Report On:

The Biotic Condition of Crosby Brook and Exploration of the Environmental Stressors on the Aquatic Communities.

prepared by

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Objective: Describe the biotic condition of stream reaches within the Crosby Brook (CB) watershed, and identify the primary environmental stresses on the aquatic communities by stream reach. The analysis should provide the building blocks for management actions that will restore those reaches found to have degraded aquatic communities.

General watershed description:

Crosby Brook is a direct tributary to the Connecticut River located in the south east corner of Vermont, within the towns of Dummerston and Brattleboro. The headwaters are located in the hills of Dummerston at an elevation of about 1000 ft, and its mouth is in Brattleboro just below the Rt 9 Bridge to NH at about 230 ft. The brook flows for about 6 miles with an average grade of 1%. The entire CB watershed area is 15 km^2, and is divided into two primary sub-watersheds. The larger is considered Crosby Brook (CB) proper, with a watershed area of 9.5 km^2, above their confluence. The smaller of the two is referred to in this report as the South Branch Crosby Brook (SBCB), with a watershed area of 4.5 km^2. The SBCB joins CB immediately below the I-91 exit just above the junction of Rt 5 and 9.

Crosby Brook is classified as Class B/Coldwater fish habitat water pursuant to the Vermont Water Quality Standards. Since I-91 was completed in the 1970s, land use within the lower part of the watershed has exhibited a trend of conversion from agricultural use to residential and commercial use. The I-91 project was responsible for a relocation of stream reaches on both the main stem of CB and SBCB. Some historical accounts refer to the brook as Black Mountain, and Sergeant Brook. We have used the name Crosby Brook at the request of the Dummerston Conservation Commission.

This report will first present biotic assessments and an interpretation of the community fingerprint based on the biometrics affected, species composition and habitat observations by site. Secondly, based on the assessments, and community stressor fingerprinting, data for a number of the most likely water quality stressors on the aquatic communities is presented under the stressor section. Finally a discussion of the potential sources of the water quality stressors on the aquatic biota is presented.

Biotic Community assessments and habitat observations:

The macroinvertebrate and fish communities have been sampled at nine reaches within the Crosby Brook watershed to directly measure and assess their biotic integrity. The sample reaches were selected to evaluate the temporal condition of previously assessed sites and the longitudinal condition of the aquatic communities from the mouth to the headwaters, which are influenced to varying degrees by environmental stresses tied to

anthropogenic watershed land uses and stream channel/habitat modifications which maybe sources of stress on the aquatic biota. The stream reach sites sampled are identified by stream name (CB or SBCB) and mile up from their mouth or confluence with the next river/stream. **Table 1** gives a brief location description, the latitude and longitude, elevation in ft and watershed size in km^2 for each of the stream reaches sampled. **Figures 1a and 1b** show the locations of the assessed stream reaches in relationship to roads and watershed land use. Photographs of the biotic assessment reaches are found in **Appendix 1**.

Table 1: Biotic and Water Quality assessment reaches within the Crosby Brook Watershed. F=Fish community, M=Macroinvertebrate community, WQ= water quality data

Location	Site	Town	WBID	DA km2	Elev ft	Latitude	Longitude	Community	Description
Crosby Brook (CB)	**0.3**	Brattleboro	VT13-13	15	236	425255	723318	MF WQ	Located adjacent to Connecticut Road (Private) across from first house.
	0.4	Brattleboro	VT13-13	14.5	255	425301	723319	MF WQ	Located above RR bridge, to below Rt 5 50m, adjacent to parking lot for restaurant.
	0.5	Brattleboro	VT13-13	14	260	425305	723328	F	Located just below confluence with SBCB, below I-91 exit ramp 100m.
	0.6	Brattleboro	VT13-13	9.5	265	425306	723329	WQ	Located just above confluence with SBCB immediately below I-91 exit ramp
	0.7	Brattleboro	VT13-13	9.5	275	425309	723328	MF WQ	Located above I-91 exit ramp at roundabout, behind Pizza Hut and car dealers.
	1.3	Brattleboro	VT13-13	8.8	288	425333	723320	WQ	Located above I-91 just before exit ramp 3 southbound, site above small drainage entering CB from east.
	1.5	Dummerston	VT13-13	7.5	302	425344	723312	MF WQ	Located behind, adjacent to or slightly above Leader Distribution Building.
	1.8	Dummerston	VT13-13	7	354	425311	723411	M WQ	Located above 1st middle road crossing 20m.
South Branch Crosby Brook (SBCB)	**0.1**	Brattleboro	VT13-13	4.5	280	425306	724707	MF WQ	Located above confluence with CB, adjacent to and between I-91, and Cemetery .
	0.5	Brattleboro	VT13-13	4.3	312	425302	723351	MF WQ	Located above I-91 and first bridge on Black Mt road, adjacent to trailer park on Black Mt road.
	1.3	Brattleboro	VT13-13	2.9	472	425321	723412	M WQ	Located above Dickinson Road 20m, adjacent to older college building.

Figure 1 a: Locations of biomonitoring and Water Quality monitoring sites in Crosby Brook watershed.

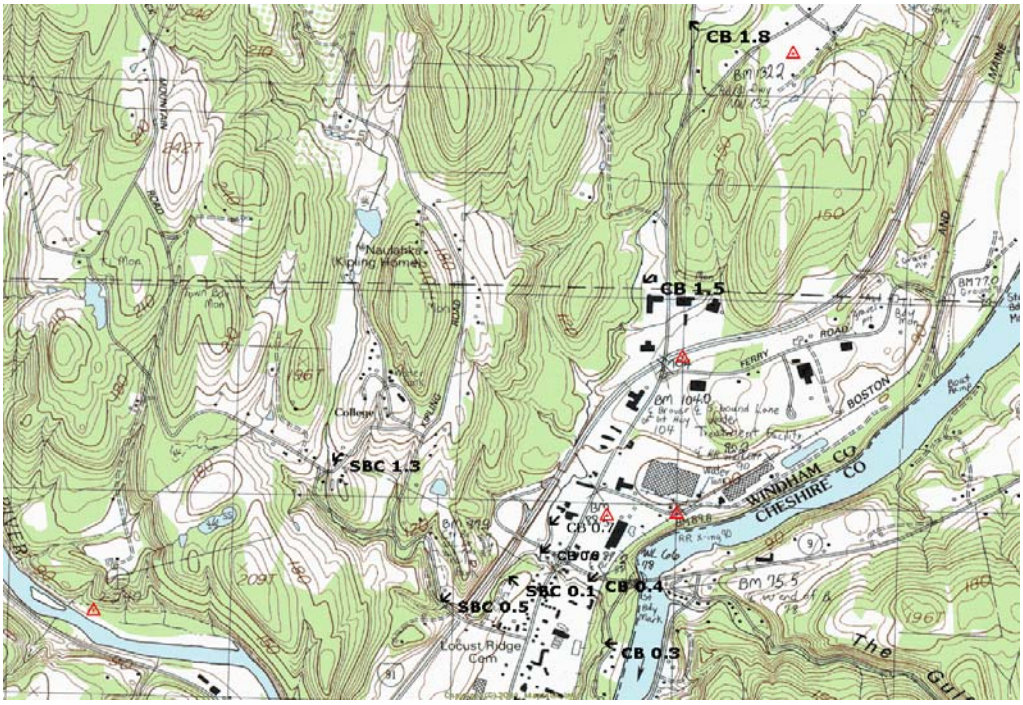


Figure 1b: Showing major land use types within the Crosby Brook watershed in relationship to monitoring stations.

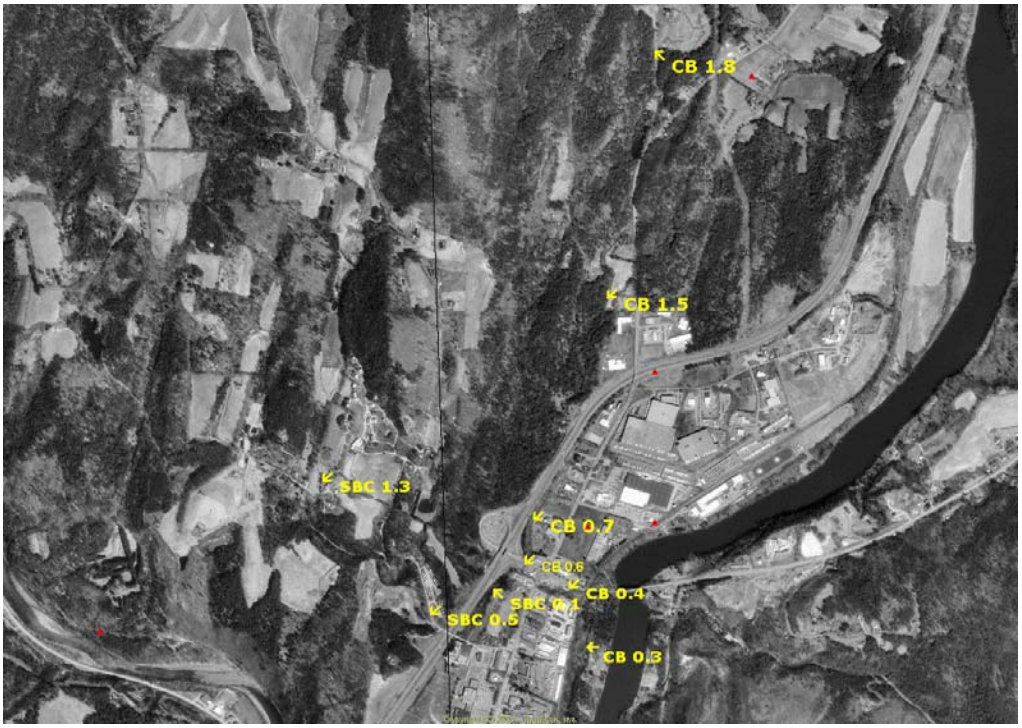


Table 2 and 3 present the macroinvertebrate and fish community assessments, and bio-metrics respectively. For macroinvertebrate assessment purposes stream riffles were targeted for sampling, following VTDEC SOP's for the habitat. The stream reaches at CB 0.4, 0.7 and SBCB 1.3 did not have well established riffles with gravel cobble substrate, however the reaches were of moderate velocity, and a combination of gravel riffles and large woody debris was targeted during sampling. For these sites best professional judgment was applied in interpreting the metric expectations to account for the habitat at the reach. All stream reaches were assigned to the Small High Gradient (SHG) macroinvertebrate stream type expectation, and the Cold Water fish Index of Biotic Integrity (CW-IBI) (VTDEC 2000).

Table 4 and 5 present the macroinvertebrate order level and functional grp composition. Physical habitat observations including substrate composition, embeddedness, silt rating, and woody debris are presented in **Table 6.** Observations on the canopy cover, and moss, macro, and micro periphyton percent cover is presented in **Table 7.** A biotic assessment and an interpretation of the community fingerprint based on the biometrics affected and species composition by site is given below. A summary of the biotic condition of the watershed is presented after the individual site/reach assessments.

Crosby Brook (CB) main stem bioassesments

CB 0.3

This site has been assessed annually for three years (2002 – 2004) for macroinvertebrates and two years for fish (2003 and 2004). The site is dominated by cobble gravel riffles, and is located between two significant falls, isolating it from upstream recruitment from the Connecticut River for fish species. It is also below most of the known storm-water discharges and non-point urban runoff within the watershed. Both macroinvertebrate and fish communities have failed to meet the Class B aquatic life expectation of "good" biotic integrity. The macroinvertebrate community rated as "fair" for the first two years and a "poor" assessment in 2004. The fish community was assessed as "poor" both years.

The macroinvertebrate community was below expectation for EPT richness and had a high percent composition of Oligochaeta. The density ranged from low the first year to low-moderate the last two years. The Bio-Index value indicates community dominance by taxa moderately tolerant to organic enrichment. The community has been consistently dominated over all years sampled by two tolerant taxa, the Trichopteran *Hydropsyche betteni*, and Oligochaeta *Lumbriculidae*. These two taxa are often indicative of high levels of fine particulate organic matter and sediment stress on the community. The orders Ephemeroptera and Plecoptera were notably low in abundance. The poor abundance of Plecoptera and high percent *Hydropsyche betteni* can also indicate potential elevated temperature, and base flow stress on the stream community.

The fish community was dominated by the tolerant blacknose dace (*Rhinichthys atratulus*) and creek chub (*Semotilus atromaculatus*) with a low density of brook trout (*Salvelinus fontinalis*). This community composition is indicative of a poor biotic condition. Blacknose dace and creek chub are considered eurythermal generalists. The dominance of the fish community by these two species also indicates sediment and temperature may be major stresses within the reach.

CB 0.4

This site was sampled for fish and macroinvertebrates once in 2004. This site is relatively low gradient with a sand/gravel substrate, deep pools and a large amount of woody debris. The velocity through the reach is such that most of the habitat is scoured sand and gravel, not depositional fine sediments. The section had good riparian shrub cover and trees, with woody debris creating a good variation in pool depth and velocity throughout the reach. Both the macroinvertebrate and fish community were rated using best professional judgment (BPJ) since the reaches sampled were of low gradient. The fish assemblage was assigned a "good" biotic integrity rating, and the macroinvertebrate community a "fair-good" rating, indicating a moderate level of biotic community degradation and a significant degree of water quality stress in the reach.

The macroinvertebrate community was moderate in density, with high total richness and EPT richness despite the low gradient nature of the reach. The high number of EPT species may be attributed to the amount of large woody debris in the reach, the moderate velocity, and good upstream colonization sources. The metric of concern was the moderate to high percent Oligochaeta (12.7%). A high percent Oligochaeta is an indication that sediment/silt is a likely stress on the community at the site. Other moderately tolerant taxa also among the dominant taxa at the site were the Trichopteran *Hydropsyche betteni*, and the Ephemeropteran *Baetis tricaudatus*.

Because of the habitat limitations of the reach the Coldwater Index of Biotic Integrity (CWIBI) was not directly applied to the site and instead Best Professional Judgment (BPJ) was used to properly interpret the fish CWIBI metrics . The reach is pool/run dominated, with numerous large woody debris accumulations forming pools, and short gravel riffles between pools. Pool/run habitat naturally favors species such as blacknose dace and creek chub; these species are also considered tolerant to poor water quality. The intolerant species within the watershed, brook trout and slimy sculpin, do not normally prosper in stream reaches dominated by fine sediments and pool/run habitat. The tolerant blacknose dace and creek chub dominated the site; however brook trout made up 19% of the community at RM 0.4. Brook trout density was found to be acceptable (4.1/100m^2), and three brook trout age classes were present at the site indicating reproduction within the reach. The high proportion of tolerant species (71%) however, and lack of other intolerant or intermediately tolerant species, suggests that the site is undergoing stress and can only be rated as "good".

CB 0.5

CB 0.5 was situated behind a convenience store, with the riparian zone consisting of mowed grass. This site was sampled once for fish in 2003. The fish assemblage of RM 0.5 was evaluated on the basis of BPJ. The reach is similar in habitat to CB 0.4 being mostly run of moderate velocity, without well established riffles/pools. Woody debris was absent but undercut banks created some pool cover. The tolerant blacknose dace and creek chub dominated the site; however brook trout made up 8% of the community. Brook trout density was acceptable (6.0/100 m^2), and three brook trout age classes were present, indicating reproduction in the reach. The high proportion (75%) of tolerant species and lack of other intolerant or intermediately tolerant species suggests that the site is undergoing stress and can only be rated as "good".

CB 0.7

The reach had been relocated from its former channel to make way for construction of the Interstate. The sampled section was straightened and had little to no woody debris for stable habitat which is especially important in lower gradient streams. The substrate composition was dominated by fine particles of silt, sand and gravel. This site was sampled in 2004 for both macroinvertebrates and fish. The reach is mostly a low-moderate gradient run, without established riffles. As a result BPJ was used in interpretation of the metrics, and the overall assessment. The macroinvertebrate density and EPT richness were low, and the percent of Oligochaeta was elevated. The dominant taxa are a mixture of sensitive and more tolerant taxa indicating that a moderate level of stress is present at the site. As a result the reach was assessed as "fair-good" with at least a moderate level of degradation evident in the community. The sensitive taxa present are *Dolophilodes sp.* and immature Peltoperlidae stoneflies. The tolerant taxa present are the Trichoptera *Hydropsyche betteni, Chuematopsyche sp,* and the Oligochaeta *Lumbriculidae,* and *Enchytraeidae*. These taxa are tolerant of high levels of suspended particulate matter, temperature, and sand/sediment deposition.

The fish community at CB 0.7 was clearly impaired as evidenced by a hyperdominance of blacknose dace and low total population density. This section had the poorest physical habitat of any site sampled on the brook. The stream channel had been straightened with the expected result of decreased habitat diversity. The entire section was devoid of pools, consisting of one long monotonous shallow run with little variation in velocity and almost no resting habitat or cover of any type. The lack of suitable habitat is thought to account for the low total density as well as the paucity of brook trout. For these reasons the fish community was rated as "fair-poor".

Based on both the macroinvertebrate and fish community assessments, the biotic integrity of the reach has been adversely impacted. The community composition and habitat observations indicate that both macro-habitat alteration and sediment deposition are most likely sources of stress within the reach.

CB 1.5

This reach was assessed for both macroinvertebrate and fish community integrity for two years - 2003 and 2004. The reach appears to have been straightened and is located below a very low gradient section of the stream that is periodically impounded by beaver. The reach is dominated by riffle/run habitat with little pool development. The reach was originally sampled because it was located above all influence from the urbanized lower reaches of the watershed, and associated non-point storm water based stresses. Over the two-year period the macroinvertebrate community has been in “fair” to “good” condition, while the fish community has rated “excellent” to “very good”.

The macroinvertebrate community was present in low to moderate in densities, with the number of sensitive EPT species low both years. In 2003 the Bio Index was elevated and the PMA-O, and PPCS-F also indicated dissimilarity to the SHG model. The order level composition showed the Trichoptera to be hyper-dominant with the Ephemeroptera and Plecoptera underrepresented. The functional feeding group composition was skewed toward hyper-dominance by filter feeding animals, with collector gatherers and predators mostly underrepresented. The community was dominated by two tolerant Trichoptera *Hydropsyche betteni,* and *Cheumatopsyche sp.* These taxa are both tolerant of particulates and elevated temperature. In 2004 a high flow event caused a beaver impoundment to breach and cause considerable streambed scour within the reach several weeks prior to biotic sampling. The community was again low in mean EPT taxa, however the total EPT taxa increased with an increase in the number of Ephemeroptera and Plecoptera taxa present. The order and functional composition was more similar to the SHG model and the Bio Index was not elevated. It appears that the beaver impoundments on the brook had a moderately detrimental effect on the macroinvertebrate structural and functional composition. The stressors most likely responsible are temperature and particulate organic matter.

The fish community supported five species the first year and two species the second year. The species absent the second year were both tolerant and intolerant species collected in low abundance the first year. The density of brook trout, and blacknose dace also dramatically decreased the second year. These alterations in the fish community may be linked to the beaver impoundment breach and resulting stream scour event several weeks prior to the 2004 sampling. Present and dominant during both years were brook trout and blacknose dace, in about equal proportions. Due to the higher abundance of brook trout and intolerant species present in 2003, the fish assessment was rated “excellent”. In 2004, the community assessment was downgraded to “very good”, in part due to the absence of slimy sculpin a very temperature sensitive intolerant species.

CB 1.8

This reach was sampled in 2004 for macroinvertebrates to bracket the influence of the beaver-impounded low gradient section located above site 1.5 described above. The stream is of moderate gradient, riffle-run dominated with clean coarse gravel and gravel dominated substrate. Little to no large woody debris was observed within the reach. The macroinvertebrate community was rated as “very good” to “excellent” in 2004.

The macroinvertebrate community was moderate to high in density and high in both species richness and sensitive EPT taxa. The EPT/EPT-c ratio was high and the Bio Index only very slightly above an excellent rating, indicating slight enrichment. The periphyton assessment showed little to no moss, macro- or micro algae growth at the site. The community was similar in composition to the SHG model in order and functional group composition. The Plecoptera were slightly underrepresented, and the Coleoptera overrepresented. The functional group composition shows the Shredder-detrivore group to be slightly under-represented and the scraper group to be over-represented. While many of the dominant taxa *Dolophilodes sp, Promoresia tardella, Rhycophila minor,* and *Oulimnius latiusculus,* are considered sensitive, a few such as *Baetis tricaudatus,* and *Tipula sp* are considered more tolerant. The two tolerant Hydropsychidae taxa that have been among the dominant taxa at the lower CB sites were absent or in very low abundance, indicating that temperature stress and or particulate organic matter is not influencing the community composition at this upper most site.

S.Branch Crosby Brook bioassessments

SBCB 0.1

This reach was sampled in 2004 for macroinvertebrates and fish. It is located directly within the influence of the I-91 drainage system. The macroinvertebrate and fish community both rated as "good". The reach is of moderate gradient with riffles dominated by gravel and coarse gravel. Several iron seeps were noted from the I-91 side of the stream. These seeps appeared to be associated with storm water drainage and fill materials from the highway.

The macroinvertebrate community was generally low in density, and EPT taxa. The sample replicates were, however highly variable in density and richness, indicating considerable habitat variability thru the reach. The Bio Index was low and EPT/EPT&c high indicating enrichment was not influencing the community. The periphyton assessment supports this conclusion as evidenced by low levels of periphyton growth. The community was also low in percent Oligochaeta and similar to the SHG model for order level and functional grp composition.

The fish community was dominated by the more tolerant blacknose dace. This species made up 71% of the total with brook trout providing the remaining 29 %. The density of brook trout was acceptable and three age classes were represented, indicating reproduction within the reach. Because of this, the overall condition of the fish community was assigned a "good" rating.

SBCB 0.5

This site has been sampled twice (2003 and 2004) for both macroinvertebrates and fish. The reach was selected to bracket both the influence of I-91 (as the upper site to SBCB 0.1), and the local gravel back roads (as the lower site to SBCB 1.3). Both communities rated the site "very good" to "excellent" both years. The reach is adjacent to

Black Mt. road, with little to no riparian zone on the road side, but with an extensive riparian zone on the opposite side. Because of its small width however, the canopy cover is over 60% of the stream width. The reach is moderate in gradient with substrate dominated by gravel and coarse gravel, with significantly high amounts of sand. The embeddedness rating however, scored “very good” (5-25%) both years.

The macroinvertebrate community was moderate in density the first year and low in the second. The richness metrics were also better (high) the first year compared to the second. As mentioned, the second year sampling of the CB sites took place after a significant freshet event, with evidence of scour. This scour could account for the slight decline in density and richness. The Bio Index and EPT/EPT & c show no indication of enrichment at the site. The periphyton assessments showed little to no algal growth present either year. Several sensitive and ubiquitous taxa were among the dominants including Chloroperildae, Peltoperlidae, *Dolophilodes sp*., *Apatania* s*p.,* and *Lepidostoma sp.*. The moderately tolerant *Baetis sp.,* a rapid colonizer and indicator of recent scour disturbance, was the dominant taxon in 2004.

The fish community was composed of brook trout (95-98% of total) and blacknose dace (2-5%). The reach scored 42 out of a possible 45 with the CW IBI for both years, The ratio of intolerant to tolerant species (brook trout to blacknose dace) resulted in an “excellent” fish community assessment.

SBCB 1.3

This reach was sampled once for macroinvertebrates in 2004, as an upper-most control for the SBCB watershed. It is located above the influence of the local gravel roads including Black Mt., Dickinson, and Kipling. The reach was assessed as having “very good” biotic integrity, despite the reach being of lower gradient less then optimal for a SHG stream type. The community was moderate in density with moderate to high richness and EPT taxa present. The Bio Index and EPT/EPT & c show no evidence of enrichment influence on the community. The reach did have notable moss cover present, and a high amount of woody debris. These features added to the diversity of macroinvertebrate habitat within the reach, and appear to have more then compensated for the lower gradient and resultant small substrate size at the site compared to most SHG streams.

Table 2 : Macroinvertebrate community assessments from reaches sampled within Crosby Brook watershed. * - Refers to a reach of lower gradient habitat then SHG model for these sites. As a result, BPJ was relied on for assessment and PMA-O, and PPCS-F. Shaded/Bold are most recent samples (2004).

Location	Site (mi)	Date	Assessment	Density	Richness	Ept	PMA-O	BI 0-10	Oligo%	Ept/Ept&C	PPCS-F
Crosby Brook	0.3	9/17/2002	Fair	302	38.0	12.0	59.6	4.36	17.6	0.80	0.57
	0.3	9/18/2003	Fair	1458	30.0	9.5	50.8	5.09	11.3	0.74	0.33
	0.3	**9/3/2004**	**Poor**	855	33.5	14.5	49.6	4.47	25.2	0.94	0.44
	0.4	**9/3/2004**	**G-Fair ***	1572	52.0	22.0	69.5*	3.54	12.7	0.71	0.55*
	0.7	**9/2/2004**	**G-Fair ***	653	38.0	16.0	79.2*	3.13	11.6	0.77	0.59*
	1.5	9/18/2003	Fair	1574	29.0	13.5	48.0	5.05	0.1	0.93	0.37
	1.5	**9/3/2004**	**G-Fair**	576	33.5	13.5	68.7	3.15	2.8	0.81	0.51
	1.8	**9/3/2004**	**Ex-Vgood**	1936	49.0	23.0	76.9	3.33	0.4	0.82	0.71
Crosby Brook South Branch	0.1	**9/2/2004**	**Good**	460	41.0	17.0	75.6	2.81	1.6	0.92	0.66
	0.5	9/18/2003	Ex-Vgood	1788	35.0	20.0	74.3	2.57	0.0	0.87	0.64
	0.5	**9/2/2004**	**VGood**	802	39.5	19.0	83.3	3.20	0.4	0.90	0.60
	1.3	**9/2/2004**	**VGood**	1780	33.0	19.0	74.7*	3.22	1.1	0.74	0.61*

Table 3: Fish community assessments from reaches sampled within the Crosby Brook watershed. * Reach of lower gradient dominated habitat, as a result BPJ used for assessement. Shaded/Bold are most recent samples (2004).

Location	Site (mi)	Date	Assessment	CW IBI [1]	Richness	Intol. Spp No	Blacknose Dace %	General Feed %	Top Carnivore %	Cold Water Spp %	BKT Density	BKT Age Class	Total /100m2
Crosby Brook	0.3	9/18/2003	Poor	12	4	1	57.4	39.9	2.7	2.7	0.5	1.0	35.5
	0.3	**9/3/2004**	**Poor**	12	4	1	68.1	18.8	13.0	13.0	1.9	3.0	14.5
	0.4	**9/3/2004**	**Good**		3	1	70.9	19.2	9.9	9.9	4.1	3.0	41.2
	0.5	9/25/2003	Good		3	1	75.1	16.9	8.0	8.0	6.0	3.0	74.4
	0.7	**9/2/2004**	**Fair-Poor**	(24)	2	1	89.6	0.0	10.5	10.5	1.9	3.0	18.4
	1.5	9/18/2003	Excellent	39	5	2	38.8	7.1	48.2	53.5	24.9	3.0	51.5
	1.5	**9/3/2004**	**Very Good**	39	2	1	49.1	0.0	50.9	50.9	8.6	3.0	17.0
Crosby Brook South Branch	0.1	**9/2/2004**	**Good**	33	2	1	71.2	0.0	28.9	28.9	9.7	3.0	33.6
	0.5	9/18/2003	Excellent	42	2	1	5.3	0.0	94.7	94.7	27.6	3.0	29.2
	0.5	**9/2/2004**	**Excellent**	42	2	1	1.5	0.0	98.5	98.5	32.3	3.0	32.8

1. CWIBI range = 9 - 45

Table 4: Percent composition of the major macroinvertebrate orders from reaches sampled within the Crosby Brook watershed. Shaded are most recent samples (2004).

Location	Site (mi)	Date	Coleoptera %	Diptera %	Ephemeroptera %	Plecoptera %	Trichoptera %	Oligochaeta %	Other %
Crosby Brook	0.3	9/17/2002	7.3	20.9	1.3	3.0	36.1	17.6	13.9
	0.3	9/18/2003	1.4	38.0	1.2	0.1	45.8	11.3	2.1
	0.3	9/3/2004	4.3	8.8	4.5	3.0	50.3	25.2	3.9
	0.4	9/3/2004	5.1	30.0	29.3	7.9	13.5	12.7	1.5
	0.7	9/2/2004	8.0	27.1	7.4	16.2	28.8	11.6	0.9
	1.5	9/18/2003	5.4	10.8	2.3	0.9	79.5	0.1	1.0
	1.5	9/3/2004	9.8	32.6	8.4	4.4	41.5	2.8	0.5
	1.8	9/3/2004	25.2	22.9	21.5	6.6	20.9	0.4	2.5
South Branch Crosby Brook	0.1	9/2/2004	7.0	22.3	20.7	36.3	8.6	1.6	3.5
	0.5	9/18/2003	6.3	17.0	49.0	8.3	19.2	0.0	0.2
	0.5	9/2/2004	7.4	16.7	36.8	17.5	20.6	0.4	0.7
	1.3	9/2/2004	16.9	29.7	7.4	11.2	31.7	1.1	2.0

Table 5: Percent composition of the macroinvertebrate major functional feeding groups from reaches sampled within the Crosby Brook watershed. Shaded are most recent samples (2004).

Location	Site (mi)	Date	CGath%	CFilt%	Predator%	ShrdDet%	ShrdHerb%	Scraper%
Crosby Brook	0.3	9/17/2002	32.5	38.4	3.3	3.6	1.0	21.2
	0.3	9/18/2003	36.8	47.9	2.6	0.7	7.3	4.7
	0.3	9/3/2004	31.6	48.8	6.9	0.9	0.0	11.7
	0.4	9/3/2004	51.7	17.3	10.9	3.6	4.8	8.1
	0.7	9/2/2004	30.7	37.0	9.3	10.7	0.7	11.0
	1.5	9/18/2003	6.1	75.0	7.6	2.5	1.7	6.8
	1.5	9/3/2004	21.7	50.6	10.1	5.4	0.3	11.9
	1.8	9/3/2004	26.4	20.5	12.4	9.3	1.2	26.0
South Branch Crosby Brook	0.1	9/2/2004	26.6	15.5	34.2	13.7	0.4	8.8
	0.5	9/18/2003	35.3	11.2	11.9	6.5	0.0	9.6
	0.5	9/2/2004	37.6	21.4	19.9	4.0	0.2	9.4
	1.3	9/2/2004	22.7	35.3	10.8	13.7	0.2	17.3

Table 6: Habitat measures of Substrate composition (pebble ct method), Embeddedness, and Silt rating (0-5), from Crosby Brook biomonitoring sites. * Observational substrate composition only. Shaded are most recent samples (2004).

Location	Site	Date	Clay %	Silt %	Sand %	Gravel %	CGravel %	Cobble %	Boulder %	Ledge %	Embeddness %	SiltR 0-5	Snags
Crosby Brook	0.3	9/17/2002	0	0	9	30	35	23	2	1	50-75	3	1
	0.3	9/18/2003	0	0	7	13	19	59	1	1	25-50	3	0
	0.3	9/3/2004	0	0	13	14	45	22	4	2	50-75	3	2
	0.4*	9/3/2004	0	2	30	20	20	5	10	0	NA	2	10
	0.7*	9/2/2004	0	16	42	39	2	0	1	0	NA	2	2
	1.5	9/18/2003	0	0	8	26	37	26	3	0	25-50		4
	1.5	9/3/2004	0	1	12	23	28	29	7	0	25-50	2	8
	1.8	9/3/2004	0	2	6	24	58	8	1	1	25-50	1	1
South Branch Crosby Brook	0.1	9/2/2004	0	0	17	34	44	5	0	0	50-75	3	3
	0.5	9/18/2003	0	0	19	21	38	18	4	0	5-25	1	0
	0.5	9/2/2004	0	0	12	29	38	17	4	0	5-25	1	0
	1.3	9/2/2004	1	0	18	29	29	6	6	0	NA	2	10

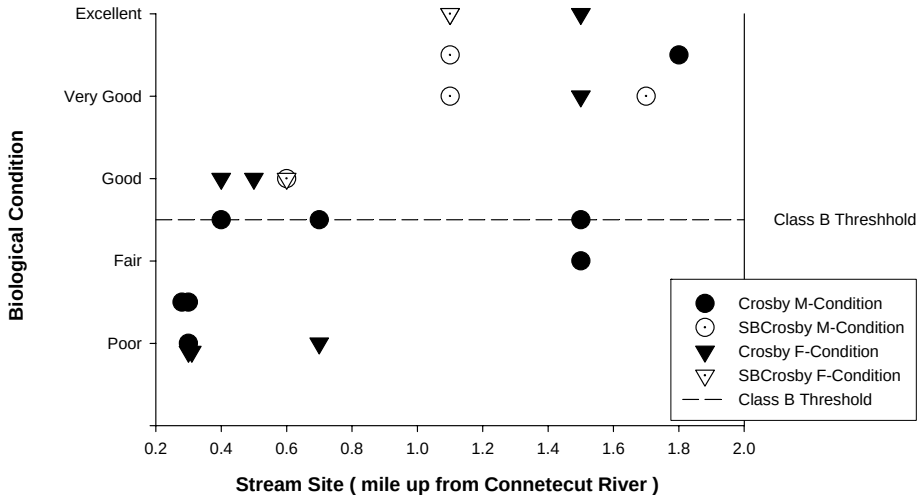
Table 7: Canopy cover and standardized periphyton (pebble count with algal density categories) assessments from Crosby Brook watershed biomonitoring sites. Reported as weighted averages (range 0-10), for three algal types: Moss, Macro, Micro. Shaded are most recent samples (2004).

Location	Site	Date	% Canopy	Moss	Macro Algae	Micro Algae
Crosby Brook	0.3	9/17/2002	80	0.2	0.0	0.4
	0.3	9/18/2003	80	0.4	1.3	0.4
	0.3	9/3/2004	70	0.4	0.1	0.2
	0.4	9/3/2004	40			
	0.7	9/2/2004	100			
	1.5	9/18/2003	90	0.0	0.5	0.4
	1.5	9/3/2004	80	0.2	< 0.1	0.3
	1.8	9/3/2004	90	0.2	0	0.2
South Branch Crosby Brook	0.1	9/2/2004	50	0	0	< 0.1
	0.5	9/18/2003	60	0.7	<0.1	0.4
	0.5	9/2/2004	70	0.4	0.0	0.2
	1.3	9/2/2004	90	2.14	0	0.08

Summary of the biotic condition of Crosby Brook

Crosby Brook and the South Branch Crosby Brook were sampled for fish and or macroinvertebrates at a total of nine sites over three years. These assessments have allowed for an evaluation of the spatial and temporal extent of the biotic condition of CB, and SBCB. **Figure 2** illustrates the biotic condition of the macroinvertebrate and fish communities longitudinally within the watershed by site and over multiple years. It is evident that the upper reaches on both CB and SBCB are generally of high ("very good" to "excellent") biotic condition. The exception being the CB 1.5 site where the macroinvertebrate community only rated "fair" to "good" over two consecutive years. Based on the assemblage characteristics, and habitat observations this site maybe stressed by temperature, fine particulate organic matter and channel straightening.

Figure 2: Biotic condition of both the macroinvertebrate and fish assemblages at several sites on Crosby Brook and South Branch Crosby Brook. Data points represent the macroinvertebrate or fish assemblage for a single sampling event from 2002-2004. Reach locations are relative miles up from confluence with the Connecticut River. SBCB data points are associated with tabular data from sites 0.1, 0.5 and 1.3. At river mile 1.0, land use changes from "rural residential" to more "urban".



The lower part of the watershed, starting from CB 0.7 down to CB 0.3, and SBCB 0.1, are generally degraded compared to the upper watershed sites. Based on the assemblage characteristics and habitat observations, temperature, sediment/silt, and stream channel straightening appear to be the most likely stressors to various degrees at each individual site. Finally, it is clear that the lowest site, CB 0.3, has been consistently assessed as "fair" to "poor" by both assemblages for three consecutive years. The assemblage characteristics and habitat observations at this site point strongly toward sediment/silt and, temperature as the primary stressors.

Environmental Stressors

Water Quality parameters:

Based on the above analysis of the macroinvertebrate and fish community assemblages, temperature and sediment were identified as likely stressors. Chemical and physical water quality sampling was conducted at all biomonitoring sites to better define the differences in sediment related parameters at all biomonitoring sites. Monitoring was also conducted on CB and SBCB under different flow conditions, base and freshet. Freshet flows were further categorized as moderate or high discharge events based on observations at the time of sampling. Results of water chemistry measures - pH, alkalinity, conductivity, nutrients Total Phosphorus (TP), Dissolved Phosphorus (TDP), Total Nitrogen (TN) - and physical parameters related to sediment stress - Turbidity, and Total Suspended Solids (TSS) - are summarized in **Appendix 2**. Water chemistry data was also collected for chloride (Cl), sulfates (SO4), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), and manganese (Mn). Results are summarized in **Appendix 3**. In addition to these parameters, the following metals were sampled for, but were either below their detectable limits, or if detected were well below their Chronic Water Quality Aquatic Life Support (ALS) criteria - aluminum (Al), arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), zinc (Zn).

All sites sampled show the Crosby Brook watershed to have relatively moderate levels of alkalinity and pH. The pH values were unremarkable and ranged from a low of pH 7.17 during a moderate freshet at CB 1.5 to 7.92 during base flow at CB 0.3. Likewise, alkalinity values ranged from 41mg/l during a high freshet at CB 0.3 to 109mg/l at base flow at SBCB 0.5. These values are within the expected range of natural condition and indicate that acidification is not a threat to the aquatic life in the Crosby Brook watershed.

Conductivity was also unremarkable and ranged from a high of 309 umhos/cm at SBCB 0.1 during base flow to 100 umhos/cm at CB 0.6 during a high freshet flow. Maximum chloride and sodium concentrations were 35 and 22 mg/l respectively, indicating slightly elevated but bioticly insignificant levels. Both chloride and sodium do appear to increase slightly as one moves down the watershed in both branches of Crosby Brook. SBCB 1.3 had the lowest levels of chloride at 2 mg/l. This site is least influenced by road systems, and is an indication that both unimproved town roads as well as paved highways do influence the water chemistry of all other sites sampled.

Base flow iron (Fe) levels ranged from 102 – 328 ug/l, while high freshet Fe levels ranged from 309 – 1830ug. The Water Quality Chronic Criterion for iron is 1000 ug/l. This criterion was exceeded at several sites in both the upper and lower watershed for both branches of Crosby Brook during two high freshet flow events - one in the spring and the other in the summer. These exceedences do not seem to have any effect on the aquatic life since they occurred at sites generally with good or better biotic integrity. In fact CB 0.3, the most bioticly degraded site, never exceeded the iron criterion. Possible sources of dissolved iron present within the watershed are several small

on-stream ponds and ground water seeps. These may be causing some localized iron precipitation habitat effects, however the biotic data show that the stream communities are not significantly affected by iron.
No other metals were either detected or were well below their ALS Water Quality criteria. Copper, lead, nickel, and zinc were detected once at two sites (SBCB 0.1 and 0.5) during a freshet event. Concentrations were below chronic criteria and occurred in conjunction with high iron concentrations.

Sediment related Water Quality Stressors

The mean and maxima for total suspended solids (TSS), Turbidity, and total phosphorus (TP) at biomonitoring sites under base, moderate freshet and high freshet flows are presented in **Table 8.** Turbidity measurements provide an estimate of total suspended solids; as such turbidity and TSS values should be closely related.

Turbidity criteria for Class B waters in cold water fish habitat should not exceed 10 NTU. Base flow turbidity values ranged from 0.4 – 1.6 NTU. This shows that there are no point sources of turbidity within the watershed that produce any significant amount of chronic sediment stress. Freshet flow turbidity levels were higher then base flows at all sites, with the highest turbidity values associated with bioticly degraded sites in the lower watershed.

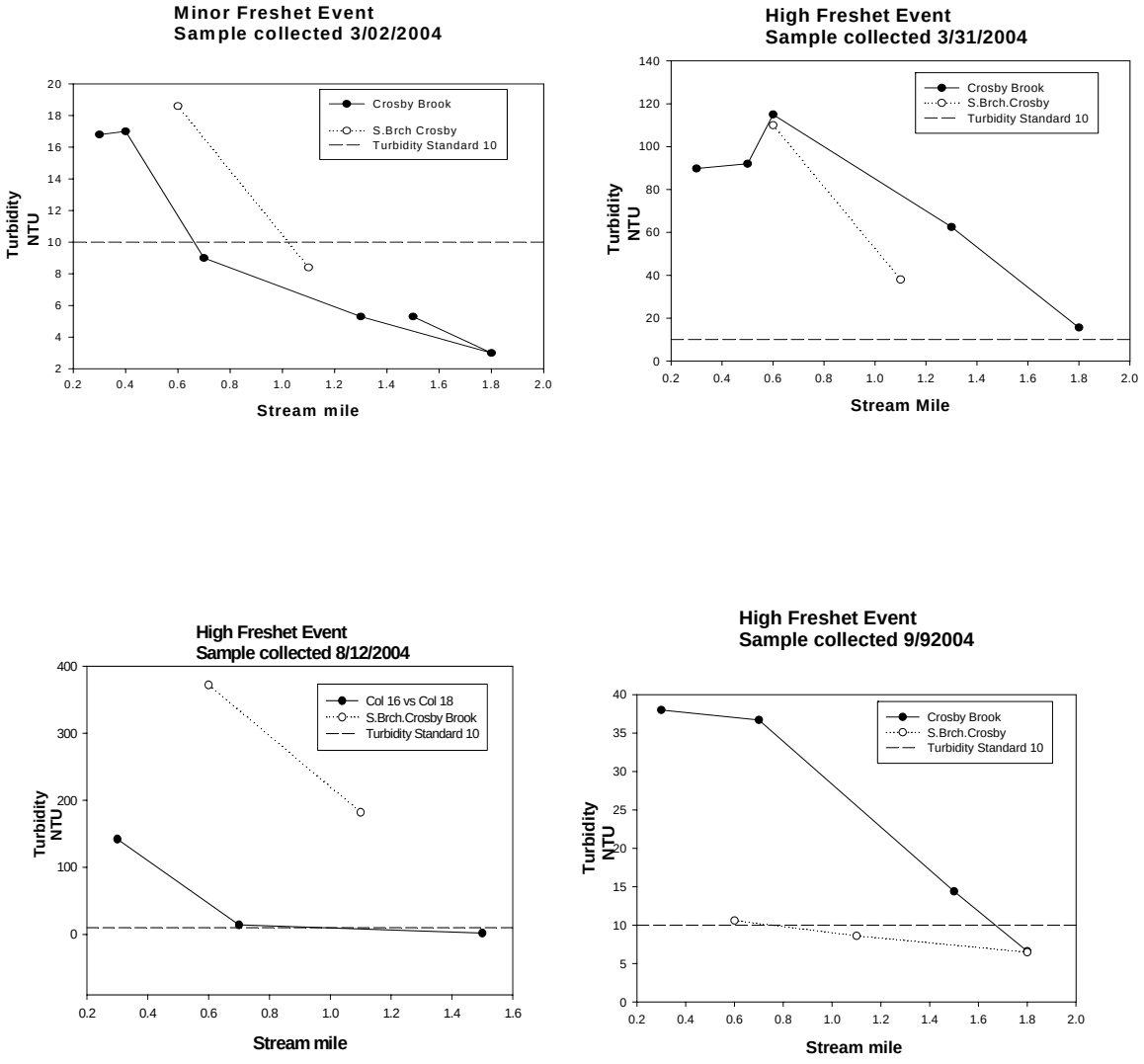
Table 8. TSS, Turbidity, and TP at biomonitoring sites within Crosby Brook watershed under different flow types (base, freshet) and freshet categorical levels (M =moderate, H=High). Data are arranged by site and flow category. Range for each parameter by flow category are also presented. Data reported as mean and **maximum** (bold) for all measures.

Location	Site	Turbidity (NTU)			TSS (mg/l)			TP (ug/l)		
		Base	Freshet		Base	Freshet		Base	Freshet	
			M	H		M	H		M	H
Crosby Brook	**0.3**	1.2 1.6	12.1 **17.0**	89.9 **142**	4.5 **7.5**	21.1 **21.1**	138.5 **214**	13.0 **18.0**	20.0	177.7 **242.0**
	0.5	-	8.4	92.0	-	-	256		-	237
	0.6	0.4	5.8 **9.0**	53 **113**	-	16.4	141 **296**	8.0	20	153.3 **263**
	1.5	0.7	5.3	8.1 **14.0**	4.0	18.2	28.5 **48.8**	9.7	-	49.5 **77**
	1.8	0.3 **0.4**	3.0	11.1 **15.6**	0.5	3.2	31.4 **34.1**	7.5 **8.0**	-	66.5 **72**
South Branch Crosby Brook	**0.1**	0.8 **0.9**	10.2 **18.6**	110.0 **372**	0.5	32.9	146 **277.0**	13.0 15.0	18.0	186 **387**
	0.5	0.8 1.1	8.4	38 **182.0**	1.0	16.4	56.5 **308.0**	10.7 **11.0**	-	115 **417.0**
	1.3	0.9	-	6.5	1.6	-	19.2	13.0	-	64.0
Range by Flow	Min-max	0.4 – 1.6	3.0 – 18.6	6.5 - 372	0.5-7.5	3.2 – 32.9	19.2 - 308	7.5 - 15.0	18 – 20	64 – 417

High freshet flows produced the highest turbidity levels with an 8-20 fold increase from moderate freshets at sites lower in the watershed. These high freshet values were about a 100-fold increase from base flow levels. Sites below Interstate 91 associated with bioticly degraded sites in the lower watershed recorded turbidity values above 100 NTU. The highest turbidity values recorded were at SBCB 0.1 (rm 0.6 on graphs), with a high of 372 NTU (mean 110), followed by CB 0.3 with a high of 142 NTU (mean 89). SBCB site 0.5 (rm 1.1 on graphs) also recorded high turbidity values under high freshet flows. SBCB 0.5, although it was considered above most of the more "urban" land use, it is adjacent to and below an extensive section of gravel road. The only site that did not exceed the 10 NTU criterion during high freshet flows was SBCB 1.3 (rm 1.8 on graphs). This site is located above the influence of most of the gravel roads within the SBCB sub-watershed. CB sites 1.5 and 1.8 increased in turbidity, with a high of 15.6 NTU recorded during one high freshet at site 1.5. This indicates that the gravel roads within the upper watershed of CB proper are only having a slight influence on stream turbidity and resultant sediment movement downstream.

Figure 2 illustrates how turbidity values increased longitudinally from upstream to downstream in CB and SBCB during moderate and high freshet event types. Under a moderate freshet event, turbidity was found to be highest at sites lower in the watershed, increasing by 10-18 times their base flow levels, with turbidity at sites CB 0.3 and SBCB 0.1 above the 10 NTU standard. Sites higher in the watershed only increased 3-10 times their base flow levels during moderate flow events, with no site recording a turbidity value above the 10 NTU standard.

Figure 2. Turbidity values from stream sites in Crosby Brook watershed during one "minor freshet" event and three "high freshet" events. Stream miles shown are relative to distance from mouth. The turbidity water quality criterion for Cold Water Habitat Waters (10 NTU) is shown for reference on each graph (dashed line).



TSS (Total Suspended Solids)

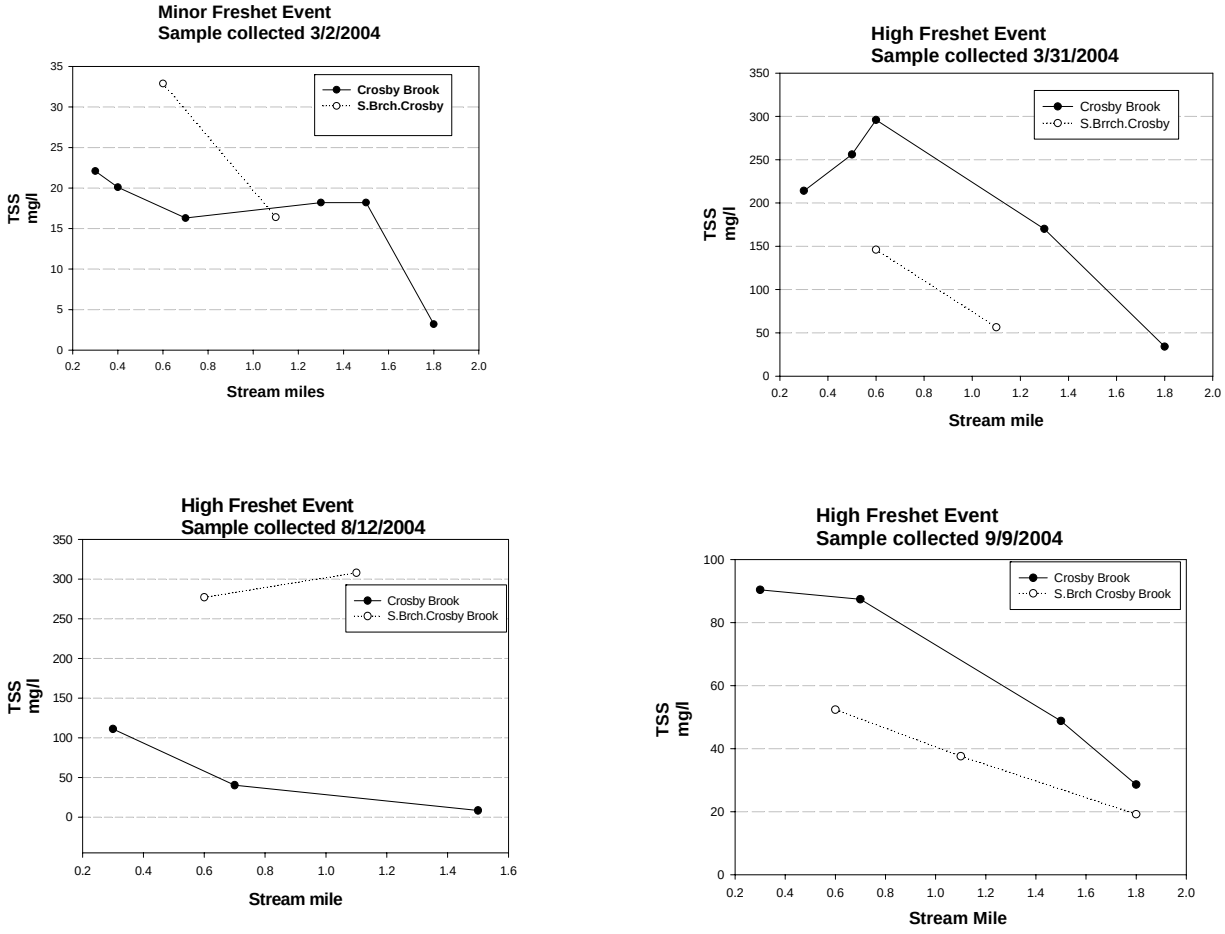
Base flow TSS values ranged from 0.5 – 7.5 mg/l . This shows that there are no point sources of TSS within the watershed that produce any significant amount of chronic sediment stress.

Freshet flow TSS levels were higher than base flows at all sites, with the highest TSS values associated with bioticly degraded sites in the lower watershed. **Figure 3** illustrates how TSS values increase longitudinally from upstream to downstream in CB and SBCB during moderate and high freshet event types. Moderate freshets produced about a four to five-fold increase in TSS levels at most sites. The uppermost CB site 1.8 only increased slightly from base flow to just over 3.0 mg/l TSS. Most of the other sites showed a significant but moderate increase in TSS (16 – 22 mg/l). SCB

site 0.1 was the exception with a TSS value of 32.9 mg/l, indicating some TSS at the site is likely due to I-91 stormwater under moderate freshets.

High freshet flows produced TSS values that averaged over 100 mg/l, with values approaching 300 mg/l at all CB and SBCB sites in the lower watershed (below Interstate 91), and associated with moderate to severe biotic degradation. SBCB site 0.5 also had similarly high TSS values, however the site was not bioticly degraded. Figure 3 shows that TSS significantly increased between CB 1.8 and 1.5 during three of the four freshet flows sampled, even though mean values show the sites to be similar in TSS during high freshet flows with mean values around 30 mg/l. The macroinvertebrate community at the CB 1.5 site also indicated significant degradation compared to CB 1.8. SBCB 1.3 TSS values did not exceed 20 mg/l, the lowest recorded during a high freshet flow.

Figure 3. TSS values from stream sites in Crosby Brook watershed during one "minor freshet" event and three "high freshet" events. Stream miles shown are relative to distance from mouth.



In summary, turbidity and TSS are highly correlated measures of silt, sediment addition and transport in the Crosby Brook watershed. Both parameters appear to be directly related to general land use in the watershed, as well as perhaps some identifiable sources, generally increasing with greater percentages of human land use with-in the watershed (**Figure 1b)**. **Figure 2 and 3** clearly show that on the SBCB turbidity and TSS values increase dramatically at site 0.5, just above I-91, especially during high freshet flow events. It is at this point that the brook runs adjacent to a gravel road for an extended period of time. Just below I-91, turbidity and TSS continue to increase slightly, remaining relatively high. The main stem of CB increases in turbidity and TSS slightly between sites 1.8 and 1.5. Secondary roads, and on stream beaver ponds may cause the increase in TSS values between these sites. Both turbidity and TSS continue to increase on the main stem of CB at site 0.6 located below I-91 but above the confluence with SBCB, and at site 0.5, and 0.3 below the confluence with SBCB.

Given that the turbidity criterion is 10 NTU, fish and other aquatic biota may show signs of stress during these events. However, the temporal nature of the freshet flows recorded help to mitigate adverse impacts directly associated with high turbidity and TSS events. Chronic turbidity and TSS associated with base flow that persists for longer periods of time would be a more significant problem for the aquatic biota. High turbidity and TSS associated with freshet flow events, as in this case, may be an indication of habitat related degradation and stress on the aquatic biota from siltation or embeddedness of the stream bed.

Total phosphorus (TP) levels also responded directly to flow types, increasing as flows increased. Nutrients such as phosphorus are almost always adsorbed to soil particles and transported by the movement of sediment, so it is not surprising that as TSS and turbidity increased coincidently with TP levels.

Base flow TP levels were the lowest, with values ranging from 7.5 – 18.0 ug/l. Moderate freshets produced a marginal increase in TP levels. The highest TP during a moderate freshet was 20.0 ug/l. High freshets, however, produced a 10-20 fold increase in TP levels compared to base flows, with TP levels ranging from 64 – 417 ug/l.

Environmental Stressors:

Water Temperature

Temperature data loggers (HOBO® Temp) were used to monitor temperature fluctuations at three locations on the main stem of Crosby Brook (CB sites 0.3, 0.5, 1.8) and one location on South Branch Crosby (SBCB site 0.5). The temperature data loggers were used to determine whether temperature stress could be a factor affecting the biotic health of the streams. Instream temperatures were recorded every hour, thus portraying a precise picture of the diurnal temperature fluctuations that occur. The four data loggers were deployed for approximately 3- 4 weeks at each site, spanning from mid-July to mid-August (**Table 9**).

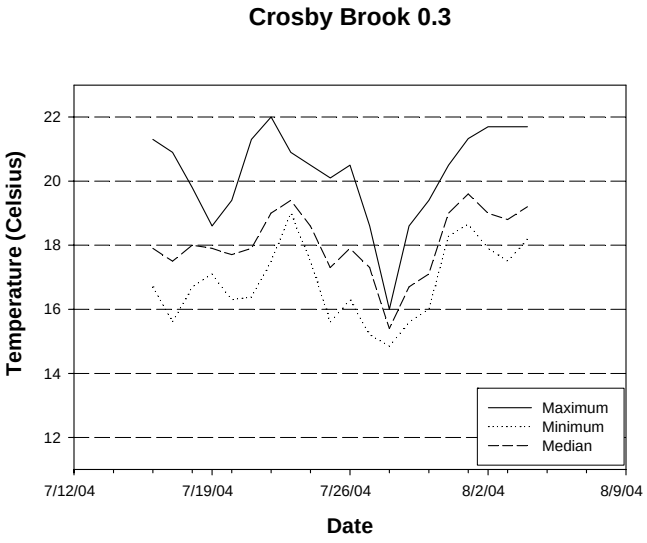
Table 9 : Temperature data logger deployment by site

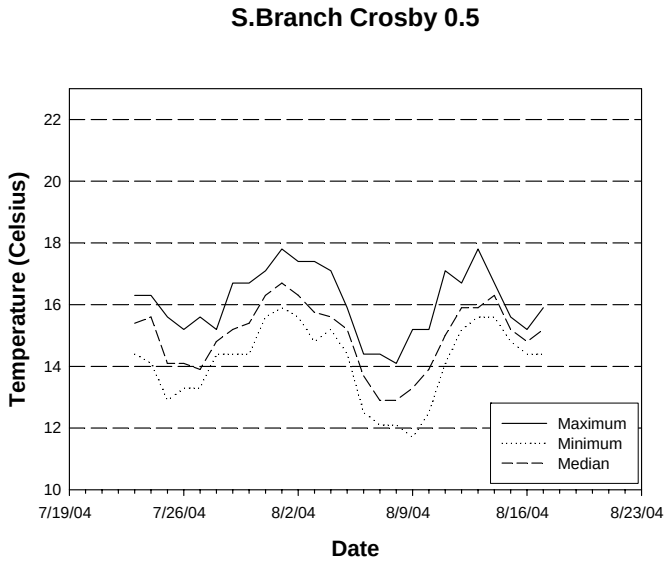
Site	Data Loggers Deployed	# days deployed	Approx. # of Temp. Readings
Crosby Brook 0.3	July 15 – August 5, 2004	20 days	480
South Branch Crosby 0.5	July 23 – August 17, 2004	25 days	600
Crosby Brook 1.5	July 16 – August 5, 2004	20 days	480
Crosby Brook 1.8	July 20 – August 16, 2004	27 days	648

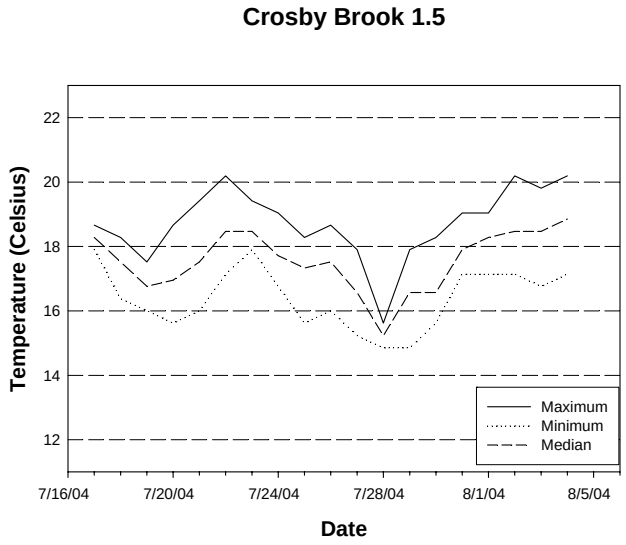
The daily maximum, minimum and median temperature values recorded at the four Crosby Brook watershed sites are presented in **Figure 4**. The coolest water temperatures were recorded at the SBCB 0.5 site; the maximum temperature at SBCB 0.5 site did not exceed 18^{o}C. Water temperatures at the CB 1.8 site did not exceed 19.5^{o}C and were the coolest recorded for the main stem of CB. The highest water temperatures on CB were recorded at the 0.3 site; maximum daily temperatures exceeded 21^{o} C for several consecutive days at this site. At CB 1.5, located just a short distance downstream from CB 1.8, the maximum daily water temperature exceeded 20 ^{o}C on a few days.

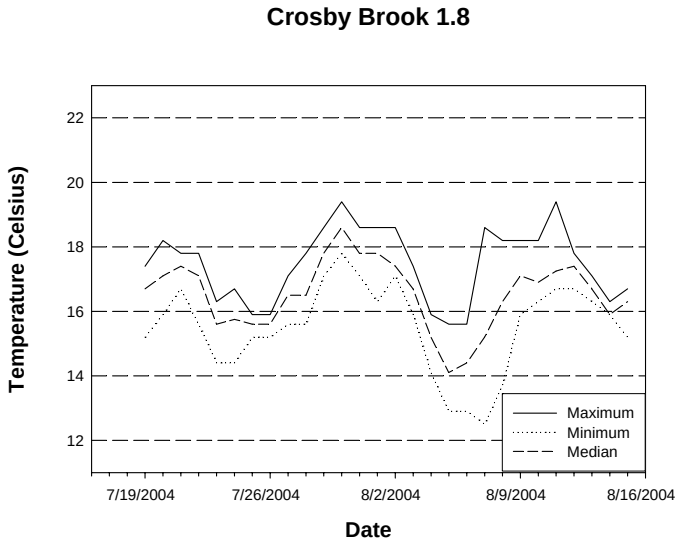
The lowest water temperature recorded, 11.7 ^{o}C was from S. Branch Crosby 0.5. Water temperatures in small headwater streams such as this one may be dominated by groundwater temperatures. In contrast, the highest temperature recorded, 21.7 ^{o}C, was recorded near the mouth of Crosby Brook at Crosby 0.3.

Figure 4. Daily maximum, minimum and median temperature values recorded at four Crosby Brook sites. (Stream temperatures below 19.0°C are considered good for cold-water aquatic biota, temperatures between 19 – 21 °C are considered marginal and temperatures above 21.0 °C are considered poor.)





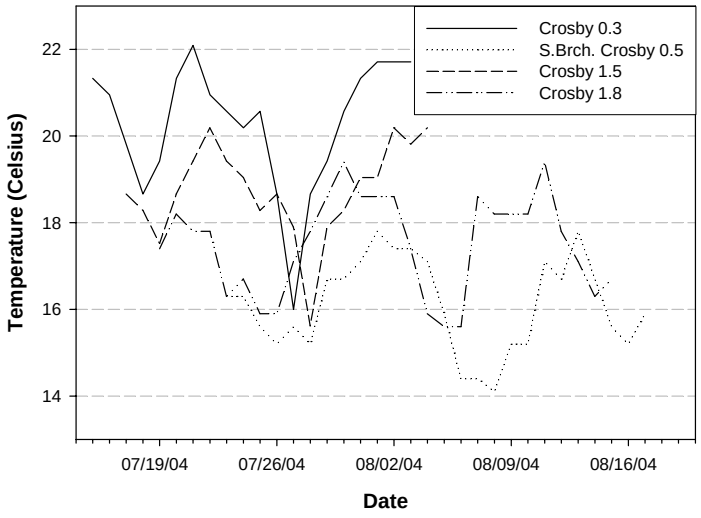




The optimal water temperature range for cold water species such as brook trout is between 14 – 19^{o}C. Water temperatures that frequently exceed 20^{o}C will most likely result in sub-optimal and potentially stressful conditions for brook trout and other stenothermal aquatic species. Fish community surveys conducted at Crosby 0.3 revealed a sub-marginal brook trout population, as might be expected with observed maximum daily temperatures exceeding 21^{o}C for several consecutive days (**Figure 5**).

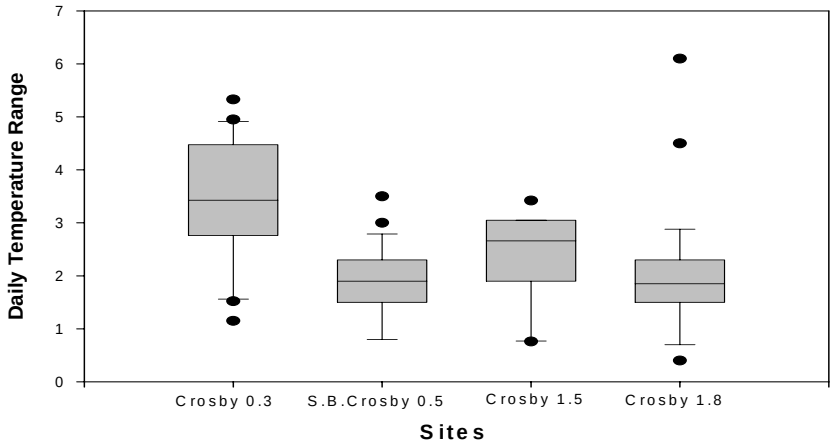
Maximum daily air temperatures recorded at the RVCU Weather Station on Putney Road in Brattleboro, VT, coincided well with maximum observed stream water temperatures at all sites. The highest air temperatures recorded during the data logger's deployment exceeded 38^{o}C (100^{o}F) for several days in early August. In **Figure 5**, a maximum water temperature line shows a peak for all sites during this early August period.

Figure 5: Maximum Daily Temperatures for all Crosby Brook sites



Anthropogenic reduction in the efficiency of stream buffers to suppress temperature fluctuations will likely result in higher maximum and lower minimum daily temperatures in the stream. The continuous (hourly) data recording that the data loggers provided captured the daily maxima and minima temperatures. These daily temperature ranges for all Crosby Book sites are presented in **Figure 6**.

Figure 6: Crosby Brook Temperature Range at all Crosby Brook sites



The greatest daily temperature fluctuations were consistently recorded at CB 0.3, the median range for CB 0.3 was about 3.5 ^{o}C. This site is below the most urban areas of the watershed (**Figure 1b)**. The median temperature range for CB 1.8 and SBCB 0.5 was less than 2.0^{o}C; these were the lowest temperature fluctuations recorded. These two sites are least effected by paved surfaces or on stream beaver impoundments. The median range for CB 1.5 was slightly higher at 2.5 ^{o}C. This site maybe influenced in part by natural beaver flowages, but is also below stream reaches adjacent to secondary roads. These results also appear to be consistent with stream temperature research that observe water temperatures near a stream's mouth are more likely to be influenced by mean daily air temperature (greater fluctuations) than groundwater temperatures.

Conclusions and Recommendations:

It is clear that the biotic integrity of the lower reaches of Crosby Brook proper are degraded. The lowest reach sampled has consistently been assessed as “fair” to “poor” for three consecutive years. Reaches sampled above the more urban land-use area in the lower watershed have been consistently assessed as “very good” to “excellent” in fish community integrity. This has also been true for the macroinvertebrate community except for a reach at CB 1.5. This site consistently shows some level of degradation when compared to the uppermost reach on CB 1.8.

Two stressors, sediment and temperature, have been shown to increase significantly longitudinally, and to be at levels high enough at CB 0.3 to be stressful to aquatic life. In the case of sediment, it appears that during high flows, the SBCB begins to carry a significant sediment load from areas above SBCB 0.5. The stream runs immediately adjacent to a long reach of gravel road immediately above this site. On CB proper sediment measures appear to significantly increase at CB 0.6. This is the first reach on CB that is within a more urban landuse setting and receives stormwater runoff. Sediment measures tend to remain constant or increase from these to points mentioned above to the lowest reach sampled CB 0.3. Sediment addition to the stream is clearly related to freshet runoff events, and does not appear to occur during base flows.

Temperature has been shown to be high enough at the lowest site CB 0.3 to be stressful to cold-water aquatic life. It has also been shown to be marginal at CB 1.5. At CB 1.8 temperature maximums have been shown not to rise to stressful levels however several data points did show a high diurnal fluctuation at the reach. SBCB has been shown to be consistently cool, and does not appear to be stressed by temperature. In fact, it is a source of cold water to CB at their confluence. Sources of temperature stress are therefore of greater concern in the mainstem CB.

It is recommended that:

1- Town Gravel road drainage be assessed especially in the lower reaches of SBCB.

2- Stormwater discharges be completely inventoried within the lower “Urban” part of the watershed and assessed as to their current condition and point of discharge to CB. Increased levels of stormwater treatment should be sought for significant contributors.

3- Streambed stability “geomorphic condition” be evaluated as a potential source of sediment especially within the SBCB.

4- The riparian zone of CB proper from its upper falls area, just below the RR crossing up to at least CB 1.8 be assessed for its quality in terms of buffering the stream from thermal stress.

5- On stream ponds on CB proper be identified and assessed for their effects on stream temperatures.

Acknowledgements

The Vermont Department of Environmental Conservation would like to thank the following local individuals who made the collection of much of this data possible. Simon Norton who volunteered to collect water quality samples following rain events during high water freshets in a timely manner. Mike Euphart an intern with the West River association who helped set and retrieve a temperature data logger on the South Branch of Crosby Brook. Emmie Richards from the West River Alliance for help in coordinating with these local volunteers and supplying a temperature data logger for the project.

The Department would also like to thank Craig Shillinglaw formerly of Dummerston who first noticed the turbid condition of Crosby Brook and requested that its water quality be assessed. Lastly the Department would like to thank Gary Nadeau property owner, and Casey Donovan general manager of LEADER Distribution System for allowing access to Crosby Brook at sometimes unconventional times during this past year of sampling.

Appendix 1: Photos of biomonitoring reaches sampled for fish, macroinvertebrates, temperature and water quality in the Crosby Brook watershed.






Crosby at mouth and RM 0.2




Crosby Brook 0.3




Crosby Brook 0.4

Crosby 1.5

Crosby 1.8


S.Brch Crosby 0.1


S.Brch Crosby 0.5


S. Brch. Crosby Brook 1.3

Appendix 2: Water chemistry measures from the Crosby Brook watershed presented by site and date, collected under different flow types (base, freshet) and categorized levels (low,moderate,high).

Location	Site	Date	Flow Type	pH s.u.	Alk mg/l	Cond uohoms	Turb. ntu	TSS mg/l	TP ug/l	TN mg/l	TDP ug/l	Flow Level
Crosby Brook	0.3	9/17/2002	Base	8.02	78	246*						Low
Crosby Brook	0.3	9/18/2003	Base	7.78	91.2	277	1.36			0.27		Low
Crosby Brook	0.3	9/24/2003	Freshet	7.74	70.8	207	2.7		20	0.27		Moderate
Crosby Brook	0.3	3/2/2004	Freshet	7.46	62.5	276	16.6	21.6	45	0.47		Moderate
Crosby Brook	0.3	3/31/2004	Freshet	7.72	51.8	169	89.8	214	242	0.83		High
Crosby Brook	0.3	7/16/2004	Base		91.5	266	1.56		11			Low
Crosby Brook	0.3	8/12/2004	Freshet		41.3	125	142	111	170			High
Crosby Brook	0.3	9/3/2004	Base	7.95	83.4	226	1.37	7.5	18	0.26	7	Moderate
Crosby Brook	0.3	9/9/2004	Freshet		50.8	131	38	90.4	121			High
Crosby Brook	0.4	3/2/2004	Freshet	7.47	63.1	251	17	20.1	56	0.59		Moderate
Crosby Brook	0.5	3/31/2004	Freshet	7.74	68.4	205	92	256	237	0.93		High
Crosby Brook	0.6	9/24/2003	Freshet	7.49	65.8	185	2.7		20	0.27		Moderate
Crosby Brook	0.6	3/2/2004	Freshet	7.32	58	246	9	16.3	24	0.5		Moderate
Crosby Brook	0.6	3/31/2004	Freshet	7.74	45.7	147	115	296	263	0.83		High
Crosby Brook	0.6	7/16/2004	Base		75	232	0.39		8			Low
Crosby Brook	0.6	8/12/2004	Freshet		33.7	100	14.2	40.2	85			High
Crosby Brook	0.6	9/9/2004	Freshet		48.4	124	36.7	87.4	112			High
Crosby Brook	0.7	9/2/2004	Base	8.13	74.2	204	0.74	3.8	14	0.23	8	Moderate
Crosby Brook	1.3	3/2/2004	Freshet	7.17	61.3	210	5.3	18.2	23	0.49		Moderate
Crosby Brook	1.3	3/31/2004	Freshet	7.7	51	148	62.5	170	203	1.04		High
Crosby Brook	1.5	9/18/2003	Base	7.77	80.2	230	1.04		9	0.23		Low
Crosby Brook	1.5	3/2/2004	Freshet	7.17	61.3	210	5.3	18.2	23	0.49		Moderate
Crosby Brook	1.5	7/16/2004	Base		77.4	239	0.46		9			Low
Crosby Brook	1.5	8/12/2004	Freshet		76.7	206	1.87	8.3	22			High
Crosby Brook	1.5	9/3/2004	Base	7.67	78.1	206	0.57	4	11	0.23	6	Moderate
Crosby Brook	1.5	9/9/2004	Freshet		53.5	138	14.4	48.8	77			High
Crosby Brook	1.8	3/3/2004	Freshet	7.53	63.5	200	3	3.2	11	0.42		Moderate
Crosby Brook	1.8	3/31/2004	Freshet	7.53	55.1	156	15.6	34.1	61	0.65		High
Crosby Brook	1.8	7/16/2004	Base		79.8	237	0.26		7			Low
Crosby Brook	1.8	9/3/2004	Base	7.46	81.9	213	0.41	0.5	8	0.21	7	Moderate
Crosby Brook	1.8	9/9/2004	Freshet		56.8	138	6.61	28.6	72			High
Crosby Brook South Branch	0.1	9/24/2003	Freshet	7.53	87.2	228	1.9		18	0.29		Moderate
Crosby Brook South Branch	0.1	3/2/2004	Freshet	7.5	68	254	18.6	32.9	82	0.48		Moderate
Crosby Brook South Branch	0.1	3/31/2004	Freshet	7.94	68.1	214	110	146	186	0.64		High
Crosby Brook South Branch	0.1	8/12/2004	Freshet		52.9	182	372	277	387			High
Crosby Brook South Branch	0.1	9/2/2004	Base	7.91	103	258	0.61	1.7	15	0.28	10	Moderate
Crosby Brook South Branch	0.1	9/9/2004	Freshet		63.9	150	10.6	52.4	106			High
Crosby Brook South Branch	0.1	7/16/2005	Base		110	309	0.98		11			Low
Crosby Brook South Branch	0.5	9/18/2003	Base	7.98	114	254	0.72		11	0.22		Low
Crosby Brook South Branch	0.5	3/2/2004	Freshet	7.6	74.1	244	8.4	16.4	28	0.45		Moderate
Crosby Brook South Branch	0.5	3/31/2004	Freshet	7.88	67	168	38	56.5	115	0.7		High
Crosby Brook South Branch	0.5	7/16/2004	Base		112	275	1.14		11			Low
Crosby Brook South Branch	0.5	8/12/2004	Freshet		70.3	197	182	308	417			High
Crosby Brook South Branch	0.5	9/2/2004	Base	7.82	103	246	0.5	1	10	0.29	9	Moderate
Crosby Brook South Branch	0.5	9/9/2004	Freshet		62.3	145	8.61	37.6	70			High
Crosby Brook South Branch	1.3	9/2/2004	Base	7.84	105	238	0.94	1.6	13	0.26	7	Moderate
Crosby Brook South Branch	1.3	9/9/2004	Freshet		62.2	142	6.48	19.2	64			High

Appendix 3: Water chemistry measures from the Crosby Brook watershed presented by site and date, collected under different flow types (base, freshet) and categorized levels (low,moderate,high). T=Total,D=Dissolved

Location	Site	Date	Flow	DFe ug/l	DMn mg/l	TCl mg/l	TSO4 mg/l	DCa mg/l	DMg mg/l	DNa ug/l	DK ug/l	Level
Crosby Brook	0.3	9/18/2003	Base	157	101	32.3	9.58	36	4.17	21.5	1.26	Low
Crosby Brook	0.3	9/24/2003	Freshet	126	50	12.9	8.16	25.3	3.33	11.2	1.2	Moderate
Crosby Brook	0.3	3/2/2004	Freshet	179	58.9	23.6		28.1	3.1	20.8	1.1	Moderate
Crosby Brook	0.3	8/12/2004	Freshet	312	44.4	12.2	6.5		1.7	7.78	1.63	High
Crosby Brook	0.3	9/3/2004	Base	267	23.8	12.4	9	32.7	3.81	9.64	1	Moderate
Crosby Brook	0.4	3/2/2004	Freshet	188	55.5	25.8		28.7	3.18	16.3	1.04	Moderate
Crosby Brook	0.4	3/31/2004	Freshet	493	41.4	16		20.1	2.49	9.62	0.83	High
Crosby Brook	0.4	9/3/2004	Base	256	22.8	12.3	9	31.3	3.86	9.64	1.02	Moderate
Crosby Brook	0.4	9/9/2004	Freshet	411	32.4	5.1	6.04	19.1	2.32	4.32	1.18	High
Crosby Brook	0.5	3/31/2004	Freshet	1830	82.4	14.4		20.9	2.53	8.67	0.84	High
Crosby Brook	0.6	9/24/2003	Freshet	126	50	12.9	8.16	22.5	3.17	9.4	0.93	Moderate
Crosby Brook	0.6	3/2/2004	Freshet	150	39.1	27.5		26	3.09	17.5	0.78	Moderate
Crosby Brook	0.6	3/31/2004	Freshet	312	28.5	11.8		17.5	2.33	7.39	0.73	High
Crosby Brook	0.6	8/12/2004	Freshet	152	24.3	7.9	5.1		1.58	5.66	0.98	High
Crosby Brook	0.6	9/9/2004	Freshet	271	25.6	5.1	6.06	17.9	2.2	4.57	1.06	High
Crosby Brook	0.7	9/2/2004	Base	245	20.8	11.1	8.36	29.2	3.58	9.05	0.91	Moderate
Crosby Brook	1.3	3/2/2004	Freshet	148	19.6	14.8		27.3	3.22	9.6	0.7	Moderate
Crosby Brook	1.3	3/31/2004	Freshet	1410	89.3	9.2		19.9	2.47	5.68	0.78	High
Crosby Brook	1.5	9/18/2003	Base	102	50	21.9	9.26	35.7	3.7	8.8	1.4	Low
Crosby Brook	1.5	3/2/2004	Freshet	148	19.6	14.8		27.3	3.22	9.6	0.7	Moderate
Crosby Brook	1.5	8/12/2004	Freshet	233	28.6	17.6	7.8		3.31	11.4	0.99	High
Crosby Brook	1.5	9/9/2004	Freshet	258	32.9	5.3	6.19	20	2.37	4.46	1.04	High
Crosby Brook	1.8	3/3/2004	Freshet	136	6.6	10.8		28.7	3.11	6.95	0.79	Moderate
Crosby Brook	1.8	3/31/2004	Freshet	482	39.6	8.8		23.4	2.6	5.24	0.76	High
Crosby Brook	1.8	9/3/2004	Base	187	6.8	9.9	8.67	32.4	3.72	8	0.96	Moderate
Crosby Brook	1.8	9/9/2004	Freshet	209	10.7	4.4	5.94	21	2.48	3.76	1.08	High
Crosby Brook South Branch	0.1	9/24/2003	Freshet	193	54.1	13	8.84	35.7	3.7	8.8	1.4	Moderate
Crosby Brook South Branch	0.1	3/2/2004	Freshet	206	62.2	23.5		31.8	3.28	13.9	1.19	Moderate
Crosby Brook South Branch	0.1	3/31/2004	Freshet	332	38.4	17.6		29.8	3.12	10	1.1	High
Crosby Brook South Branch	0.1	8/12/2004	Freshet	1240	383	19.9	8.94		2.64	11.9	3.1	High
Crosby Brook South Branch	0.1	9/2/2004	Base	290	26.1	11.8	9.62	40.8	4.41	8.86	1.33	Moderate
Crosby Brook South Branch	0.1	9/9/2004	Freshet	287	23.3	4.6	5.92	23.9	2.59	3.92	1.38	High
Crosby Brook South Branch	0.5	9/18/2003	Base	110	50	10.3	9.86	46.6	4.54	7.32	1.13	Low
Crosby Brook South Branch	0.5	3/2/2004	Freshet	189	66.6	17.1		34.6	3.56	9.82	1.11	Moderate
Crosby Brook South Branch	0.5	3/31/2004	Freshet	1410	101	16.8		29.9	3.14	9.64	1.22	High
Crosby Brook South Branch	0.5	8/12/2004	Freshet	1840	488	15.7	10		3.4	8.26	3.12	High
Crosby Brook South Branch	0.5	9/2/2004	Base	254	8	6.3	9.63	41.8	4.48	5.17	1.3	Moderate
Crosby Brook South Branch	0.5	9/9/2004	Freshet	272	24.9	3.3	5.87	23.9	2.61	2.44	1.37	High
Crosby Brook South Branch	1.3	9/2/2004	Base	328	23.6	2.7	10.1	40.8	4.65	2.79	1.25	Moderate
Crosby Brook South Branch	1.3	9/9/2004	Freshet	1120	132	2	5.88	23.2	2.65	1.51	1.28	High