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TO: Sharon Jackson, Town Manager, Fryeburg, Maine

FROM: Peter Garrett

DATE: May 3rd, 2011

RE: **Flow in Wards Brook. Update based on 2010 Data and Review**

Background

In my last report to the Town, dated July, 2010, I addressed the issue of monitoring flow in Wards Brook, and gave a summary history of our work for the Town in modeling groundwater flow through the aquifer. I also noted how the removal of water for off-site transport and bottling inevitably reduces flow in Wards Brook.

From the results of our modeling, we recommended that groundwater withdrawals for the bottled water industry be limited to 603,000 gallons per day (gpd) in order to retain a reasonable flow in the Brook. The volume of water removed from the watershed by the WE Corporation and Nestle Waters North America (a.k.a. Poland Spring Bottling) amounted to about half or less of the recommended 603,000 gpd limit during 2008 and 2009.

I described the difficulties of measuring flow in the Brook, and our efforts with the Fryeburg Water District in 2009, to construct a weir and flume to accurately gauge flow in Wards Brook. Because we were not permitted to construct a weir and flume in the Brook, we resorted instead to calibrating a "rating curve" during the summer of 2010. To do so, we measured flow across the Brook and compared flow to water level in the Brook. However, as explained below, we were not satisfied with its accuracy for several reasons.

In this report I discuss the important issue of baseflow in Wards Brook and other rivers. This is intended as useful background information for a discussion of water flow out of the Aquifer, water withdrawals from the Aquifer, and measurements of flow in Wards Brook.

Baseflow in Wards Brook and Elsewhere

Baseflow is a concept that has evolved over several decades of study. Baseflow includes the flow of water in a stream that is derived from groundwater discharge. It is sometimes referred to as dry weather flow and is distinct from rapid runoff (from rainfall or snow melt) much of which never enters groundwater or enters shallow soils only briefly. Rapid runoff (also known as "quickflow") causes flow in streams to increase greatly above baseflow.

Baseflow is derived from groundwater that is in temporary storage in the Aquifer. Baseflow changes on an annual cycle. It decreases as aquifer storage is depleted during summer season and droughts. It increases to a maximum in springtime when snow melt is added to rainfall, or after heavy rain when shallow flow through groundwater is added to the quickflow derived from rapid runoff.

Hydrographs (graphs of rate of flow vs. time for a particular stream gauge) show peaks and valleys of flow. Baseflow is represented more or less by a line connecting the valleys, which represent the lowest flows during any given period of time. The graph below, from a USGS web site from which one can download measured flows at specific points throughout the US, illustrates the concepts.

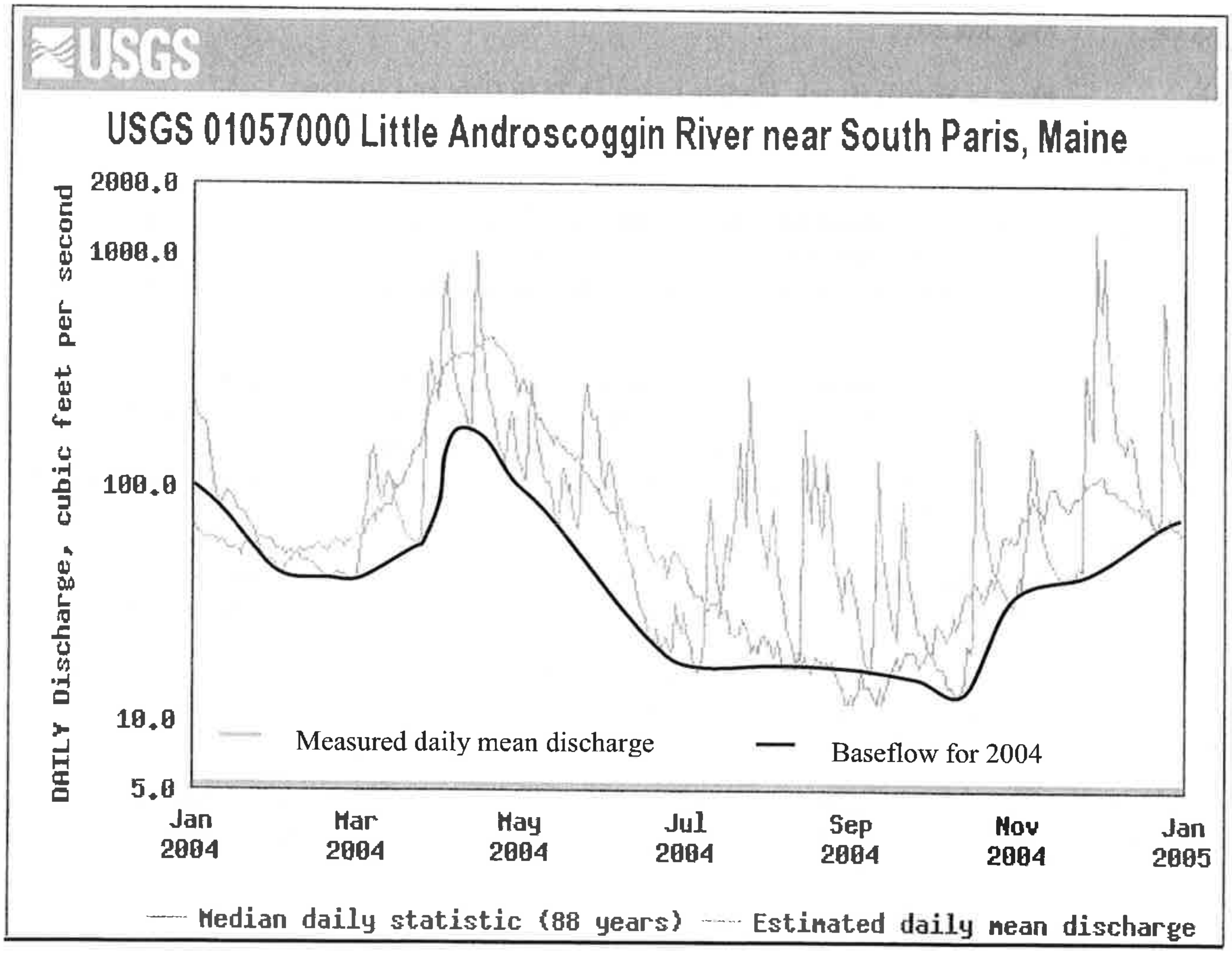


Figure 1: Hydrograph for the Little Androscoggin near South Paris, Maine, the nearest US Geological Survey gauge site to Fryeburg. Data is for the year 2004.

USGS hydrographs require some explanation, which follows:

- Flows are measured in cubic feet per second (cfs). One cfs is equivalent to about 450 gallons per minute, or 646,000 gallons per day.

- Flow is represented on a log scale, where each major unit is 10 times the value of the one below it. The log scale tends to emphasize drought flows and diminish the graphic peak of flood flows which can be 100 times (2 orders of magnitude) greater than baseflow in a drought. In the case of the Little Androscoggin River drought flow can be about 10 cfs, while the highest flood flows can exceed 1000 cfs.
- The blue line represents actual measured flow (red segments are estimated flows). Peaks represent quickflow added to baseflow.
- The brown line is the average daily flows for the 88 years of record at this particular gauge.
- The baseflow (black) is a line joining the valleys between peaks.

The flow in Wards Brook will not be the same as in the Little Androscoggin. In fact hydrographs for different rivers, even in the same general area, can look strikingly different due mainly to three factors:

- Size of the drainage basin above the stream gauge. Larger drainage basins drain more water and thus flows are higher.
- The proportion of the watershed of the river that is underlain by sand and gravel. Higher proportions of sand and gravel will create a less peaked hydrograph with higher baseflow. This is because snowmelt and rain tend to soak into such soils and emerge slowly as baseflow over several months or longer.
- Local precipitation patterns. Summer rainstorms, for instance, can be localized, and hills tend to get rained on more than valleys.

For these reasons, hydrographs of rivers in neighboring valleys are similar, though not identical. Nevertheless, there is at least a seasonal correlation of flow in all rivers in a region, with an annual double high and low flow pattern typical of hydrographs throughout New England. Maximum flows tend to occur in spring and fall. Lowest flows tend to occur in mid-winter (due to mostly frozen precipitation) and in summer (due to excess of evaporation and transpiration over precipitation).

The actual flow in the Little Androscoggin River in 2004 departed from its median flow considerably over the course of the year. Highest flows were in early December and resulted from a heavy rainstorm, whereas lowest flows were in early October 2004. The actual flow (blue line) was usually either above or below the median flow on any particular date.

The reason for considering the 2004 hydrograph for the Little Androscoggin River is to see if there is any reasonable correlation with data derived from Wards Brook, as measured by Eric Carlson for Pure Mountain Spring at the former V-notch weir beneath Route 113 on a monthly basis, and detailed in a memorandum to the Fryeburg Planning Board. Figure 2 (next page) shows the comparison, with blue points showing the 13 measurements taken on Wards Brook in 2004.

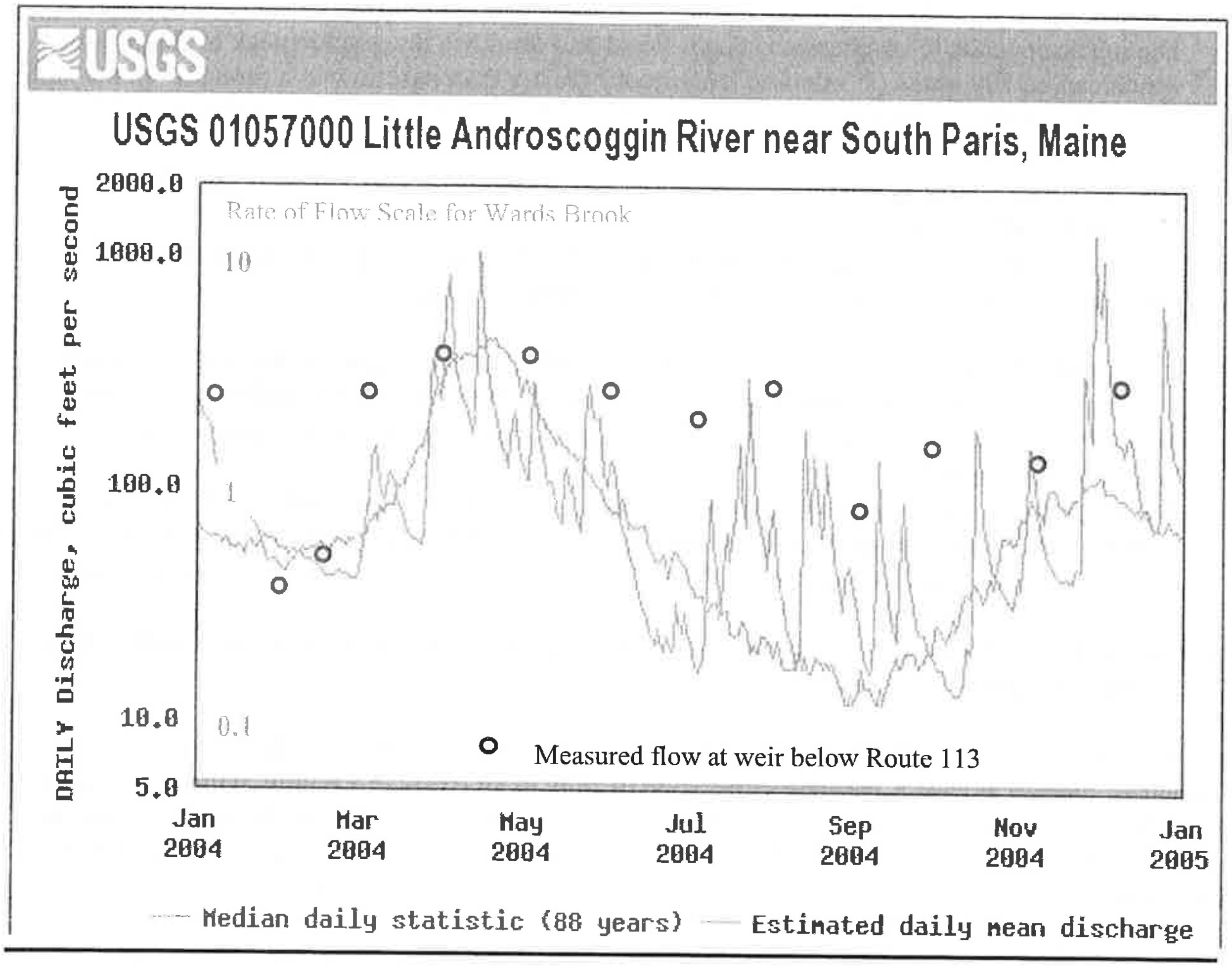


Figure 2. Middle Wards Brook flow compared to Little Androscoggin.

Note that the scale of this graph is still a log scale, but rather than units of 10, 100 and 1000 cfs, the points are plotted on a scale of 0.1, 1 and 10 cfs. This is necessary because the drainage basin of upper Wards Brook (above the Route 113 and Wards Pond) is considerably smaller than that of the Little Androscoggin at South Paris, and thus flows are considerably less.

The two measurements taken in February were lowest, probably because Wards Pond, which drains out beneath Route 113, is frozen in winter. If we ignore those two points, the range of flows was relatively subdued compared to flows in the Little Androscoggin River. The comparison of the USGS daily readings on the Little Androscoggin with the monthly flow measurements for Wards Brook is not entirely fair. Nonetheless, it is noticeable that the range of flow in Upper Wards Brook is slight, varying from 0.75 to 3.4 cfs, or about 0.5 orders of magnitude. This compares with the annual range in the Little Androscoggin which is about 1.2 orders of magnitude.

A relatively subdued annual range in flow is typical of brooks that are primarily spring-fed, such as Wards Brook. High flows in the Wards Brook watershed will cause flood flows, which may not have been captured with the monthly measurements. However, much of the precipitation that falls on the Wards Brook watershed tends to percolate into the sandy aquifer and emerge over the entire year from springs. This results in a relatively high baseflow with subdued peak flows.

One further point about the 2004 hydrograph pertains to the observation of low flow in August, which we used in our 2005 groundwater modeling study to estimate allowable withdrawals of water for bottling to protect the biological integrity of the Brook. The one measurement that was then available to use in our calculations was the August 2004 low flow measurement of 400 gallons per minute (0.75 cfs). However, it can be seen from the Little Androscoggin hydrograph that flows in that river were relatively high during the summer of 2004. Thus the 400 gallons per minute value for August low flow was probably on the high (conservative) side for protection of flows in Wards Brook.

Observations of Spring Flow at Fryeburg Water Company site

On September 16th 2010, during a dry spell following a relatively dry summer, I took a tour of the Fryeburg Water Company well site, where FWC Production Wells #1 and #2 are located. That site is also the historical site of the springs that were once the Water Company's water source. This was prior to the time the wells were drilled, installed and put into service.

The FWC Well #1 is currently used exclusively for Nestle's withdrawals via their pumping station and loading dock. FWC #2 is used every day to withdraw approximately 64,000 gallons to supplement withdrawals from the Water Company's major source, which is FWC #3, located further up in the watershed, off the Porter Road.

During the summer of 2010, according to USGS stream gauge data available on line, flow in the Little Androscoggin River was below the median except during isolated rainstorms. During the previous three and a half months prior to my visit, Nestle had been withdrawing about 500,000 gallons per day. Yet what was impressive about the Fryeburg Water Company site was that much of the property was waterlogged, even around the Well #1 pump house, where a French drain has been installed to keep the ground dry enough to walk over. All springs were flowing abundantly, and Well #2 was overflowing at between 100 and 150 gpm when not pumping (as during my site visit). Abundant flow into Wards Brook, estimated at several hundred gallons per minute, was occurring from the site at three locations beneath the fence that separates the site from the Brook.

Spring Flow elsewhere in the Wards Brook Watershed

Springs are present in several distinct portions of the Wards Brook watershed. The uppermost is in the vicinity of Fryeburg Water Company (FWC) Well #3. The most prolific springs are located in the vicinity of FWC Wells #1 and 2, as described above. There is also a smaller set of springs downstream towards Lovewell Pond. Groundwater also flows out of the Aquifer in minor seeps and springs at many locations along the Brook and its tributaries.

Water Withdrawals from the Wards Brook Aquifer

In my memo of July 2010, I presented data for water withdrawals by the WE Corporation and Nestle. These two entities take water out of the watershed and thereby reduce the flow of water through Wards Brook. The total average daily withdrawals for bottled water in 2008 totaled 305,538 gallons, and in 2009, 241,338 gallons. In 2010 monthly and average daily withdrawals were as in Table 1, below.

Table 1: Water Withdrawals from Commercial Wells, 2010, in gallons

Month	WE Corporation		Nestle	
	Total	**Avg Day**	**Total**	**Avg Day**
January	**74,800**	**2,413**	**4,487,390**	**144,755**
February	**91,050**	**3,252**	**4,235,897**	**151,282**
March	**123,400**	**3,981**	**3,707,585**	**119,600**
April	**215,600**	**7,187**	**10,084,608**	**336,154**
May	**239,900**	**7,739**	**11,984,016**	**386,581**
June	**296,600**	**9,887**	**13,608,790**	**453,626**
July	**309,755**	**9,992**	**17,620,087**	**568,390**
August	**325,925**	**10,514**	**15,159,394**	**489,013**
September	**277,337**	**9,245**	**9,154,616**	**305,154**
October	**122,507**	**3,952**	**5,208,356**	**168,011**
November	**130,622**	**4,354**	**1,771,928**	**59,064**
December	**236,823**	**7,639**	**2,082,780**	**67,186**
Average Daily Withdrawal		6,679		270,735
Total Avg Daily Withdrawal			277,414	

You will notice that total average daily withdrawals from both bottled water wells were less than half the recommended water withdrawal for bottled water export (603,000 gpd), based on our modeling.

Measurement of Flow in Wards Brook

As you will recall, plans to accurately measure flow in Wards Brook by construction of a weir with flume at the Grist Mill site were negated in 2010. The decision against construction of a weir with flume was made by the Army Corps of Engineers and US Fish and Wildlife Service and supported by Maine Inland Fisheries and Wildlife after work had already started on construction of the weir. Maine DEP then reversed a permit by rule that had been awarded in preparation for weir construction. In discussions with the Army Corps, DEP and IF&W, we agreed to measure flow by installation of a staff gauge in a relatively straight segment of Wards Brook and to calibrate vertical water level readings on that gauge with measurements of flow in the Brook using a flow meter. This is the more traditional manner of measuring flow in streams, but is considerably less precise than our proposed weir and flume, especially for low flows, which were our major concern.

A flow gauging site was chosen near where the weir with flume was to have been located. This location was chosen for two reasons, because: a) there are no significant springs in the vicinity; and b) large rounded boulders of granite, typical of glacial till and not found elsewhere in the Wards Brook Aquifer, are present in the bed of the Brook upstream from the site. We interpret the presence of these boulders to represent the presence of a glacial till barrier beneath Wards Brook in this vicinity. The important hydrologic consequence of this interpretation is that the Wards Brook Aquifer is not present beneath this site, and therefore all springs emerging from the Aquifer into the Brook must be upstream of the flow gauging site.

The site is also located a few tens of feet upstream of a set of large square blocks that now lie in the bed of the Brook. These blocks fell into their present position from the collapse of a grist mill dam that was once located at the site. The last standing remnants of the dam can be seen close by (Photo 1).

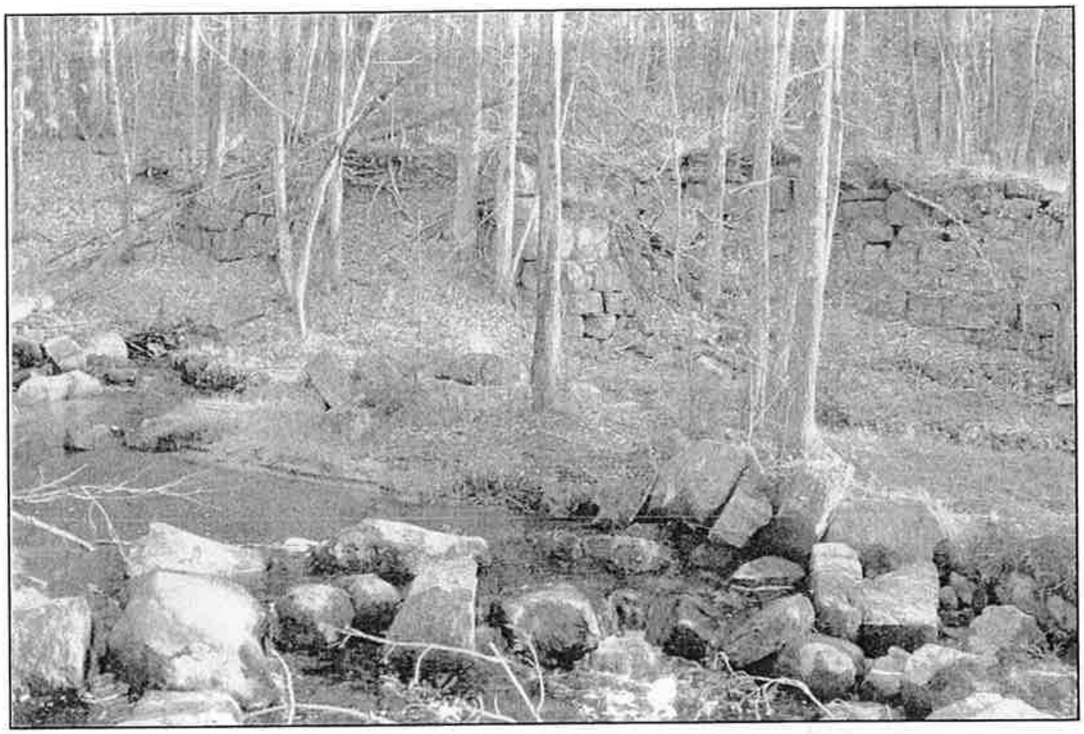


Photo 1: Remnants of the Grist Mill and dam across Wards Brook, downstream from the chosen stream gauging site.

This location for a gauging station meets many of the criteria recommended by in a recent USGS publication[1], namely:

- The stream bed has streamlines more or less parallel to each other;
- It is free of large rocks, weeds, and obstructions that would create eddies, slack water, and turbulence;
- The measurement section is roughly parabolic or rectangular.
- Flow velocities, for the most part, are greater than 0.5 ft/s, and depths are greater than about 0.5 ft.

The USGS publication notes that in reality ideal sites with all favorable characteristics are rarely to be found, and one must usually be satisfied with something that is less than ideal. In this case there are two features of the streambed at this location that are less than favorable. They are that:

[1] Turnipseed, D. P. and V. B. Sauer, 2010, Discharge Measurements at Gaging Stations, Techniques and Methods, Chapter 8 of Book 3, Section A. US Geological Survey

- The stream bottom is a rippled sand bed, which has been observed to shift between flow measurements.
- Downstream from the stream section large logs that were carried down Wards Brook in flood flows over the years have become lodged on the remnant Grist Mill blocks. Though normal flows in the Brook tend to go under or around the logs, the logs are responsible for a partial obstruction of flow due to the accumulation of leaves and debris in the gaps through which the water flows (Photo 2).

Photo 2: Wards Brook downstream from the stream gauging site, with lodged logs that cause an unpredictable accumulation of leaves and debris.

We were hopeful that the second of these unfavorable features, the lodged logs, could be removed. However, we were informed by DEP staff that in order to do so we would be required to file for a permit that would be reviewed under Maine's Natural Resource Protection Act (NRPA). Further discussion of this issue is given later.

Calibration of Flow in Wards Brook

During 2010, we were permitted to remove as much of the debris and leaves from between the lodged logs as necessary to obtain more or less reliable streamflow measurements. Ten sets of measurements were taken over a period from June through August, 2010.

The method used was to string a tape across the chosen Brook segment, then take measurements of flow with a Global Water FP101 Flow Probe at ten points along the tape (Photo 3). The total estimated discharge in the Brook is equal to the velocity of flow multiplied by water depth at each point, and the width of the stream. This is known as the Mid-section Velocity-area method, and is a standard USGS protocol. It was only modified in Fryeburg by taking 10, not 20 measurements of flow and depth because this is a relatively narrow Brook.

Flow calculated by this method was then compared with water level in the stream gauging segment. Water level was read from one of three redundant means of measurement: a) a white metal staff gauge with markings in hundredths of a foot, or b) down from the top of a nearby green metal stake, or c) in feet below a screw set in the tree that partially overhangs the Brook at this location (Photo 4).

Photos 3&4: Stream gauging in Wards Brook. Above, measurements are being taken of flow beneath a tape. To right, water level in the stream section is gauged relative to a staff gauge (or down from the top of a metal stake anchored in the bed of the Brook).

Stream gauging resulted in a rating curve with somewhat widely scattered points (Figure 3).

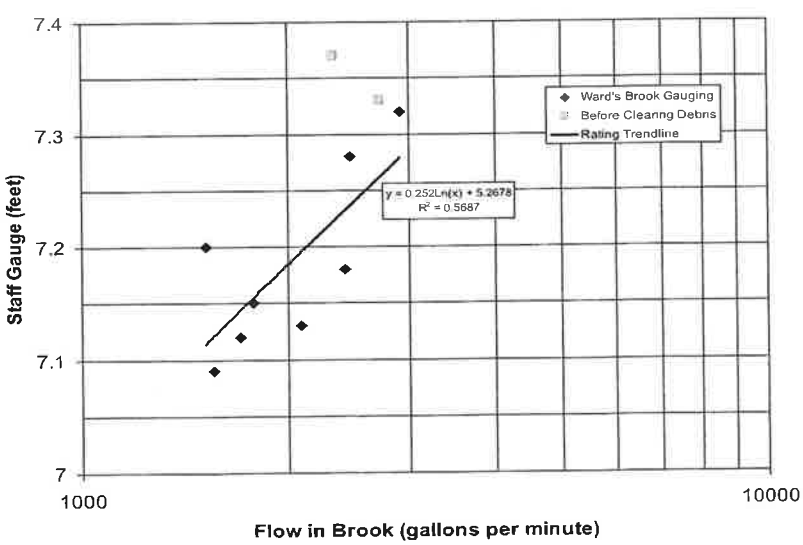


Figure 3: Rating Curve for Wards Brook, Fryeburg.
The wide scatter of points that comprise this curve are likely due to the accumulation of leaves and debris upstream of the lodged logs mentioned above, and to a lesser extent to shifts in the sandy bed of the stream that were apparent from one measuring date to another. We cannot recommend using the rating curve to determine flow from water level until the logs are removed.

Applying for a Natural Resources Protection Act Permit

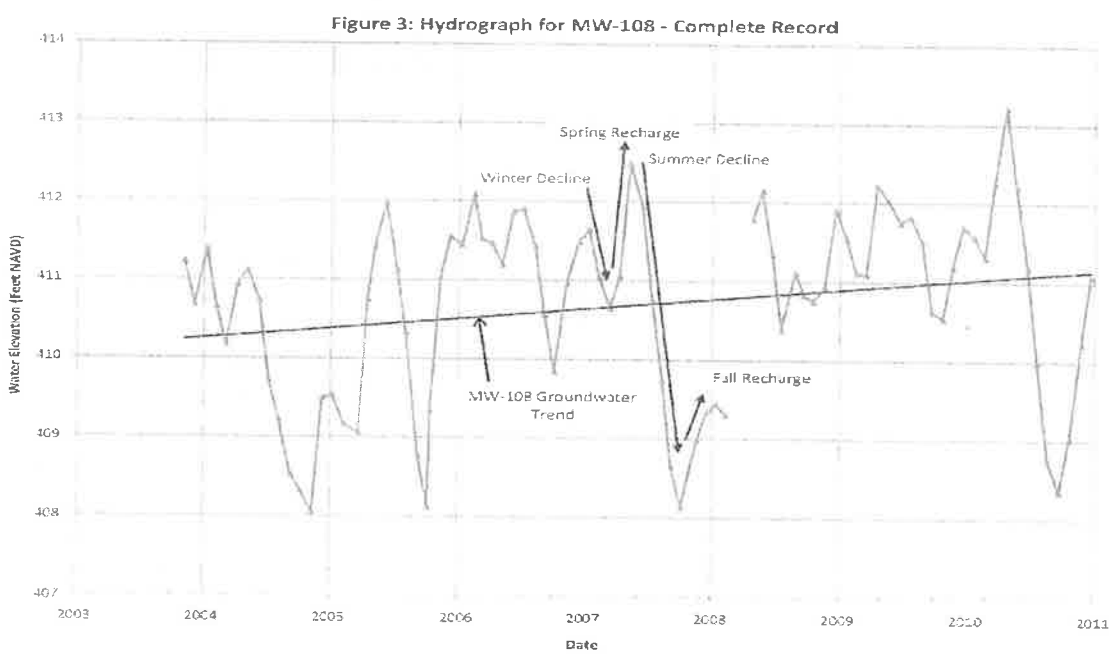
We had been informed by DEP staff that an NRPA Permit would be required to remove the logs lodged on the boulders downstream of the chosen stream gauging site. However, it was later agreed that a permit would not be required because EGGI's contract is with the Town of Fryeburg, and thus this effort can be considered a public works project. As such, under the statute of the Natural Resources Protection Act, public work projects that affect protected natural resources are exempt from permitting (38 M.R.S.A § 480-Q (9)). An activity which is exempt under this subsection must employ erosion control measures to prevent sedimentation into the Brook, must not block fish passage, and must not result in any additional intrusion of the public works into the protected natural resource.

Our understanding is that the logs in question can be cut out and removed, though portions that are lodged in the stream bed should stay there. With the logs removed there is far less opportunity for debris and leaves to accumulate, so that a more precise rating curve of water level versus flow should be possible.

Review of 2010 Monitoring of Aquifer and Brook by Ed Luetje

We have reviewed the 2010 Annual Aquifer Monitoring Report prepared by Luetje Geological Services (LGS) and McDonald Morrissey Associates for Nestle Waters North America, Inc. Several interesting points emerge, some of which were not noted by Luetje. They are as follows:

- Precipitation in Fryeburg was about average for the year, but was below normal for the months of April, May, July, August and September, 2010.
- The relatively dry summer months led to an unusually high range of water levels in the aquifer, as shown in Luetje's Figure 3 (reproduced below). This shows that the water level variation measured monthly in monitoring well MW-108 was 4.87 feet over the year in 2010. This compares to an annual variation of between 2 and 4 feet in the years 2004 through 2009.



- It is clear from the above graph that the upward trend of water levels in the aquifer as measured at MW-108 continued into 2010, with the highest recorded water level in that well in April, 2010. However, there is a large variation from year to year and season to season.
- The annual range in monthly water levels in all monitoring wells located throughout the Wards Brook valley varied between 3.15 and 7.22 feet in 2010.
- The highest groundwater levels recorded in all monitoring wells in the Wards Brook valley was recorded on April 20th, 2010. Lowest groundwater levels recorded varied from August through November.
- All surface water monitoring sites (three in Wards Brook and one in the Saco River) showed peaks in mid-March. The lowest flow was likely to have been at some time in August. (Note that water levels, not flows, are measured once per month in the Saco and Wards Brook by Ed Luetje).
- Luetje's graph of water levels in the Wards Brook Aquifer at MW-108 shows the lowest groundwater levels in September, around the time that I visited the Fryeburg Water Company's well and spring site. Despite the seasonally low groundwater levels and ongoing water withdrawals from FWC Wells #1 and 2, water was pouring out of the springs into the Brook at hundreds of gallons per minute.

Conclusions

1. Flow in Wards Brook has never been gauged with the precision and frequency of measurement that is commonplace at USGS gauging stations across the nation, for instance at the Little Androscoggin River near South Paris. Nevertheless, the monthly measurements of flow taken in 2004 at a weir located beneath Route 113 appear to be characteristic of a relatively high baseflow compared to baseflow in the Little Androscoggin.

2. A relatively high baseflow is to be expected in Wards Brook because much of the watershed is underlain the Wards Brook Sand and Gravel Aquifer, which stores groundwater on a temporary basis, releasing it slowly as discharge from springs.

3. The site of the largest springs that feed into Wards Brook is also the site of Fryeburg Water Company's Wells #1 and #2. FWC Well #1 is used exclusively for withdrawals of water for Nestle, which currently average about 270,000 gallons per day. FWC Well #2 is also pumped at 64,000 gallons per day to serve the FWC public water system. These rates are equivalent to a steady pumping at about 230 gallons per minute from the Aquifer in the vicinity of the springs.

4. Despite these large withdrawals, groundwater emerges from springs feeding Wards Brook at rates of several hundred gallons per minute even during September, the month with the lowest groundwater levels in most monitoring wells.

5. For the past three years, total withdrawals from the Aquifer for bottled water have been less than half of the recommended allowable withdrawal of 603,000 gallons per day, a rate that was based on our 2004 modeling report.

6. Stream gauging in Wards Brook at a site just upstream from the Grist Mill site was attempted in 2010. Its purpose was to produce a rating curve of flow versus water level in the Brook. Our efforts were to some extent confounded due to the damming effect of logs located downstream of the gauging site, which tend to accumulate floating debris after storms. We were not allowed to

remove those logs in 2010 per orders of DEP staff. However, DEP has since reversed that ruling and allowed the logs to be removed without the necessity of a permit following the Natural Resource Protection Act 38 M.R.S.A § 480-Q (9). Removal of the logs will cause the stream bed to readjust to the new conditions so that a more precise measurement of flow in Wards Brook can be made.

Recommendations

We recommend that the Town of Fryeburg Department of Public Works remove the logs that cause minor damming of streamflow in Wards Brook, and that the stream bed be allowed to readjust to its new conditions during summer and fall of 2011, and winter and spring of 2012. We further recommend that stream gauging be resumed, following USGS protocol, at the same location, during summer months of 2012.