Penjajawoc Stream a Summary of Water Quality Data from the 2008 Field Season

A Progress Report for the Maine Stream Team Program

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I. Introduction

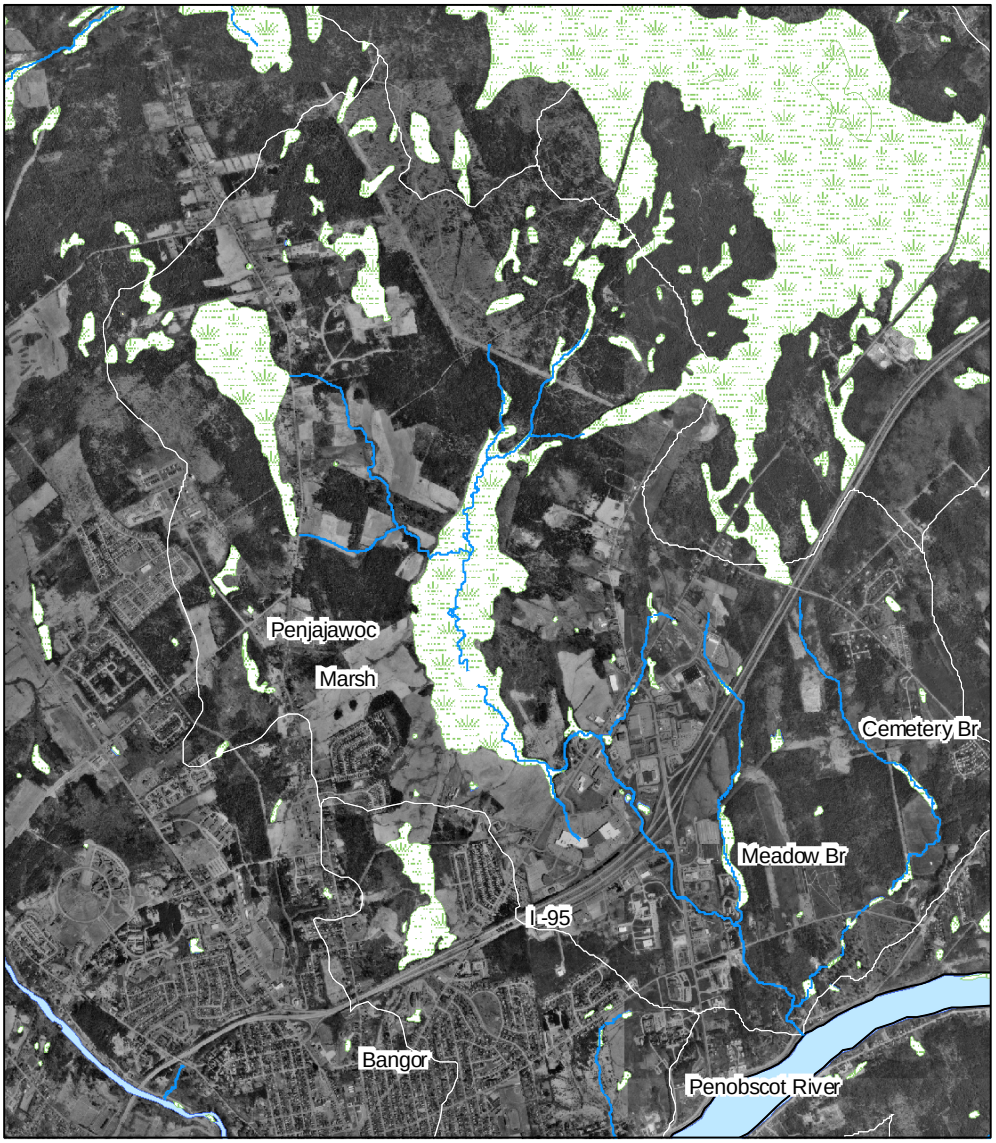
Penjajawoc Stream is a second order stream that is located in the City of Bangor. Because of urban development, the stream has poor water quality and impaired aquatic communities. In the interests of promoting environmental stewardship and community involvement in a planned restoration, the City of Bangor and the Maine Department of Environmental Protection (DEP) equipped and trained a local volunteer "stream team" to monitor water quality. This is a report of the findings from our 2008 "baseline" field season.

The headwaters of Penjajawoc Stream begin in vast wetlands in the northern part of the watershed (Figure 1) which then flow south to Penjajawoc Marsh. Below the marsh, the stream reforms and flows through a large commercial development along Stillwater Avenue, past the Bangor Mall complex, and then under interstate highway I-95. Below the interstate, the stream continues south past Eastern Maine Community College and a number of commercial developments on the Hogan Road. Still flowing south, the stream enters the largely wooded Evergreen Woods professional park and combines with Meadow Brook. After flowing under Mt Hope Avenue, the stream flows through a residential area where it combines with an unnamed stream that drains Mount Hope Cemetery. We called the unnamed stream "Cemetery Brook." The Penjajawoc then passes under US Route 2 where it joins the Penobscot River. The total watershed area is 8.57 square miles (22.20 square kilometers).

The Maine DEP has a Water Classification Program which assigned Penjajawoc Stream and its tributaries Class B status (a middle of the road water quality, see also Methods section regarding Maine's water classification program). However, urban

development has caused the mainstem and its largest tributary, Meadow Brook, to not meet this classification. These streams are currently listed as "impaired." The problem is primarily defined by seasonal high temperatures, low oxygen, and impaired biological communities (see DEP Biomonitoring Program in References section).

DEP has been monitoring Penjajawoc Stream since 1997 (DEP 2007). In the fall of 2007, the City of Bangor and the DEP Stream Team Program (see References section for web resources) collaborated in the organization, training, and equipping of a volunteer Stream Team to follow up on these earlier studies. The purpose of the Stream Team monitoring is to demonstrate progress as the City and its private landowner partners implement stormwater management improvements. The Stream Team monitoring was recommended as part of the strategic Watershed Management Plan and our 2008 field season represents the baseline for the project. This paper has two parts, a summary of the Stream Team's findings and a discussion of DEP's data sonde studies that supplemented the volunteer effort.



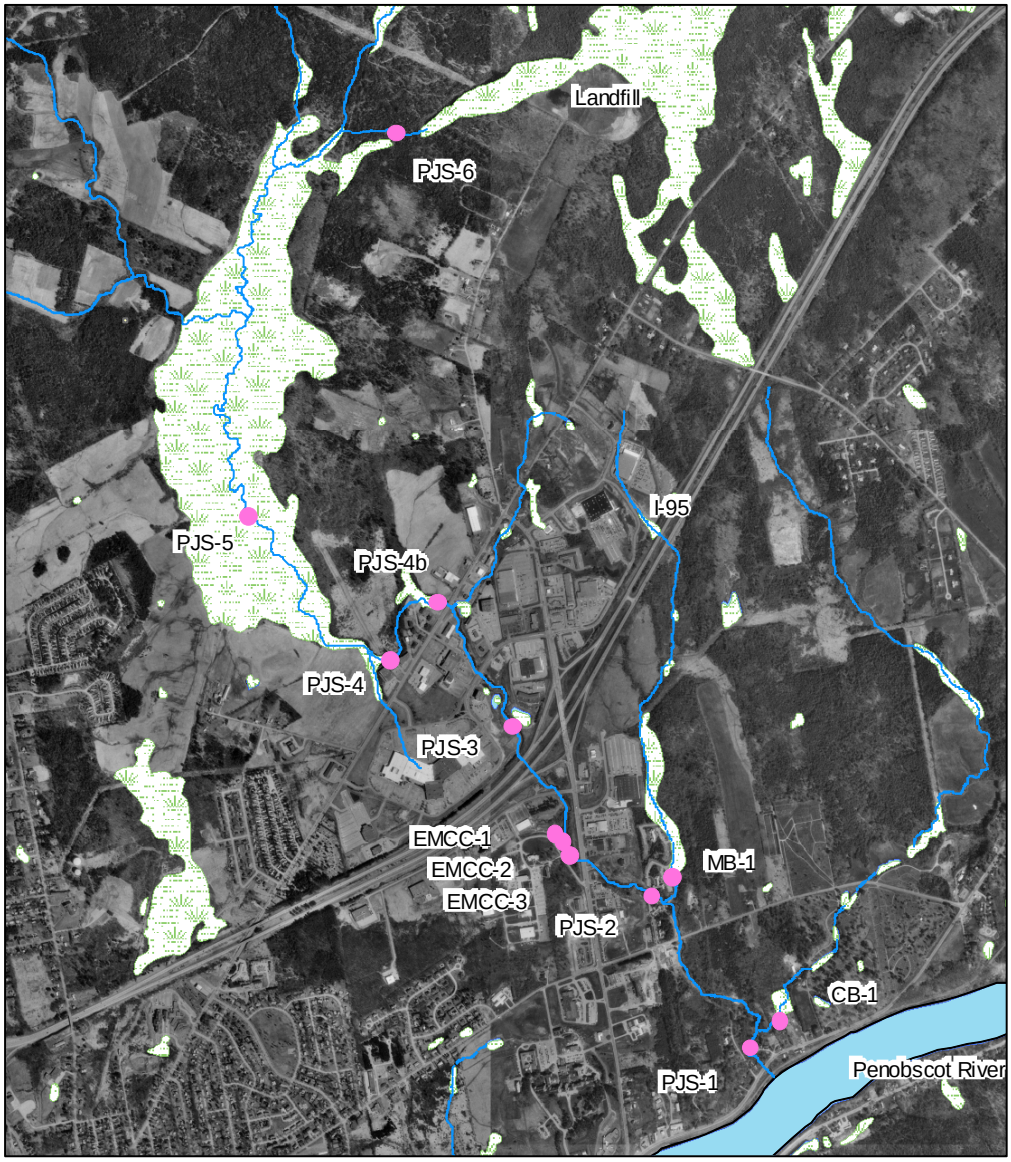
Penjajawoc Stream, Watershed Map

Meters
0 2,000 4,000

Figure 1. Map of the Penjajawoc Stream watershed, showing the stream, Penjajawoc Marsh, principal tributaries, and headwater marshlands. The watershed divide is a white line.

Sample Sites

The Penjajawoc Stream Team started with seven sample sites (PJS-1 through PJS-5, MB-1, and CB-1) (Figure 2). Because of access issues at PJS-4 another site was added at the professional office complex on 33 Penn Plaza (this became PJS-4b). This was often used instead of PJS-4. Another new site was added in September at the request of the Bangor Land Trust, which owns an un-developed and wooded parcel in the upper watershed (PJS-6). The PJS-6 stream site is a rocky riffle between two marshes. PJS-6 is located downstream of the old Kittridge Road Landfill. This landfill accepted general municipal and demolition debris until it was closed in the late 1990's. Note that the landfill is bounded by wetlands to the north and west. Additional sample sites were added when a professor at Eastern Maine Community College became part of the Stream Team group and started monitoring an intermittent storm drainage that crosses the EMCC campus (EMCC-1 through EMCC-3).



Penjajawoc Stream, Bangor
Stream Team Sites

Meters
0 1,000 2,000

Figure 2. Sample stations used by the Penjajawoc Stream Team volunteers are in red. Stations PJS-1 through PJS-6 are on the Penjajawoc, while MB-1 is on Meadow Brook, and CB-1 is on the unnamed stream that we called Cemetery Brook. The EMCC sites are on an intermittent storm drainage on the Eastern Maine Community College Campus.

II. Methods

Field Methods

We used two different strategies for field sampling, namely (1.) volunteers who are distributed throughout the watershed (8 sites) and who sampled at approximately the same time and (2.) automated environmental recorders called "data sondes" that provided a lot of detail from a single site. The sondes were programmed to sample at hourly intervals. Depending on the probes installed on the sonde, they may record water depth, water temperature, specific conductance, pH, dissolved oxygen, and turbidity. Volunteers measured water temperature, dissolved oxygen (DO), and specific conductance or total dissolved solids (TDS). In addition, water samples were taken in the summer and fall for *Escherichia coli* (*E. coli*) bacteria. Samples were taken for turbidity analysis any time the water looked muddy. The bacteria and turbidity samples were analyzed in the DEP lab in Bangor. Volunteers used various sample strategies organized primarily by season. In the fall of 2007, and in the spring of 2008 samples were collected after storm events whenever there was at least an inch of rain recorded at the Bangor International Airport. In the summer of 2008, volunteers collected weekly samples. Finally, in the fall of 2008, sampling was scaled back to once per month.

The volunteers usually collected samples on their way to work in the morning or on their way home in the late afternoon. Thus, samples were taken within 8 hours of each other. It was not

possible to fine-tune the storm event sampling with any relationship to stages of the storm or runoff (i.e., we did not try to sample the "first flush" of pollutants from the early part of a storm). Also, in terms of analysis, early morning water temperatures are often the lowest of the day while late afternoon temperatures are often the highest. Oxygen also follows a daily cycle in aquatic environments, with early morning generally representing the low point of the day (due to no photosynthesis over night) and late afternoon is often the high point. All of our volunteer data was a mixture of early or late in the day samples.

Field measurements by volunteers were made with hand-held mercury-free thermometers, Oakton TDS or Hanna conductivity pens. Dissolved oxygen was measured with LaMotte syringe-style Winkler titration kits. The TDS/conductivity pens were calibrated in the fall of 2007 using a single point calibration. Volunteers practiced using the Winkler kits at Bangor High School using an oxygen-saturated solution. Field samples were collected in 100 ml polycarbonate bottles from the stream bank or from the middle of the stream for bacteria and turbidity analysis. *E. coli* were analyzed using the IDEXX Colilert process and turbidity was analyzed using a Hach 2100 turbidity meter. The turbidity meter was calibrated initially at the beginning of the season using a three point calibration. Prior to the analysis of any samples, the Hach 2100 meter was tested against 3 turbidity standards.

Data sondes are automated programmable environmental recorders. The units we used were YSI model 600-XLM, 6920 or 6600 EDS units. The sondes were calibrated and serviced according to USGS protocols for stream deployments (USGS 2000). Most of our sondes were equipped with depth sensors, but the 6600 EDS was not. The turbidity probes are only compatible with the 6920 and 6600 EDS units. Since turbidity is known to be a problem in the lower Penjajawoc, the turbidity probes were

deployed at Evergreen Woods in Meadow Brook (site MB-1) and in Penjajawoc Stream (PJS-2) in late winter and spring.

Data Analysis

Our data is represented graphically and some summary statistics are used for comparative purposes. Median values are used instead of means, because of the nature of the conductivity and turbidity results (brief spikes of extreme values). A median is a value that represents the middle of a population of values, so that one-half of all values are below this value and one-half lie above. A mean is the same thing as an average, and is more sensitive to a few large values that pull the mean away from the central tendency. We wanted a value that best described the central tendency of a group of data points.

In order to help explain causal relationships, we relied on weather data from the Bangor International Airport (BIA). This is available on-line from the NOAA National Climatic Data Center (http://www.ncdc.noaa.gov/oa/ncdc.html). Daily air temperature and precipitation data is available on-line (and is free to other government agencies). The depth sensors from the sondes, when available, were used to show changes in stream stage.

Our water quality results were interpreted in terms of the state classification system for natural waters MRSA Title 38, Article 4A (see References). Penjajawoc Stream and its tributaries are classified as Class B. See Table 1 for Maine's legal criteria for Class B waters.

Table 1. A summary of Maine's water quality criteria for Class B waters.

Aquatic uses	Suitable for drinking water supply after treatment, fishing, reacreation in and on the water

	and as habitat for fish and other aquatic life
Habitat	Shall be characterized as unimpaired
DO	Shall not be less than 7.0 ppm or 75% whichever is higher, except that for the period from October 1st through May 14th, in order to ensure spawning and egg incubation of indigenous fish species the 7-day mean DO shall not be less than 8.0 ppm in identified fish spawning areas. However, were natural conditions, including marshes bogs, and abnormal concentrations of wildlife cause DO to fall below the minimum standards, those waters will not be considered to be failing.
Bacteria	Between May 15th and September 30th, the number of Escherichia coli bacteria of human origin in these waters may not exceed a geometric mean of 64 colonies per 100 ml or an instantaneous level of 427 colonies per 100 ml

III. Monitoring Results and Discussion

Water Temperature

Temperature has profound impacts on aquatic organisms. All living things have optimal ranges of temperatures for feeding, growth, and reproduction, and become stressed when temperatures exceed those ranges. For instance, Atlantic salmon thrive in waters that range from 15-19º C (59-66º F) (Danie et al 1984) and are excluded from stream reaches where summer temperatures exceed 24º C (75º F) for several days. Brook trout prefer stream reaches where temperatures do not exceed 18ºC (64º F) (EBTJV 2005) and can tolerate exposures up to 24ºC (75ºF) for 24 hours or less (Brungs & Jones 1977). Temperatures influence the solubility of oxygen and other gasses, so that even unpolluted warm water can have critically low oxygen levels. Temperature also influences respiration rates, so that bacterial decomposition uses up much

more oxygen (called “biological oxygen demand”) at higher temperatures.

Temperature summary statistics are presented in Table 2. The median for PJS-4 was not calculated, since this site is over-represented with spring and fall (cold) values. Given the current conditions, Penjajawoc Stream appears to be too warm in the summer to support salmonids and other coldwater species. On the other hand, note how different Meadow Brook is compared to other tributaries or reaches of the Penjajawoc. It is at least 5º colder (9º Fahrenheit) than other bodies of water in this watershed and appears to have a temperature regime that would support brook trout. One of our volunteers who grew up in the area, says that brook trout were found in the watershed “about 20 years ago” but disappeared “soon after beaver became established.” The last 20 years has also seen a lot of development along the Hogan Road and in the US I-95 parts of the watershed.

Table 2. Volunteer data for water temperature, the summary statistics are given for most sites. Values are in degrees C. No values exist for PJS-6. Site PJS-4 (where we had access problems) had only 5 values, one summer value and the rest from spring or fall. The range is probably representative but the median (4º) is not and was not put in the table. The Penjajawoc Stream sites are listed from the highest to the lowest in the watershed and the two most important tributaries Meadow and Cemetery Brooks are listed at the bottom. The EMCC sites are relatively new, with limited data, and are not discussed in this report.

	No. values	Median	Range
PJS-6			
PJS-5	3	24º	24-27º
PJS-4	5		0-27º
PJS-4b	21	20º	5-25º
PJS-3	28	17.5º	0.5-25.5º
PJS-2	22	17.5º	0-28.5º
PJS-1	18	18º	0-27º
MB-1	22	12º	0-16º
CB-1	17	17.5º	0-23º

The seasonal water temperature pattern in the lower river (site PJS-1) is provided in Figure 3. While air temperatures remained 20-35º C (in the 70's and 80's F) during the day from July through August, July was dry while August was wet. Rain storms and higher flows moderated stream temperature in August. However, during summer low flows the Penjajawoc exceeds state water temperature criteria for cold water fishes.

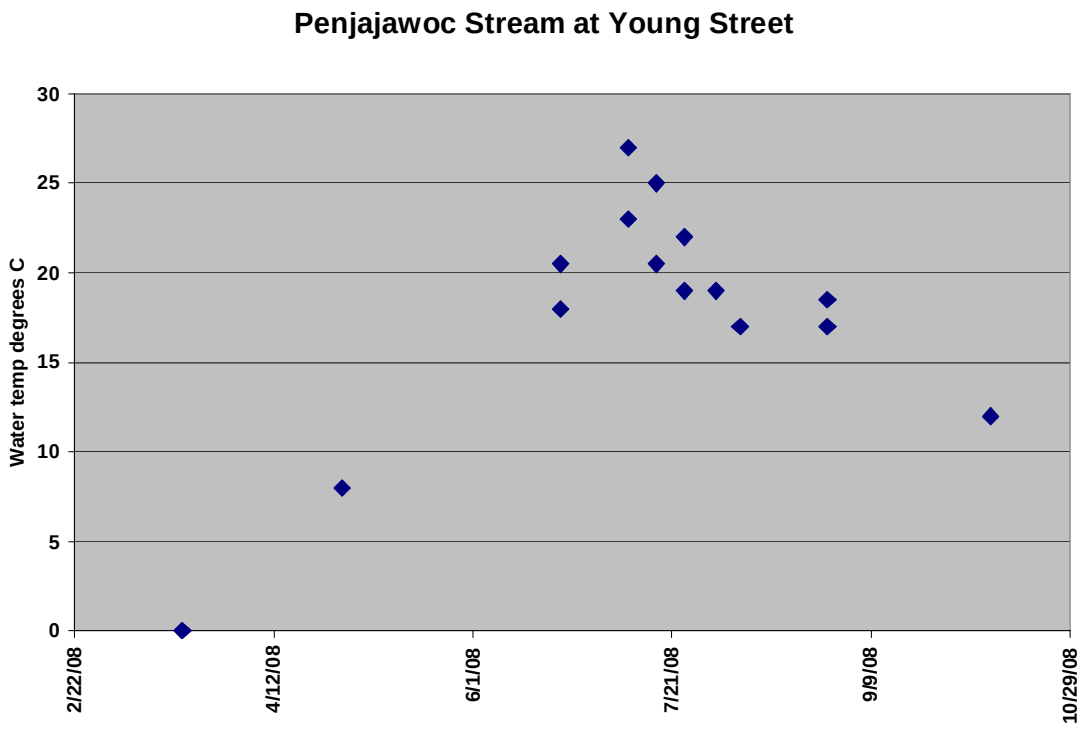


Figure 3. Volunteer water temperature data from the Penjajawoc at Young's Street (PJS-1) near the confluence with the Penobscot River. Volunteers mostly sampled in late afternoon after work, 5:00-6:00 pm.

Dissolved Oxygen

Oxygen is one of the limiting factors that led to Penjajawoc Stream being listed as impaired. While oxygen is 20% of the air that we breathe, oxygen is not very soluble in water. Instead of a percentage (parts per hundred), we measure dissolved oxygen in parts per million (ppm, also sometimes expressed as mg/L). Water that has 12 ppm is thought to have a lot of oxygen. Dissolved oxygen (DO) levels of at least 7.0 ppm or 75% oxygen saturation are needed for good stream health and to maintain the most sensitive aquatic organisms. Many animals are excluded, or survive only on the margins when DO levels are below this threshold. Since no fish spawning areas have been identified in the

Penjajawoc watershed, the Class B water quality criteria require a value of at least 7.0 ppm or 75% saturation, unless the low DO is attributed to natural conditions. Acute lethal limits for brook trout and many other fish species range from 2-4 ppm for 92 hour exposures (Raleligh 1982).

DO concentrations are influenced by mixing with the atmosphere (as with water turbulence), water temperature (oxygen is less soluble in warm water), biological respiration (the use of oxygen by plants, animals and bacteria), and by photosynthesis (a daytime process that produces oxygen). All of these influences are important for the Penjajawoc. The volunteer results are summarized in Table 3.

Table 3. A summary of the median and ranges of dissolved oxygen values (in parts per million, or ppm) is given for all the stream and tributary sites. The Bangor Land Trust site (PJS-6) was added late in the season and did not have a dedicated volunteer to do the monitoring, and so only has two measurements, one from late summer and one from fall. All sites are listed from the highest to the lowest position in the watershed. The two principal tributaries, Meadow Brook and Cemetery Brook are set off from the mainstem sites.

	No. values	Median	DO Range
PJS-6	2	6.2 ppm	5.2-7.2 ppm
PJS-5	8	3.2 ppm	1.8-7.8 ppm
PJS-4	5	4.7 ppm	2.1-8.3 ppm
PJS-4b	21	5 ppm	1.6-8.5 ppm
PJS-3	27	5.4 ppm	2.0-11.0 ppm
PJS-2	18	8.4 ppm	6.7-13.0 ppm
PJS-1	18	7.2 ppm	6.2-8.6 ppm
MB-1	18	6.8 ppm	3.0-12.2 ppm

CB-1	12	8.5 ppm	6.3-12.5 ppm

In the upper watershed, site PJS-6 on the Bangor Land Trust parcel, DO values is a bit low, but not too bad given the origin in the upstream marsh. Otherwise, the upper watershed sites (PJS-5, PJS-4, and PJS-4b) had low oxygen except during high spring flows when the stream was cold and fast. Almost all summer values are below 7.0 and many are below 5.0 or even below 4.0. This is true of both morning and late afternoon samples. The lowest values coincide with the lowest flows (the end of July and mid to late August). The median values for the study period are in the range where severe impairment of the aquatic community is expected. This is also what the DEP Biomonitoring Program found. When the median is 5.0 ppm, then 50% of the DO values are below this value. In this case, notice that the ranges show the lowest values where oxygen is nearly depleted. Oxygen values in the lower watershed (PJS-2 and PJS-1) and Cemetery Brook are relatively good.

Not shown in this data, low dissolved oxygen was observed in late winter as open water developed during February thaws. The old railroad bed in Penjajawoc Marsh was not accessible this time of year. However, extremely low DO values were observed behind Joanne Fabrics and 33 Penn Plaza (PJS-4 and PJS-4b) and a pungent organic odor, similar to sewage was noted. DO values were around 1-2 ppm in spite of high flows due to rain-on-snow events. Access was also available at Evergreen Woods (PJS-2) where the organic odor was noticeable, but not as strong. Here DO levels were much improved, ranging from 12-15 ppm. Bacteria samples from this period show that this odor was not due to sewage (see bacteria discussion below). The low DO and odor were apparently due to the development of anoxic conditions underneath the snow and ice cover on Penjajawoc Marsh. The peaty stream channel and dead marsh vegetation provided food for

microbial respiration. In the absence of photosynthesis under the snow cover, and with gas exchange with the atmosphere prevented by ice cover, oxygen was depleted in the winter. Late winter thaws, especially rain on snow events created floods that opened up some access points and allowed the water to ventilate. The odor is "marsh gas," which is actually a mixture of gasses. This decomposition under winter ice is a natural process, but the resulting odor and low oxygen may be influenced by a dam remnant behind Joanne Fabrics. The dam reduces circulation through the mash, thereby accentuating oxygen problems.

The site below Staples at the Bangor Mall (PJS-3) was influenced by beaver activity, and so our results here were not typical for a free-flowing stream. The box culvert at the Interstate I-95 crossing may also contribute to ponding in this area. There was some improvement at downstream sites relative to the 33 Penn Plaza site (PJS-4b). DEP staff monitored DO with an electronic meter while walking downstream from behind Joanne Fabrics (PJS-4) (this is the first riffle area below the Penjajawoc Marsh and is often the site of odor complaints in the spring). DEP found some partial DO recovery by 33 Penn Plaza (PJS-4b). DO improved some more in the riffles below Stillwater Avenue but dropped a little in the slower, ponded water below Staples (PJS-3). The volunteer data reflect this general pattern.

The Evergreen Woods area is the most scenic part of the lower stream. The professional park was developed with substantial forest buffer left intact. Stream shading is good overall. Meadow Brook is also shaded, but much of the stream floodplain in this area is marshy. The plant canopy is limited to willow and alder scrub. The Meadow Brook channel is incised throughout much of this reach with vertical banks 1-5 feet deep. This channel erosion was identified in the Parish & Kleinschmidt (2006) geomorphology report. Rocky riffles in Penjajawoc Stream (PJS-2) maintained good oxygen levels, even during the low flow period

of mid to late July. Only one value of 18 values was below 7.0 ppm (and 6.7 was probably close enough to 7.0 for aquatic organisms). On the other hand, Meadow Brook had poor DO during summer low flows. This stream is smaller than the Penjajawoc at the same level in the watershed, and it does not have as much rocky riffles. Summer heat, lower low flows, and less turbulent mixing are important contributors to seasonal low DO in this tributary. In spite of low DO (often in the 4's in the summer, and as low as 3.0 ppm) some minnows (an unidentified dace) were observed throughout the summer months at this site. Based on some July and August samples where we have both morning and afternoon data from the same sites, the daily range in DO is less than 1 ppm at PJS-1 and MB-1.

The influence of photosynthesis and the impact of respiration in Penjajawoc Marsh can be observed in a comparison of sonde records from Joanne Fabrics (PJS-4) with Evergreen Woods (PJS-2) (Figure 4). DO climbs during the day due to photosynthesis and falls at night when there is only respiration. In this case, DO is given as a percentage relative to potential oxygen saturation (100%). Large daily swings in DO (20% in this case) show that there was a lot of both photosynthesis and respiration. The low oxygen levels in the March are due to ice and snow cover on the marsh and oxygen depletion by bacterial decomposition above PJS-4. The Joanne Fabric site has extensive year-around moss cover on submerged rocks. In the summer, this site also has a lot of submerged and emergent vascular plants. All of the other sample sites have very little vascular plant material, but many have some algal growth (PJS-1 and PJS-2) and some have a lot (PJS-3). DO levels fell in late April at PJS-4 due to warmer temperatures, high respiration (high biological oxygen demand), and a dry spell that reduced flow and turbulence. The reduced flows caused some algae-covered rocks to dry out at Evergreen Woods, thereby reducing the daily DO range, but DO remained high due to

turbulence in the riffles. A huge storm on April 29 (3.09 inches of rain in 24 hours) improved flows and re-wetted aquatic habitat.

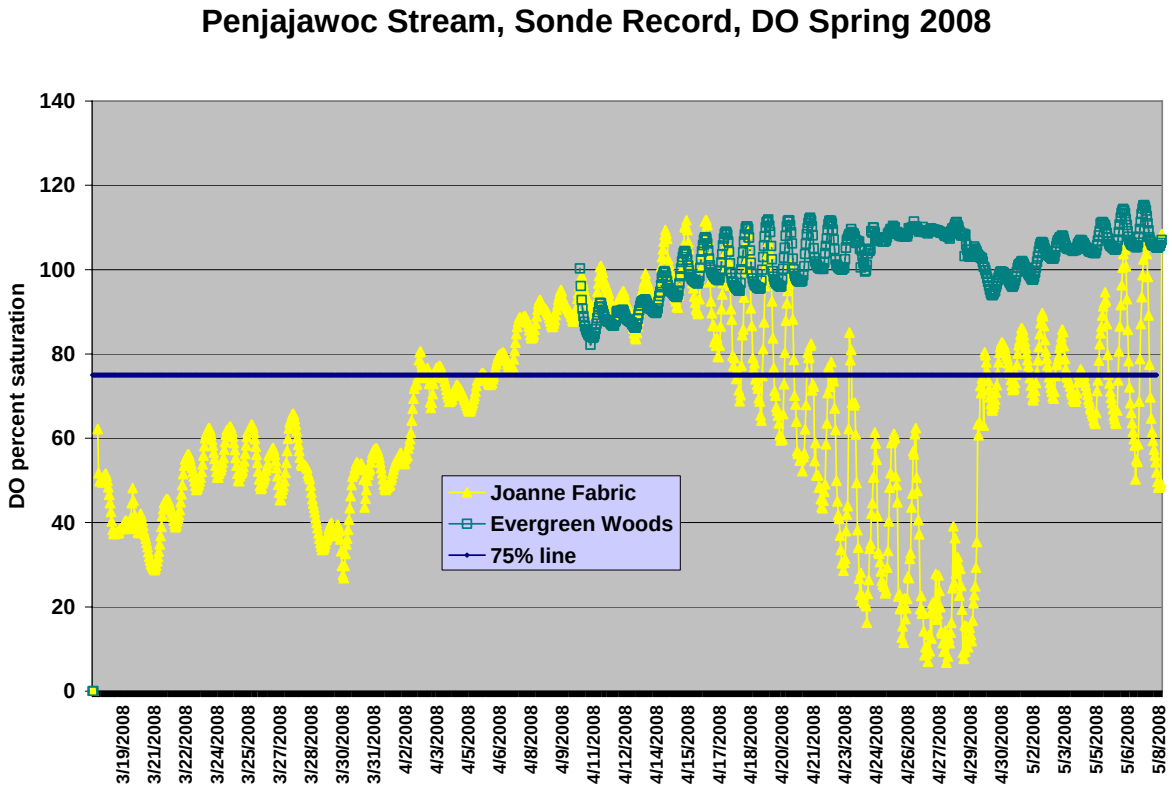


Figure 4. The sonde dissolved oxygen (DO) record for two sites. DO values are here given as percent saturation. A DO of 75% saturation (the blue line) is a threshold for maintenance of aquatic communities. Values exceeding 100% saturation are due to an abundance of photosynthesis.

Conductance and Total Dissolved Solids

Conductivity (the ability of a sample to conduct an electrical current) is dependent on the Total Dissolved Solids (the amount of mineral and organic salts in a sample). The two are closely related and easily converted from one into the other (we used specific conductance in uS X 0.707 = TDS in mg/L). Due to a mix up in ordering equipment, we ended up with some of each type of meter.

For simplicity, we will discuss our results in terms of specific conductivity. We found a general trend from low conductivity to high as one traveled lower in the watershed (Table 4). Background specific conductance is probably about 113 uS based on the uppermost site. The strongest salt sources in the watershed are the interstate highway I-95 and the development along the Hogan Road, most easily seen in the maximum values. Based on median values, Meadow Brook appears to be more strongly influenced by salt (median 1307 uS) than the larger Penjajawoc Stream (median 523 uS at PJS-2). But the Penjajawoc has the most extreme values. Cemetery Brook is in the lower watershed but lacks large parking areas and has fewer busy roads. The seasonal character of the salt spikes indicate winter salt sand is the predominant source. Salt also soaks into the ground and is released gradually through the spring and summer.

Table 4. Specific conductance values from volunteer collections with medians and ranges. Values are in micro-Siemens (uS) per cm. The sample sites are arranged from the upper watershed to the lower, and the two major tributaries are listed separately.

	No. values	Median	Range
PJS-6			
PJS-5	5	113 uS	99-113 uS
PJS-4	5	155 uS	85-268 uS
PJS-4b	20	250 uS	84-510 uS
PJS-3	27	410 uS	146-800 uS
PJS-2	23	523 uS	165-4254 uS
PJS-1	15	593 uS	189-3200 uS
MB-1	23	1307 uS	565-1583 uS
CB-1	15	311 uS	135-382 uS

Data sondes were deployed in late winter and spring at Evergreen Woods to examine conductivity/salinity and turbidity in the lower watershed. Like the volunteer grab samples, Meadow Brook had much higher median conductivity but the Penjajawoc had the highest maximum values. In the sonde records, specific conductance in Penjajawoc Stream varied from 187 to 10,305 micro-Siemens (uS) and had a median value of 726 for the February 4 to March 7 deployment (Figure 4). At Meadow Brook specific conductance varied from 532 to 8,650 uS and had a median value of 1,684 uS for January 30 through May 8 (Figure 5). Interestingly, the maximum values occurred on different storms for the two sites (the sites are about 100 m (300 ft) apart). All of these conductivity values were most variable in late winter (February and early March) as opposed to the spring (sonde records continued into April). Sharp spikes of high conductivity were generally associated with rain on snow and/or thaw events. An exception is March 3 which was cold with 8 inches of snow and resulted in mid-afternoon blizzard conditions. Road salt applications were heavy throughout the day. We believe that salt spray from traffic and salt-induced melting on the paved road led to the conductivity spike.

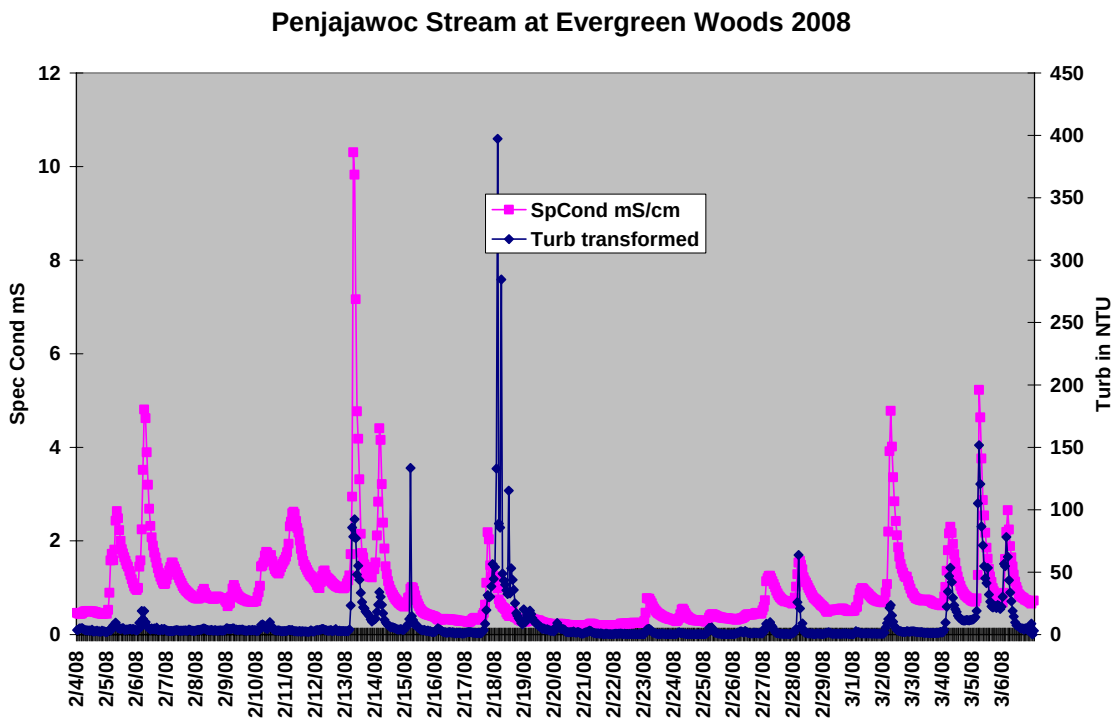


Figure 4. Sonde recording of specific conductance and turbidity in Penjajawoc Stream at Evergreen Woods (site PJS-2). Only the February to March deployment are shown. Specific conductance is given here in mS while turbidity is given in NTU. One mS is 1,000 uS. Since each data point is approximately an hour, notice how short the maxima were.

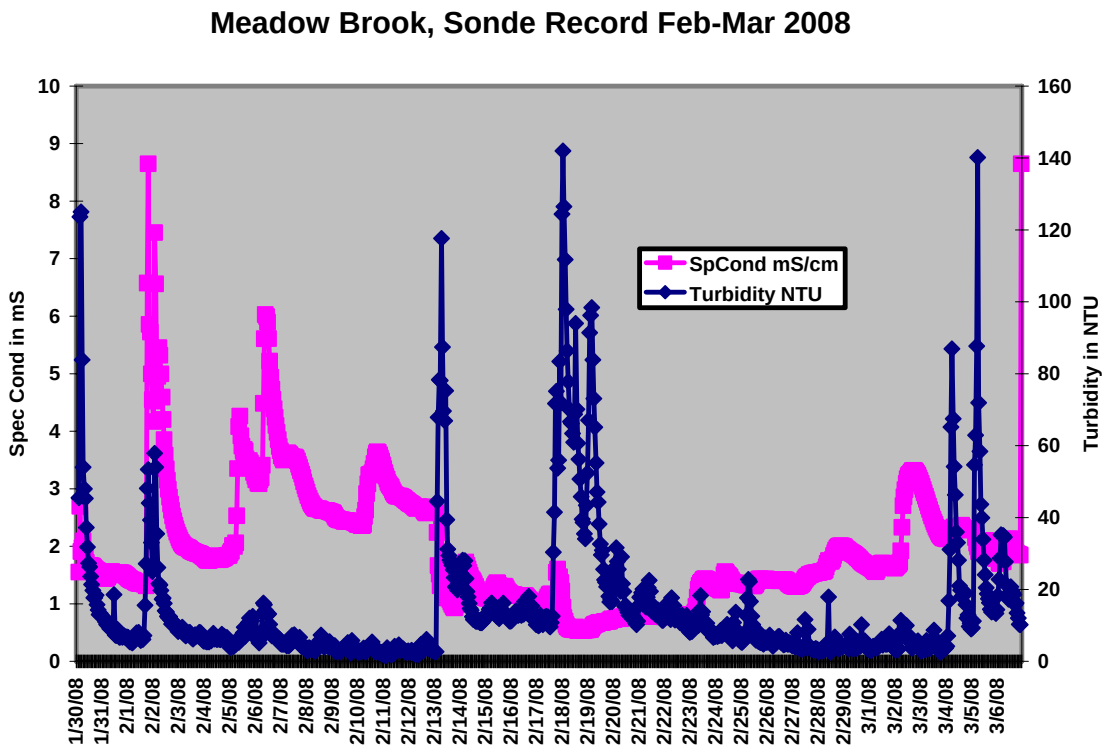


Figure 5. Sonde record for specific conductance and turbidity at Meadow Brook is shown for Evergreen Woods (site MB-1). Only the February to March deployment is shown. Specific conductance is given here in mS while turbidity is given in NTU.

Smaller spikes (e.g., February 23, 24, and 25) occurred during the day and were due to minor thaw events. After a thaw on March 20, specific conductance varied only 106 to 2,073 uS in the Penjajawoc and ranged from 163 to 960 uS at Meadow Brook. The record has mild undulations that represent daily thaw events with only one peak over 1,000 uS during a storm. A heavy rainstorm with 3.09 inches of rain occurred on April 29. There was a spike of conductivity at the Penjajawoc site (2,073 uS) but at the same time a dip occurred at Meadow Brook. Our lowest values of the sonde records occurred during (Meadow Brook) and immediately after this storm (Penjajawoc Stream). This late in the year, without new salt applications on the roads, rain diluted the salt that had accumulated in soils.

Maine does not have numerical water quality criteria for conductivity or TDS, but the narrative standard that water quality be adequate to support natural aquatic communities would apply. New Hampshire's Dept. Environmental Services also does not have a numerical standard, but DES does consider streams with chronic conductivity exceeding 501 uS to be "highly impacted" (DES 2008). DES further notes that conductivity is generally closely related to chloride concentration and that any conductivity greater than 850 uS is likely to exceed the state chloride standard for chronic exposure of 230 mg/L. Maine uses the same chloride standard and only the lowest Penjajawoc site (PJS-1) and Meadow Brook appear to exceed this standard.

A study of Dinsmore Brook in Windham New Hampshire by DES (DES 2007) shows that this partially urban (30%) and partially rural (60% forested) watershed is heavily impacted by winter salt sand. The watershed is 0.55 square miles. Dinsmore Brook with an average flow of only 0.97 cubic feet per second (cfs) and an average Cl concentration of 148.9 mg/L is exporting 92.44 tons of chloride per year. Roads are the largest source of salt (71%) and parking lots are second (26%). There were no salt sand storage piles in the watershed. Water softeners and atmospheric deposition were very minor contributors (0.7 and 1.7% respectively). Application rates on roads varied from 3-10 tons per linear mile, with the heaviest applications on highways. The application rate on parking lots was 4.8 tons per acre. For Dinsmore Brook, all of the violations of state water quality standards for chloride occurred in summer during the low flow period.

Turbidity

The data sonde records for turbidity are displayed with conductivity in Figures 4-5. Like conductivity, the variability in turbidity was very high in the winter and spring. Also like

conductivity, the largest spikes occurred with storms, especially rain on snow events, and to a lesser extent with the melting of snow and ice. Meadow Brook had a higher background turbidity (median 8.1 NTU) than the Penjajawoc (3 NTU). However, the range was greater in the Penjajawoc (Penjajawoc 0-397 NTU, Meadow Brook 2-142 NTU). Unlike conductivity, turbidity spikes continued in the summer and fall during strong storms at both sites. Another difference is that specific conductance was often strongly influenced by light rain or mild thaws, while turbidity responded to strong storms and thaws that generated a lot of runoff and high current velocity. In other words, salt was easily carried by any moving water, but road sand transport and stream bed scour occurred only when lots of water was moving fast. Turbidity was an issue even in the summer, long after road crews had swept up accumulated road sand. Sediments are clearly stored and re-suspended from within the stream bed.

During summer baseflows conditions, the water was normally clear in the Penjajawoc but ranged 0-9 NTU. In Meadow Brook late winter and spring baseflow turbidities ranged around 3 NTU at night and around 6 NTU during the daily melt cycles. In the summer, Meadow Brook was often clear like the mainstem. Stormwater turbidities were as high as 736 NTU (a volunteer grab sample from Meadow Brook during the April 29 storm).

DEP does not have a numerical standard for turbidity, but there are direct links with turbidity to the health of fish and invertebrate communities. New Hampshire DES requires that water clarity be “as naturally occurs” in Class A waters and be no more than 10 NTU greater than natural for Class B (New Hampshire only has the two classes of flowing freshwater) (DES 2008).

In Maine, we interpret turbidity in terms of its impact on the need to maintain “habitat for fish and other aquatic life...” and that the habitat be characterized as “unimpaired.” In order to interpret

turbidity exposure into an impact on fish according to Newcomb & Jensen (1996) the turbidity data (an optical property) has to be converted into total suspended solids (TSS, a weight of suspended material expressed in mg/L). The impacts to fish come from both the intensity of the stress (the authors use TSS) but also the duration. We do not have both turbidity and TSS data for the Penjajawoc. However, we do have a regression equation that we used to interpret turbidity in NTU as mg/L TSS based on data from the Sheepscot River (Whiting 2009). If we use this model, then for Penjajawoc Stream our worst-case example was approximately 2 hours where there was at least 350 mg/L TSS. This translates as a "moderate stress" for non-salmonid freshwater adult fishes and is also moderate for eggs and fry. However, for the longer term exposures in Penjajawoc Stream, we had 2 days with variation around 50 mg/L TSS which is a "severe stress" for adults and a "paralethal effect" for eggs and fry. For Meadow Brook we have 2 days with TSS variation around 55 mg/L which is also a severe stress for non-salmonid adult fishes and a paralethal effect for eggs and fry. The longer term but weaker exposure scenario is 2 weeks with variation around 20 mg/L TSS. This is a severe stress for non-salmonid adults and a "lethal effect" that is expected to result in about 20-40% losses of eggs and fry.

We need to be aware that an interpretation of TSS in the Penjajawoc based on data from the Sheepscot is a rough approximation. Still, in spite of the uncertainty in the interpretation, the conclusions are striking. The observed ranges of turbidity and the number of hours or days duration are known to range from moderate stresses to lethal conditions for non-salmonid freshwater fish species (Newcomb & Jensen 1996). Fish eggs and fry are most vulnerable.

Bacteria

High bacteria counts were observed at all sites (Table 5). The highest values occurred in the upper and lower parts of the watershed. Since most of the medians are greater than 80 colonies per 100 ml, there is good reason to have health concerns about contact with the water. However, these results do not necessarily violate Maine's bacteria standards. Because there were high values in the upper watershed, it is probable that at least at PJS-5 the bacteria source was wildlife (beaver and water fowl are common in this reach). There was also an active beaver pond below the Staples site (PJS-3).

Table 5. A summary of *E. coli* bacteria results for weekly summer samples. Samples taken during both low and high flows are represented. Values are in number of *E. coli* colonies per 100 ml sample and are "most probable number" estimates using the IDEXX Colilert method. The maximum number possible with this method is 2,419.

	No. values	*E coli* colonies Median	*E coli* colonies Range
PJS-6			
PJS-5	4	90	58-2419
PJS-4			
PJS-4b	5	75	61-113
PJS-3	5	210	120-517
PJS-2	14	131	13-2419
PJS-1	6	131	13-2419
MB-1	5	59	13-166
CB-1	2	128	18-238

The highest bacteria count possible with the IDEXX method is "greater than 2,419 colonies." In order to calculate medians, these had to be converted to a number, so 2,419 was used. This is the lowest possible number for this result, and so this causes the median value to be underestimated. Because there are also many

low values and so few very high values, we assume the results are not due to leaking sewer lines.

Residential neighborhoods can be a significant source of *E. coli* due to non-point source (NPS) pollution due to inadequate cleanup after domestic animals. In the Penjajawoc watershed, residential areas are limited to the east side of Meadow Brook and the lower part of the Penjajawoc. Sites MB-1 and PJS-1 actually tend to have low bacteria counts (except for after rains at PJS-1).

The Landfill

The Bangor Land Trust site (PJS-6) was added in late summer due to the concern about the Kittridge Landfill. The landfill was closed over a decade ago, but it does have wetlands on two sides. PJS-6 is downstream of the landfill and there were concerns about potential water quality impacts. DEP visited the site on September 15 and found that pH was 7.23. A water sample was taken for analysis at the Sawyer Environmental Chemistry Research Lab at the University of Maine. While heavy metals were very low, the alkalinity was very high (2,327 ueq/L or 116 mg/L). It is possible that the extreme alkalinity was due to the landfill. Given the amount of wetlands on at least half of the landfill perimeter, some problems are likely. DEP plans some monitoring follow-up in the summer of 2009.

IV. Summary

Penjajawoc Stream is an urban stream that is currently impacted by the amount of development in its watershed. For instance, hydrologic changes have caused stream bed erosion in some locations and sediment deposition in other areas (Parish & Kleinschmidt 2006). Summer low flows and loss of riparian vegetation has led to seasonal high temperatures and low oxygen that causes impairment of aquatic communities (DEP 2007). This

is especially true in the middle of the watershed, and there is a partial recovery at the bottom. In addition to human impacts, Penjajawoc Marsh develops anoxic conditions under winter ice and snow cover. This generates strong odors during winter-spring runoff and causes very low oxygen in spite of strong flows. Beaver also influence water quality, by increasing solar heat gain in the summer and by reducing stream velocity and circulation.

In this paper, we have confirmed earlier assessments, and have generated some baseline data for future comparisons as stormwater improvements are implemented. The bacteria data suggest that the Penjajawoc and its tributaries may be unsafe at times for recreation. However, our preliminary results suggest the sources of bacterial contamination may be wildlife. We have also documented salt sand and turbidity impacts on the lower river. Salt contamination is known to cause impairment of aquatic communities. Turbidity has another strong negative impact on aquatic communities in this watershed. Turbidity values spiked during storms and runoff events, and were a significant stress for fish. The observed ranges and our initial interpretation of the turbidity data suggest that fish will struggle to survive in this stream. Fish communities have been impaired due to multiple stressors (including low flows, warm water, low DO, high conductance/chloride and turbidity/TSS). Although we did not study invertebrate communities, we know that they are influenced by the same issues. Our results are similar to those found in other Maine urban streams (DEP 2005), including Birch Stream which is also found in Bangor.

The good news is that the City of Bangor, local businesses, and citizen partners are currently engaged in a watershed management plan to improve the aesthetics and water quality of this small stream. Contractors have been engaged in stormwater modeling and in the development of stormwater retrofits that will lead to

improvements in stream quality. And now a local Stream Team is trained and prepared to monitor the recovery process.

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