Baseline Characterization of Natural Resources of Wards Brook and Lovewell Pond in Support of Assessment of Potential Groundwater Withdrawal Impacts

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TOWN OF FRYEBURG

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EXECUTIVE SUMMARY

Normandeau Associates Inc. was contacted by the Fryeburg Aquifer Resource Commission (FARC), Town of Fryeburg, regarding potential impacts associated with proposed additional water level withdrawals from the Wards Brook aquifer on the ecology of Wards Brook and Lovewell Pond. Following several discussions with Mr. Gene Bergoffen, Normandeau understands that FARC's primary ecological concerns for the brook include:

- a paucity of existing information on the biota (fish and invertebrates) in Wards Brook and Wards Pond,
- impacts of groundwater withdrawal on these biota and water quality,
- impacts of groundwater withdrawals on the wetland at the confluence of Wards Brook and Lovewell Pond.

In support of addressing these ecological concerns Normandeau conducted a program of field studies to characterize the natural resource condition of Wards Brook and certain aspects of Lovewell Pond.

Trends in water temperature in Wards Brook were dominated by trends in air temperature. Because of local landscape influences on temperature, i.e., ponds and wetland areas that tend to slow flow and warm water, parts of the brook habitat may be considered a cool/coldwater system and other parts approach a warmwater system, based on peak summer temperatures above 18.3° C. Groundwater contribution to Wards Brook would be expected to help maintain cool water temperatures, important to brook trout population, during more extreme hot and dry years.

As for water quality of Lovewell Pond we concluded that the maximum probable impact of withdrawal 220 million gallons from the Wards Brook aquifer on Lovewell Pond in-lake phosphorus concentrations would be to increase phosphorus concentrations by less than 1 μg/l. A more detailed accounting of likely phosphorus concentrations from the various inflow sources to Lovewell Pond could very well reduce this value significantly, even to the point where no change in in-lake total phosphorus concentrations would be expected, as in our first example. Irrespective of the actual amount, it is safe to conclude that the potential impact of groundwater withdrawals from the Wards Brook aquifer on water quality in Lovewell Pond is likely to be minor and indistinguishable from existing water quality conditions.

Fisheries sampling in Wards Brook captured eight species. Brook trout were the most abundant species from the old mill site and upstream to Route 113, which was an area of colder water. Largemouth bass and yellow perch, both habitat generalist and cool-water/warm-water species, were the most abundant species downstream of the old mill. The most sensitive species to potential habitat and temperature perturbation by groundwater withdrawal would be brook trout.

Baseline macroinvertebrate (non-mussel) community sampling revealed that the benthic that immediately below Route 113 (Upstream station) and at the old mill site (Downstream station) communities were consistent with the types of communities normally found in similar habitats of other streams. The Upstream Station was overwhelmingly numerically dominated by filter feeding insects, which are often abundant downstream of impoundments. The Downstream Station supported a benthic community typically found in first to third order woodland streams.

Because macroinvertebrate insects are tolerant of low water depth, changes in water depth with reduced flow from potential groundwater withdrawal would not likely impair macroinvertebrate habitat. The most probable way that macroinvertebrate habitat in Wards Brook would be influenced by increasing groundwater withdrawal would be reduced water velocities from reduced stream flow or increases in peak summer temperatures. Both of these effects would typically be a problem only during low flow periods, which is usually late summer, or periods of below normal precipitation in general.

The qualitative mussel survey conducted in Lovewell Pond in December 2006 found that the mussel community was composed exclusively of eastern elliptio, *Elliptio complanata*, a very common species found throughout New England and very tolerant of a wide range of habitat conditions.

Wetlands were unevenly distributed in the study area. The vast majority of the wetlands occurred in the upper reaches of the brook, south of Wards Pond. The topography dropped substantially toward Lovewell Pond so that Wards Brook cut a narrow ravine through the stratified drift. Relatively little wetland development occurred along this section of the brook, and was confined to occasional narrow shelves within the floodplain. At the junction of the brook with Lovewell Pond, a moderately sized emergent marsh/floodplain wetland has developed. Beaver have constructed a series of dams throughout this wetland, further slowing flows and impounding water

Wards Brook supports three distinct wetland types: a large upper forested wetland plain, scattered streamside wetlands along the steeper gradient of the stream, and emergent/floodplain wetlands at the junction with Lovewell Pond. The effects of water withdrawal can impact wetlands in two ways: 1) lower the water table, and 2) altered stream hydrology. The effects of a lowered water table would be a chronic condition, most pronounced in the late growing season, when the water table is typically at its lowest point. The herbaceous layer is most sensitive to water level changes, because the live root zone is typically shallow and confined to the upper soils. The shrub and tree roots are often deeper rooted and most species, once established, can tolerate a wider range of fluctuations. Woody seedlings are an exception, and resemble the herbaceous layer in their response to altered water levels. Altered stream hydrology would be most likely to affect only the lowest wetlands by reducing base stream flow and drawing down ground water immediately adjacent to the stream. Unless the system underwent a severe withdrawal, high water levels during spring melt and storms would be virtually unaffected, and the scour and flooding effects in the streamside wetlands would remain unchanged.

The impacts of water withdrawal from the vicinity of the commercial springs are likely to be minor in all areas, but most pronounced along the small streamside wetlands in the middle section of the stream. The effects of both a lowered groundwater table and a reduced base flow of the stream would be most pronounced in the herbaceous layer, where obligate wetland species may be reduced or eliminated and Facultative species could encroach. Woody growth could further reduce sunlight and reduce the percent cover of the herbaceous layer. No destabilization of the wetlands would be expected unless a severe change in stream flow or groundwater levels occurred.

I. Introduction

Normandeau Associates Inc. was contacted by the Fryeburg Aquifer Resource Commission (FARC), Town of Fryeburg, regarding potential impacts associated with proposed additional water level withdrawals from the Wards Brook aquifer on the ecology of Wards Brook and Lovewell Pond. Following several discussions with Mr. Gene Bergoffen, Normandeau understands that FARC's primary ecological concerns for the brook include:

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In support of addressing these ecological concerns Normandeau proposed a program of field studies to characterize the natural resource condition of Wards Brook and certain aspects of Lovewell Pond.

II. Methods

Review of Existing Information

In addition to using the information provided in the Wards Brook groundwater flow model report (EGGI 2005), relevant data on the Brook and Lovewell Pond was collected from other reports specific to the project area. These may have included permit applications for water withdrawals by the water bottling companies and the Town of Fryeburg, or monitoring reports by the same entities. Other available information may include fisheries and water quality data; NRCS soil maps, National Wetland Inventory maps, geologic resource maps, and aerial photos. Many of these sources were available on the Maine Office of Geographic Information as GIS layers. Some information was collected from Agencies or organizations such as FARC, Lovewell Pond Association members, Maine Department of Inland Fish and Wildlife, and Maine Natural Heritage Program.

Wards Brook

Temperature

Water temperature is a strong ecological signal for defining ecological communities and for important life history functions. At the level of the individual, it affects metabolic demand which consequently controls growth/development of individuals. At the level of the biotic community, it determines community type. For example, when summer maximum temperatures are frequently above 18.3°C, an aquatic community of warmwater species is present. If summer maximum temperatures were limited to less than 18.3°C, then most of the species currently present would not thrive, and coldwater or coolwater species would dominate.

Water withdrawal can increase travel time and decrease groundwater contribution to streams, which may increase water temperature. It can also change the amount of influence other factors can have on instream temperature such as the effect that upstream ponds or lakes may have on stream temperature.

Normandeau evaluated the baseline water temperature conditions and qualitatively assessed the potential for water temperature change. Water temperature assessment included one year of monitoring at five sites. Analysis described water temperature magnitude, duration (time), and spatial extent (longitudinal change) in the brook. Potential impacts of change on the present fauna were then evaluated qualitatively based on an understanding of how temperature influences aquatic biota.

Fish

There was no known baseline data for the fish community in the stream. To characterize fish species and relative abundance in Ward Brook we sampled sections of the stream using backpack electrofishing. Two persons, one operating the electrofishing equipment and one person dip-netting stunned fish, sampled three sites; each site was 15 to 21 bank-full stream widths. This distance would allow sufficient stream length to get multiple samples (two or three) of mesohabitat types such as riffle or pool within each site. Sampling was conducted once during late summer and performed in an upstream direction. One sample was taken at the snow mobile bridge, one at the old mill site, and one downstream of the old mill site in the open canopy, braided channel of the wetland area.

At the snowmobile site, electrofishing was conducted for 30 minutes in the upstream direction. The survey was performed over 37.5 m along the thalweg. At the old mill site, sampling was performed for a total of 58 minutes for 46 m along the thalweg depth, effort approximately split among habitats upstream and downstream of the walking bridge where a habitat shift is evident. Finally, sampling occurred in the wetlands about 91 m downstream of the old mill site for 16 minutes over 28 m along the channel thalweg length where habitat type had clearly shifted from upstream sites.

Captured fish were placed in buckets of fresh stream water and identified to species, grouped into one of three life stages based on length (adult, juvenile, young-of-year) and enumerated. Lengths used to identify adult from pre-adult life stages for each species were obtained from the literature.

To assess the fish communities present, we report the species richness and community composition. The abundance of fishes in samples were too few in number to apply an Index of Biotic Integrity rating system, but the samples were evaluated qualitatively using concepts of ecological integrity such as structure (who is present), function (how they live), and community characteristics such as the number of native species or non-native species, the presence of different types of reproductive behavior (nest builders versus open substrate spawning), the presence of intolerant and sensitivity to pollution/disturbances, and feeding strategies (trophic levels) such as omnivores, piscivores, and insectivores.

Aquatic Benthic Macroinvertebrates

Artificial substrate samplers (rock bags) were deployed for 26 days (20 July to 15 August 2006). Rock bags are 056 m long, 6.45 cm^2 mesh bags made of nylon twine. The bags were filled with clean, washed, bank-run cobble (3.8 to 7.6 cm round stone) obtained from a sand and gravel supply company. During deployment, three replicate rock bags were placed at each of two sampling locations. The Upstream Station was located in a riffle approximately 22.9 to 30.5 m downstream of Route 113. The Downstream Station was located approximately 12.2 to 15.25 m upstream of the snowmobile bridge.

Samplers remained *in situ* for a period of 28 days (± 4 days) and each sampler was deployed in an area that was expected to maintain adequate water depth (0.16 cm) throughout the incubation period. Also, habitat conditions at each station were recorded on Maine DEP's *Biological Monitoring Unit*

Stream Macroinvertebrate Field Data Sheet (Davies and Tsomides 2002). All sampling and data analysis procedures followed guidelines provided in the Maine DEP's Methods for Biological Sampling and Analysis of Maine's Rivers and Streams (Davies and Tsomides 2002).

Replicate samples were individually processed in the laboratory. Due to an excessive number of macroinvertebrates in the samples, a 100-organism sub-sample was removed and analyzed from each sample. Samples were divided into 64ths, and randomly selected 64ths were sorted under a dissecting microscope until a minimum of 100 organisms were removed from the sample. Once sorting was initiated in a 64th, all organisms were removed; therefore sub-sample size from all samples was more than 100 organisms. Calculations of analytical metrics were based on total number of organisms in the sample, extrapolated from the sub-sample count and sample volume processed.

The Maine DEP uses several analytical metrics (parameters) in its Linear Discriminant Model to assess water quality conditions for its River and Stream Biological Monitoring Program. Fourteen of these metrics, which were considered the most appropriate for evaluating impacts associated with fluctuating water levels due to ground water withdrawal, were used to analyze the benthic data collected from Wards Brook, including (parentheses indicate expected response to water withdrawal):

- Total Mean Abundance (decrease)
- Generic Richness (decrease)
- Shannon-Wiener Generic Diversity (Shannon and Weaver 1963) (decrease)
- EPT – Diptera Richness Ratio (decrease)
- EPT Generic Richness (decrease)
- Plecoptera Mean Abundance (decrease)
- Relative Plecoptera Abundance (decrease)
- Ephemeroptera Mean Abundance (decrease)
- Relative Ephemeroptera Abundance (decrease)
- Chironomidae Mean Abundance (increase)
- Relative Chironomidae Abundance (increase)
- Relative Oligochaeta Abundance (increase)
- Hydropsyche Mean Abundance (decrease)
- Cheumatopsyche Mean Abundance (decrease)

Freshwater Mussels

The shoreline of Lovewell Pond was qualitatively searched for the presence of freshwater mussels (Unionidae) by boat on 11 October 2006. The substrate was scanned from the boat at 0.6 to 0.9 m water depths, traveling at idle speed or stopped, using a view tube. While scanning the substrate, mussel density was estimated as: Abundant (>10 mussels / 0.25 m^2), Common (5-10 mussels / 0.25 m^2), or Rare (<5 mussels / 0.25 m^2). At three representative locations where mussels were found, 0.25 m^2 quadrats were established and searched by hand to a depth of 15.2 cm. Mussels found within those quadrats were removed, identified to species, measured to the nearest mm, and replaced on the substrate. Quadrat data were collected to provide information on the relative abundance of mussel species and the sizes of mussels in the pond. Latitude and longitude of quadrat locations and areas where the substrate was searched while the boat was stopped were recorded using a hand-held GPS.

Wards Brook was searched for mussels during fish, macroinvertebrate, and wetlands field work.

Wetlands

FARC's interest in wetlands relates to the potential for groundwater withdrawals at the commercial wells to impact the functional capacity of wetlands bordering Wards Brook. Normandeau addressed this question by characterizing wetland communities at representative transects along the brook. The cross-sections developed at these transects were analyzed using stage-discharge relationships to estimate existing water levels under several flow regimes, and to predict changes in water levels that might occur as a result of groundwater withdrawal. From these predictions, potential changes in wetland community structure and functions could be made.

On August 22, 2006, Normandeau visited a range of wetland types along the brook and selected four representative sites to establish transects. One transect was located on the flats upstream of Wards Pond (Figure 2-1). Two transects were located at the middle reaches of Wards Brook below Wards Pond, and a fourth transect was placed in the lower section of the stream. Each transect encompassed the stream channel, and wetlands bordering one or both sides of the stream. Semi-quantitative vegetation community data were collected at each transect, including species composition, and relative percent cover by layer. The data were collected in the wetland within several meters of the transect. Percent cover class categories were <1%, 1-5%, 5-25%, 26-50%, 51-75% and >75%.

Relative topographic data were collected in 3-foot increments across Transects 2 and 3 at the time of vegetation data collection. To measure ground surface, a fiberglass tape measure was stretched level across the stream using a plum gage. The depths to ground surface below the tape were then measured and plotted relative to the shallowest point. The cross-sections were remeasured in 0.5-foot increments on June 19, 2007 during additional stream gauging. Topographic data were collected at Transects 1 and 4 for two reasons: 1) the hydrology at both was dominated by sources other than Wards Brook (groundwater at Transect 1 and the beaver dam at Transect 4), and 2) the terrain was generally flat and could not be cleanly related to the stream-gauging analysis.

Instream Habitat Assessment

In a small stream like Wards Brook the potential habitat impact of water withdrawals on aquatic fauna are reduction in amount of wetted area along the stream bottom (wetted perimeter), increases in water temperature, and reduction in flow causing decreasing quality or quantity of habitat . Changes in water velocity and depth can also influence habitat for macroinvertebrates changing the quality or quantity of prey available.

A typical instream flow habitat assessment uses cross-section data for selected sites, stage and discharge estimates at those cross-sections, and habitat suitability criteria (depth, velocity, substrate) to estimate changes in habitat. During the proposal phase Normandeau understood that EGGI was installing four stream gages on Wards Brook, and planned to collaborate with EGGI to ensure that the data will be suitable for instream flow assessment.

Using transect data associated with the gauging sites, habitat suitability indices (HSI) from the literature for fish, and macroinvertebrates as a group, would used to estimate habitat at the transects for different flows. Also known as habitat suitability criteria, or HSC, HSI for this study were depth, water velocity, and substrate conditions. HSI represent habitat suitability across a range of each factor, e.g., depth, and are considered a biological model of suitable habitat. At points along the transect, field measurements of each physical factor are assigned a habitat value by comparing them to the habitat suitability criteria for a species. Values for individual factors at the each point are multiplied to get an overall habitat value for that spot. Then, a weighted-average value is assigned to distances along the transect and the values summed to rate overall habitat at the transect.

For this study, HSI for two or three species found in Wards Brook and for macroinvertebrates as a group would be used to evaluate habitat at each transect. In order to frame flow conditions during ths study, regional precipitation conditions were used as an index to the type of water year (dry, typical, wet) that occurred during the study. This information would be evaluated qualitatively against potential changes in flow that could be induced by groundwater withdrawal to evaluate potential changes to habitat that could affect the fish community.

Low flow during late summer is the typical limiting factor for river habitat in eastern rivers. Riffles during late summer would be the habitat type most likely to experience any potential problem from groundwater withdrawal on streamflow. Additional observations of water depth and water velocity in riffles during low flow conditions in late summer would be made to supplement other habitat observations.

LOVEWELL POND

Water Quality

The two key water quality issues related to changes in flow in Wards Brook are temperature and nutrient input. Temperature impacts are addressed elsewhere in this proposal. Although we are aware of no water quality data for Wards Brook, it is assumed that water quality discharging from Wards Brook to Lovewell Pond is of a higher quality than that entering the lake from the Saco River. Under this assumption, a reduction in flow from Wards Brook may result in a change in the in-lake concentration of nutrients, particularly phosphorus resulting from the loss of dilution water. Although Normandeau was not tasked with field studies for evaluating water quality in Wards Brook, except temperature, or Lovewell Pond, we reviewed existing information on water quality of Lovewell Pond to assess the status of the Pond water quality and used it to fit a general lake model (described below). Both activities allowed Normandeau to qualitatively assess the potential for Wards Brook water quality to influence Lovewell Pond. Information evaluated included the groundwater report by ECGI and water quality sampling of Lovewell Pond by the Saco River Corridor Commission.

As part of our evaluation, Normandeau predicted changes in in-lake phosphorus concentrations that can be attributed to a change in the flow of Wards Brook using a Vollenweider type input-output lake model. These changes will be put in context with historic lake concentrations and the likelihood of a change in the trophic status of the lake with changes in Wards Brook flow. The results of the lake analysis were presented in a spreadsheet format that can easily be updated in the future as more monitoring data become available or other withdrawal scenarios are proposed.

Groundwater Inputs

To evaluate the impact of the groundwater withdrawals on local groundwater flow, Normandeau reviewed the existing water elevation data that is being collected as part of the groundwater production and supply operations. The data was reviewed to determine if there is sufficient information to identify any changes and will then be evaluated to assess potential impacts on groundwater recharge to Wards Brook and its associated wetland.

III. Results

Wards Brook

Water Temperature

In surface streams, particularly small streams like Wards Brook, air surface temperature typically determines the overall water temperature trend. Air temperature records were obtained for Eastern Slopes Regional airport in Fryeburg, ME (Figure 1). Daily average air temperature peaked in late June and July around 26°C; high temperatures during this period were in the range of 26 to 34°C. Daily average air temperatures were mostly below freezing from late November through the beginning of April, and low daily temperatures would get below freezing from early September to mid-May.

Water temperature loggers were set in five locations for the period of July 2006 to June 2007 (Figure 2). Data loggers recorded temperature hourly just upstream of the old mill, upstream of the snow mobile trail, below the Route 113 culvert outfall, and in the headwaters to Wards Pond, downstream of a dirt road and another wetlands/beaver pond. The sensor set at the mouth of Wards Brook malfunctioned and no data was obtained.

Diurnal variations of water temperature were checked against daily variation in air temperature records to look for potential periods when monitors may have been out of water. No periods were found where water temperature variation matched the range of air temperature; therefore, we believe that monitors were submerged for the whole period.

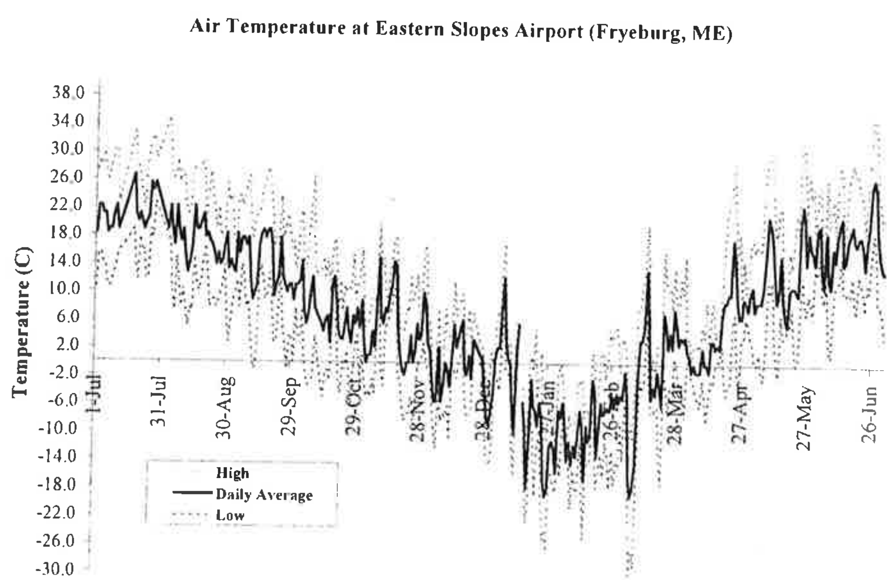

Figure 1. Air temperature as reported at the Eastern Slopes Regional Airport during the study period.

Water temperature at all stream locations followed the same overall trend. Water temperature peaked with air temperature in June and July, with the highest water temperatures occurring in July and early August. Water temperature exceeded 22°C for several weeks. Low water temperatures occurred mid-January to late-April. Water temperature rose rapidly, with air temperature, in late April trending upward to peaks in June/July.

Beyond the overall trend of water temperature with air temperature, local factors influence the temperature throughout the stream. These factors often affect peak temperature, low temperature or diurnal variation. For example, peak temperatures at all sites were not similar. Water temperatures above Wards Pond and immediately below Route 113 exceeded 18.3°C for a sufficient time (weeks), that it would make it difficult for coldwater species to thrive (Figures 3 and 4) and possibly exist. Yet, as distance increases downstream from thermal sinks like Wards Pond, it is clear that groundwater mitigates changes in water temperature relative to warming effects of the pond. Peak water temperatures upstream of Wards Pond exceeded 27°C (Figure 3), near 28°C, and downstream of Wards pond they reached nearly 26°C (Figure 4), but mostly staying around 25°C. Peak temperatures at the snow mobile trail site reached 21.5°C (Figure 5) while further downstream at the old mill site peak temperatures reached 19.5°C (Figure 6), but they were not maintained at peaks for as long as sites upstream. During field work, strong spring seeps were identified at the snow mobile trail and upstream of old mill site where flow of groundwater into the stream was evident through undercut banks.

Low water temperatures at all sites were relatively similar and driven by air temperature. Low temperature typically dropped to 1°C. Temperatures approaching freezing were recorded for short periods, for example in March, at the site above Wards Pond, at the old mill site, and an occasional dip at the snow mobile trail. Flow from Wards Pond may have mitigated against the affects of cold air temperature on water temperature because downstream of Route 113, low water temperature was the highest of all sites staying above 1.5°C most of the time. Likewise, low water temperature at the snow mobile trail also stayed around 1.5°C, which suggests that the ample ground water contribution observed at the site during spring and summer may continue in winter and mitigate against colder temperatures.

The day to day variation at sites varied with location. For example, from mid-July to mid-August, 2006, the daily water temperature at the headwater site ranged 4°C to 5°C, or more. Water temperature below Route 113 and near the snow mobile trail varied about 2°C during the same period, and at the old mill site variation was typically about 1.5°C. Diurnal water temperature changes at sites below Route 113 were influenced by Wards Pond and groundwater contribution. Ponds tend to buffer water temperature changes in outflows when they have sufficient storage. Likewise, contribution of groundwater to surface flow will also stabilize temperature reducing diurnal changes. Wards Pond seems to have sufficient storage to stabilize daily temperature changes in its outflow while the wetlands/pond above the headwater monitoring site did not.

During November, there is a noticeable reduction in diurnal temperature changes below Route 113. When this monitor data was copied in June, it was buried under 12 inches of sand. Because the pattern of hourly temperature clearly tracks the trends of other monitors, this indicates that temperature was accurately tracking surface temperature. However, because diurnal variation in the record is substantially reduced after 30 October, it means that the monitor was buried on or near that time and water temperature being recorded reflects non-flowing water in the substrate that mixed

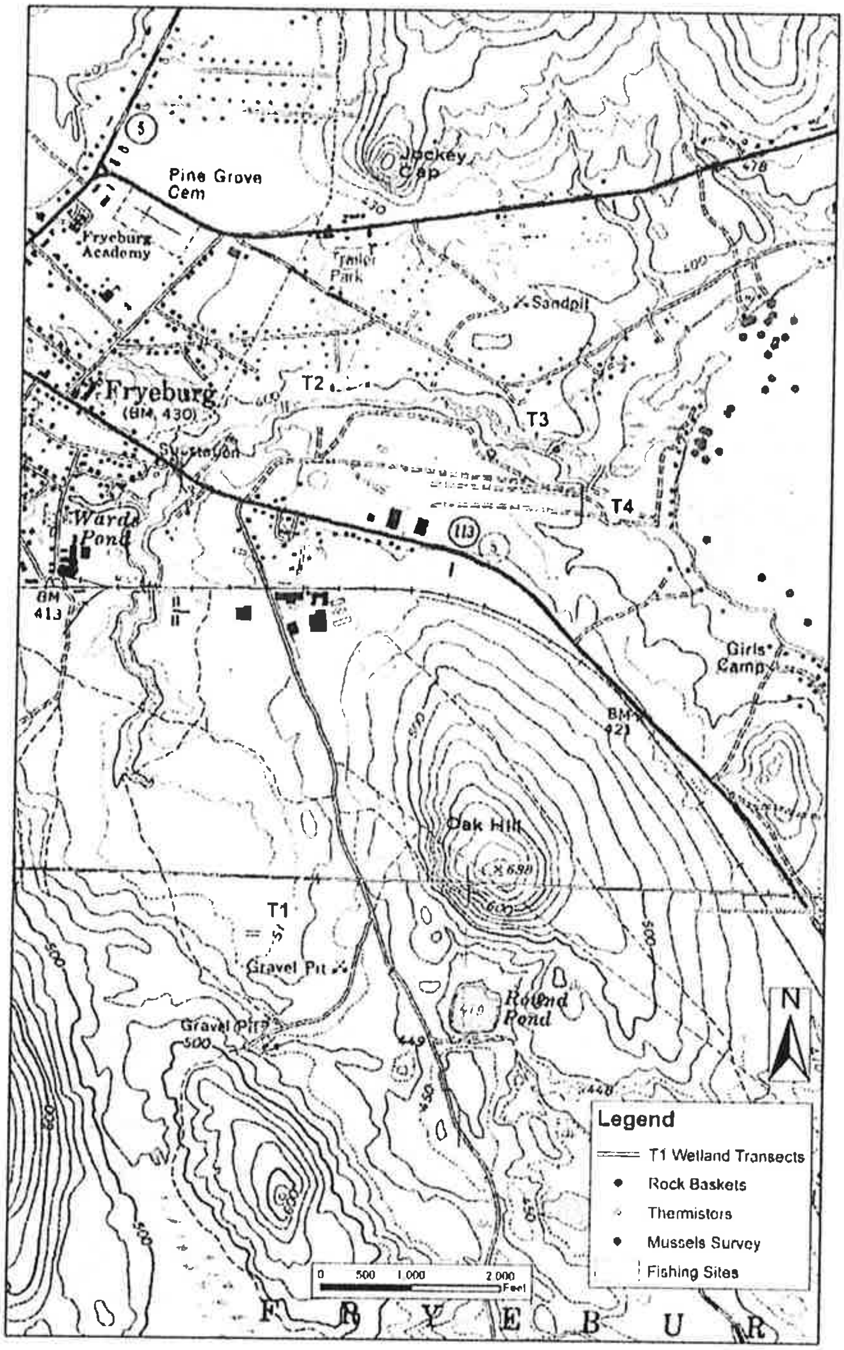

Figure 2. The locations of monitoring stations at Wards Brook. A more detailed map of mussel survey locations is provided with results of the mussel survey. The upstream thermistor is located south of T1 (wetlands transect).

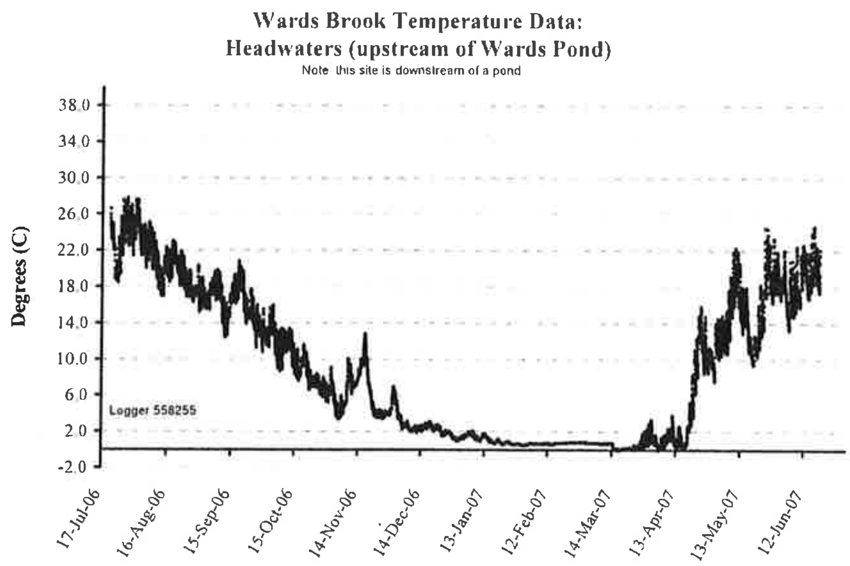

Figure 3. Stream temperature upstream of Wards Pond. The monitor was located in a fully canopied area, but downstream of another wetlands area or beaver pond.

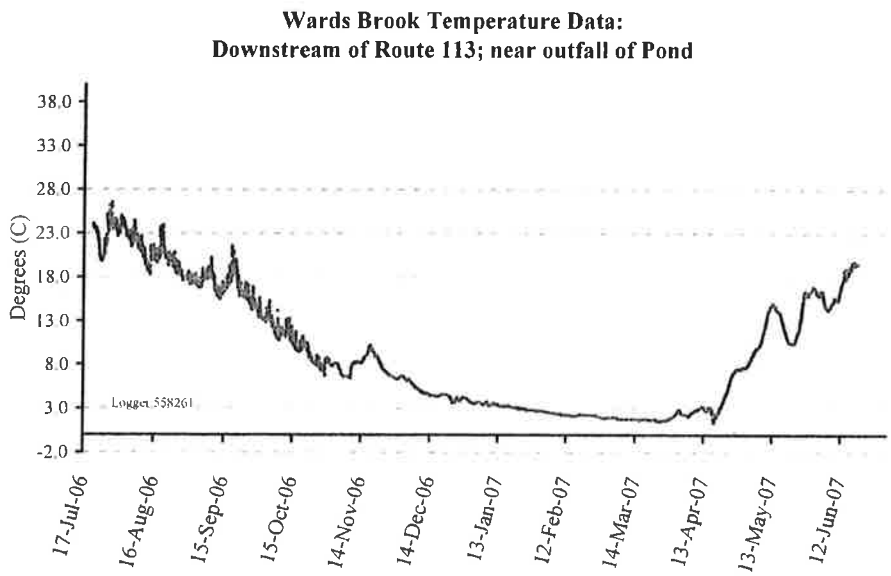

Figure 4. Water temperature as recorded downstream of the outfall of Wards Pond. Temperature leaving the pond was above 18.3°C, favorable to brook trout, for several weeks of the year. Daily variation in water temperature decreased about 30 October. The thermistor was buried under nearly 12 inches of sand, which would have reduced the variation.

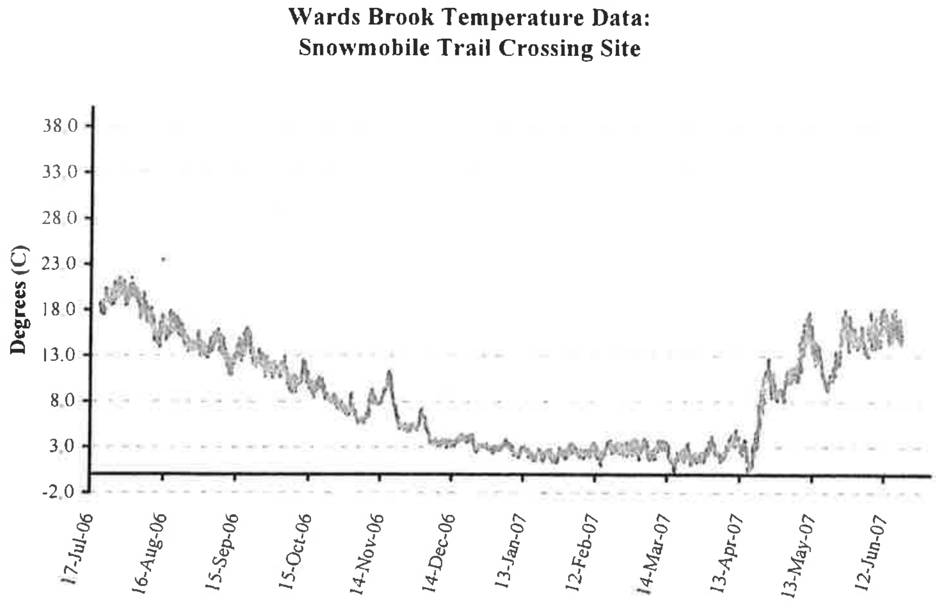

Figure 5. Water temperature upstream of the snowmobile trail crossing. High temperature periods were nearly 5°C lower compared to temperatures downstream of Wards Pond. Low water temperatures were similar. There is considerable groundwater contribution evident in this area.

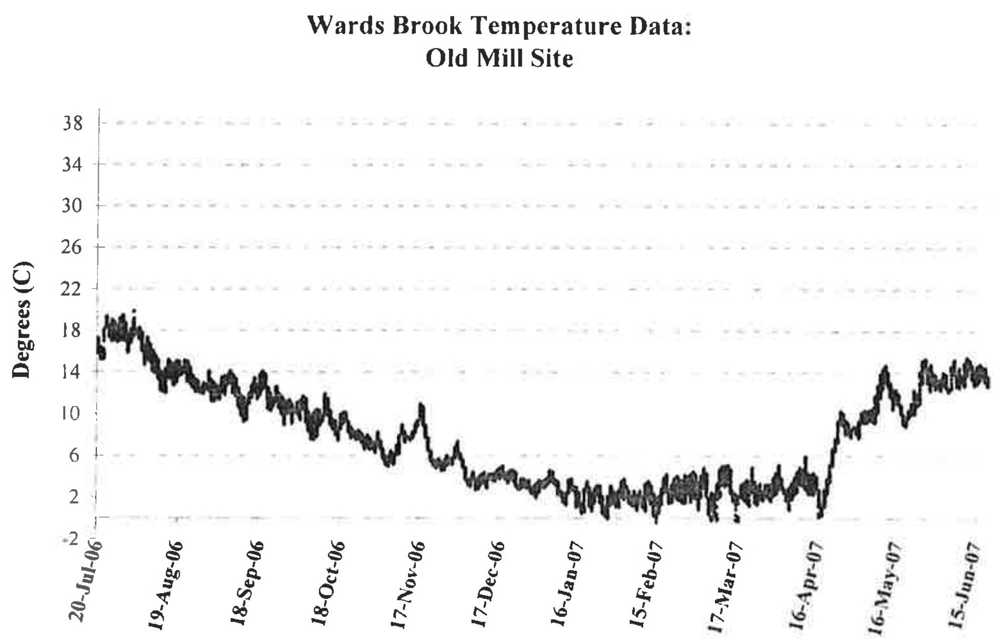

Figure 6. Water temperature trends at the old mill site. Peak temperature at the site remained near 18° C or less, which represents favorable conditions for brook trout. Goundwater input through undercut banks was evident at this site during summer.

slowly with surface flow. For the monitor below Route 113, the diurnal variation record is not representative of surface flow temperature after 30 October.

Fish Community

At the snowmobile site, the channel width was typically 1.2 m, although often reaching 2.5 to 3.0 m. Flow was typically 0.30 m/s. Depths ranged from 0.15 to 0.46 m with mostly a sandy substrate. A unique feature to this site was the presence of undercut banks. Woody debris was common throughout; at least two trees had recently fallen into the brook. The canopy cover was closed and dense, and no submerged aquatic vegetation was present. At the snowmobile site, two brook trout, four yellow perch, and two, brown bullhead were captured. In addition, frogs were frequently encountered.

At the old mill site, sampling was conducted in the channels around the island directly upstream of the walking bridge and in the brook section directly downstream of the bridge. This site has a closed canopy and the surrounding land use is forest. Submerged aquatic vegetation and algae were present throughout the site.
Upstream of the bridge a total of 21 m of thalweg length was sampled, with a typical width of 1.2 m. The habitat of the right bank channel was riffle with large rocky substrate and woody debris. In this area 10 brook trout and seven largemouth bass were captured. On the left bank side of the island, the channel habitat was very different; it was narrow, about 0.6 m wide, shallow (0.06 to 0.20 m), and mostly sand and silt substrate. Two species were captured here including two largemouth bass and one brook trout.. In a small pool on the left side of the channel, about 3.5 m by 1.2 m, situated just upstream of the walking bridge, one white sucker was captured. Some woody debris was present along the shoreline and the pool had a depth of 0.18 to 0.46 m.

Below the walking bridge, a thalweg length of 25 m was sampled with a typical width of 1.2 m. Three brook trout, two emerald shiner, one brown bullhead, and six largemouth bass were captured. In the upper half to one third of this survey area, the substrate was rocky with sand. However, in the lower portion the substrate shifted to sand with silt. There was more woody debris in the upper half and faster water velocities than in the lower section. In addition the fish captured at the old mill site, salamanders and aquatic insects were commonly picked up in the net.

At the wetlands sampling site, about 91 m downstream of the old mill site, the habitat shifted substantially. In this section water velocities were generally low (0.15 m/s) with a greater water depth (mostly 0.6 m or greater). Substrate type had also shifted to primarily sand. In some areas depths exceeded 0.9 m. Overhanging vegetation (within 0.3 m of stream surface) was abundant. The canopy was open and the land cover was primarily emergent vegetation. Instream cover was heavy areas of submerged aquatic vegetation and woody debris. In the wetland the flow becomes braided among channels constructed by beavers. Water level was controlled by the beaver dam downstream. The faster water velocities were associated with logjams in the channels.

Electrofishing sampled 28 m along the thalweg that was about 1.2 m and a short section (1.2 m) that had a width of 2 to 2.5 m. No brook trout were captured at this site. Instead the fish community consisted of fallfish, largemouth bass, brown bullhead, chain pickerel, and yellow perch. In addition to the fish, aquatic insects were commonly picked up in the net.

A summary of the fish captured at each location broken down by the length of the fish is provided in Table 1. All fishes captured in Wards Brook were known in 1955 surveys of Lovewell Pond by Maine Department of Inland Fisheries and Wildlife, except brook trout and emerald shiner.

1. Fishes Captured at Each Site and Their Body Size in Total Length.

l Upstream of Walking Bridge		Old Mill Below Walking Bridge		Wetland Below Old Mill		Snowmobile Trail	
	Total length (mm)	Species	Total length (mm)	Species	Total length (mm)	Species	Total length (mm)
rout	218	Brook Trout	185	Largemouth Bass	59	Brook Trout	165
	135		64		55		149
	155		81		50	mean	157.0
	162	mean	110.0		44		
	145			mean	52.0	Brown Bullhead	110
	130	Largemouth Bass	49				93
	127		52	Brown Bullhead	185	mean	101.5
	78		50				
	63		59	Chain Pickerel	70	Yellow Perch	122
	54		54		80		99
	72		52	mean	75.0		85
Mean	121.7	mean	52.7				90
				Fall fish	178	mean	99.0
uth Bass	53	Brown Bullhead	68				
	65			Yellow Perch	91		
	56	Emerald Shiner	58		60		
	49		56	mean	75.5		
	53	mean	57.0				
	55						
	59						
	55						
	50						
Mean	55.0						
ucker	65						

Instream Habitat Assessment

During the course of the study, it became apparent that the instream flow data that was anticipated in the proposal would not become available during this study. To provide a baseline assessment of current habitat conditions, Normandeau installed a pressure transducer at one site in Wards Brook to provide continuous measurement of water level (stage) changes. Additionally, a cross-section was established at the site of the transducer to correlate the continuous monitoring with independent stage and discharge measurements. The stage-discharge relationship would be used to convert continuous stage data to a record of flow for the site, which in turn would be related to habitat. Water depth upstream of the old mill site was plotted in Figure 7.

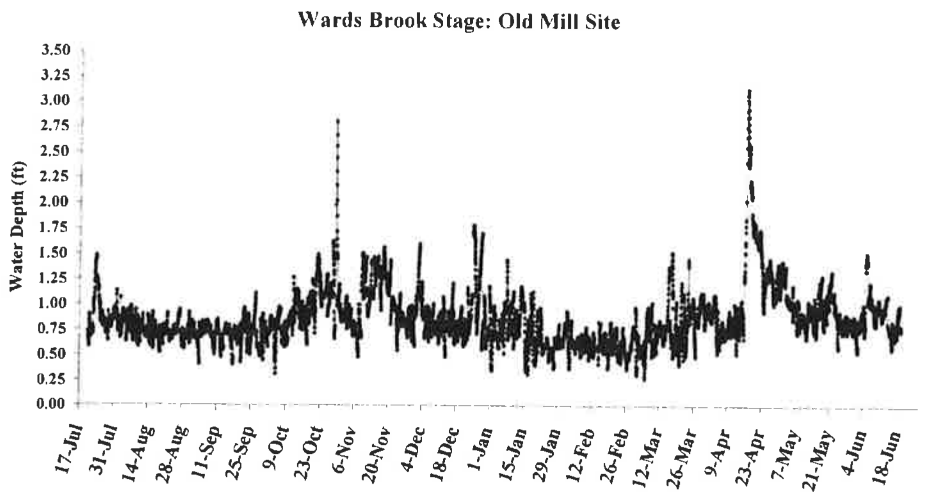

Figure 7. Wards Brook water depth as recorded upstream of the old mill.

The two largest changes in stage during the study, greater than 0.6 m, occurred in October and April precipitation events (Figure 7). Records of precipitation at the Eastern Slopes Regional Airport indicated that 2.5 inches of rain fell on 28 October, and that the system had been primed with over 3 inches of precipitation from 17 to 23 October (Figure 8). The rise in stage in mid-April occurred with a 4.5 inch precipitation event (rain/snow) that was preceded and followed by days with nearly 0.9 inches of rain, each. Large stage changes were infrequent during the study. More frequently, changes in depth associated with precipitation events was about 0.3 m. Water level changes associated with precipitation events typically lasted about 24 hours, except the large event in April that occurred at the beginning of a general rise in streamflow level.

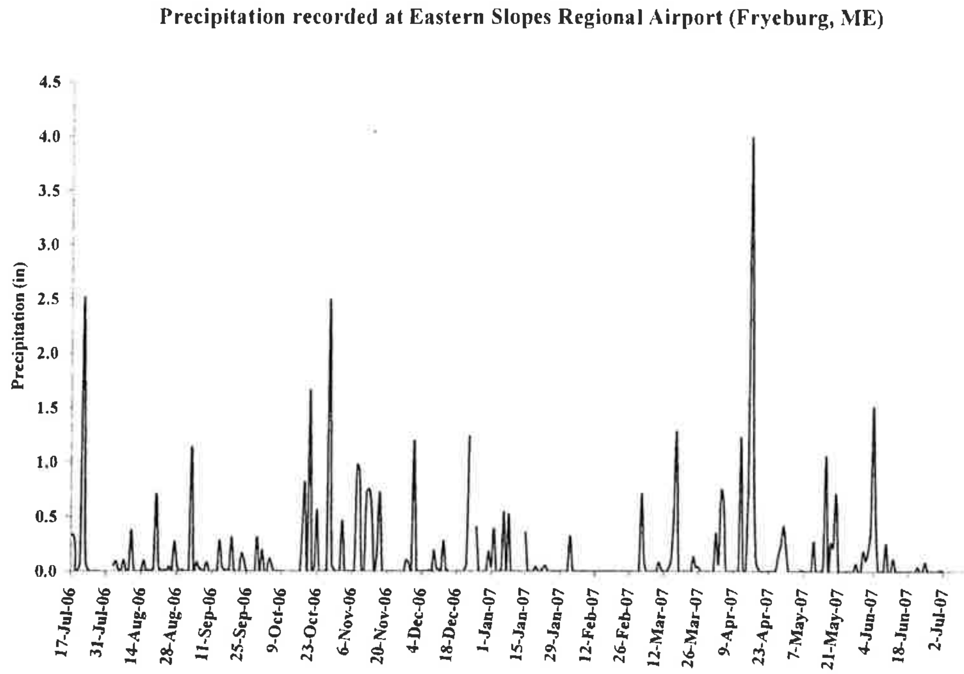

Figure 8. Precipitation recorded at Eastern Slopes Regional Airport (Fryeburg, ME) as reported through weatherunderground.com. There were thirteen days in the record without data, including 29 Jul to 2 Aug., 11 to 12 Oct., 16 to 17 Dec., 24 to 25 Dec., 28 Dec., and 14 Jan.

Typically, the lowest flow in eastern rivers occurs in late summer, months like July, August, or September and high water months occur in spring such as April and May. Water levels in Wards Brook were lowest in winter, January and February, of 2006-2007 instead of late summer (Figure 9). Higher flows were evident in late spring, April and May (Figure 9), coincident with the normal spring flow pattern. Yet, overall minimum stage in 2006, i.e., flow, was relatively stable throughout the year (Figure 7).

The June, 2006, to July, 2007, period exhibited atypical flow related to atypical climate trends. For example, according to the national weather service precipitation reports for Portland, ME, December, 2006, was unusual because of the near absence of precipitation (snowfall) and unusually warm average temperatures (second highest on record) that extended into January. Further, the 2006 calendar year was the 4th wettest on record in Portland, departing normal precipitation by 15 inches. October was the wettest month and fifth wettest October on record for the station. Overall, for the state of Maine, calendar year 2006 ranked 101 of 112, making it an above average wet year (Figure 10) and October ranked 110 of 112 (http://www.ncdc.noaa.gov/img/climate/research/2006/us-final/10Statewideprank-pg.gif 31 October 2007).

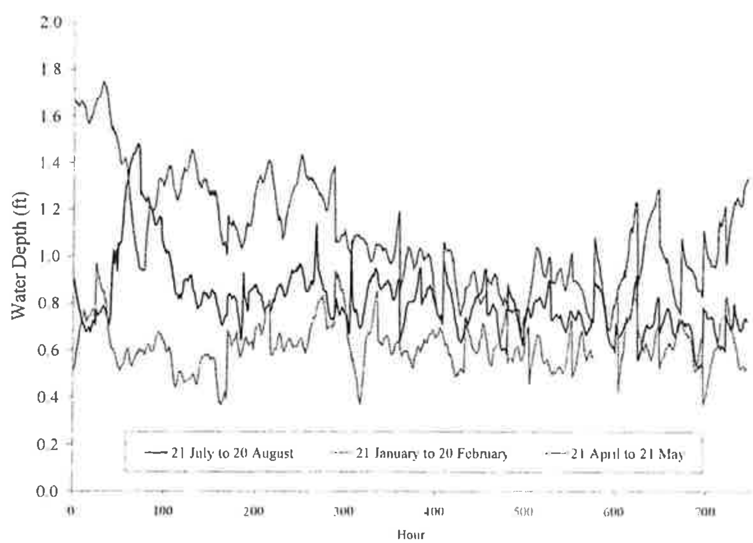

Figure 9. Water depth recorded at the transducer upstream of the old mill. Select values on, or near, 14 February, 2007, have been removed since pressure changes recorded by the transducer were affected by a heavy snowfall event.

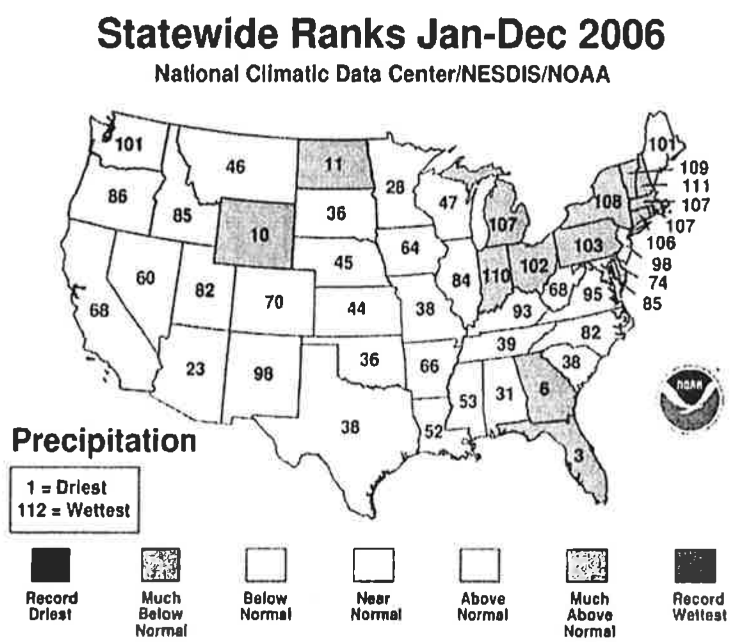

Figure 10. Statewide precipitation ranks as reported by National Climatic Data Center (http://www.ncdc.noaa.gov/img/climate/research/2006/us-final/01-12Statewideprank-pg.gif 31 October 2007).

Water elevation upstream of the old mill was recorded on three occasions (16 May 2006, 19 June 2007, and 7 August 2007) to develop a stage-discharge relationship for the site. However, the channel bed form changed during the study period, which negated the ability to use the transect measurements for this purpose (Figure 11). The channel shape changed between May and June observations when a low elevation area filled with substrate disrupting the stage-discharge relationship that was being developed. Consequently, it was not possible to convert the transducer data into a streamflow (cfs) record at this time. Discharge observed during the three measurements was estimated at 5.2 cfs (0.15 cms), 3.5 cfs (0.10 cms), and 4.3 cfs (0.12 cms), respectively. On those days, wetted width was 3.4 m, 4.08 m, and 3.81 m, respectively.

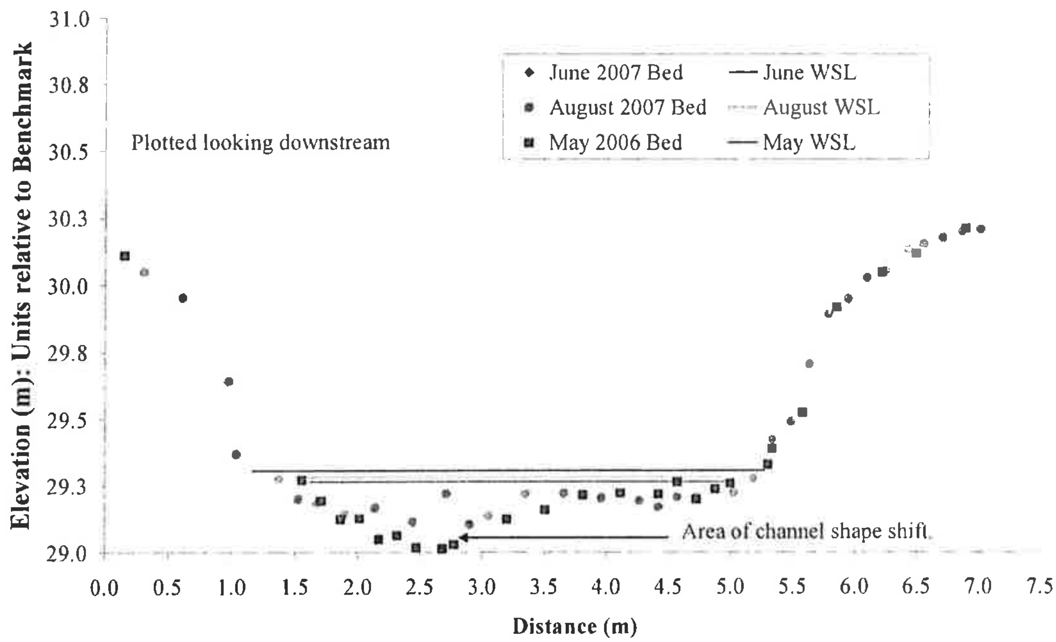

Figure 11. Water elevation (stage) upstream of the old mill for three discharge measurements. Note: the benchmark was arbitrarily set to 30.5 m elevation and axes in this figure are not on a 1:1 scale in order to better illustrate stage.

Four additional measurements of habitat conditions were collected on 7 August, 2007, as a series of point measurements of depth and velocity at transects near the old mill site (Table 2). The channel width upstream of the old mill site flows over some bedrock formation and the channel widens in response to a channel that can not cut downward. Transects were spaced 15.2 to 22.9 m apart in the upstream direction starting at the discharge transect. Although average depth was similar at all sites, average velocity was different. Average velocities at the upstream sites (TR30 and TR40) were lower because of the wider channel. The average velocity at TR20 was higher than at sites TR30 and TR40 because most of the flow was concentrated in half of the channel due to shallow non-flowing water occurring in the other half due to a bedrock formation. At TR10, below the footbridge, channel shape changes; the channel is narrow and more u-shaped without obstruction, which permits high water velocities.

Table 2. Wetted width, average depth, and average velocity for measured transects, mostly in riffles upstream of the old mill site. Riffle habitat would be the most senstivie habitat to groundwater withdrawal affects on flow.

Site	Wetted width (m)	Average Depth (m)	Average Velocity (m/s)
TR10 – Downstream of Old Mill Site	2.77	0.09	0.64
TR20 – Upstream of Old Mill Site	2.47	0.11	0.29
TR30 – Upstream of Old Mill Site	4.88	0.10	0.14
TR40 – Upstream of Old Mill Site about	5.21	0.11	0.17
Discharge Transect Site – May 2007	3.44	0.15	0.26
Discharge Transect Site - June 2007	4.11	0.13	0.21
Discharge Transect Site - August 2007	3.66	0.11	0.23

Representative habitat suitability for several fish species caught in samples and generalized criteria for benthic macroinvertebrates were identified. Suitability index values are scaled from 0 (not suitable) to 1 (optimal habitat). When SI values are plotted they are represented by a straight line between the key habitat points listed in the table, which means that SI values in between habitat levels listed in the table can be interpreted based on the rate of change between two points. When suitability indices were not available, observations of useable water depths and water velocities or habitat guilds were identified.

Brook trout habitat preferences were found in Raleigh (1992) (Table 3). Adult brook trout prefer greater depth and would generally reside in pools while juveniles may reside in both pools (without competition from adults) and riffle areas, since depths of 0.09 to 0.18 m were still fairly suitable for juveniles (SI>0.5). Good spawning depth suitability (0.5) would start around 0.12 m. Velocity preferences for adult and juveniles were the same; velocities over 0.05 m/s are very suitable. Preferred spawning velocities are higher with the most suitable velocities (SI>0.5) starting around 0.18 m/s.

Comparing suitable depths and velocities of brook trout habitat to field observations indicated that habitat was suitable for brook trout throughout the year with no period during the study where values of habitat were significantly depressed. Temperature was a more limiting factor for brook trout habitat during the study period.

Largemouth bass was another common fish found during sampling. Largemouth bass were considered generalists in habitat use, leaning towards lake-like (lacustrine) microhabitats (Normandeau Associates 1998). All largemouth bass observed in Wards Brook samples were young-of-year or juveniles based on length; therefore, results for habitat assessment focus on this life stage. Habitat suitability indices for largemouth bass (Stuber 1982) generally focused on factors not measured in this study, which were more appropriate for large rivers and juveniles. However, there was some information on current velocity that was useful. Average current velocities during summer for riverine habitat for juveniles, at 60% of depth, were very suitable (SI=1) less than 0.06 m/s, dropping to SI of 0.5 at about 0.13 m/s, and approached an SI of 0.3 around 0.15 m/s (Stuber et al. 1982). A habitat assessment from Normandeau Associates (1998) indicated that juveniles in the Ohio River could be considered members of a margin-generalist guild. Aadland (1993) analyzed fish-habitat relationships for six Minnesota rivers, all much larger than Wards Brook. Those results placed juvenile, largemouth bass in a medium pool guild, along with most centrarchids. A medium-pool guild was associated with depths of 0.6 to 1.5 m and velocities less than 0.3 m/s.

Because largemouth bass are habitat generalists, field observations indicated that habitat of Wards Brook was suitable for rearing young largemouth bass in sections of Wards Brook, specifically the deeper channel areas upstream of the riffles at the old mill site, but more appropriately in the lower brook where the water elevation was controlled by a beaver dam and the brook is linked to Lovewell Pond. Habitat was not appropriate for adult life stages or spawning in the flowing brook sections proper; the lower brook that has been inundated by impoundment of the beaver dam may support some of this life stage and spawning activity, as well as Wards Pond.

Yellow perch were the third most abundant fish captured in sampling. Yellow perch are also macrohabitat generalist, occupying both rivers and lakes, but also can be found in brackish water as well as freshwater systems. Aadland (1993) found that adult yellow perch occupied a slow-riffle habitat guild in Minnesota streams where depth was less than 0.6 m and water velocities were 0.3 m/s to 0.58 m/s. Yellow perch juveniles occurred in the medium pool guild along with largemouth bass. Yellow perch where only captured in Wards Brook in the wetland site and at the Snow Mobile trail site; both sites had more run and pool habitat with deeper water depth than the old mill site, which was primarily riffle habitat and shallow.

Yellow perch habitat was present in sections of Wards Brook. The lower section of the brook where there is abundant aquatic vegetation would be good habitat for yellow perch. The cooler water temperatures of the brook add value to the habitat in Wards Brook and are probably the more likely route of any potential impact to yellow perch habitat by groundwater withdrawal.

Emerald shiner habitat use was available in Aadland (1993) where it was identified as habitat generalist. Emerald shiner adults were associated with the slow-riffle habitat guild (same as adult yellow perch). Young-of-year individuals were found to occupy a shallow-pool guild with water depths less than 0.58 m and water velocities less than 0.3 m/s (Aadland 1993). Wards Brook supported suitable habitat for emerald shiner. Because emerald shiner are capable of doing well in low water depths and slower flowing water, habitat for emerald shiner would be less influenced by potential impacts of groundwater withdrawal.

Generalized suitability indices for macroinvertebrates were obtained from the Vermont Agency of Natural Resources (Rod Wentworth, personal communication), which were recently used in an instream habitat assessment on the upper Connecticut River. Suitable depth for benthic macroinvertebrate peaks from 0.12 to 0.9 m, with mid-points (SI=0.5) at approximate depths of 0.07 m (low end) and 1.5 m (high end) If suitable habitat is defined as an SI greater than 0.3, which is the upper two-thirds range of SI values, then suitable depths include depths from about 0.06 m to 1.9 m. Generalized suitability for water velocity peaked from 0.46 m to 1.07 m/s at SI value of 1.0. A water velocity of 0.30 m/s provided the mid-point suitability index value of 0.5, at the low end of velocities, while a velocity of 1.40 m/s provides the same SI on the high end. A velocity of 0.27 m/s would score an SI value of 0.3, and high velocities reach an SI of 0 at 2.4 m/s.

Based on field observations, habitat in Wards Brook was very suitable for macroinvertebrate. Riffle habitat would be the most sensitive habitat for macroinvertebrates from potential groundwater withdrawals. The likely route of any impact would be to changes in water velocity from reduced flow, as macroinvertebrates are very tolerant of low water depths. Water temperature records suggested that water temperatures were very suitable for macroinvertebrate insects. Water

Table 3. Brook Trout Suitability Indices (SI) Adapted from Data of Raleigh (1982).

Adult Preferred Depths (m)	Adult SI	Juvenile Preferred Depths (m)	Juvenile SI	Spawning Preferred Depths (m)	Spawning SI
0.00	0.00	0.00	0.00	0.00	0.00
0.30	0.20	0.09	0.50	0.09	0.25
0.60	0.30	0.18	0.80	0.18	1.00
1.00	0.60	0.30	1.00	0.30	1.00
1.50	1.00	0.46	1.00	0.46	1.00
2.00	1.00	0.61	1.00	0.61	1.00
4.00	1.00	1.22	1.00	1.22	1.00
Adult Preferred Average Velocity (m/s)	**Adult SI**	**Juvenile Preferred Average Velocity (m/s)**	**Juvenile SI**	**Spawning Preferred Average Velocity (m/s)**	**Spawning SI**
0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.30	0.02	0.30	0.15	0.40
0.05	0.60	0.05	0.60	0.30	1.00
0.07	1.00	0.07	1.00	0.50	1.00
0.11	1.00	0.11	1.00	0.65	1.00
0.15	1.00	0.15	1.00	0.70	0.60
0.20	0.60	0.20	0.60	0.90	0.00
0.25	0.30	0.25	0.30	1.00	0.00
0.30	0.00	0.30	0.00		

Table 4. Generalized Macroinvertebrate Suitability by Vermont Agency of Natural Resources for stream with high abundance of cover and abundant velocity refuges.

Depth (m)	SI	Velocity (m/s)	SI
0.00	0.0	0.00	0.0
0.03	0.0	0.15	0.0
0.12	1.0	0.46	1.0
0.91	1.0	1.07	1.0
1.52	0.5	1.40	0.5
1.98	0.3	2.44	0.0
2.44	0.2		
3.05	0.2		
30.48	0.0		

temperature change from reduced surface flow or groundwater input due to groundwater withdrawal would be unlikely to impact habitat of macroinvertebrate insects unless it substantially changed conditions, for example raising peaking temperatures in the areas downstream of Route 113 for extended periods of time.

Aquatic Macroinvertebrates

The Upstream Station was located approximately 22.9 to 30.5 m downstream of Route 113 (Figure 2), and was directly influenced by the impoundment immediately upstream of Route 113. Samplers were placed in a riffle with a partly open canopy, channel width was 0.9 m, depth was 0.15 m, and the substrate was composed of 25% cobble, 10% gravel, and 60% sand (Table 5).

The coarse substrate and close proximity to Wards Pond resulted in a benthic community numerically dominated by filter-feeding organisms at the Upstream Station. The numerically dominant taxa found at this station were the net-spinning caddisflies *Hydropsyche betteni* and *Cheumatopsyche* sp. (Table 6). Mean abundance of three rock basket samplers was 3747.6 organisms, representing over 12 taxa. At this station, high metric values were seen for Hydropsyche Abundance, Cheumatopsyche Abundance, and Chironomidae Abundance (Table 7). The lack of Ephemeroptera (mayflies) and Plecoptera (stoneflies) at this station resulted in low metric values for EPT Generic Richness, Plecoptera Abundance, Relative Plecoptera Richness, Ephemeroptera Abundance, Relative Ephemeroptera Richness, and Perlidae Abundance.

The Downstream Station was located approximately 12.2 to 15.2 m upstream of a snowmobile bridge crossing Wards Brook (Figure 2). Rock bags were placed in a riffle with a partly open canopy, a channel width of 4.6 m, a depth of 0.3 m, and a substrate composed of 5% boulders, 40% cobble, 10% gravel, and 45% sand (Table 5). The substrate was somewhat coarser than the substrate found at the Upstream Station; also, this station was not influenced by an upstream impoundment.

The Downstream Station was numerically dominated by the fingernet caddisfly *Dolophilodes* sp. (Table 6), and the second most abundant macroinvertebrate was the black fly *Simulium* sp. Total abundance was substantially lower at the Downstream Station than at the Upstream Station; conversely, Generic Richness and Shannon-Wiener Generic Diversity were considerably higher at the Downstream Station (Table 7). In general, higher metric values were seen at the Downstream Station than at the Upstream Station, primarily due to a more diverse benthic community and the presence of Ephemeroptera and Plecoptera, which were not present at the Upstream Station.

Freshwater Mussels

Substrate composition along the shoreline of Lovewell Pond was conducive to supporting freshwater mussels. Along the western shoreline from the boat ramp to WPT 5 (Figure 12), the substrate was generally sand and silty sand with patches of submerged aquatic vegetation (SAV). Mussel density was common (5 to 10 mussels per 0.25 m^2) at the southern end near waypoint 1 (WPT1, Figure 12). At this location, water depth was 0.61 m, water temperature was 13.9°C, dissolved oxygen was 7.4 mg/l, and specific conductance was 50.5 µS/cm. From WPT 1 to WPT 5 (Figure 12), mussel density was rare (<5 mussels per 0.25 m^2).

At Waypoint 7 (WPT 7, Figure12), located at the northwest corner of Lovewell Pond, the substrate was composed of silty-sand with patches of SAV, water depth was 0.46 m, water temperature was

Table 5. Physical Habitat conditions at Wards Brook, ME Benthic Sampling Stations During Summer 2006.

	Upstream Station	
	Deployment	Retrieval
DATE	20-Jul-06	15-Aug-06
DEPTH (m)	0.15	0.12
FLOW (cm/sec)	59	63
DISSOLVED OXYGEN (mg/l)	6.1	7.0
TEMPERATURE (°C)	23.4	20.7
pH	6.5	7.8
SPECIFIC CONDUCTANCE (µS/cm@25°C)	102	108
SUBSTRATE (% comp)		
boulders (>10")		
cobble (3-10")	25	
gravel (0.13-3")	10	
sand (<0.13", gritty)	60	

	Downstream Station	
	Deployment	Retrieval
DATE	20-Jul-06	15-Aug-06
DEPTH (m)	0.31	0.31
FLOW (cm/sec)	45	46
DISSOLVED OXYGEN (mg/l)	8.6	9.8
TEMPERATURE (°C)	17.3	15.1
pH	7.1	7.8
SPECIFIC CONDUCTANCE (µS/cm@25°C)	132	145
SUBSTRATE (% comp)		
boulders (>10")	5	
cobble (3-10")	40	
gravel (0.13-3")	10	
sand (<0.13", gritty)	45	

Table 6. Total and Mean Replicate Abundance of Benthic Macroinvertebrates Collected in Rock Bag Samplers from Wards Brook, ME in 2006.

GROUP/TAXON		Upstream Station				Downstream Station			
		Rep A	Rep B	Rep C	Mean	Rep A	Rep B	Rep C	Mean
AMPHIPODA	*Gammarus sp.*					2			0.7
COLEOPTERA	*Promoresia tardella*						4	16	6.7
	Stenelmis sp.		32		10.7				
	Stenelmis humerosa-sinuata gr.			96	32.0		4		1.3
DIPTERA	*Antocha sp.*						4		1.3
	Brillia sp.					4			1.3
	Eukiefferiella sp.						20		6.7
	Parametriocnemus sp.		32	32	21.3	6	8	24	12.7
	Polypedilum sp.	64		64	42.7			12	4.0
	Polypedilum fallax						4	16	6.7
	Polypedilum flavum					1	20		7.0
	Rheocricotopus sp.	21	64	32	39.0	4			1.3
	Rheotanytarsus sp.	192	288		160.0				
	Simulium sp.	277	384	32	231.0	14	40	64	39.3
	Tanytarsus sp.		32		10.7	8	16	28	17.3
	Thienemanniella sp.			32	10.7				
	Thienemannimyia gr.	149	32	32	71.0	6		4	3.3
	Trissopelopia sp.						4		1.3
	Tvetenia bavarica					4		8	4.0
	Hemerodromia sp.	21	32		17.7	2		4	2.0
	Oreogeton sp.						4		1.3
EPHEMEROPTERA	*Baetis sp.*					6		4	3.3
	Paraleptophlebia sp.					8	44	24	25.3
	Serratella sp.					6	32	12	16.7
HOPLONEMERTEA	*Prostoma graescense*		96	32	42.7				
MEGALOPTERA	*Sialis sp.*						4	4	2.7
ODONATA	*Boyeria vinosa*			32	10.7				
OLIGOCHAETA	Lumbricidae						4	4	2.7
	Naididae			32	10.7			4	1.3
	Nais sp.					2	20	24	15.3
	Tubificidae imm. w/o capilliform chaetae					2	4	16	7.3
PLECOPTERA	*Isoperla sp.*					4	28	8	13.3
	Leuctra sp.					6	4		3.3
	Peltoperla sp.							12	4.0
	Tallaperla sp.					2	8		3.3
TRICHOPTERA	*Cheumatopsyche sp.*	640	768	1184	864.0	4			1.3
	Chimarra aterrima	405	960	320	561.7				
	Diplectrona modesta					6	12	20	12.7
	Dolophilodes sp.					80	104	184	122.7
	Hydropsyche betteni	747	1184	2336	1422.3	2			0.7
	Hydropsyche sparna						4		1.3
	Limnephilidae						4		1.3
	Ptilostomis sp.							4	1.3
	Rhyacophila sp.					2	16		6.0
VENEROIDA	*Musculium sp.*		32		10.7				
	Pisidium sp.	85	256	192	177.7				

Table 7. Analytical Metric Results of Rock Bag Samples Collected from Wards Brook, ME on 15 August 2006.

Metric	Upstream Station				Downstream Station			
	Rep. A	Rep. B	Rep. C	Mean	Rep. A	Rep. B	Rep. C	Mean
Total Abundance	2603	4192	4448	3747.56	182	416	496	364.67
Generic Richness	10	14	14	12.67	23	24	20	22.33
Shannon-Wiener Generic Diversity	1.87	1.95	1.44	1.76	2.32	2.64	2.33	2.43
EPT - Diptera Richness ratio	0.50	0.43	0.50	0.48	1.22	1.25	1.14	1.21
EPT Generic Richness	3	3	3	3.00	11	10	8	9.67
Plecoptera Abundance	0	0	0	0	12	40	20	24.00
Relative Plecoptera Abundance	0	0	0	0	0.07	0.10	0.04	0.07
Ephemeroptera Abundance	0	0	0	0	20	76	40	45.33
Relative Ephemeroptera Abundance	0	0	0	0	0.11	0.18	0.08	0.12
Chironomidae Abundance	427	448	192	355.56	34	72	92	66.00
Relative Chironomidae Abundance	0.16	0.11	0.04	0.10	0.19	0.17	0.19	0.18
Relative Oligochaeta Abundance	0	0	0.01	0.00	0.02	0.15	0.26	0.14
Hydropsyche Abundance	747	1184	2336	1422.22	2	4	0	2.00
Cheumatopsyche Abundance	640	768	1184	864.00	4	0	0	1.33

14.3°C, dissolved oxygen was 8.0 mg/l, and specific conductance was 66.1 µS/cm. A total of four eastern elliptios (*Elliptio complanata*) were found at this location.

Waypoint 8 (WPT 8) was located in the northern end of Lovewell Pond (Figure 12). At this location, the substrate was composed of silty-sand with patches of necrotic SAV, water depth was 0.46 m, water temperature was 14.7 °C, dissolved oxygen was 8.4 mg/l, and specific conductance was 53.5 µS/cm. A total of 5 *Elliptio complanata* were collected from a quadrat sample, with a mean length of 55.6 mm (range = 50 to 61 mm).

Waypoint 9 (WPT 9) was located along the eastern shoreline (Figure 12), where sand (60 to 70%) and silt (30 to 40 %) comprised the substrate, water depth was 0.46 m, water temperature was 14.9 °C, dissolved oxygen was 6.1 mg/l, and specific conductance was 50.9 µS/cm. A total of 20 *Elliptio complanata* were collected from a quadrat sample, with a mean length of 60.1 mm (range = 38 to 79 mm). Mussel density was abundant (>10 mussels per 0.25 m^2) within the cove where WPT 9 was located.

In general, the eastern shoreline of Lovewell Pond, south of WPT 9, was coarser than the western shoreline. Substrate composition in this area was predominately boulders, cobble, and gravel covered with silt, which resulted in poor mussel habitat quality.

Waypoint 10 (WPT 10, Figure 12) was located in the cove south of WPT 9. This cove was searched from the boat using a view tube. It was approximately 0.61 to 0.9 m deep and had a substrate composed of large cobble with interstitial sandy silt; mussel abundance was estimated to be 5 to 10 mussels per 0.25 m^2.

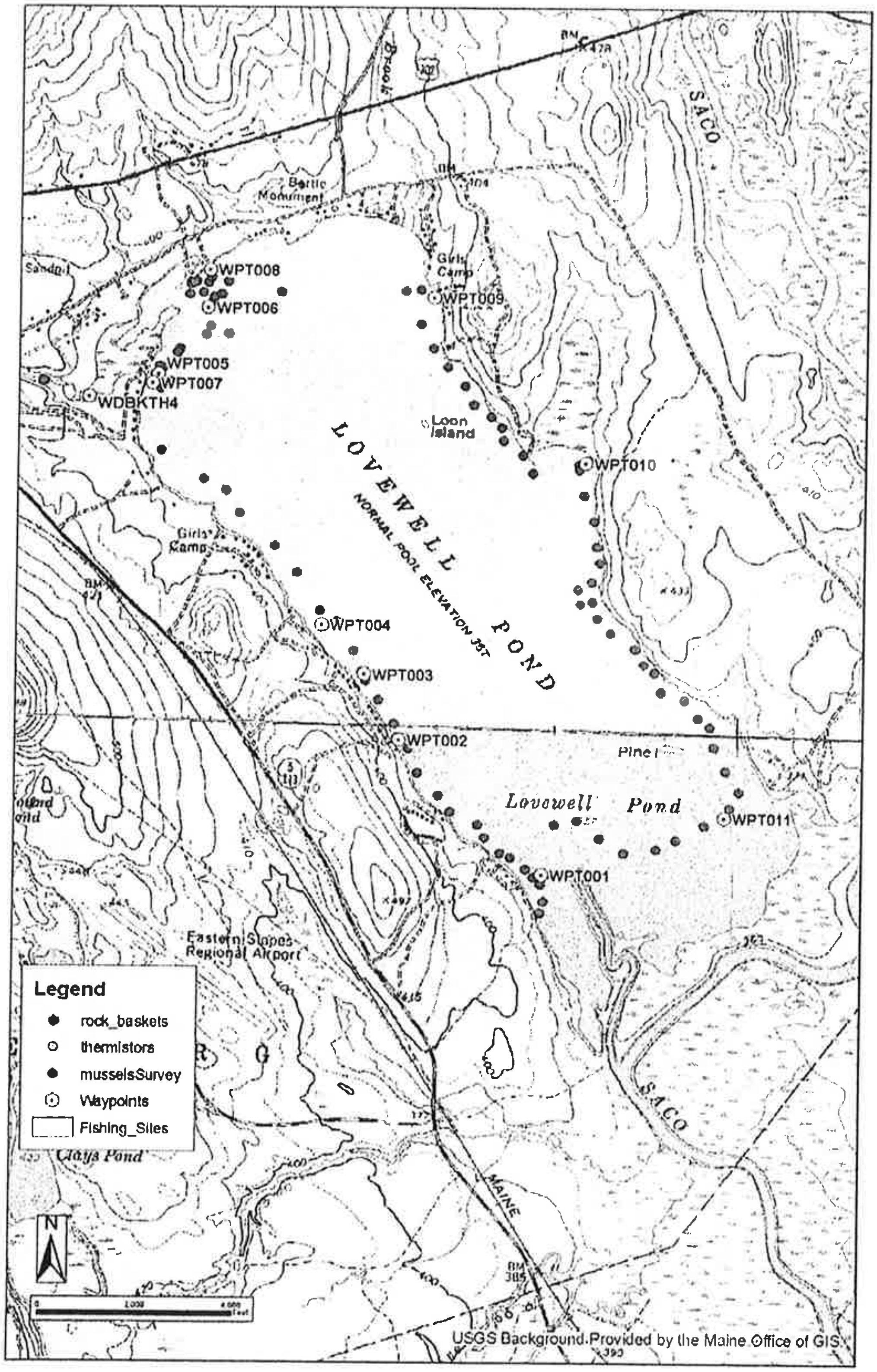

Figure 12. Lovewell Pond, ME mussel survey search locations on 11 October 2006.

Waypoint 11 (WPT 11) was located at the southern end of Lovewell Pond (Figure 12). Water depth was 0.61 m and the substrate was composed of hard packed sand with patches of necrotic SAV. Mussels were abundant (>10 mussels per 0.25 m^2) and composed of *Elliptio complanata*.

Wetlands

The four wetland transects describe four distinct wetland habitats. Transect 1 was placed in the headwater wetland upstream of Wards Pond in an extensive deciduous/coniferous forested wetland defined by shallow groundwater and level topography (Figure 2). Transect 2 was established in a narrow forested floodplain in the vicinity of the commercial springs (Figure 2). Transect 3 was established below the withdrawal sites encompassing a higher gradient section of Wards Brook near the old grist mill site (Figure 2). Transect 4 documented the extensive emergent marsh and forested floodplain behind a beaver dam as Wards Brook enters Lovewell Pond (Figure 2).

Transect 1 – Upper Wards Brook

This transect was located approximately 0.8 km upstream of Wards Pond near the municipal wells. The terrain is flat with moderate microrelief and the water table is close to or at the ground surface in depressions. Wetlands predominate on the landscape, although some upland inclusions occur on slightly higher ground. Wards Brook flows in a well-defined channel approximately 1.8 to 3.0 m wide, with water depths ranging from 0.15 to 0.3 m at the time of the 2006 site visit. The bottom was a mix of sand and organic fines, with substantial coarse debris in the form of branches and logs.

The wetland canopy provided between 50 and 60 percent cover, comprised of a mix of red maple (*Acer rubrum*), red spruce (*Picea rubra*) and eastern hemlock (*Tsuga canadensis*) (Table 8). Shrub cover was patchy but sparse overall with 25% cover. Regenerating tree species made up approximately half of this layer, with winterberry holly (*Ilex verticillata*) prevalent along the stream. Where the stream banks were more gradual, speckled alder (*Alnus incana*) was dominant. In the understory, Sphagnum moss (*Sphagnum* spp.) was abundant and covered between 50 and 60 percent of the ground surface. Ostrich fern (*Matteuccia struthiopteris*) was also abundant, with many other species in relatively small amounts. While a gradient of species occurred between the stream banks and the upland edge, the Obligate and Facultative Wetland classification of most species found here clearly reflect the level terrain and long-term shallow water table. Relatively small amounts of aquatic vegetation occurred in the stream, primarily watercress (*Nasturtium officianale*) and mosses.

Based on the pronounced microrelief, the very wet vegetation in depressions, the nearby artesian wells and relatively bank-full stream, the hydrologic regime for this area is seasonally saturated (the substrate is saturated to the surface for extended periods during the growing season (Cowardin et al 1979)).

Transect 2 – Snowmobile Culvert

Located about 15 m upstream of the snowmobile trail and culvert, this transect was located in a narrow floodplain wetland that borders both sides of Wards Brook. The stream was well incised in this location with a sandy bottom imbedded with abundant fine and coarse woody debris. The stream gradient was moderate with a swift, quiet current draining into the culvert. The riverbanks were wooded and well vegetated with steep banks that were undercut but appear quite stable. Sand deposits

Table 8. Species, percent cover and wetland indicator status of vegetation by zone at Wetland Transect 1 on Wards Brook.

Transect	Location	Layer	Scientific Name	Common Name	% Cover	Wetland Indicator Status
Transect 1 Headwater	**In-stream**	**Herb**	Moss	moss	6 - 25%	NI
			Nasturtium officinale	Watercress	3 - 5%	OBL
	Main body	**Tree**	*Acer rubrum*	Red maple	6 - 25%	FACW+
			Betula populifolia	Grey birch	< 1%	FAC
			Picea rubens	Red spruce	6 - 25%	FACU
			Pinus strobus	White pine	< 1%	FACU
			Tsuga canadensis	Hemlock	6 - 25%	FACU
		Shrub	*Abies balsamea*	Balsam fir	3 - 5%	FAC
			Acer rubrum	Red maple	< 1%	FACW+
			Fagus grandifolia	Beech	< 1%	FAC+
			Ilex verticillata	Winterberry	6 - 25%	FACW+
			Nemopanthus mucronata	Mountain holly	< 1%	OBL
			Picea rubens	Red spruce	3 - 5%	FACU
			Tsuga canadensis	Hemlock	6 - 25%	FACU
			Viburnum cassinoides	Northern wild raisin	< 1%	FACW
		Herb	*Aralia nudicaulis*	Wild sarsaparilla	3 - 5%	FACU
			Arisaema triphyllum	Jack-in-the-pulpit	3 - 5%	FACW-
			Athyrium filix-femina	Lady fern	< 1%	FAC
			Clintonia borealis	Bluebead lily	< 1%	FAC
			Coptis trifolia	Goldthread	6 - 25%	FACW
			Cornus canadensis	Bunchberry	3 - 5%	FAC-
			Dryopteris cristata	Crested wood fern	< 1%	FACW+
			Glyceria borealis	Floating mannagrass	< 1%	OBL
			Linnaea borealis	Twinflower	< 1%	FAC
			Matteuccia struthiopteris	Ostrich fern	26 - 50%	FACW
			Sphagnum sp.	Sphagnum moss	51 - 75%	NI
			Trientalis borealis	Starflower	< 1%	FAC
			Vaccinium sp.	Blueberry	< 1%	
	Sloping streamside	**Shrub**	*Alnus incana*	White alder	6 - 25%	NI
		Herb	*Aster acuminatus*	Whorled aster	3 - 5%	UPL
			Athyrium filix-femina	Lady fern	< 1%	FAC
			Carex sp.	Sedge sp.	3 - 5%	NI
			Chelone glabra	Turtlehead	< 1%	OBL
			Clintonia borealis	Bluebead lily	< 1%	FAC
			Coptis trifolia	Goldthread	3 - 5%	FACW
			Lycopus uniflorus	Water-horehound	3 - 5%	OBL
			Maianthemum canadense	Canada mayflower	< 1%	FAC-
			Poaceae	Grass sp.	3 - 5%	NI
			Rubus hispidus	Trailing bramble	< 1%	FACW
			Rubus pubescens	Dwarf raspberry	< 1%	FACW
			Sphagnum sp.	Sphagnum moss	51 - 75%	NI
			Vaccinium sp.	Blueberry	< 1%	
			Viola sp.	Violet	< 1%	

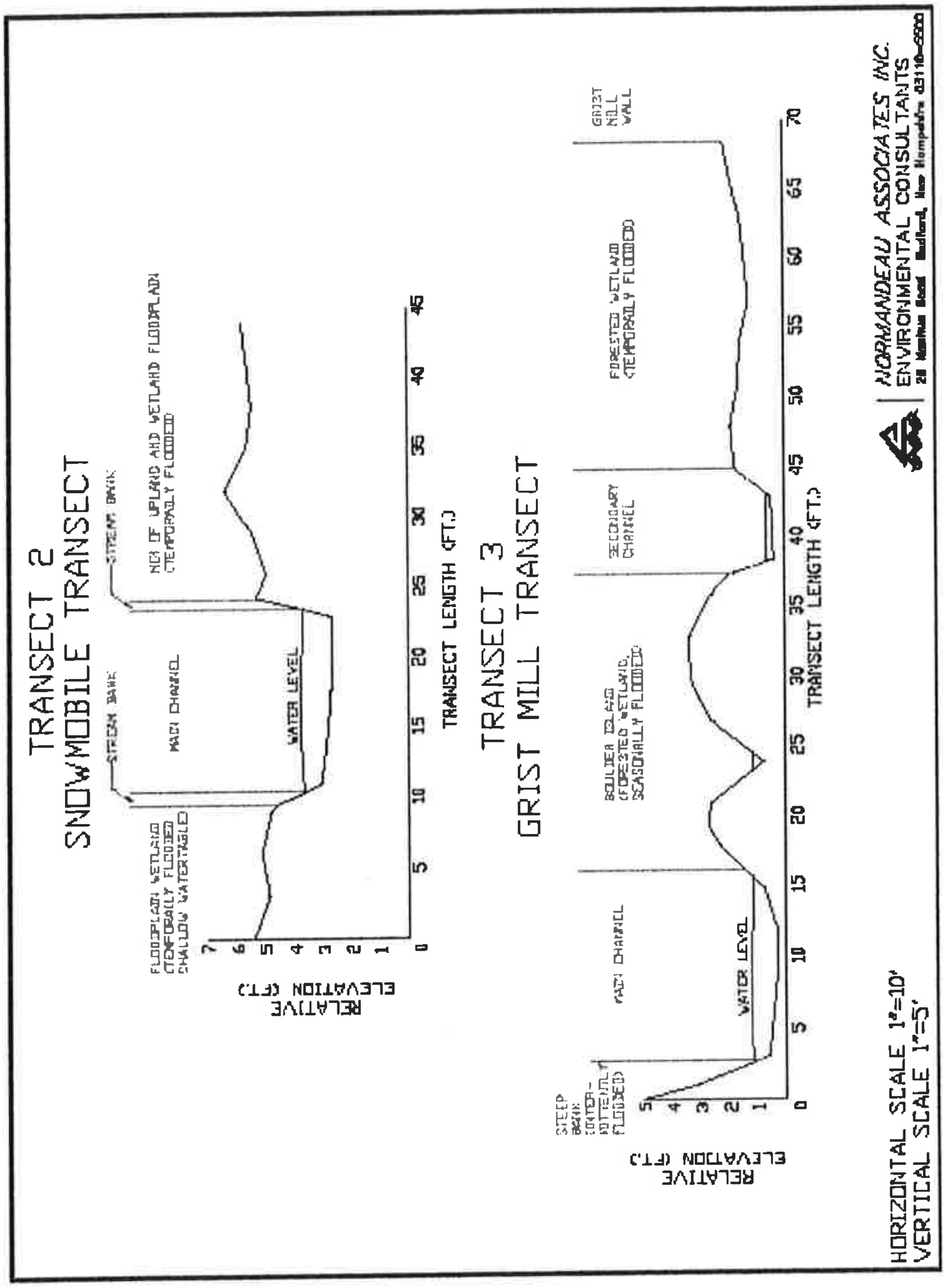

Figure 13. Cross-section and vegetation zones of two transects on section of Wards Brook potentially influenced by groundwater withdrawal.

from flooding were visible on both the north and south sides, but most pronounced on the lower, more frequently flooded south side.

The north side of the stream was somewhat higher than the south side (Figure 13). Away from the streambank, the mature canopy provided approximately 75 percent total cover, dominated by red maple and red oak (*Quercus rubrum*) (Table 9). The sparse shrub layer comprised about 10% cover, with only balsam fir (*Abies balsamea*) in any abundance. The herb layer was well developed, with ostrich fern as a clear dominant. The next most abundant species were wood grass (*Brachyeletrum erectum*) and red oak, which attest to the drier nature of this floodplain.

On the southern side of the stream, the canopy remained approximately the same in composition and structure as the north side. The shrub layer was more dominant at 30 percent cover with balsam fir and maleberry (*Lyonia ligustrina*) most abundant. The herb layer reflected the influence of a nearby seep, with fringed sedge (*Carex crinita*) dominating in the lowest areas. Ostrich fern remained abundant and the rest of the species were low in percent cover.

Along the stream banks, small trees and saplings of red maple, balsam fir and yellow birch (*Betula alleghaniensis*) predominated. Shrubs were very sparse and consisted of regenerating eastern hemlock and balsam fir. Erect herbs were also sparse and dominated by water horehound (*Lycopus uniflorus*), ostrich fern, wood grass and manna grass (*Glyceria borealis*). Mosses formed approximately 75 percent cover on this bank.

The hydrology, scour patterns and vegetation suggest that this area is temporarily flooded on both sides of the stream (surface water is present for brief periods during the growing season, but the water table lies well below the soil surface for most of the season). Vegetation that can grow in both uplands and wetlands are typical of this hydrologic regime. On the south side, wetland conditions persist most of the year due to the effects of the adjacent groundwater seep.

Transect 3 – Grist Mill

This section of Wards Brook was steep in gradient as it dropped toward Lovewell Pond, resulting in high velocities and steep stream banks. The substrates remained predominantly sand, but boulders from the former grist mill site formed much of the in-stream and wetland habitat. The wetlands and stream-side uplands showed evidence of frequent scour and debris. The transect extended from a steep upland bank across the main stem of the stream to an island of boulders emersed from the stream (Figure 13). Sand and organics have collected among the boulders to provide substrate for early successional vegetation. The transect continued to the north across a smaller, 0.61 m wide secondary stream channel that barely flowed during low water. The transect terminated at a remnant granite vertical wall, presumably from the old mill.

The vegetation on the south side of the transect was sparse in the vicinity of the transect, due to both the steep topography and shade. Large white pine and eastern hemlock dominated the canopy, with smaller amounts of red maple and American beech (*Fagus grandifolia*) (Table 10). The shrub layer was empty, and the herb layer was sparse with an estimated 10% cover. The dominant species was spinulose wood fern (*Dryopteris spinulosa*). Much of the soil was bare or had a slight litter layer. Scouring from high flows was apparent 0.9 to 1.5 m up the bank.

On the boulder island and northern side, small red maple trees have colonized and provided approximately 80 percent cover. Shrubs remained sparse. The herbaceous community was very diverse, with no clear dominant. Major species included whorled aster (*Aster acuminatus*), lady fern

Table 9. Species, percent cover and wetland indicator status of vegetation by zone at Wetland Transect 2 on Wards Brook.

Transect	Location	Layer	Scientific Name	Common Name	% Cover	Wetland Indicator Status
Transect 2 – snowmobile culvert	North side	Tree	*Abies balsamea*	Balsam fir	< 1%	FAC
			Acer rubrum	Red maple	26 - 50%	FACW+
			Fagus grandifolia	Beech	3 - 5%	FAC+
			Quercus rubra	Northern red oak	6 - 25%	FACU-
		Shrub	*Abies balsamea*	Balsam fir	6 - 25%	FAC
			Fagus grandifolia	Beech	< 1%	FAC+
			Quercus rubra	Northern red oak	< 1%	FACU-
			Viburnum cassinoides	Northern wild raisin	< 1%	FACW
		Herb	*Aster acuminatus*	Whorled aster	3 - 5%	UPL
			Athyrium filix-femina	Lady fern	< 1%	FAC
			Betula alleghaniensis	Yellow birch	< 1%	FAC
			Brachyelytrum erectum	Wood grass	6 - 25%	UPL
			Carex crinita	Fringed sedge	3 - 5%	OBL
			Coptis trifolia	Goldthread	< 1%	FACW
			Impatiens capensis	Jewelweed	< 1%	FACW
			Lycopus uniflorus	Water-horehound	< 1%	OBL
			Maianthemum canadense	Canada mayflower	3 - 5%	FAC-
			Matteuccia struthiopteris	Ostrich fern	51 - 75%	FACW
			Mitchella repens	Partridge-berry	3 - 5%	FACU
				Mosses	< 1%	
			Quercus rubra	Northern red oak	6 - 25%	FACU-
			Trientalis borealis	Starflower	3 - 5%	FAC
			Uvularia sessilifolia	Sessile bellwort	3 - 5%	FACU-
	South side	Tree	*Acer rubrum*	Red maple	51 - 75%	FACW+
			Quercus rubra	Northern red oak	6 - 25%	FACU-
		Shrub	*Abies balsamea*	Balsam fir	6 - 25%	FAC
			Lyonia ligustrina	Maleberry	6 - 25%	FACW
			Pinus strobus	White pine	< 1%	FACU
			Tsuga canadensis	Hemlock	3 - 5%	FACU
		Herb	*Aralia nudicaulis*	Wild sarsaparilla	< 1%	FACU
			Betula alleghaniensis	Yellow birch	< 1%	FAC
			Brachyelytrum erectum	Wood grass	3 - 5%	UPL
			Carex crinita	Fringed sedge	26 - 50%	OBL
			Maianthemum canadense	Canada mayflower	3 - 5%	FAC-
			Matteuccia struthiopteris	Ostrich fern	6 - 25%	FACW
			Pteridium aquilinum	Bracken	< 1%	FACU
			Quercus rubra	Northern red oak	3 - 5%	FACU-
			Trientalis borealis	Starflower	< 1%	FAC
			Uvularia sessilifolia	Sessile bellwort	< 1%	FACU-
			Viburnum cassinoides	Northern wild raisin	< 1%	FACW
	Streambank	Tree	*Abies balsamea*	Balsam fir	6 - 25%	FAC
			Acer rubrum	Red maple	26 - 50%	FACW+
			Betula alleghaniensis	Yellow birch	6 - 25%	FAC
		Shrub	*Abies balsamea*	Balsam fir	3 - 5%	FAC
			Tsuga canadensis	Hemlock	3 - 5%	FACU
		Herb	*Abies balsamea*	Balsam fir	< 1%	FAC
			Brachyelytrum erectum	Wood grass	3 - 5%	UPL
			Glyceria borealis	Floating mannagrass	3 - 5%	OBL
			Lycopus uniflorus	Water-horehound	6 - 25%	OBL
			Matteuccia struthiopteris	Ostrich fern	3 - 5%	FACW
				Moss	> 75%	NI
			Prenanthes alba	White rattlesnake root	< 1%	FACU
			Scutellaria lateriflora	Mad-dog skulcap	< 1%	FACW+
			Thalictrum pubescens	Tall meadow-rue	< 1%	FACW+
			Uvularia sessilifolia	Sessile bellwort	< 1%	FACU-

Table 10. Species, percent cover and wetland indicator status of vegetation by zone at Wetland Transect 3 on Wards Brook.

Transect	Location	Layer	Scientific Name	Common Name	% Cover	Wetland Indicator Status
Transect 3 - Grist Mill	In river	Herb		Moss	26 - 50%	NI
			Sparganium sp.	Burreed	3 - 5%	
	Island & north side	Tree	*Abies balsamea*	Balsam fir	< 1%	FAC
			Acer rubrum	Red maple	> 75%	FACW+
			Pinus strobus	White pine	3 - 5%	FACU
		Shrub	*Abies balsamea*	Balsam fir	6 - 25%	FAC
			Lyonia ligustrina	Maleberry	< 1%	FACW
			Quercus rubra	Northern red oak	< 1%	FACU-
			Quercus rubra	Northern red oak	< 1%	FACU-
			Ulmus americana	American elm	3 - 5%	FACW-
		Herb	*Arisaema triphyllum*	Jack-in-the-pulpit	< 1%	FACW-
			Aster acuminatus	Whorled aster	6 - 25%	UPL
			Aster vimineus	Small white aster	< 1%	FAC
			Athyrium filix-femina	Lady fern	6 - 25%	FAC
			Brachyelytrum erectum	Wood grass	3 - 5%	UPL
			Carex sp.	Sedge sp.	3 - 5%	NI
			Carex interior	Inland sedge	26 - 50%	OBL
			Clintonia borealis	Bluebead lily	< 1%	FAC
			Coptis trifolia	Goldthread	< 1%	FACW
			Galium sp.	Bedstraw	< 1%	NI
			Glyceria borealis	Floating mannagrass	6 - 25%	OBL
			Impatiens capensis	Jewelweed	< 1%	FACW
			Onoclea sensibilis	Sensitive fern	< 1%	FACW
			Pinus strobus	White pine	< 1%	FACU
			Polygonum spp.	Smartweed	< 1%	FACW-OBL(FACW)
			Prenanthes alba	White rattlesnake root	< 1%	FACU
			Quercus rubra	Northern red oak	< 1%	FACU-
			Sambucus canadensis	Elderberry	3 - 5%	FACW-
			Scutellaria lateriflora	Mad-dog skulcap	< 1%	FACW+
			Solidago rugosa	Rough-leaved goldenrod	< 1%	FAC
			Thalictrum pubescens	Tall meadow-rue	3 - 5%	FACW+
	South Bank	Tree	*Acer rubrum*	Red maple	6 - 25%	FACW+
			Fagus grandifolia	Beech	3 - 5%	FAC+
			Pinus strobus	White pine	26 - 50%	FACU
			Tsuga canadensis	Hemlock	26 - 50%	FACU
		Herb	*Aster acuminatus*	Whorled aster	< 1%	UPL
			Dryopteris spinulosa	Spinulose shieldfern	6 - 25%	FAC+
			Glyceria borealis	Floating mannagrass	< 1%	OBL
				Moss	< 1%	NI

(*Athyrium filix-femina*) and manna grass. The litter layer was sparse and scoured sand was visible in bare areas.

Aquatic mosses were common on the boulders in the stream, and the floating-leaved form of burreed (*Sparganium* sp) was found in a quieter section of flow.

The hydrology on the island and the north side of the stream are best described as seasonally flooded, with surface water present for extended periods, especially in the early spring, and the water table remaining close to the surface for most of the year (Cowardin et al 1979). The steep south bank is intermittently flooded for brief periods of time during high flows.

Transect 4 – Beaver Dam

This lowest transect in the watershed was located in an extensive emergent marsh and remnant floodplain forest behind a low beaver dam. Below the dam, Lovewell Pond dominated the water levels and quality. Above the dam, Wards Brook meandered through the wetland in sinuous channels. Standing water was common in small pools and old stream channels. Water levels behind the beaver dam appeared to be stable and had little evidence of extreme high water. It is likely that beavers move the dam around periodically to take advantage of desirable vegetation, but that the general area has been impounded for many years. The large standing-dead trees in the wetland attest to at least several decades of flooding. The beaver dam impounding this section of wetland appeared abandoned, as it was in poor repair.

Along the southern edge of the wetland, the bank was quite steep and dropped abruptly to the wetland. A shelf of poorly drained wetland formed a transition between the upland and the flooded wetland. This shelf supported red maple and limited white pine, with witch hazel (*Hamamelis virginiana*) providing a sparse shrub layer (Table 11). The herbaceous layer was dominated by interrupted fern (*Osmunda claytoniana*) with royal fern (*Osmunda regalis*) established along the wetter fringe.

In the main body of the wetland, much of the forested canopy had been killed by high water. Large-diameter standing-dead trunks of red maple and possible elm were scattered through the wetland. Live red maple formed a partial canopy in some areas, while others were quite open. Shrubs were few but for clumps of maleberry and meadowsweet (*Spirea latifolia*). The emergent wetland was dominated by a mixture of grasses, sedges and forbs: rice cutgrass (*Leersia oryzoides*), royal fern, false nettle (*Boehmeria cylindrica*), marsh fern (*Thelypteris palustris*), tearthumb (*Polygonum spp.*), and jewelweed (*Impatiens capensis*) were all prevalent in the floodplain, often forming dense stands. Sphagnum moss was abundant throughout the wetland underneath the shrubs and herbs. The small pools supported rice cutgrass, burreed and beggar's tick (*Bidens frondosa*) around the edges, and arrow arum (*Sagittaria latifolia*) and tearthumb in the standing water.

The hydrologic regime varies over this wetland transect, ranging from seasonally saturated near the upland to permanently flooded in the standing pools. The predominant condition appears to be semipermanently flooded with surface water persisting throughout the growing season in most years (Cowardin et al 1979).

Table 11. Species, percent cover and wetland indicator status of vegetation by zone at Wetland Transect 4 on Wards Brook.

Transect	Location	Layer	Scientific Name	Common Name	% Cover	Wetland Indicator Status
Transect 4 Beaver Dam	**Floodplain close to bank**	**Herb**	*Aster vimineus*	Small white aster	< 1%	FAC
			Chelone glabra	Turtlehead	< 1%	OBL
			Galium sp.	Bedstraw	< 1%	NI
			Glyceria striata	Fowl-meadow grass	< 1%	OBL
			Triadenum virginicum	Marsh St Johns wort	< 1%	
			Impatiens capensis	Jewelweed	< 1%	FACW
			Leersia oryzoides	Rice cut-grass	26 - 50%	OBL
			Lycopus uniflorus	Water-horehound	3 - 5%	OBL
			Onoclea sensibilis	Sensitive fern	3 - 5%	FACW
			Osmunda regalis	Royal fern	26 - 50%	OBL
			Open water	Open water	6 - 25%	
			Polygonum sagittum	Arrow-leaf tearthumb	6 - 25%	OBL
			Scutellaria lateriflora	Mad-dog skulcap	6 - 25%	FACW+
			Sphagnum sp.	Sphagnum moss	26 - 50%	NI
			Thalictrum pubescens	Tall meadow-rue	3 - 5%	FACW+
			Thelypteris palustris	Marsh fern	6 - 25%	FACW+
			Viola sp.	Violet	< 1%	
	Higher ground in floodplain	**Tree**	*Acer rubrum*	Red maple	6 - 25%	FACW+
		Shrub	*Lyonia ligustrina*	Maleberry	3 - 5%	FACW
			Spiraea latifolia	Meadowsweet	6 - 25%	FAC+
		Herb	*Boehmeria cylindrica*	False nettle	3 - 5%	FACW+
			Carex sp.	Sedge sp.	26 - 50%	NI
			Eupatorium perfoliatum	Boneset	3 - 5%	FACW+
			Lyonia ligustrina	Maleberry	3 - 5%	FACW
			Onoclea sensibilis	Sensitive fern	6 - 25%	FACW
			Osmunda regalis	Royal fern	6 - 25%	OBL
			Scirpus cyperinus	Woolgrass	3 - 5%	FACW+
			Solanum dulcamara	Bittersweet	< 1%	FAC-
			Verbena hastata	Blue vervain	< 1%	FACW+
	Mid-floodplain	**Herb**	*Boehmeria cylindrica*	False nettle	26 - 50%	FACW+
			Calamagrostis canadensis	Bluejoint grass	3 - 5%	FACW+
			Cicuta bulbifera	Poison water-hemlock	3 - 5%	OBL
			Impatiens capensis	Jewelweed	6 - 25%	FACW
			Leersia oryzoides	Rice cut-grass	26 - 50%	OBL
			Polygonum sagittum	Arrow-leaf tearthumb	6 - 25%	OBL
			Sagittaria latifolia	Arrowhead	3 - 5%	OBL
	Upland edge	**Tree**	*Acer rubrum*	Red maple	26 - 50%	FACW+
			Pinus strobus	White pine	3 - 5%	FACU
		Shrub	*Hamamelis virginiana*	Witchhazel	3 - 5%	FAC-
		Herb	*Coptis trifolia*	Goldthread	3 - 5%	FACW
			Lysimachia terrestris	Swamp candles	3 - 5%	OBL
			Onoclea sensibilis	Sensitive fern	6 - 25%	FACW
			Osmunda claytoniana	Interrupted fern	26 - 50%	FAC
			Osmunda regalis	Royal fern	3 - 5%	OBL
			Uvularia sessilifolia	Sessile bellwort	< 1%	FACU-
	Wet holes in back of floodplain	**Herb**	*Bidens frondosa*	Beggar-ticks	26 - 50%	FACW
			Galium sp.	Bedstraw	< 1%	NI
			Leersia oryzoides	Rice cut-grass	26 - 50%	OBL
			Onoclea sensibilis	Sensitive fern	3 - 5%	FACW
			Polygonum sagittum	Arrow-leaf tearthumb	6 - 25%	OBL
			Sagittaria latifolia	Arrowhead	6 - 25%	OBL
			Sparganium sp.	Burreed	26 - 50%	

LOVEWELL POND WATER QUALITY

Emery and Garrett (2005) concluded that the potential impact of groundwater withdrawal from the Wards Brook Aquifer, even at a maximum recommended rate of 220 million gallons per year, would have an insignificant impact on water quality in Lovewell Pond "because the water level, water temperature and water quality of the pond is dominated by the influence of the Saco River". We provide a more quantitative evaluation of the potential impact below.

Table 12. Select physical and chemical data for Lovewell Pond, as obtained from the Maine Voluntary Lake Monitoring Program, Emery and Garrett (2005) and WEM (2007).

Parameter	Value
Surface Area	1,120 acres (453 ha)
Volume	21,157 acre-feet
Drainage area – not including Lovewell Pond or the Saco River including the Saco River	3,100 acres (1254.5 ha)
Sub-drainage area of Wards Brook	2,000 acres (809 ha)
Water loading rate	24 inches (0.61 m) per year
Flushing time (from MEDEP as reported by WEM 2007)	0.5 years
Recent In-lake Total Phosphorus Concentration	7-10 μg/l

A flushing time of 0.5 years means that the estimated annual water loading to the pond is twice the pond volume or 42,314 acre-feet. Since the watershed plus the pond surface area only provide about 8,440 acre-feet (3,100 acres + 1,120 acres x 2 feet per year), the remaining 33,874 acre-feet is estimated to come from the Saco River (~2.5 floods of 12'per year). Thus, 80 percent of the water loading to Lovewell Pond is expected to come from the Saco River.

Given measured in-lake phosphorus concentrations and reported flushing time, we applied the equation developed by Vollenweider (1976) to estimate average annual phosphorus loading to Lovewell Pond and to estimate how in-lake phosphorus concentration might change with the removal of 220 million gallons of water from the annual inflow from the Ward Brook Aquifer.

The Vollenweider equation is:

$$[P]_{in\text{-}lake} = L/q_s/(1+\sqrt{\tau_w})$$

Where $[P]_{in\text{-}lake}$ = the in-lake total phosphorus concentration in g/m^3

L = total phosphorus loading in $g/m^2/yr$

q_s = water loading in $m^3/m^2/yr$

τ_w = flushing time in yr

Also note that $L/q_s = [P]_{inflow}$ = the average annual total phosphorus loading concentration

Therefore:

$$[P]_{in\text{-}lake} = [P]_{inflow}/(1+\sqrt{\tau_w})$$

Assuming an in-lake total phosphorus concentration of 10 μg/l it can be calculated that the average annual total phosphorus inflow concentration is approximately 17.071 μg/l. If we assume that the inflow phosphorus concentration is the same from all portions of the watershed, then Wards Brook would be expected to provide an annual contribution of 17.071 μg/l for its respective water loading. Removing 220 million gallons of water from the Wards Brook aquifer will do two things to Lovewell

Pond. It removes some of the phosphorus loading that was associated with Wards Brook, and it increases the flushing time because less water is entering the lake. In this case, the flushing time now becomes 0.503 years instead of the reported 0.5 years. With 220 million gallons of water removed from Wards Brook, it can be calculated that the expected in-lake phosphorus concentration would now be:

$$[P]_{in\text{-}lake} = ((17.071e^{-3} \times 52.194e^{6}) - (17.071e^{-3} \times 0.833e^{6}))/(52.194e^{6} - 0.833e^{6}) /(1+\sqrt{0.503})$$
$$= 0.009988 \text{ g/m}^3 = 9.988 \ \mu\text{g/l}$$

Therefore, we would predict that if the concentration of phosphorus in the water removed from the Wards Brook aquifer is the same as the inflow concentration from the entire watershed to Lovewell Pond, we would expect the in-lake phosphorus to actually decline slightly as a result of the groundwater removal. The expected decline would in fact be negligible, immeasurable by conventional laboratory analysis methods and unobservable in terms of biological response in the lake.

In reality, inflow phosphorus concentrations are not equal throughout the watershed, although levels have not been quantified for most inflow sources. We do know that phosphorus concentrations in the Saco River can be greater by an order of magnitude or more than concentrations in Lovewell Pond (WEM 2007). Since Saco River water inflow dominates inflow into Lovewell Pond (estimated at ~80 percent of the total water inflow), then this high water loading combined with relatively high phosphorus levels suggests that actual phosphorus concentrations from the remainder of the watershed are likely to be considerably less than ~17 µg/l. If it is then assumed that Wards Brook aquifer water is substantially lower in total phosphorus concentration (which it probably is), say 5 µg/l, then the contribution from the rest of the watershed would estimated to be about 18.332 µg/l (to be consistent with the Vollenweider inflow prediction). Using the Vollenweider equation, we would then estimate the expected in-lake total phosphorus concentration to be:

$$[P]_{in\text{-}lake} = ((18.332e^{-3} \times 52.194e^{6}) - (5.0e^{-3} \times 0.833 \ x^{6}))/(52.194 \ x^{6} - 0.833 \ x^{6}) /(1+\sqrt{0.503})$$
$$= 0.010852 \text{ g/m}^3 = 10.852 \ \mu\text{g/l}$$

Thus, we conclude that the maximum probable impact of withdrawal 220 million gallons from the Wards Brook aquifer on Lovewell Pond in-lake phosphorus concentrations would be to increase phosphorus concentrations by less than 1 µg/l. A more detailed accounting of likely phosphorus concentrations from the various inflow sources to Lovewell Pond could very well reduce this value significantly, even to the point where no change in in-lake total phosphorus concentrations would be expected, as in our first example. Irrespective of the actual amount, it is safe to conclude that the potential impact of groundwater withdrawals from the Wards Brook aquifer on water quality in Lovewell Pond is likely to be minor and indistinguishable from existing water quality conditions.

IV. Discussion

Water Quality

Trends in water temperature in Wards Brook were dominated by trends in air temperature. Water temperature peaked above 18.3° C for several weeks in late summer during the study period, which suggests that overall the stream is a cool water system. Because of local landscape influences on temperature, parts of the brook habitat may be considered a cool/coldwater system and other parts approach a warmwater system, based on peak summer temperatures. Upstream wetlands and Wards Pond affect the water temperature significantly, raising water temperature during dry summer periods, but also buffering cold water temperatures in winter, for some distance downstream of Route 113. An abundance of ground water contribution below Route 113 mitigated the warming effect of Wards Pond and kept the peak water temperature suitable for brook trout in the reach from the snow mobile trail downstream to the old mill.

During the study period, Maine experienced one of its wettest years on record, which suggests that groundwater contribution may have been higher than normal. Increased precipitation caused greater groundwater contribution to the stream and turnover of the Ponds would have been increased (less warming). Therefore, the cooling effect on stream temperature by groundwater may have been higher than a typical year, and turnover of the Ponds would have been greater (less warming). During more extreme hot and dry years, ground water addition to the stream would be more important to maintaining colder water (lower peak temperatures), as well as providing cold-water refuges to brook trout to survive higher surface temperatures, of late summer months of July, August and September.

Fish

Wards Brook contained a limited diversity of fish. Brook trout were the most abundant species from the old mill site and upstream; this was the area of cold water. Largemouth bass and yellow perch, both habitat generalist and cool-water/warm-water species, were the most abundant species downstream of the old mill where Wards Brook interacts with the Lovewell Pond. These three species comprised 80 percent of the fishes captured overall; the remaining 20 percent of the community was comprised of five species, which were all habitat generalist. The most sensitive species to potential habitat and temperature perturbation by groundwater withdrawal would be brook trout.

Brook Trout

Brook trout are native to northeastern North America. They live in cold, small clean streams, although it can exist in ponds, including beaver ponds, and lakes. A cold stream being one that mostly stays below 65° F or 18.3°C so that the water can be highly oxygenated. Brook trout are sensitive to stream disturbances in particular temperature changes, sedimentation, and invasive, competitive trout species, many of which are often stocked for sport fishing.

Most wild brook trout survive no more than five years, and as adults reach from 5 to 18 inches (127 to 457 mm). In small streams a mature fish may only be 4 to 5 inches (101 to 127 mm). Small adults of small streams produce fewer eggs per adult since body size is limited. Ten of the 17 brook trout captured during surveys may have been spawning size for a small stream. A number of fish that were in the 40 to 50 mm range would have been potential young of year fishes.

Brook trout spawn in the fall, from mid-September to November. Eggs are deposited in depression nests, called a redd, constructed by females in gravel areas and then covered with a small layer of gravel without further parental care. Nest sites are optimal where water flow through interstitial space among the gravel is present, especially where groundwater flow through the gravel occurs. Eggs develop over winter and hatch in late winter or spring, depending on water temperature which affects egg incubation. As fish become large adults they often will move downstream then migrate upstream into small streams or headwater sections to spawn. Brook trout feed on aquatic and terrestrial insects, crustaceans and small fish.

Based on field observations, riffles were suitable for brook trout and habitat existed to support the full life cycle of brook trout. To significantly influence the suitability of habitat for brook trout it would take a relatively large change in streamflow (stage). Potential impacts of groundwater withdrawal on brook trout would more likely come from temperature changes (higher peaking temperatures) than changes in habitat suitability from reduction of flow. The presence of water temperature during late summer that was not suitable for brook trout habitat suggest that groundwater inflow to the stream is important for providing summer habitat refuge for brook trout. Brook trout are the fish species most likely to experience any potential impact of groundwater withdrawals.

Largemouth Bass

Largemouth bass is a widespread and tolerant species of cool and warmwater fish communities. Largemouth bass are more prevalent in lakes than streams. All largemouth bass captured in Wards Brook where young fish, possibly young of year or slightly older.

Adult largemouth bass are large and prey mostly on life fish. The habitat of Wards Brook was not conducive to the complete life cycle of largemouth bass because it was shallow and a large supply of forage was not present indicating that young fish had either moved up into the stream from the lake or been transported downstream from ponds above the sampling site. Wards Brook was good nursery habitat for young largemouth bass which feed on insects until they reach about 2 inches or 50.8 mm. As largemouth bass grow they would migrate downstream in search of deep water and more abundant fish prey.

Largemouth bass also build nests to spawn, but they spawn in spring or early summer, after water temperatures typically are 65°F or 18.3° C. Males guard the nests until fry swim up. They build nests along the shorelines of lakes or rivers, usually in water several feet deep. The habitat of Wards Brook upstream of the old mill site was certainly not typical of largemouth bass habitat, but some habitat in the wetlands areas in lower Wards Brook may suport small adults and possibly spawning sites, if adults had access from the lake. Because largemouth bass are habitat generalists it is unlikely that changes in groundwater withdrawal would significantly alter habitat for young largemouth bass in Wards Brook.

Yellow Perch

Yellow perch adults are about 15 cm to 20 cm, but may reach 30 to 35 cm in larger systems. Yellow perch are adaptable and easily live in ponds and large lakes as well as streams and rivers. They are freshwater fish but also tolerant of estuarine conditions. They can live in warm or cool water, and because of their broad habitat capability they are macrohabitat generalist.

Yellow perch are native to Atlantic coast watersheds and common in clear streams with vegetation. They are intolerant of pollution and heavy siltation. Yellow perch spawn in the spring when temperatures are in the 7.2°C to 10°C range. They spawn by broadcasting their eggs in long, gelatinous strands. Strands of eggs often adhere to underwater structure such as vegetation, wood debris, or other structure or settle to the bottom. Adults do not provide care after spawning. Yellow perch eat a variety of prey including aquatic insects, crustaceans and other invertebrates, and small fish.

Six yellow perch were captured during samples. The habitat of Wards Brook was conducive to the preferred habitat of yellow perch. All fish were less than four inches suggesting they were not adults. Most likely adults occur in Lovewell Pond and migrate upstream to spawn or sub-adults migrate after spawning in search of nursery habitat. Yellow perch would prefer habitat in lower Wards Brook in the wetlands/marsh area with plentiful vegetation and upstream of the riffles at the old mill site where the channel is deeper. Water temperatures were very good for supporting yellow perch. Because yellow perch are tolerant species, it is unlikely that any potential groundwater withdrawal significantly affect

Macroinvertebrates

The Wards Brook benthic macroinvertebrate communities at the Upstream Station and the Downstream Station appeared to be consistent with the habitat where they were found. The Upstream Station was heavily influenced by the outlet from Wards Pond, located 23 to 30.5 m upstream. The benthic community at the Upstream Station had high values for Total Abundance, Chironomidae Abundance, Hydropsyche Abundance, and Cheumatopsyche Abundance, and low values for Generic Richness, EPT Richness, and Shannon-Wiener Diversity, when compared to metric values from the Downstream Station. These metric values are consistent with values that would be expected from a lake outlet.

Benthic communities downstream of impoundments are typically characterized by having lower taxa richness, lower EPT richness, and higher biomass (abundance) of filter-feeding organisms (Bode 2002). Bode (2002) found that the reduction in taxa richness and EPT richness was primarily due to the lack of recruitment from upstream resources. Lake outlets often support dense populations of filter-feeding organisms such as *Simulium* sp. (black flies), *Hydropsyche* sp. and *Cheumatopsyche* sp. (common net-spinning caddisflies), Sphaeriidae (fingernail clams), and *Rheotanytarsus* sp. (midges), due to the abundance of phytoplankton, zooplankton, and seston carried downstream from the impoundment (Bode 2002, Resh and Rosenberg 1984, Wallace and Merritt 1980, Boon 1979, Hynes 1970). The influence of lake outlets on benthic communities usually extends a short distance downstream (Bode 2002); as plankton are consumed and removed from the water, downstream benthic communities become more diverse, and the food base shifts from autotrophic, dominated by autochthonous material such as phytoplankton, zooplankton, and seston, to heterotrophic, which is dominated by allochthonous material such as leaf litter, twigs, and branches.

The Downstream Station benthic community was composed of organisms typically associated with small, second order woodland streams. Taxa richness, diversity, and EPT metrics were high, and total abundance was low, compared to the Upstream Station. The overwhelming abundance of filter-feeding organisms such as Hydropsychidae (*Hydropsyche* sp., *Cheumatopsyche* sp.), *Rheotanytarsus* sp., and *Pisidium* sp. was not seen, probably due to the substantial reduction of autochthonous material (i.e., plankton and seston) in the water. Many headwater streams are influenced strongly by the riparian vegetation, which reduces autotrophic production by shading and contributes large amounts of allochthonous detritus (Vannote et al. 1980). This shift from autotrophy to heterotrophy results in a benthic community that is composed of organisms that, break down and consume organic matter that falls into the stream, scrape periphyton on rocks and plants, and are predaceous on other organisms.

In conclusion, baseline rock bag data collected from Wards Brook in 2006 indicated that the benthic macroinvertebrate communities at the Upstream Station and the Downstream Station were consistent with the types of communities normally found in similar habitats. The Upstream Station was overwhelmingly numerically dominated by filter feeding insects, which are often abundant downstream of impoundments. The Downstream Station supported a benthic community typically found in first to third order woodland streams.

Because macroinvertebrate insects are tolerant of low water depth, changes in water depth with reduced flow from potential groundwater withdrawal would not likely impair macroinvertebrate habitat. The most probable way that macroinvertebrate habitat in Wards Brook would be influenced by increasing groundwater withdrawal would be reduced flow from reduced stream flow or increases in peak summer temperatures. Both of these effects would typically be a problem only during low flow periods, which is usually late summer, or periods of below normal precipitation in general.

Freshwater Mussel

Physical habitat conditions along the shoreline of Lovewell Pond were suitable to support a freshwater mussel community. Mussels were found at 0.6 to 0.9 m depths along the entire shoreline, except in coarse substrate (boulder, cobble) areas along the eastern shoreline. Mussels were rare to common along the western and northern shores, but were abundant at suitable habitat areas along the eastern and southern shores.

The qualitative mussel survey conducted in Lovewell Pond in December 2006 found that the mussel community was composed exclusively of eastern elliptio, *Elliptio complanata*, a very common species found throughout New England. It is the freshwater mussel most commonly found in the state of Maine, and it is found in virtually every water body in Maine that is capable of supporting freshwater mussels (Nedeau et al. 2000).

Wetlands

Wetlands were unevenly distributed in the study area. The vast majority of the wetlands occurred in the upper reaches of the brook, south of Wards Pond (Figure 2). These were a mix of coniferous and deciduous forested wetlands on an extensive low-lying level plain through which Wards Brook meandered. Below Wards Pond (north of Route 113), the topography dropped substantially toward Lovewell Pond so that Wards Brook cut a narrow ravine through the stratified drift. Relatively little wetland development occurred along this section of the brook, and was confined to occasional narrow shelves within the floodplain. At the junction of the brook with Lovewell Pond, a moderately sized emergent marsh/floodplain wetland has developed. Beaver have constructed a series of dams throughout this wetland, further slowing flows and impounding water. The transects were located to best describe the wetlands of Wards Brook, with a focus on the commercial water withdrawals north of Route 113.

The effects of water withdrawal can impact wetlands in two ways: 1) lower the water table, and 2) altered stream hydrology. The effects of a lowered water table would be a chronic condition, most pronounced in the late growing season, when the water table is typically at its lowest point. The herbaceous layer is most sensitive to water level changes, because the live root zone is typically shallow and confined to the upper soils. The shrub and tree roots are often deeper rooted and most species, once established, can tolerate a wider range of fluctuations. Woody seedlings are an exception, and resemble the herbaceous layer in their response to altered water levels. As water levels drop, more of the substrate becomes aerated and suitable for species that cannot tolerate long-term saturated/flooded conditions but can tolerate seasonal saturated conditions.

Altered stream hydrology would be most likely to affect only the lowest wetlands by reducing base stream flow and drawing down ground water immediately adjacent to the stream. Unless the system underwent a severe withdrawal, high water levels during spring melt and storms would be virtually unaffected, and the scour and flooding effects in the streamside wetlands would remain unchanged.

Of the four transects, a water table decrease due to the existing commercial wells would be most likely to impact only the south side of Transect 2. This area appears to be influenced by stream scour and flooding during high water events, and by groundwater levels under normal conditions. A significant groundwater outbreak on a slope upstream of Transect 2 indicates the volume and level of the water table. The dominance of fringed sedge, an Obligate Wetland species (Reed 1988), and saturated conditions at the time of the site visit suggest a higher water table than occurs on the north side of the transect.

A reduction in base flow of the stream would most likely impact Transect 3 at the Grist Mill. The wetlands in the vicinity of this transect were low-lying and formed on boulders that appeared to be a combination of natural distribution and imported for the now-derelict grist mill. Sediment deposited in the interstices and downstream of the boulders supported wetlands that undoubtedly are affected by stream levels. Many of the vegetation species here were facultative in nature, which is typical of an infrequently flooded streamside wetland. The plants are tolerant of short periods of flooding followed by long periods of water levels that reflect stream conditions.

Because of their ability to tolerate a wide range of hydrologic conditions, these plants may be able to tolerate a minor drop in stream baseflow. If more of the channel sides and bottom are exposed, plants will attempt to colonize it and probably be periodically removed by periodic extreme high water events. Woody species, both trees and shrubs, may expand as the reduced saturation may be more favorable for their growth.

Wetlands in the vicinities of Transects 1 and 4 will most likely remain unchanged by groundwater withdrawals in the commercial springs. Transect 1 is well above the withdrawal area and therefore unlikely to be influenced by withdrawals north of Route 113. It is worth noting that expansion of water withdrawal in the area of the municipal wells near Transect 1 could lower water tables there and impact a wide area of wetland. Transect 4 is located at the bottom of Wards Brook and dominated by a beaver impoundment. Unless severe withdrawals to eliminate much of the flow down the brook, these wetlands will not be influenced by minor changes in stream flow and levels.

Wards Brook supports three distinct wetland types: a large upper forested wetland plain, scattered streamside wetlands along the steeper gradient of the stream, and emergent/floodplain wetlands at the junction with Lovewell Pond. The impacts of water withdrawal from the vicinity of the commercial springs are likely to be minor in all areas, but most pronounced along the small streamside wetlands in the middle section of the stream. The effects of both a lowered groundwater table and a reduced base flow of the stream would be most pronounced in the herbaceous layer, where obligate wetland species may be reduced or eliminated and Facultative species could encroach. Woody growth could further reduce sunlight and reduce the percent cover of the herbaceous layer. No destabilization of the wetlands would be expected unless a severe change in stream flow or groundwater levels occurred.

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