (T3.02). Known or reported organisms in riparian areas downstream of the culvert include river otter, wood turtles, and mink.

Table 7. Public road crossing structures, Pond Brook main stem.

Reach/ Segment	Town	Road	Structure Type	Constriction Status	AOP Coarse Screen	AOP Geomorphic Compatibility	Replacement/ Retrofit Priority
T3.04	Monkton	Mountain Rd	Culvert	18%	Reduced AOP	Mostly Compatibile	Low
T3.04	Monkton	Church Rd	Culvert	33%	Full AOP	Fully Compatible	Low
T3.03	Monkton	Mountain Rd	Culvert	28%	Reduced AOP	Mostly Compatibile	Low
T3.03	Monkton	States Prison Hollow Rd	Bridge		n/a	n/a	Low
T3.03	Monkton	Tyler Bridge Rd	Culvert	31%	Full AOP	Mostly Compatible	Low
T3.01-C	Monkton	Silver Street	Culvert	38%	Reduced AOP	Mostly Incompatible	Medium

E. Flow Monitoring

Flow characteristics of the Pond Brook tributary were evaluated through a combination of methods:

- As previously mentioned, high-water conditions were observed during snow-melt and storm events through a series of windshield surveys and fly-overs to identify locations of saturation excess runoff to the Pond Brook.
- Precipitation records for nearby stations were compiled and evaluated.
- Flow records for the USGS streamflow gaging station at the Route 7 crossing of lower Lewis Creek were evaluated, creating a Flow Duration Curve. This analysis helps to provide a flow regime context for the 20+ years of historical water quality data collected in the Pond Brook and Lewis Creek watershed by ACRWC and the VTDEC.
- A temporary flow station was established on the Pond Brook to characterize the hydrology of this tributary subwatershed, in contrast to the flow characteristics of the Lewis Creek watershed as a whole. This station was also established to enable coarse seasonal estimates of phosphorus and sediment loading (minimum of Spring and Summer seasons).

1. Precipitation data

Precipitation data for the monitoring period were compiled from existing weather stations and USGS gaging stations in vicinity of the Pond Brook (Appendix D). In contrast to the previous year, calendar year 2012 was somewhat drier than normal, as recorded at regional weather stations in South Burlington (Airport), Rutland, and South Lincoln, Vermont (Table D1). Snowfall in the winter of 2011–2012 was much less than normal as recorded at these three weather stations (NOAA Online Weather Data, accessed Jan 2013).

2. Flow Duration Curve

Streamflow gaging records for the USGS gaging station on Lewis Creek at the Route 7 bridge were compiled and reviewed. A flow duration curve was developed for the available 22 years of record (Figure 7; Cleland, 2002; Cleland, 2003).

Based on 22 years of record, mean annual flows in Lewis Creek for water year 2012 (1 October 2011 through 30 September 2012) were below normal, related to the lower-than-normal rainfall and snowpack within the year (Appendix D). Ice-out in the lower Lewis Creek watershed occurred on or about 4 March 2012. In early September, the instantaneous flow in the Lewis Creek (9.7 cfs, 3 September 2012) was very near to the 99% flow duration of approximately 7.5 cfs. In other words, nearly 99% of all the DMFs recorded at this station over the 22 years of record were greater in magnitude than flows recorded on that date (USGS, 2012).

Peak flows for water year 2012 occurred on 16 May 2012 in the Lewis Creek, less than the estimated 2-year storm (Q_2) (Olson, 2002), and less than the predicted bankfull discharge ($Q_{1.5}$) (VTDEC, 2001b).

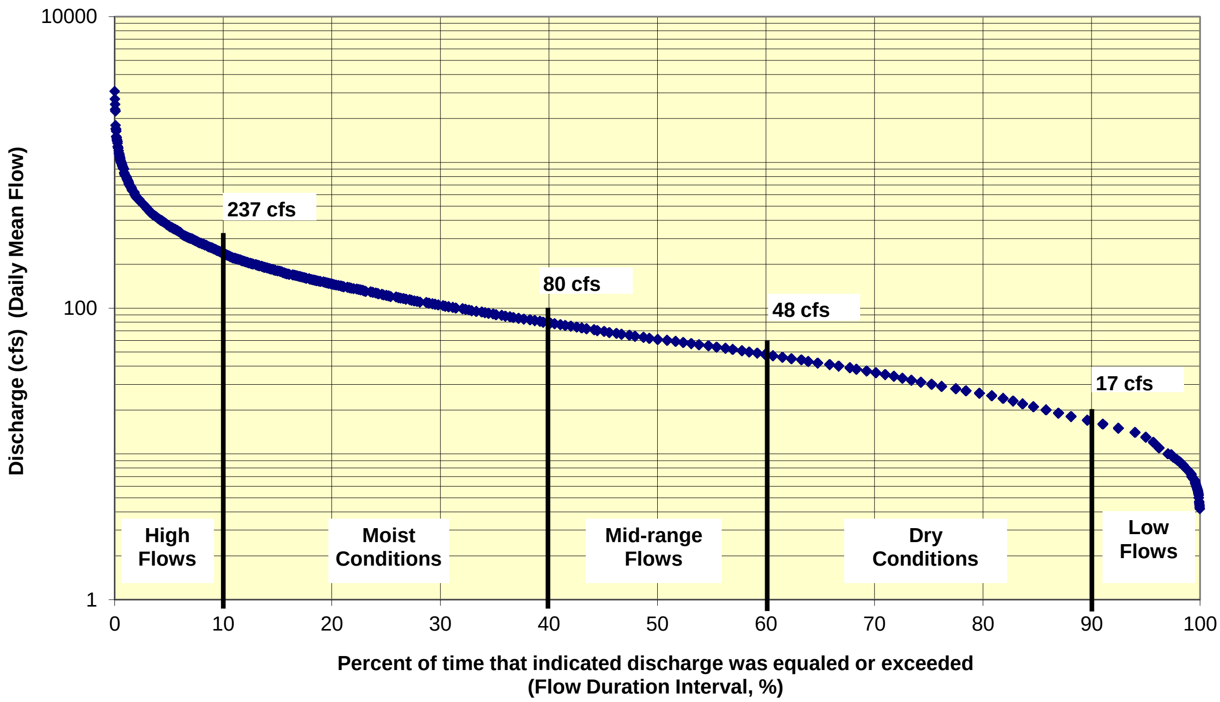


Figure 7. Flow Duration Curve for Lewis Creek at Ferrisburgh, VT
(Water Years: 1991 – 2011; USGS Stn# 04282780; 77.2 sq mi).

3. Flow Measurements

A temporary gaging site was established on Pond Brook approximately 1,400 feet downstream of the Silver Street crossing. A location map and photographs are contained in Appendix E.
A stage / discharge rating curve was developed for this gaging site based on a regression of the measured discharge to stage relationship for periodic discharge measurements collected over a range of flow conditions. Discharge was measured with a vertical-axis current meter by the area-velocity technique (USGS mid-section method; Rantz, et al, 1982). Stage was monitored at 15 minute intervals using a YSI™ Model 600LS pressure transducer. Transducers were loaned by VTDEC MAPP and were deployed on 19 April 2012. Transducers were removed from the channel on 30 December 2012 to avoid damages due to the onset of ice and snow. A staff gage was installed at the site to facilitate manual measurement of stage during sampling events and maintenance of the pressure transducer. Elevation of the staff gage was surveyed with reference to a local benchmark.

Figure 8 presents the daily mean flows (DMF) recorded at the Pond Brook station relative to DMF recorded at the USGS streamflow gaging station at the Route 7 crossing of the Lewis Creek main stem. Values are normalized to the upstream drainage area at each gage – 17.5 square miles for the Pond Brook and 77.2 square miles for the Lewis Creek. Based on this six months of record from 20 April through 30 October 2012, the Pond Brook appears to have a somewhat less flashy response to rain events than the overall Lewis Creek watershed. Peaks are lower in magnitude and somewhat broader on a unit-area basis. Factors contributing to this pattern may include storage and attenuation of flows in Bristol Pond and the large instream wetland complex at reach T3.03 on the Pond Brook.

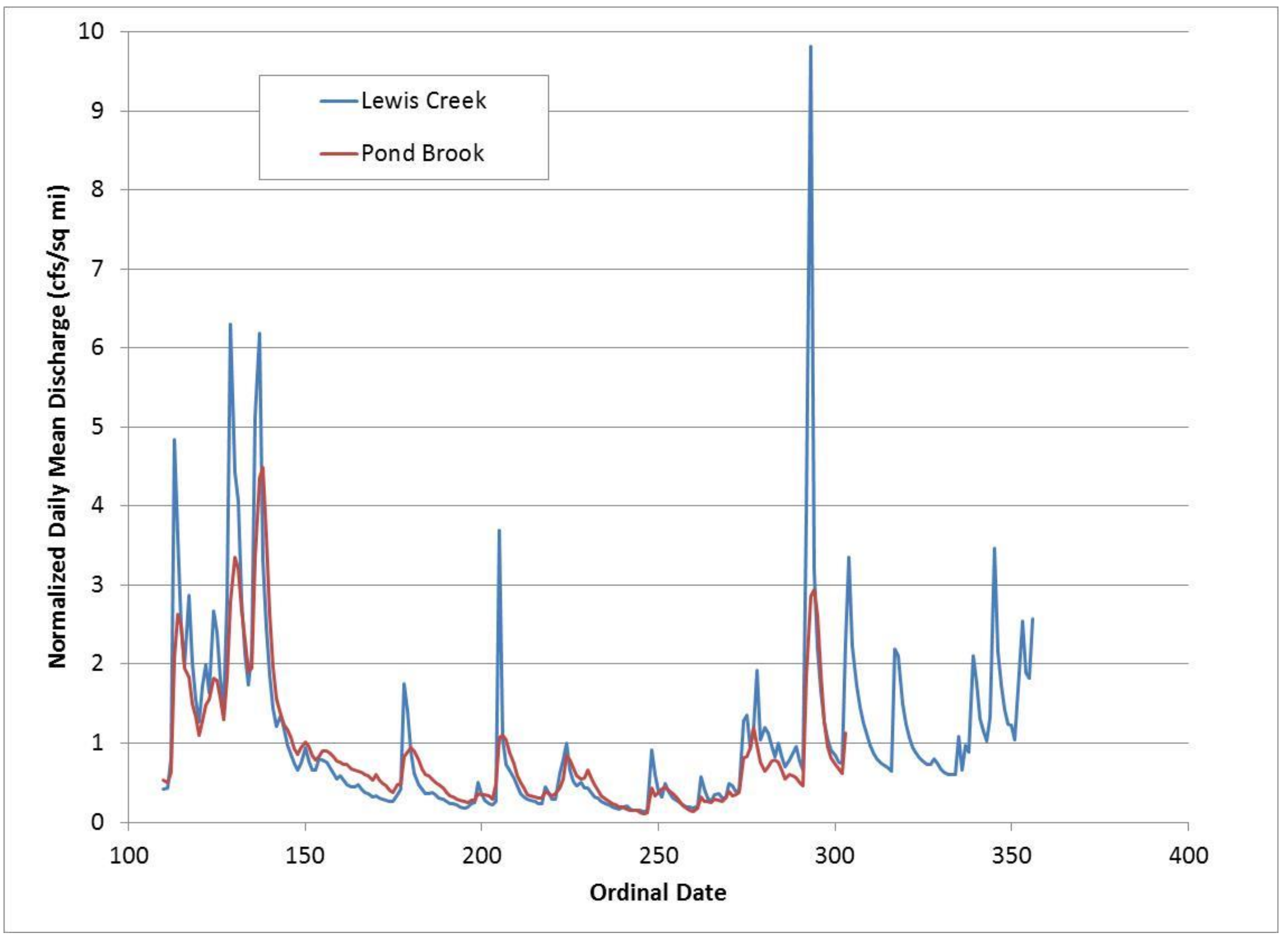


Figure 8. Daily Mean Flow on Lewis Creek (at the USGS gaging station) versus Pond Brook temporary gaging station – normalized by drainage area. *Ordinal date of 100 is equivalent to 4/10/2012 Record for Pond Bk gage was terminated on ordinal date 303 (10/30/2012) due to a low battery. Record for Lewis Creek USGS gaging station ends on ordinal date 356 (12/22/2012) due to onset of ice in the channel.*

F. Water Quality Monitoring

With cooperation and volunteer efforts of the Addison County Riverwatch Collaborative, water quality stations were established at four subunits of the Pond Brook watershed (Table 8; Figure 9). Three new stations at river miles 3.9, 8.7 and 10.5 complemented an existing station at river mile 1.4 (Silver Street crossing, LCT3D.5). Chosen sites represented road-accessible locations on the river. Physical characteristics of each subunit are summarized in Table 9.

Table 8. Pond Brook sampling stations.

Reach	Upstream River Mile	ACRWC Site No	Site Name	Incremental DA (sq mi)	Upstream DA (sq mi)
T3.01-C	1.4	LCT3D.5	Silver Street culvert	2.2	17.4
T3.03	3.9	LCT3-3.9	Mountain Street (lower)	8.4	15.2
T3.04	8.7	LCT3-8.7	Church Street	1.4	6.8
T3.04	10.5	LCT3-10.5	Mountain Street (upper)	5.4	5.4

Water quality samples were collected by ACRWC volunteers in accordance with quality assurance procedures outlined in the EPA-approved Generic Quality Assurance Project Plan prepared by VTDEC. A Quality Assurance summary report for the 2012 sampling data was submitted under separate cover (ACRWC / SMRC, 2013). Samples were delivered to the LaRosa Analytical Laboratory. Due to damages sustained at the laboratory facility in the wake of Tropical Storm Irene (28-29 August 2011) operations were moved from Waterbury and temporarily located at the University of Vermont in Burlington, Vermont. The lab was housed in Jeffords Building for the spring and summer of 2012, followed by a move to Hills Building in the fall.

During 2012, grab samples were collected at these sites during two Spring events (April and May) and four Summer events (June, July, August and September). Sampling dates were pre-determined as the first Wednesday of each month (except July to avoid the 4th of July holiday), and were not designed to capture any specific flow condition: April 4, May 1, June 6, July 11, August 1, and September 5.

Storm events which occurred outside the regular ACRWC monitoring schedule were also sampled (see Figure 8). Despite the lower-than-normal rainfall for 2012, four storm events were able to be sampled:

- April 23
- May 16 & 17
- October 20 & 22
- December 18 & 19

Figure 9. Water Quality Sampling Stations and Sub-units of the Pond Brook watershed.

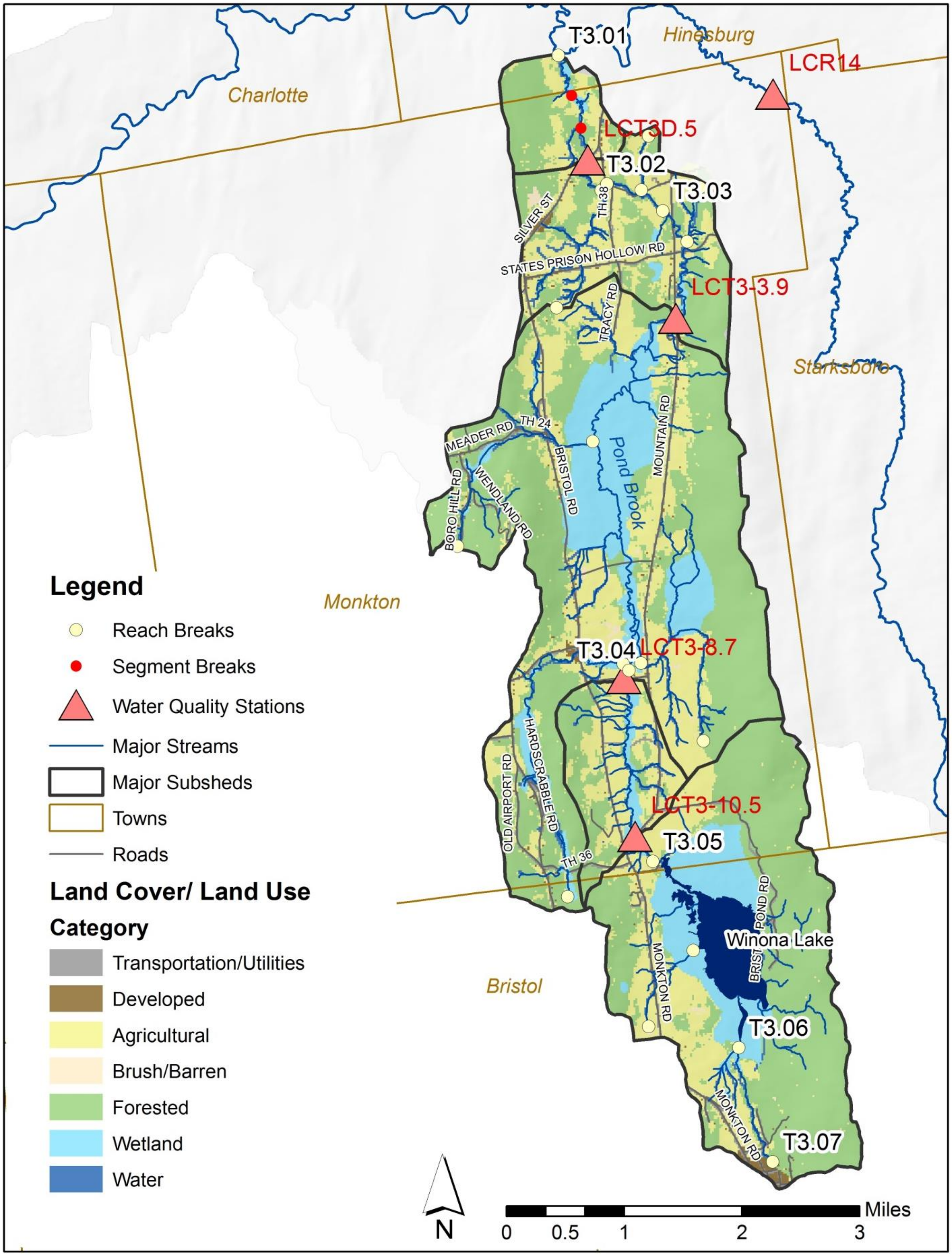


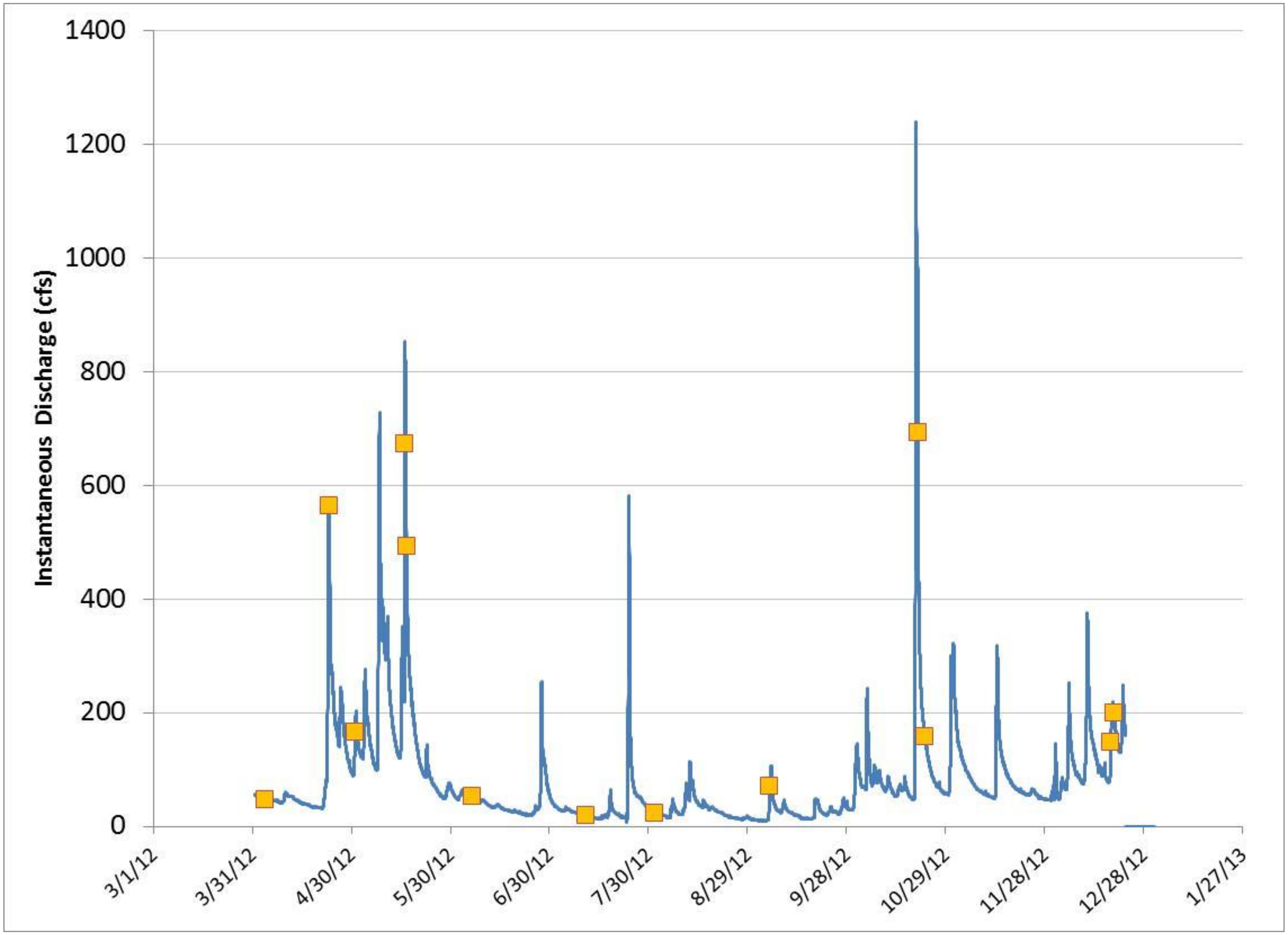
Table 9a. Percent Land Cover / Land Use by Major Subwatershed of the Pond Brook - Incremental Area

Subwatershed	Area (sq mi)	Water	Wetlands	Brush/ Barren	Forested	Agricultural	Developed	Transportation/ Utilities	Total
LCT3	0.8	3.7%	3.2%	0.2%	60.7%	30.5%	0.6%	1.2%	100.0%
LCT3-D.5	2.2	7.2%	1.4%	0.7%	41.2%	43.3%	1.8%	4.4%	100.0%
LCT3-3.9	8.5	2.6%	19.2%	0.4%	48.2%	26.1%	0.8%	2.8%	100.0%
LCT3-8.7	1.2	2.9%	8.5%	0.0%	34.0%	48.6%	0.4%	5.5%	100.0%
LCT3-10.5	5.6	7.8%	16.3%	0.2%	53.1%	19.3%	0.9%	2.4%	100.0%
	18.3								

Table 9b. Percent Land Cover / Land Use by Major Subwatershed of the Pond Brook - Cumulative Area

Subwatershed	Area (sq mi)	Water	Wetlands	Brush/ Barren	Forested	Agricultural	Developed	Transportation/ Utilities	Total
LCT3	18.3	4.8%	14.8%	0.3%	48.4%	27.7%	0.9%	3.0%	100.0%
LCT3-D.5	17.5	4.8%	15.3%	0.3%	47.9%	27.6%	0.9%	3.1%	100.0%
LCT3-3.9	15.3	4.5%	17.3%	0.3%	48.9%	25.4%	0.8%	2.9%	100.0%
LCT3-8.7	6.8	6.9%	14.9%	0.2%	49.7%	24.5%	0.8%	3.0%	100.0%
LCT3-10.5	5.6	7.8%	16.3%	0.2%	53.1%	19.3%	0.9%	2.4%	100.0%

Figure 10. 2012 Sampling Events versus Instantaneous Discharge measured at the Lewis Creek USGS streamflow gaging station.



All four Pond Brook stations were sampled during storm events (LCT3D.5, LCT3-3.9, LCT3-8.7, and LCT3-10.5). A fifth station (existing sentinel site LCR14 on the Lewis Creek main stem) was added to the flow study schedule beginning with the October and December flow events, with approval from VTDEC Watershed Management Division (Figure 9). Grab samples were collected at each station during these events to monitor changes in concentrations of Total Phosphorus, Dissolved Phosphorus, Total Nitrogen, Turbidity and Total Suspended Solids through the storm hydrograph.

Figure 11 presents the flow duration curve for the Lewis Creek watershed, annotated with the 2012 season sample dates. Spring sampling dates (April 4, May 1) coincided with low to moderate stages in area rivers associated with spring rains and snow melt (Table D-3 in Appendix B). Summer sampling dates (June 6, July 11, August 1 and September 5) generally coincided with low to base flow conditions (Figure 11; Table D-3 in Appendix D). The July 11 and August 1 dates corresponded with near 7Q10 flow conditions in Lewis Creek (and other area rivers, e.g., Little Otter Creek and the Otter Creek at Middlebury). The storm events sampled in Pond Brook of Lewis Creek (April 23, May 16 & 17, October 20 & 22, and December 18 & 19) represented discharges of 20.6% Flow Duration Interval or less (Figure 11).

Figures 12a and 12b show total phosphorus (TP) concentrations during regularly-scheduled, low- to moderate-flow conditions from upstream (right) to downstream (left) for the stations along the Pond Brook and the Lewis Creek main stem, respectively. During these generally low-flow conditions, Pond Brook TP concentrations (at LCT3D.5) were greater than the main stem concentrations (at LCR14) on April 4, June 6, July 11, and August 1 and may have accounted in part for the increase in TP concentrations on the main stem between stations LCR14 and LCR9.9. An increasing trend in phosphorus concentration was evident with distance downstream. Results for the main stem sampling sites were consistent with historical trends.

TP was detected at low to moderate concentrations during the six scheduled spring and summer sampling dates, ranging from 5 to 282 ug/L, with an average of 51 ug/L (Appendix F). The mean concentration of TP for the four low-flow summer sample dates (June 6, July 11, August 1, and September 5) at six of the seven Lewis Creek main stem sites (all except LCR27.8) exceeded the proposed criteria of 44 ug/L for the warm-water medium gradient (WWMG) wadeable stream ecotype in Class B waters (VTDEC WQD, 2009). This finding suggests the potential for impacts to Aquatic Life Support and Aesthetics uses of these waters. Mean values were particularly influenced by the elevated concentrations detected on September 5. While flows on this date were low, preceded by near 7Q10 flow conditions in the previous few days, a hard rain fell in the watershed during the evening previous to this sampling event, resulting in turbid waters observed by volunteer samplers.

Figure 11. 2012 Sampling Events with respect to Flow Duration Interval for the Lewis Creek USGS streamflow gaging station.

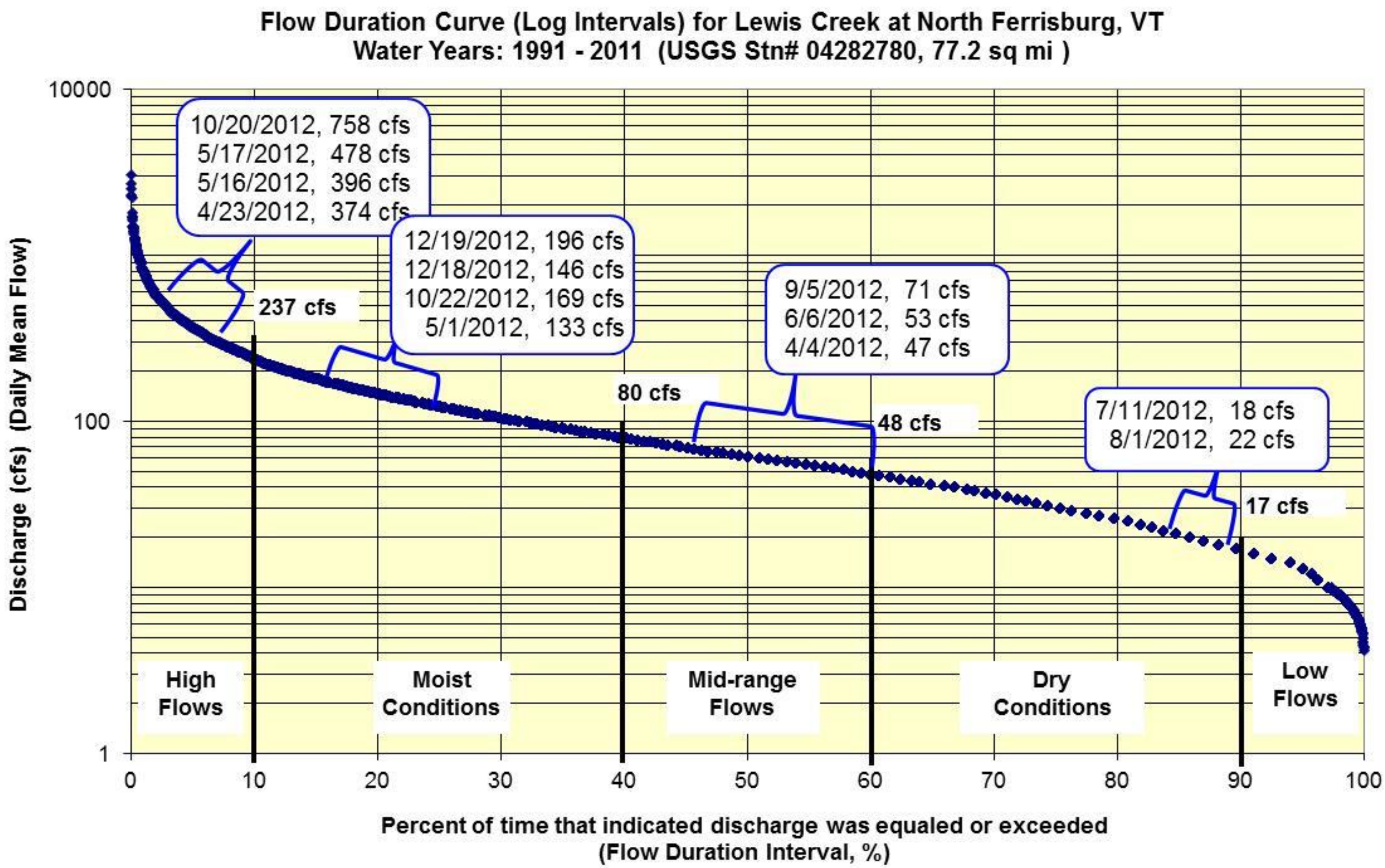


Figure 12a. Total Phosphorus concentrations during scheduled sampling events (low- to moderate-flow conditions), Pond Brook, 2012.

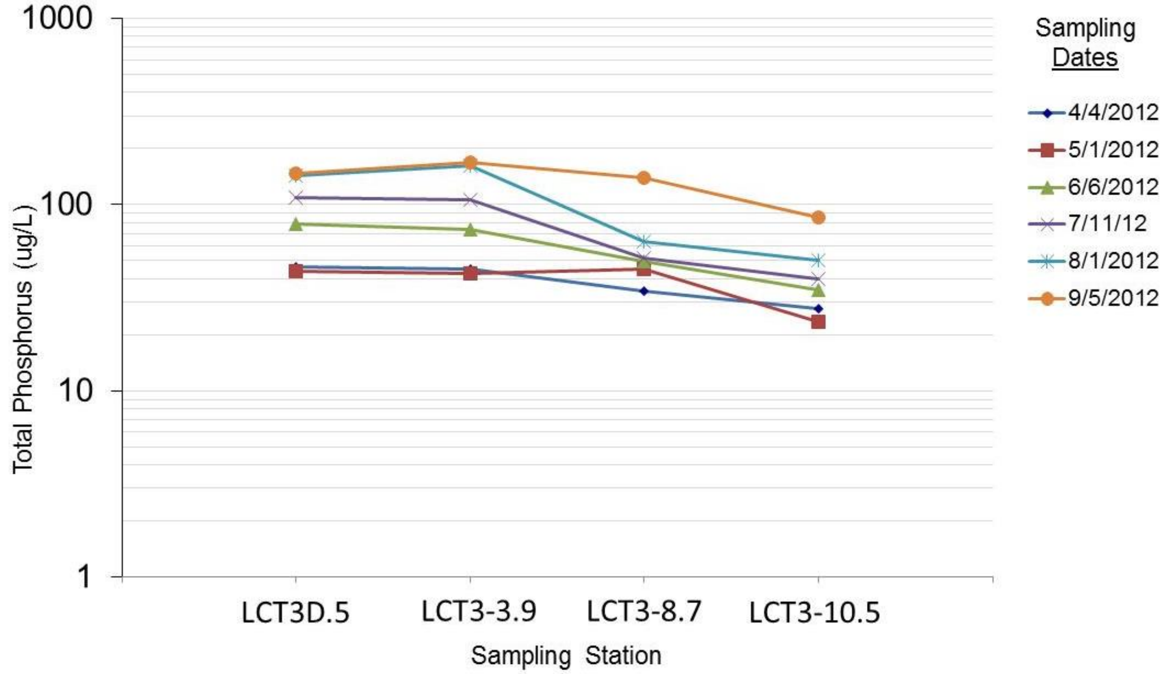
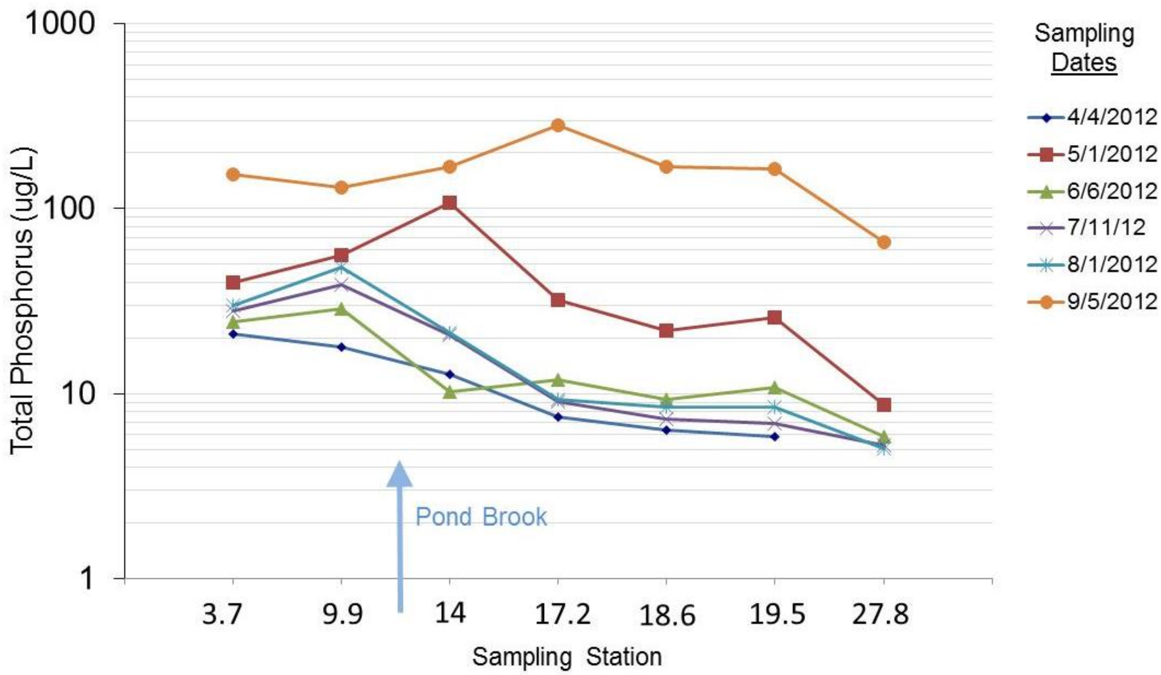
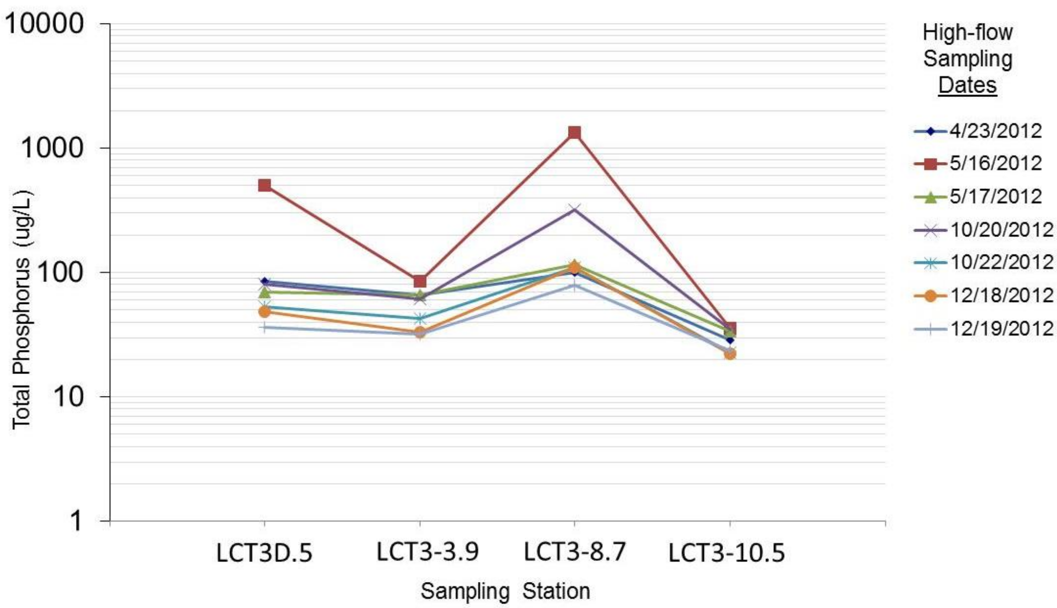


Figure 12b. Total Phosphorus concentrations during scheduled sampling events (low- to moderate-flow conditions), Lewis Creek, 2012.



TP concentrations on the Pond Brook during high-flow sampling events are presented in Figure 13. Results for 2012 indicate a spike in TP concentrations between river mile 10.5 and 8.7 for each event, in contrast to the low-flow sampling events. Concentrations ranged from 78.7 to 1,330 ug/L at station LCT3-8.7 (Appendix F). Sampling results for the May 16/ May 17 storm event were particularly revealing. A thunderstorm in the late afternoon hours of May 16 resulted in fairly intense precipitation falling on/ near the Pond Brook watershed – radar indicated up to 1 inch of rain within one to two hours. Sampling results for May 16 indicated a substantial spike in TP (as well as TSS, turbidity, and TN) between the uppermost Mountain Road station (LCT3-10.5) and Church Road station (LCT3-8.7). A similar (but lower-magnitude) increase in concentration was apparent between the lowermost Mountain Rd station (LCT3-3.9) and the Silver Street station (LCT3D.5). Windshield surveys revealed that rill & gully erosion was prevalent on Layn Farm corn fields just upstream of Church Rd during the May 16 storm event. Direct runoff from corn fields to the Pond Brook was also documented at the Church Rd crossing (field on the west just downstream of the crossing).

Figure 13. Total Phosphorus concentrations during high-flow conditions, Pond Brook, 2012.



Figures 14a and 14b show turbidity concentrations during low- to moderate-flow conditions from upstream (right) to downstream (left) for the stations along the Pond Brook and the Lewis Creek main stem, respectively. During these generally low-flow conditions, Pond Brook TP concentrations (at LCT3D.5) were greater than the main stem concentrations (at LCR14) on April 4, June 6, July 11, and August 1 and may have accounted in part for the increase in turbidity concentrations on the main stem between stations LCR14 and LCR9.9. An increasing trend in turbidity concentration was evident with distance downstream. Results for the main stem sampling sites were consistent with historical trends.

Figure 14a. Turbidity concentrations during regularly-scheduled events (low- to moderate-flow conditions), Pond Brook, 2012.

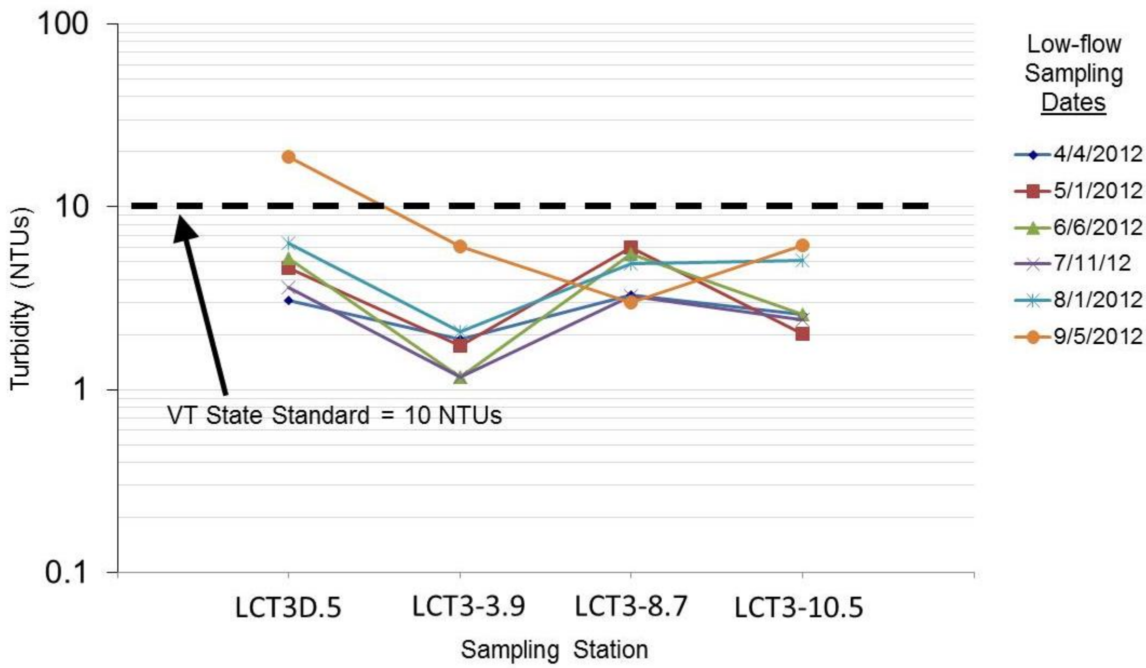
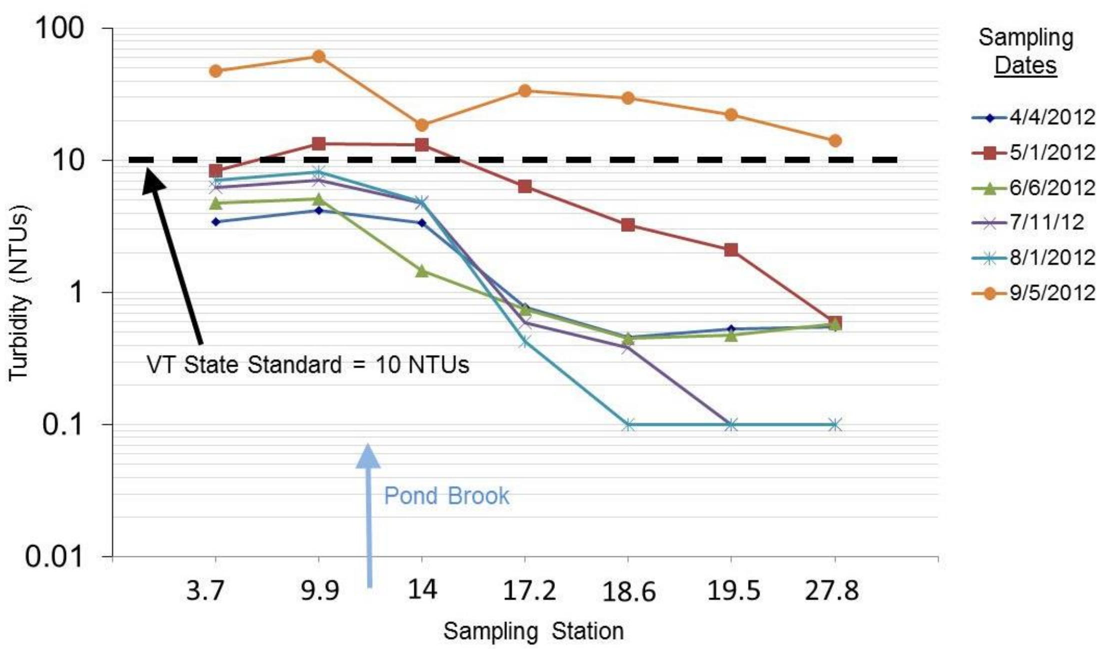


Figure 14b. Turbidity concentrations during regularly-scheduled events (low- to moderate-flow conditions), Lewis Creek, 2012.



Turbidity levels in the Lewis Creek at the sampled stations ranged from <0.2 to 61.4 NTUs, with a mean level of 8.0 NTUs for the six sample dates (Appendix F). Turbidity levels exceeded the Vermont state standard of 10 NTUs (for Class B cold-water fisheries) at stations LCR9.9 and LCR14 on May 1; flows were moderate due to spring rains. All sites exceeded the standard during low flow conditions on September 5, and may indicate the influence of algae or other organic matter. While flows on this date were low, preceded by near 7Q10 flow conditions in the previous few days, a hard rain fell in the watershed during the evening previous to this sampling event, resulting in turbid waters observed by volunteer samplers. A slight increasing trend in turbidity was evident with distance downstream (Figure 14b).

Turbidity levels in the Pond Brook on the same spring and summer dates ranged from 1.2 to 18.7 NTUs, slightly higher than turbidity on the Lewis Creek main stem (as measured at LCR14). Except for the September 5 date, a slight decrease in turbidity is evident from the Church Street crossing (8.7) to the downstream Mountain Road crossing (3.9). This may indicate the sediment attenuation role of the large wetland complex between these two stations. The pattern may also reflect dilution from groundwater and/or tributary sources between stations.

In contrast to these low-flow sampling results, turbidity concentrations increased significantly during high-flow events sampled in 2012 (Figure 15). The downstream trend in turbidity concentrations for each event is similar to the TP trends (Figure 13), showing a spike in concentration between the uppermost Mountain Road station (LCT3-10.5) and Church Road station (LCT3-8.7) and a similar (but lower-magnitude) spike was between the lowermost Mountain Rd station (LCT3-3.9) and Silver Street station (LCT3D.5). These effects were particularly pronounced during the May 16 storm event, during which rill and gully erosion leading to direct sediment runoff were documented Mountain Road and Church Road. July 2012 geomorphic assessments also revealed gully erosion in reach T3.02 which may be a contributing source to the spike in turbidity between stations 3.9 and D.5.

Total suspended solids (TSS) were also sampled in the Pond Brook tributary during low-flow and high-flow events in 2012. High-flow events were defined as having a flow duration interval (FDI) of 40% or less (“moist conditions” or “High flows” on the Flow Duration Curve, Figure 11). Low-flow events were defined as FDI between 40 and 100% (“mid-range flows”, “dry conditions”, or “low flows” on the Flow Duration Curve). Figure 16 indicates a reasonable correlation between TSS and turbidity results.

Figure 15. Turbidity concentrations during high-flow conditions, Pond Brook, 2012.

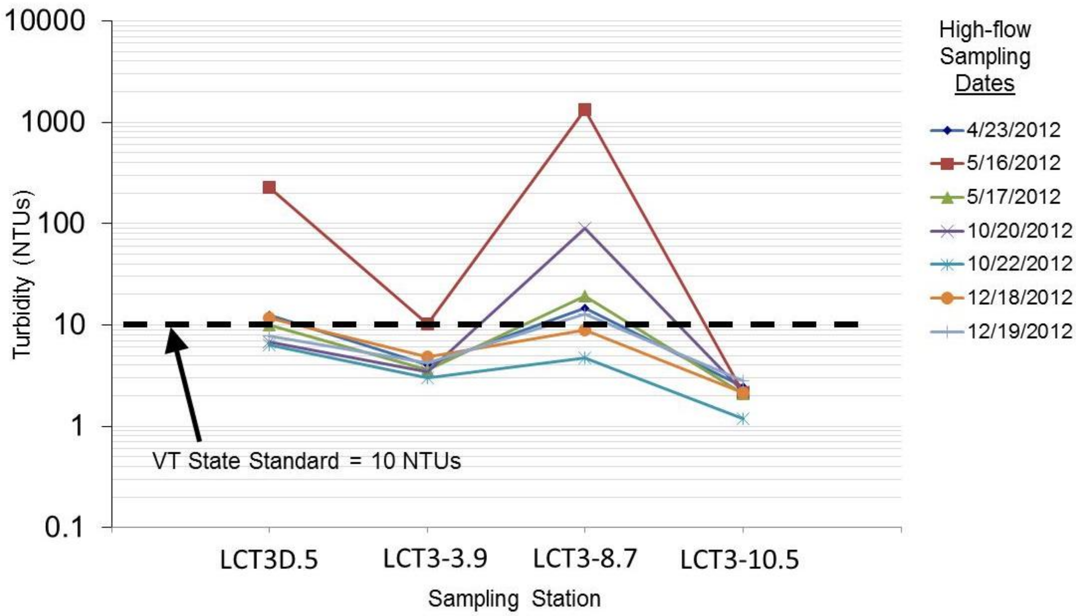
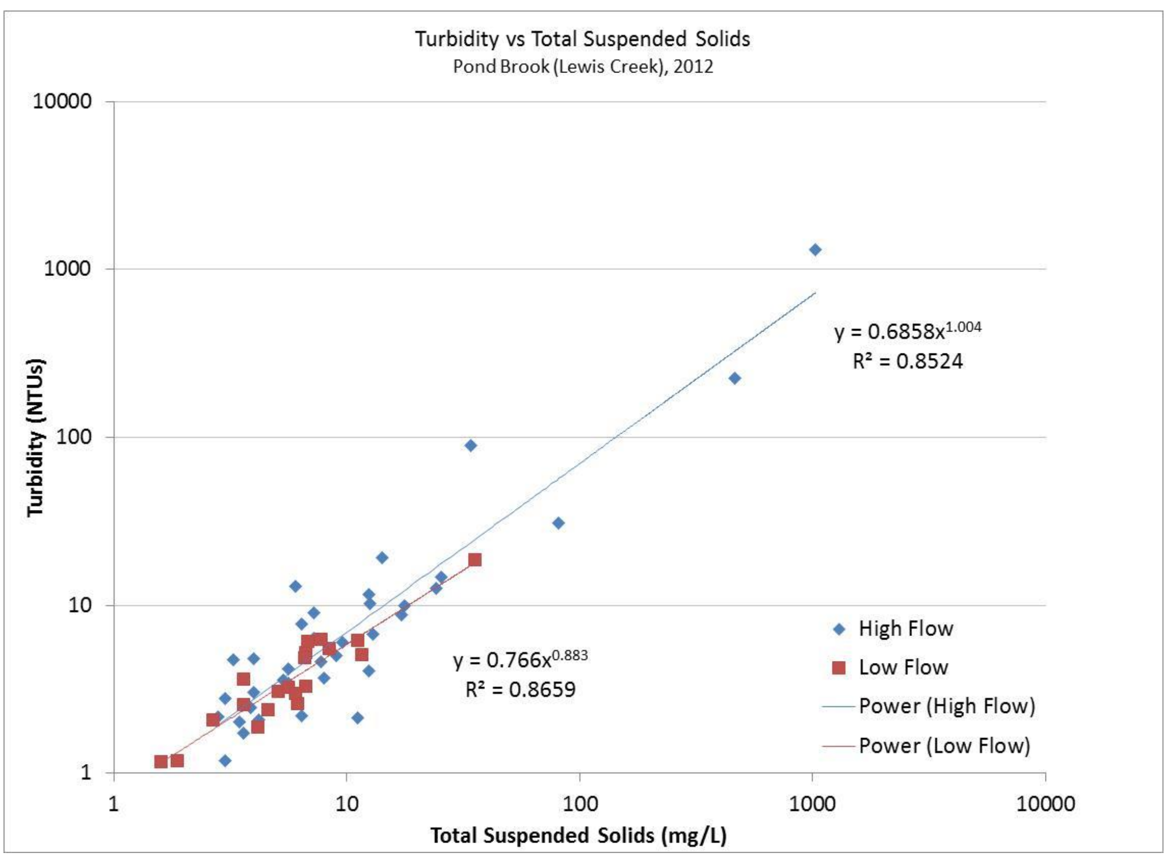
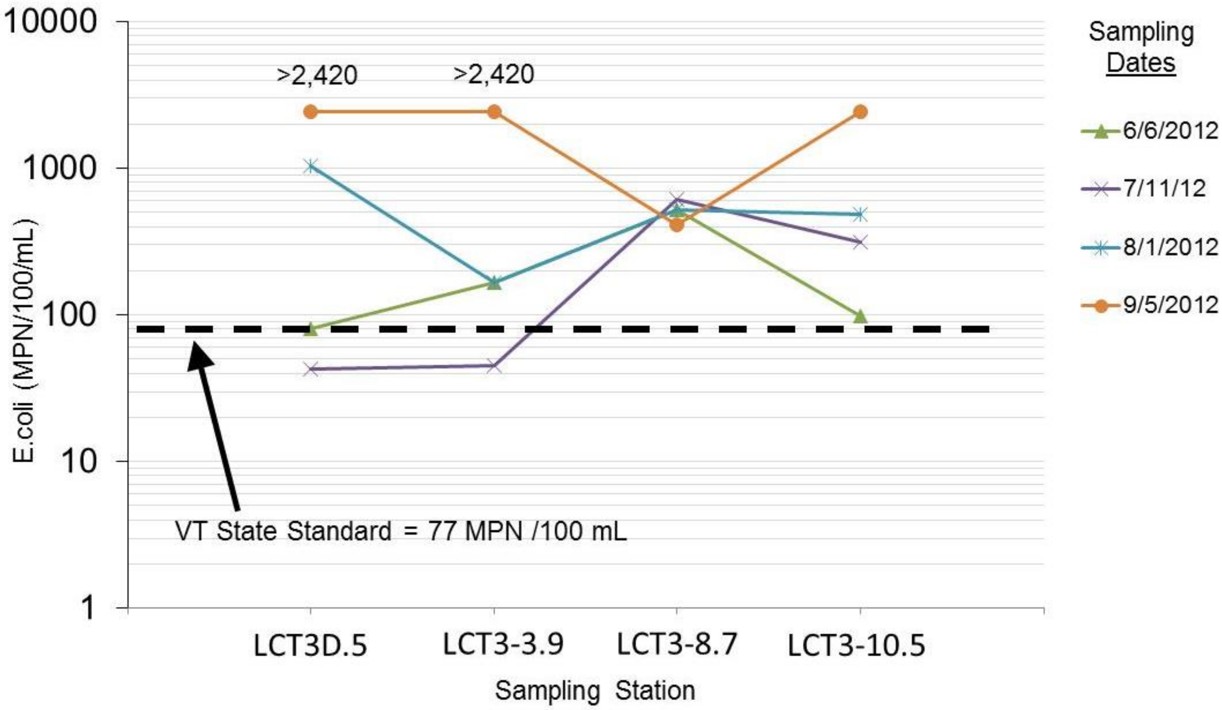


Figure 16. Turbidity versus Total Suspended Solids, Pond Brook, 2012.



E.coli was tested at the four Pond Brook stations during scheduled summer sampling events only, and not during high-flow events. Except for two downstream stations (LCT3-3.9 and LCT3-D.5) on July 11, counts at the four Pond Brook stations exceeded the state standard of 77 organisms/100 mL (Figure 17). *E.coli* counts can become elevated particularly during low-flow conditions in the warmer summer months. A similar occurrence of elevated *E. coli* counts was noted at Lewis Creek main stem sampling stations in historic drought years – e.g., 1993 and 1995.

Figure 17. *E. coli* counts during low-flow conditions, Pond Brook, 2012.



Total Nitrogen (TN) was sampled at the Pond Brook stations during low-flow and high-flow conditions. Concentrations ranged from 0.38 to 1.03 mg.L during low- to moderate-flows, and from 0.42 to 3.58 mg/L during high flow conditions. The maximum detected TN concentration occurred at station LCT3-8.7 during the May 16 storm event, coincident with previously discussed peaks of TP and turbidity. None of the concentrations exceeded the Vermont Water Quality Standard of 5 mg/L nitrogen as nitrates. The mean of the four, low-flow, summer sample results at sites LCT3-8.7 and LCT3-10.5 exceeded the recently proposed instream nitrogen criteria of 0.75 mg/L for WWMG wadeable stream ecotype in Class B waters (VTDEC WQD, 2009), suggesting potential impacts to Aquatic Life Support and Aesthetics uses of these waters.

G. Load Estimates

1. Instantaneous Loads

Instantaneous loads of TP and TSS are presented in Figures 18 and 19, respectively, for the four Pond Brook stations. Where available, loads are also graphed for the Lewis Creek main stem station LCR14. At each monitoring station, instantaneous load estimates were based on constituent concentration data reported by LaRosa Laboratory and the estimated instantaneous discharge for the nearest time interval to the sampling time at the relevant flow gaging station. Instantaneous discharge at LCR14 was estimated with reference to the USGS gaging station at Route 7, adjusted for proportional area. Similarly, instantaneous discharge at Pond Brook stations, LCT3-10.5, LCT3-8.7, LCT3-3.9 and LCT3-D.5 were estimated with reference to the temporary flow gaging station established on Pond Brook just downstream of LCT3-D.5 – adjusted for proportional area.

Instantaneous loads of TP and TSS were calculated for five of the six regularly-scheduled Spring/Summer sampling dates in 2012 (May 1, June 6, July 11, August 1, and September 5). Since the pressure transducer data from the temporary flow gaging station were available beginning on April 20, 2012 and ending on October 30, 2012, flow data were not available to calculate loading estimates for the April 4 or December 18 and 19 sample dates.

Instantaneous loads of TP by station are illustrated for the low-flow sampling dates in Figure 18a, and for the high-flow sampling dates in Figure 18b. Similarly, TSS loads for low-flow and high-flow conditions are graphed in Figures 19a and 19b, respectively.

During low-flow conditions, a general increasing trend in TP loading is apparent with distance downstream in the Pond Brook. Low-flow trends for TSS loading are not less apparent. During high-flow conditions, instantaneous loads for both TP and TSS load reflect the pattern shown by concentration data. An increase in constituent loading is evident between the uppermost Mountain Road station (LCT3-10.5) and Church Road station (LCT3-8.7). Instantaneous loading is much lower at the lowermost Mountain Rd station (LCT3-3.9). A similar (but lower-magnitude) increase is evident between station LCT3-3.9 and the Silver Street station (LCT3D.5). This pattern may suggest attenuation of sediment and nutrients in the instream wetlands that characterize the watershed downstream of LCT3-8.7

<u>Limitations</u>

Coarse estimates of instantaneous loading for the Pond Brook tributary watershed were developed to broadly guide planning and outreach in this 18.3-square-mile watershed (i.e., to focus limited resources toward sub-units of the watershed that appear to have greater loading). These data should be considered very approximate, Methods utilize proportional area to estimate instantaneous discharge at each of the Pond Brook stations, and do not account for possible variation in

Figure 18a. Instantaneous Load Total Phosphorus during Low-Flow Sampling Events, Pond Brook stations versus Lewis Creek main stem station LCR14.

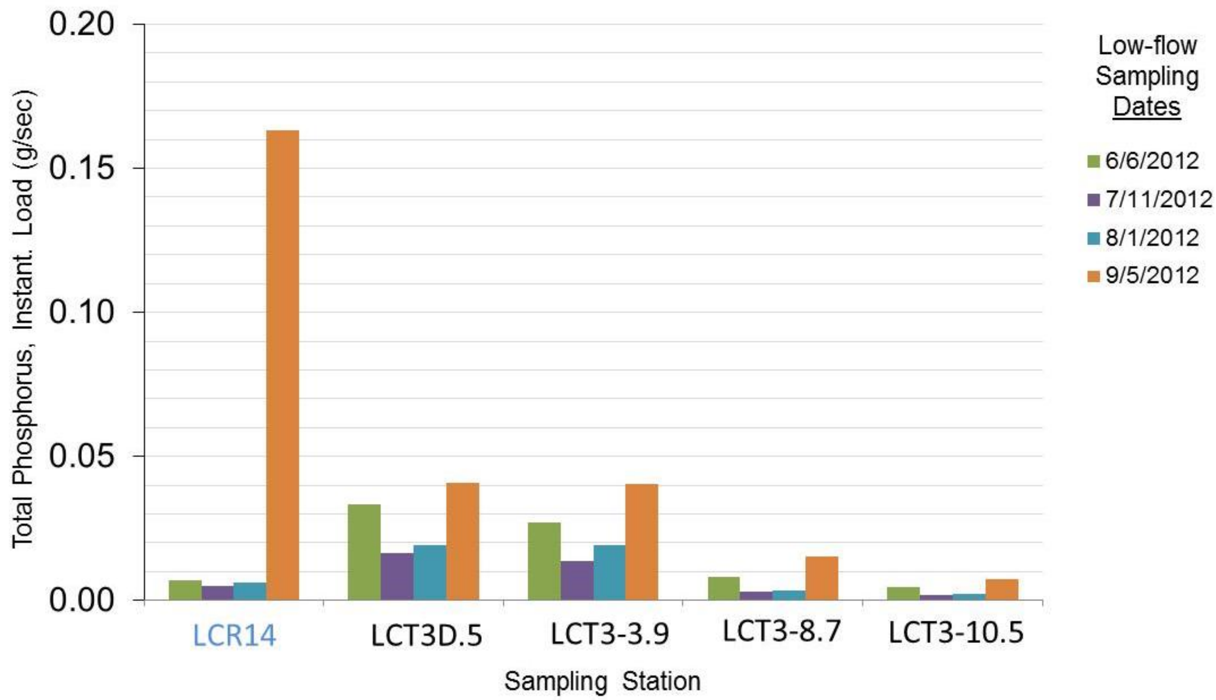


Figure 18b. Instantaneous Load Total Phosphorus during High-Flow Sampling Events, Pond Brook stations versus Lewis Creek main stem station LCR14.

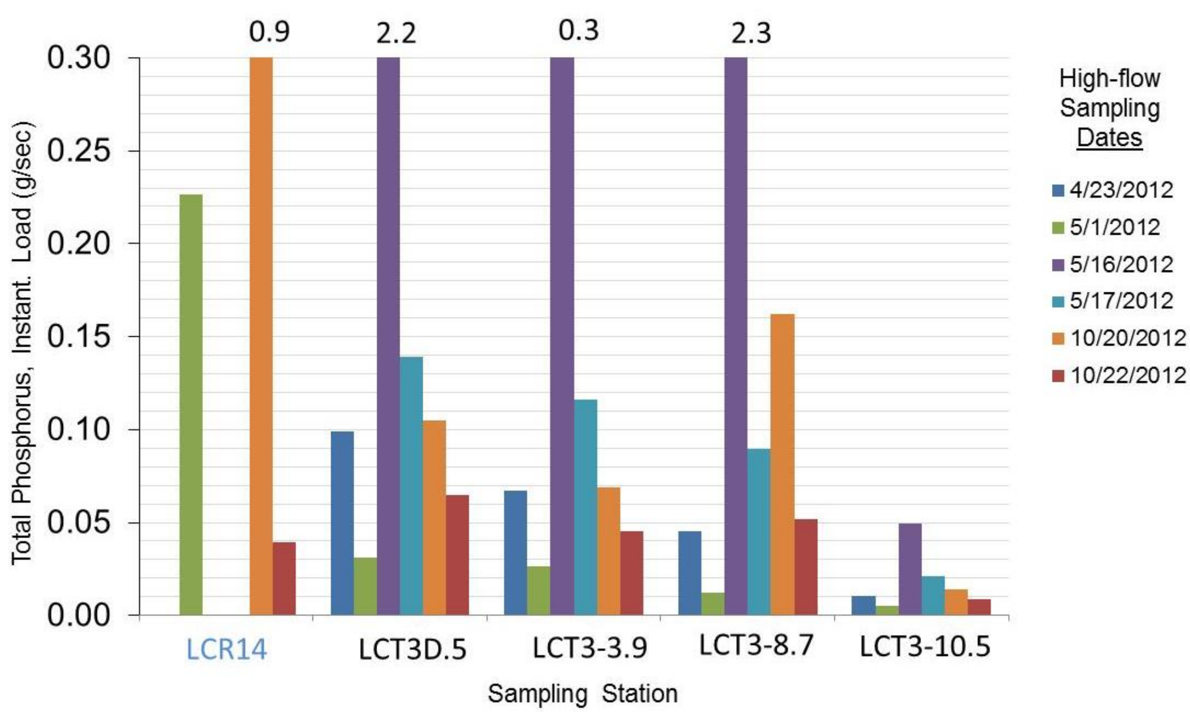


Figure 19a. Instantaneous Load Total Suspended Sediments during Low-Flow Sampling Events, Pond Brook stations versus Lewis Creek main stem station LCR14.

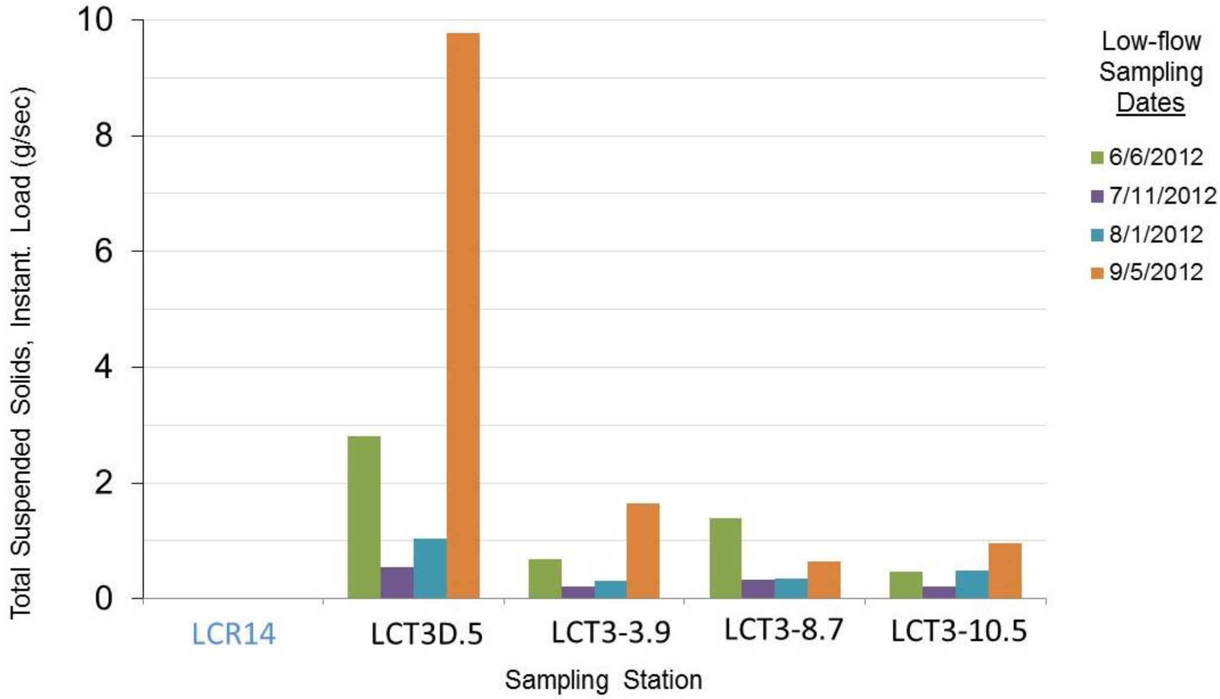
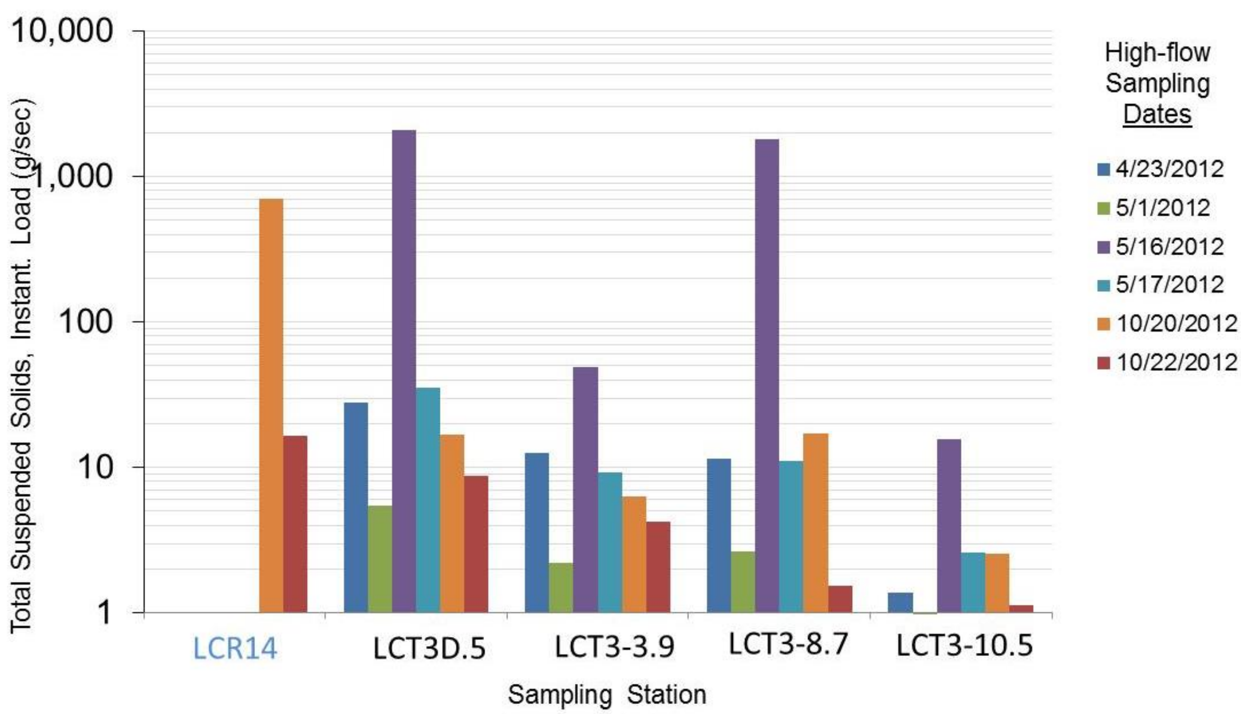


Figure 19b. Instantaneous Load Total Suspended Sediments during High-Flow Sampling Events, Pond Brook stations versus Lewis Creek main stem station LCR14.



discharge at upstream stations due to attenuation in channel-contiguous wetlands or ponds (e.g., Bristol Pond), or gain from or loss to the groundwater aquifer. There could be considerable variability in discharge which would affect estimates of instantaneous loading. Estimation methods have not addressed differences in sample times between each of the Pond Brook stations, and have not accounted for travel time of surface water (and associated constituents) between sample stations.

2. Predicted Loads/ Seasonal Loads

To enable coarse estimates of phosphorus and sediment loading from the Pond Brook for those time periods between actual sampling dates, a rating curve was developed for each constituent based on a regression of the instantaneous load (grams/second) to instantaneous discharge (cfs). The rating curve was then used to estimate instantaneous load for daily mean flow values for those dates between actual sampling dates. An assumption was made that the instantaneous load was representative of the full day's load. Thus, instantaneous load was multiplied by 86,400 to calculate the daily load. Rating curves for Total Phosphorus and Total Suspended Sediments are presented in Appendix G. For Total Phosphorus, a different relationship was evident for low flow conditions (FDI of 40% or greater) versus high-flow conditions. For the Pond Brook watershed, the Low Flow rating curve was applied for estimated DMF values of 24 cfs or less, while the High Flow rating curve was applied for all other DMF values.

The appropriate daily loads were summed to calculate Spring, Summer and Fall seasonal loads for Total Phosphorus and Total Suspended Solids. Due to project schedules and weather conditions, flow (and therefore loading) data are available for the period from 4/20/12 through 10/30/12. Thus, seasonal loads presented in Table 10, are for a Spring season lasting from 4/20/12 through 5/31/12 (42 days); a Summer season from 6/1/12 through 8/31/12 (92 days); and a Fall season from 9/1/12 through 10/30/12 (60 days).

Provisionally, these data suggest both phosphorus and sediment loading are higher in the Spring months than in the Fall and Summer months. Despite the watershed incurring a higher-magnitude peak flow in the Fall (10/20 – 10/22/12) than the Spring peak flow (5/16 – 5/17/12), loads were lower in the Fall than in the Spring.

Table 10. Coarse Estimates of Total Phosphorus and Total Suspended Sediment Loading from the Pond Brook at Station LCT3-D.5 by Season.

Pond Brook @ LCT3-D.5	Coarse Estimate of Phosphorus Load (kg) Spring 4/20 - 5/31/12 42 days	Summer 6/1 - 8/31/12 92 days	Fall 9/1 - 10/30/12 60 days	Total 4/20 - 10/30/12
Total Upstream Watershed	300	225	169	694
Yield (per square mile)	17	13	10	40
Total Upstream Average Daily Load	7.1	2.4	2.8	

Pond Brook @ LCT3-D.5	Coarse Estimate of Total Suspended Sediment Load (kg) Spring 4/20 - 5/31/12 42 days	Summer 6/1 - 8/31/12 92 days	Fall 9/1 - 10/30/12 60 days	Total 4/20 - 10/30/12
Total Upstream Watershed	78,961	17,381	23,155	119,497
Yield (per square mile)	4,538	999	1,331	6,868
Total Upstream Average Daily Load	1,880	189	386	

Limitations

Coarse estimates of seasonal loading for the Pond Brook tributary watershed were developed to broadly guide planning and outreach in this 18.3-square-mile watershed (i.e., to focus limited resources toward sub-units of the watershed that appear to have greater loading). These data should be considered very approximate, as the concentration / discharge rating curves are developed on a limited number of sample results for Spring, Summer and Fall seasons only in one calendar year (2012), which was characterized as a year with lower-than-normal precipitation and mean annual flow. In addition, the discharge values used in these regressions are themselves developed from a stage / discharge rating curve which was based on relatively few manual measurements of discharge. The stage / discharge rating curve also extended to flow values which were up to 1.4 times the magnitude of the highest measured flow. These data should not be used to develop TMDL target loads, or as supporting evidence for potential enforcement actions in the watershed.

IV. Options for Reducing Phosphorus and Sediment Loading to Pond Brook

Significant mobilization of fine sediments, phosphorus and nitrogen is occurring within the Pond Brook tributary subwatershed of Lewis Creek, related to: (1) fall-tilling, manure applications, and cropping practices in close proximity to unbuffered swales, road ditches and other locations of concentrated runoff to surface waters; (2) occasional inundation of fields beyond minimum buffer widths required by AAPs and LFO/MFO rules; (3) maintenance of drainage ditches in agricultural fields; (4) livestock pastured with direct access to surface waters; and (5) stormwater and sediment runoff from forested and developed lands and road and driveway networks.

Ultimately, best opportunities for controlling the transport and delivery of fine sediments and nutrients within the watershed are through: (1) improved management of nutrient inputs within the upstream areas of the river network; and (2) interruption of the transport processes of sediments and nutrients at their source.

This can be accomplished on multiple fronts. Remedies are discussed generally in the sections below. Site-specific projects are identified in the Implementation Table and accompanying Plate 1, presented in Section V.

A. Forest Lands

An estimated 8 to 15% of the total annual non-point phosphorus load to Lake Champlain is contributed from forestlands (Troy *et al*., 2007; Lake Champlain Basin Atlas, 2004). Approximately 57% of the Pond Brook tributary watershed is forested. The Pond Brook valley is flanked by actively-managed forests on steep slopes to the west and east. Steep-gradient skid trails and logging access roads without sufficient drainage structures can be a source of increased volumes and peaks of runoff from forested lands. For example, concentrated runoff from forested lands was identified as a contributor to field erosion during the May 16 storm event.

The importance of meeting *Acceptable Management Practices (AMPs) for Maintaining Water Quality on Logging Jobs in Vermont* was acknowledged during the project steering committee meetings. Forest management practices that maximize infiltration of rainfall and runoff will reduce peak flows from the headwaters of the Pond Brook watershed. In partnership with Vermont Family Forests, LCA has carried out two forest management workshops at forest properties in the Pond Brook region to train forest landowners to evaluate compliance with AMPs on their own lands, leading to improved stormwater attenuation and reduced sediment/nutrient loading (see Appendix H). Additional workshops in 2013 and 2014 will provide hands-on instruction in the proper siting and installation of drainage structures, such as broad-based dips, water bars, and stone-lined ditches.

B. Agricultural Lands

Increased flows from drainage tiles, ditches and erosional gullies can be addressed through design and retrofitting of tile networks to provide for energy dissipation at tile outlets; gully stabilization; and crop rotation or alternative farming practices that reduce the need for drainage tiles. Considerable technical and financial resources are available to farmers to implement these practices.

- Identify more stringent nutrient management practices in saturated runoff-contributing areas (RCAs). Where these RCAs overlap with land uses that involve fertilizers or manure, manage nutrient applications to prevent mobilization of nutrients and sediments during snowmelt and precipitation events. For example, Meals, *et al*. (2006) found nutrient management, particularly in runoff-contributing areas, to be the overriding factor in achieving greatest reductions of phosphorus export in a study of the nearby Little Otter Creek. RCAs are defined by the topography, soil characteristics, and groundwater / river interactions. They vary in aerial extent with the magnitude and intensity of rainfall events (Dunne & Black, 1997). In many locations, RCAs extend to distances from the channel banks that exceed default buffer widths specified in regulations (e.g., AAPs) or existing management agreements (e.g., CREP, nutrient management plans).
- Exclude livestock from stream channels. Fencing livestock out of the river reduces channel trampling (and nutrient / *E.coli* inputs) and allows trees and other native species to re-vegetate the channel margins. Five opportunities for livestock exclusion in the Pond Brook watershed were identified by the project Steering Committee (see Implementation Table) – all high priority. Technical and financial resources are available to farmers to implement these practices. Livestock exclusion (fencing) can be accompanied by provisions for alternative water sources and installation of stabilized livestock crossings. At present, UVM Extension Service in Middlebury has funding to implement livestock exclusion projects in the Lake Champlain Basin. Livestock exclusion can also be accomplished under FSA programs (CRP/CREP, EQIP).
- Implement changes in cropping practices to reduce concentrated runoff (and fine sediment and nutrient loading) to drainage ditches, road ditches, surface swales, inundation areas, and the Pond Brook and tributary channels. Possible measures include cover cropping, crop rotation, filter strips, grass buffers, interseeding, and no-till options in the fall of the year. Given the high clay content of Addison County soils, farmers typically till fields in the fall months, leaving them bare and subject to erosion during the wettest months. Farmers have been reticent to adopt alternative cropping practices that would reduce sediment and nutrient runoff - such as fall cover cropping and no-till or limited-till approaches. Franklin County has similar clay-rich soils and farmers there have traditionally plowed their fields in the fall. However, in recent years, local groups (WASTE NOT Resource Solutions, Friends of the Northern Waters) working with FSA, VT Agency of Agriculture and UVM Extension Service have assisted farmers to implement fall cover crops, and adopt alternative field practices such as strip cropping and reduced tillage in the spring. Rill erosion in bare fields has been reduced by strips of cover crop; rills are observed to terminate at the bare soil / cover boundary. Even cover cropping in small critical areas (e.g., edge-of-field gullies/ swales) has been particularly

effective at reducing soil loss (and sediment runoff to streams). In Addison County, UVM Extension Service in Middlebury has worked with farmers to install fall cover crops and carry out mechanical incorporation of manure - including some fields in the Lewis Creek and Little Otter Creek watershed.

- Consider taking vulnerable, and marginally-suitable lands (with uncertain yields) out of agricultural production – with the support of various state-and federally-funded cost-share programs available through FSA (e.g., CRP/CREP, EQIP, WRP, FRP) or by means of in-perpetuity easements such as river corridor easement or whole-farm easement programs available through the VTDEC and Vermont Land Trust.

C. Developed Lands

Address increased flows to the Pond Brook from drainage tiles, road-ditch networks, erosional gullies, and stormwater runoff. Stormwater flows can be managed through compliance with state regulations. The towns of Monkton and Bristol can also consider local ordinances to provide more stringent controls on stormwater runoff and which could apply to smaller developments and road / driveway installations that may not be subject to state stormwater regulations.

Residential and commercial properties in the Pond Brook watershed can take steps to reduce nutrient and sediment loading to Pond Brook:

- Limit applications of fertilizers on lawns and gardens, to only what is needed.
- Perform a soil test to determine whether fertilizers are needed.
- Apply fertilizers only once per year in the fall.
- Use phosphorus-free fertilizers.
- Minimize impervious surfaces.

D. Roads

There are approximately 32 miles of roads within the Pond Brook watershed. Six crossings of public roads occur along the main stem of the Pond Brook and several additional bridge and culvert crossings carry public and private roads over tributaries to the main stem.

There are opportunities to improve management of stormwater runoff and reduce erosion along road ditches and at culvert outlets. Road maintenance practices to mitigate for stormwater and sediment runoff may include: stabilization of road surfaces (different gravel materials), improvement of roadside ditches (excavation, stone lining and/or seeding and mulching), alternative grading practices (turnouts, check-basins); re-orientation of culvert crossings; protection of culvert headers; and gully stabilization. Technical and financial resources are available to the towns through the Better Back Roads program (Northern Vermont Resource Conservation and Development Council) as well as the VT Department of Transportation.

E. River Corridor Protection

A river in dynamic equilibrium, connected to its floodplain, with a naturally-vegetated corridor can serve many important services for a community, namely:

- Flow attenuation to reduce the peak and intensity of downstream floods;
- Sediment storage, in river meanders, the floodplain, and in riparian wetlands and flood chutes;
- Attenuation, transformation, and uptake of nutrients such as phosphorus and nitrates in riparian wetlands and the floodplain;
- Diversity of channel bedforms and riparian landforms (pools, riffles, eddies, connected wetlands) which help to regulate water temperatures and provide habitat and refuge areas for riparian and aquatic species;
- Improved filtering and treatment of particulates and contaminants contained in storm flows; and
- Increased recharge to groundwater (which in turn supports the community with drinking and process water, and which increases base flows of the river during drought conditions).

When the river and floodplain are supported through corridor protection and management, the community can achieve the goals of: (1) reduced fluvial erosion hazards; (2) improved water quality; and (3) improved aquatic and riparian habitats.

River corridor protection is being pursued through a Special Treatment Area designated in a farm easement by Vermont Land Trust for one property on the lower reach of the Pond Brook spanning the Monkton and Hinesburg town lines (see Appendix H).

F. Restoring Riparian Wetland Hydrology

While several areas of the Pond Brook floodplain are well connected to the channel and are occasionally inundated, the natural wetland functions and values of these inundated areas have been compromised by conversion to agricultural uses and impacts from field-ditch and road-ditch networks. Flood retention and filtering functions of these wetlands have been significantly reduced through historic clear-cutting of floodplain tree species, compaction and leveling of soils through repeated tillage (loss of micro-topography), and dredging of linear ditch networks to improve field drainage. These prior-converted wetland areas (both within and along the edges of inundated areas) may be serving as nutrient and sediment source areas as a result of a legacy of nutrient additions in excess of agronomic needs, fall tillage practices, absence of cover crops, and periodic dredging of soils to maintain ditch networks. Wetland restoration (e.g., through NRCS Wetland Restoration Program [WRP]) and corridor protection (e.g., through river corridor easements, or Vermont Land Trust easements) can enhance the flow and sediment attenuation role of the riparian areas surrounding the Pond Brook reaches, as well as mitigate for documented water quality impacts. During this project, several parcels within the Pond Brook valley were prioritized for outreach regarding wetland restoration by Waterscapes, LLC (under contract to Ducks Unlimited) and Vermont Land Trust. Details of site reviews are provided in Appendix H. To date, none of the landowners contacted were interested to pursue enrollment in WRP.

G. Enhanced Protections for Vulnerable Geologic / Hydrologic Settings

Significantly greater reductions in phosphorus and sediment loading to our rivers and Lake Champlain could be achieved if road ditch networks and field ditch networks were recognized as surface waters, and appropriate measures were taken to buffer them from concentrated runoff and nutrient / sediment sources. Accepted Agricultural Practices (VTAA , 2006), Large Farm Operation (LFO) rules, and Medium Farm Operations (MFO) rules are ambiguous on this point.

The geologic and hydrologic conditions of the Pond Brook subwatershed enhance its vulnerability to water quality impacts. Similar hydrogeologic conditions are characteristic of many watersheds in the Lake Champlain basin, including: Little Otter Creek, Lemon Fair River, and Otter Creek in Addison County; Rock River, Hungerford River in Franklin County; and the Hubbardton River and lower Poultney River in Rutland County. Nutrient management planning could be improved in these vulnerable settings.

- More effective nutrient management strategies, tailored to the geologic and hydrologic context, would result if available water quality and geomorphic data (VTDEC, ACRWC) and knowledge of watershed hydrology (e.g., local areas of frequent inundation) were addressed in Land Treatment Plans, Nutrient Management Plans and Wastewater Treatment Plans required of Medium- and Large-Farm Operations (and encouraged for small farms).

- Similarly, the AAPs, LFO rules, and MFO rules could be improved with consideration of such vulnerable geologic and hydrologic settings. For example, the floodplain along Pond Brook and its tributaries in inundated areas can be flooded beyond standard buffer widths (10 ft under AAP guidance; 25 feet under LFO/MFO rules).

H. Municipal Strategies

The following sections identify municipal level strategies that can be undertaken to achieve nutrient / sediment reductions, reduce potential for future fluvial erosion hazards, and restore and conserve riparian habitats. These strategies are a combination of regulatory and nonregulatory approaches. Since the study reaches cross town boundaries, and many issues of river corridor management are shared by the watershed towns, efficiency can be gained by inter-town cooperation for certain education and outreach tasks. To facilitate the watershed-level strategies discussed below, as well as the relevant site-specific projects recommended in

Section V, towns should include the appropriate enabling language in next updates to the their respective Town Plans.

1. River Corridor Overlay Districts

A river corridor management area (or Overlay District) that acknowledges the dynamic nature of rivers and which is based on the geomorphic condition of the channel has advantages over a simple, no-build setback from the river. River channels vary in width along their length, depending on the size and nature of the upstream watershed draining to a given location, and the valley setting of the channel. Rivers are also continuously adjusting their position in the landscape, both vertically and laterally, in an attempt to optimize their slope and channel dimensions to efficiently carry the water and sediment loads supplied from the upstream watershed. A default setback is often inadequate and can be difficult to administer where a river is adjusting laterally at a rate of several feet per year.

A river corridor overlay district is a footprint in the landscape, which encompasses the dynamically-adjusting river channel. The corridor varies in width along its length, accounting for the actual width of the river channel at various locations, the size and nature of the watershed draining to that particular reach, the sensitivity of the reach, knowledge of historic migration patterns of the river, and the position of the valley walls adjacent to the channel.

VT Agency of Natural Resources has developed protocols to define a zone that can be adopted by communities as a river corridor overlay district with the objective of supporting dynamic equilibrium in Vermont's channels. Methods for corridor delineation are provided in various guidance documents from VTANR (for example, see VTANR, 2008a; VTANR, 2008b; VTANR, 2009b).

2. Buffers for smaller waterways

Beyond the main stem of the Pond Brook channel assessed as part of this study, several additional miles of tributaries exist in this subwatershed. These tributaries are small enough in size that geomorphic assessment is either not practical or affordable in the near term. Yet, protection of these smaller tributaries from encroachment, channelization, dredging, berming and other impacts is critical to the overall watershed goals of mitigating for increased flows and sediment loading. While impacts to any one small tributary may be small in degree, impacts to several small-order tributaries can accumulate in the watershed to result in significant impacts to the Pond Brook and Lewis Creek.

For maximum protection of surface waters, towns can implement a combined approach of corridor protection and River Corridor Overlay districts for larger waterways, and default buffers for these smaller channels. A minimal 50-foot setback maintained with natural vegetation (i.e., a buffer) is recommended by the VT Agency of Natural Resources for channels with upstream drainage areas equal to or less than 2 square miles (VTANR, 2008a).

3. Low-impact Development

Towns can consider a variety of additional planning and zoning strategies to reduce stormwater and sediment runoff to the Pond Brook and its tributaries, such as:

- Implement Low Impact Development techniques:
  - Establish or Increase Minimum Lot Sizes
  - Establish or Reduce Maximum Lot Coverages / Minimize Percent Impervious
  - Minimize land disturbance / compaction during construction
  - Prevent stormwater outfalls from crossing vegetated buffers and entering rivers and streams without treatment or energy dissipation.
  - Specify maximum road and driveway widths.
  - Review parking space ratios for minimum impacts.

- Incorporate practices for area-based zoning, transfer-of-development rights and clustering into zoning and subdivision regulations to encourage protection of river corridors.

- Add relevant language to zoning and subdivision regulations for protection against fluvial erosion hazards – Special Flood Hazard Area regulations established for floodways defined on FEMA-FIRM maps are designed to protect against inundation (rising water) flooding. These practices do not necessarily adequately protect against erosion hazards (or sudden streambank erosion, avulsion) during flooding events.

- Consider forested (vegetative) buffers and erosion control along tributaries and unnamed streams that are not covered by corridor plans and/or River Corridor Overlay districts.

- Implement local-level stormwater ordinances for development projects that fall under the thresholds for triggering Act 250 review or the States Stormwater Management rule.

- Consider local road & driveway and bridge & culvert ordinances or review standards.

- Continue improved road maintenance practices to mitigate for stormwater and sediment runoff, including: stabilization of road surfaces (different gravel materials), improvement of roadside ditches (excavation, stone lining and/or seeding and mulching), alternative grading practices (turnouts, check-basins); re-orientation of culvert crossings; and culvert header protection.

- Coordinate educational programs to increase awareness of permit requirements for stream alteration, stream crossings, and gravel extraction

4. Maintenance and Replacement of Crossing Structures

Additional watershed-wide and town-scale strategies for installation and maintenance of bridge and culvert structures should be considered. The watershed towns could establish ordinances or identify zoning requirements which would ensure adherence to proper siting and design practices for bridge and culvert crossings. The geomorphic context should be considered when designing new and rehabilitated structures within the watershed:

- New or replacement bridges and culverts should ideally have openings which pass the bankfull width without constriction.
- Bridges and culverts should be designed to cross the river without creating channel approaches at an angle to structures. Such sharp angles can lead to undermining of fill materials and structural components.
- The historic channel migration pattern of the river should be considered when installing new or replacement crossing structures (and when constructing new roads, driveways, and buildings). Corridor protection strategies that prevent or limit placement of infrastructure within the corridor will protect structures from future erosion and flood losses.
- Planned build-out for watershed communities and resultant channel enlargement (from increased percent imperviousness) should be considered when designing new or replacement bridges and crossing structures.
- Road ditch runoff should be diverted to side-slopes where energy can be dissipated, stormwaters can infiltrate, and sediment / detritus loads can be deposited on the land and not directly to streams

V. Implementation Table

An Implementation Table is presented as an attachment to this report – which identifies site-specific restoration and conservation projects that address nutrient and sediment loading in the Pond Brook watershed. The table is intended to be dynamic and adaptive, and serve as a guide for all watershed stakeholders. The location of specific project sites is referenced on Plate 1.

A brief description of the project or practice is provided along with the specific stressors addressed. Technical feasibility and cost are rated in a qualitative sense (low, medium, high). Based on these ratings, a priority is assigned to each project with respect to the potential benefits to water quality. Independent of the priority ranking, current information regarding the landowner willingness to implement the project or practice is also provided, along with potential partner agencies and funding sources. In reality, projects may have a different priority for each stakeholder, depending on their specific organization’s mission, purview and available resources. However, the priority ranking in this table is designed to reflect the value of the project for improving water quality – regardless of whether there is landowner willingness and/or funding available to implement the project.

Additional details of each proposed project are provided in project packets contained in Appendix H – a summary of project development and outreach, to date.

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