Runoff from paved and unpaved parking lots at the Spruce Peak parking area Stowe Mountain Resort, Stowe, Vermont.

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Abstract:

There are two adjacent parking lots at the Spruce Peak area of Stowe Mountain Resort; one of these lots is paved, while the other one is not. Underneath each of these parking lots runs a stream, which has been diverted into a culvert below its respective lot. During a rainstorm on November 5th, 2001, the site was visited and water samples were collected every half-hour for three hours by sampling the water in each of the streams above and below the parking lot. This water was analyzed in the lab for suspended sediment content and organic content, and we found that the unpaved parking lot had a significantly larger amount of sediment running off into its stream. The data also revealed that there was a correlation between the amount of sediment in the water, or Total Suspended Solids [TSS], and the amount of water in the stream (flow). The peak of the stream flow came just after the peak in the Total Suspended Solids [TSS].

Introduction:

The effects that unpaved and paved parking lots have on sediment loads in streams during a storm event is an important part of the impact that human infrastructure has on an environment. In this paper, two streams, one that runs under a paved parking lot, and one that runs under an unpaved parking lot, were studied during a rainstorm to find if there was any significant amount of sediment runoff from either parking lot, and to determine the differences between them. This data will then contribute to the ongoing duel watershed studies of the Ranch Brook and West Branch (B.Wemple, personal communication).

The watersheds of Ranch Brook and West Branch are located in Stowe, Vermont (Fig. 1 and 2). The sites studied in this paper are located at the Spruce Peak parking lots off Rt. 108 (Fig.3), and are part of the West Branch Watershed. The Spruce Peak parking lots include one lot that is paved with asphalt and another that is dirt (Fig. 4). Above these areas are two different streams that enter culverts. The streams are diverted under the paved or unpaved areas, respectively (Fig. 3). The stream above the paved parking lot, designated paved upper (PU), runs down a steep slope in a line of trees between the Meadows ski trail and the Alpine Slide, and the other stream (unpaved upper (UU), Fig. 5a) runs under the unpaved lot and meanders down a steep wooded area. The streams surface below their respective lots separately (designated paved lower (PL), and unpaved lower (UL) Fig. 5b), and eventually merge about two meters downstream from the end of each culvert.

Unpaved, heavily trafficked areas are unstable because they contain loose sediment; therefore, volume of runoff can be increased, as compared to a more stable area (paved), due to the excess traffic (Macdonald et al. 2000). In regions that have been modified by road building or clear-cutting, the watersheds are left significantly changed (Hart et al. 1975). These changes can increase the sediment output during a storm event because they alter the supply of loose material (Ziegler et al. 2000). In this paper, we hypothesize that a significant amount of rainfall will increase the instability caused by traffic on the unpaved lot, and that the sediment load in the stream below the unpaved parking lot (UL) will be greater than the sediment loads in all of the other sampled areas (UU, PL, PU). Furthermore, as the storm lessens, there will be a decrease in the amounts of sediment that are available to be transported (Ziegler et al 1999). To evaluate these hypotheses, these questions will be considered. i) What types of sediment are being transported? ii) How much difference is there in sediment runoff between the sites? iii) Is there a correlation between peak flow and peak sedimentation?

Methods:

On Monday November 5th, we sampled the runoff from the two Spruce Peak parking lots every 30 minutes from 3:30pm to 6:30pm during a storm event. Two sites at each parking lot were designated for sampling. We measured both upper and lower sites of each lot simultaneously. Samples were taken by placing 1000mL bottles into the stream and moving them up and down to collect an averaged sample of the water flowing through the stream channel. This was done until the bottle was full. We then capped and marked the bottle with the date, time, and site, and placed it in the car.

The following week, we took the samples to the lab (Fig. 6) and analyzed them for total suspended solids (TSS), and total organic content. First, the samples were weighed and filtered to separate the solids. This was done with a vacuum filtering system in which we washed the fiberglass filters under the vacuum and placed them in aluminum pans numbered 1 through 30. They were then dried in an oven overnight, at a temperature of 103º F, and weighed the next day. Meanwhile, we weighed the sample bottles and recorded their weight. After 24 hours, the clean, dry filters were placed on the vacuum filter apparatus and the contents of the sample bottles were poured into the system, each in separate filters, until all the water had been evacuated. The inside of the bottle and the sides of the container on the vacuum filter were washed out with Type-III de-ionized water in order to collect any sediment that may have adhered to the sides. We transferred the filtered sediments back into their corresponding pans (Fig. 7), put them back into the 103º oven, and dried them overnight. The following day, the dry samples were weighed (Fig. 8), then placed in a furnace and heated for 30 minutes at 550º F. This intense heat burned off any organic material contained within the sediment. This process is called a Loss On Ignition (LOI). The samples were weighed again after LOI.

Lastly, we calculated and interpreted LOI and TSS. Graphs were made showing relationships between time, sediment load, and stream flow, and a statistical analysis (t-test) was completed. We compared data with USGS flow gauge information measuring stage height, downstream from the Spruce Peak parking lots (the stage height data were used as a proxy for stream flow).

Data and Calculations:

Unpaved Lower (UL):

The [TSS] ranged from 6.69 mg/L to 49.88 mg/L, with a mean of 29.87 mg/L. The final concentration of the inorganic solids collected after LOI ranged from 0.97 mg/L to 14.24 mg/L, while the percent of organic material was approximately 80%.

Unpaved Upper (UU):

The [TSS] ranged from 4.47 mg/L to 17.62 mg/L, with a mean of 7.39 mg/L. The final concentration of the inorganic solids collected after LOI ranged from 0.56 mg/L to 5.47 mg/L, while the percent of organic material was approximately 70%.

Paved Lower (PL):

The [TSS] ranged from 1.72 mg/L to 3.50 mg/L, with a mean of 2.41 mg/L. The final concentration of the inorganic solids collected after LOI ranged from 0.26 mg/L to 1.84 mg/L, while the percent of organic material was approximately 66%.

Paved Upper (PU):

The [TSS] ranged from 0.90 mg/L to 4.19 mg/L, with a mean of 1.90 mg/L. The final concentration of the inorganic solids collected after LOI ranged from 0.22 mg/L to 1.28 mg/L, while the percent of organic material was approximately 70%.

Discussion:

The data collected supports our hypothesis in that it shows a significantly larger amount of sediment runoff from the unpaved parking lot when compared to the paved parking lot. Similarly to what Ziegler et al. concluded, we feel this excess runoff is caused by human impact – people skiing, walking, and driving on the hill slopes and the unpaved parking lot, increasing erosion. Additionally, the results of the t-tests gave conclusive evidence about the amounts of sediment running off of each parking lot. The paved lot does not yield a significant difference in sediment load into the stream, while the unpaved lot does.

The LOI test performed on each of the samples revealed that the sediment running off the parking lots was mostly comprised of organic material (Fig 11). After looking at the organic content of specific sites, we concluded that the UU and PU sites had approximately the same amount of organic content (about 70%). The PL, however, had a much lower organic content (66%), while the UL had a much higher organic content (80%). These differences in organic content are clearly a result of a) the existence of pavement, allowing for the addition of fairly clean rainwater runoff which dilutes the existing stream water, and b) the surrounding brush. The unpaved lot is surrounded on three sides by dying plant matter, which can easily be washed onto the lot, while the paved lot is surrounded only on one side by this plant debris.

After analyzing [TSS] and comparing it to the stream flow data for the West Branch stream, we noticed a correlation between the amount of water flowing through the stream and the [TSS] (Figs. 9 + 10). As the flow of water increased, so did the [TSS]. These data support our hypothesis that stream flow would correlate with sediment load. The discrepancy in time, about one hour, could be due to the fact that the flow data was taken downstream from the sites of our samples, where the stream into which our streams empty (West Branch) is much larger. The flow data could therefore not be particularly significant for our streams, which were uphill from that collection site. It would be plausible that because precipitation moves from the top of the hill to the bottom, we would see an increase in flow (and thus sediment) higher up on the mountain before we would see that increase in flow downstream.

Conclusion:

The data collected indicates that there is a large amount of sediment running off of the unpaved parking lot and washing into the stream. It also shows that there is a relationship between stream flow and sediment load in the stream. The peak stream flow occurs approximately 1 hour after the peak sediment load. These data can be used in future planning for the Stowe Mountain Resort, as well as for current watershed management. Perhaps the Ranch Brook watershed, now a relatively untouched area of land, can be better managed with the understanding that parking lots, especially unpaved, bring a significant amount of sedimentation and erosion that could alter the delicate balance of a watershed.

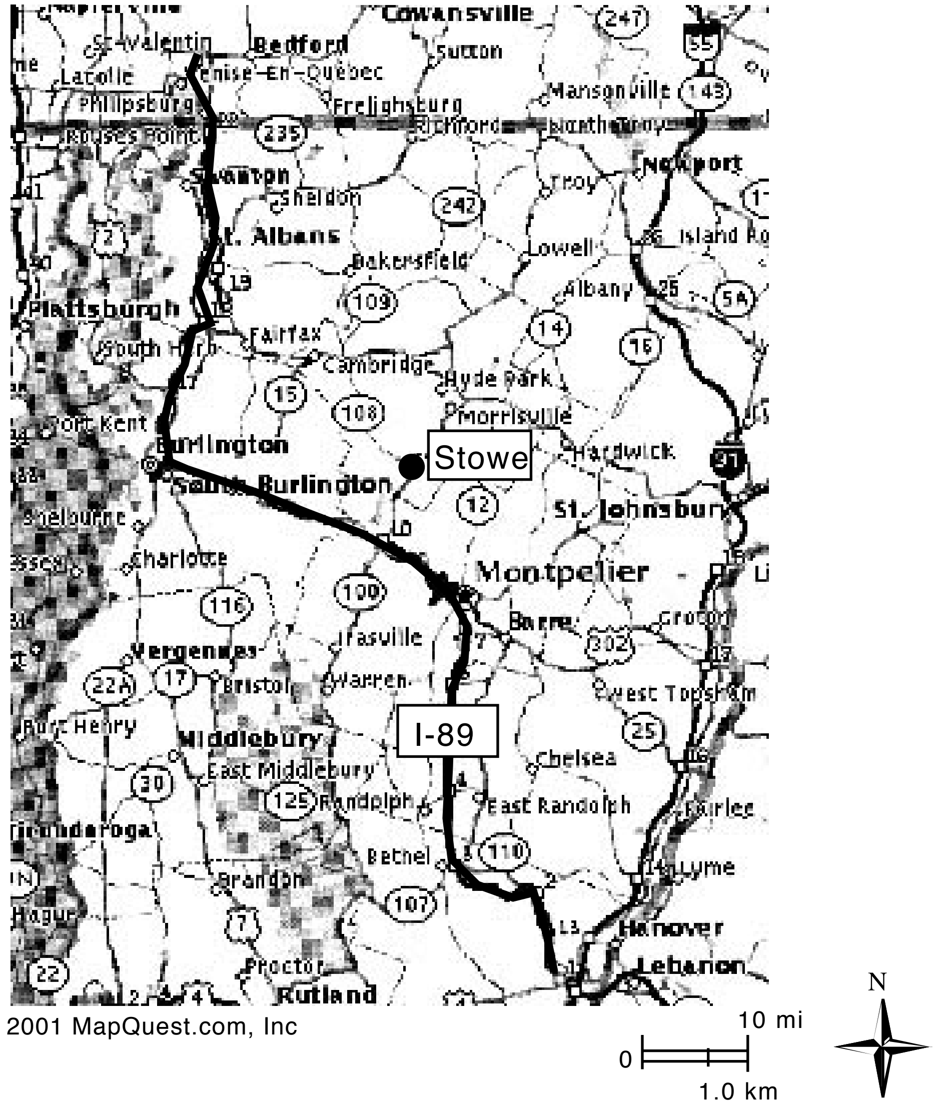

Figure 1: A road map of the northern part of Vermont, showing the location of Stowe, Vermont with respect to Interstate 89.

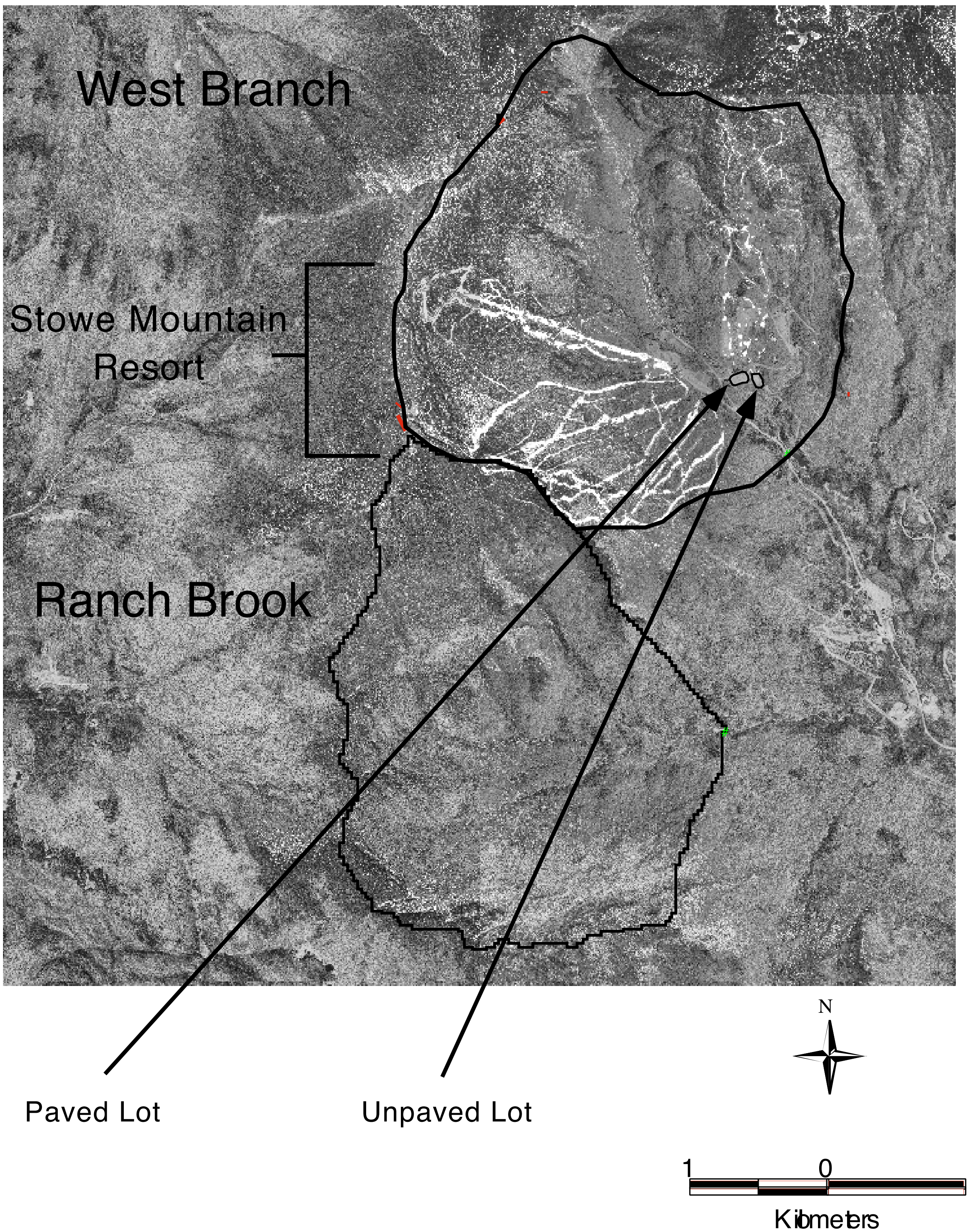

Figure 2: The duel watersheds of
West Branch and Ranch Brook. White lines indicate
ski trails at Stowe Mountain Resort, parking lot sites are shown.

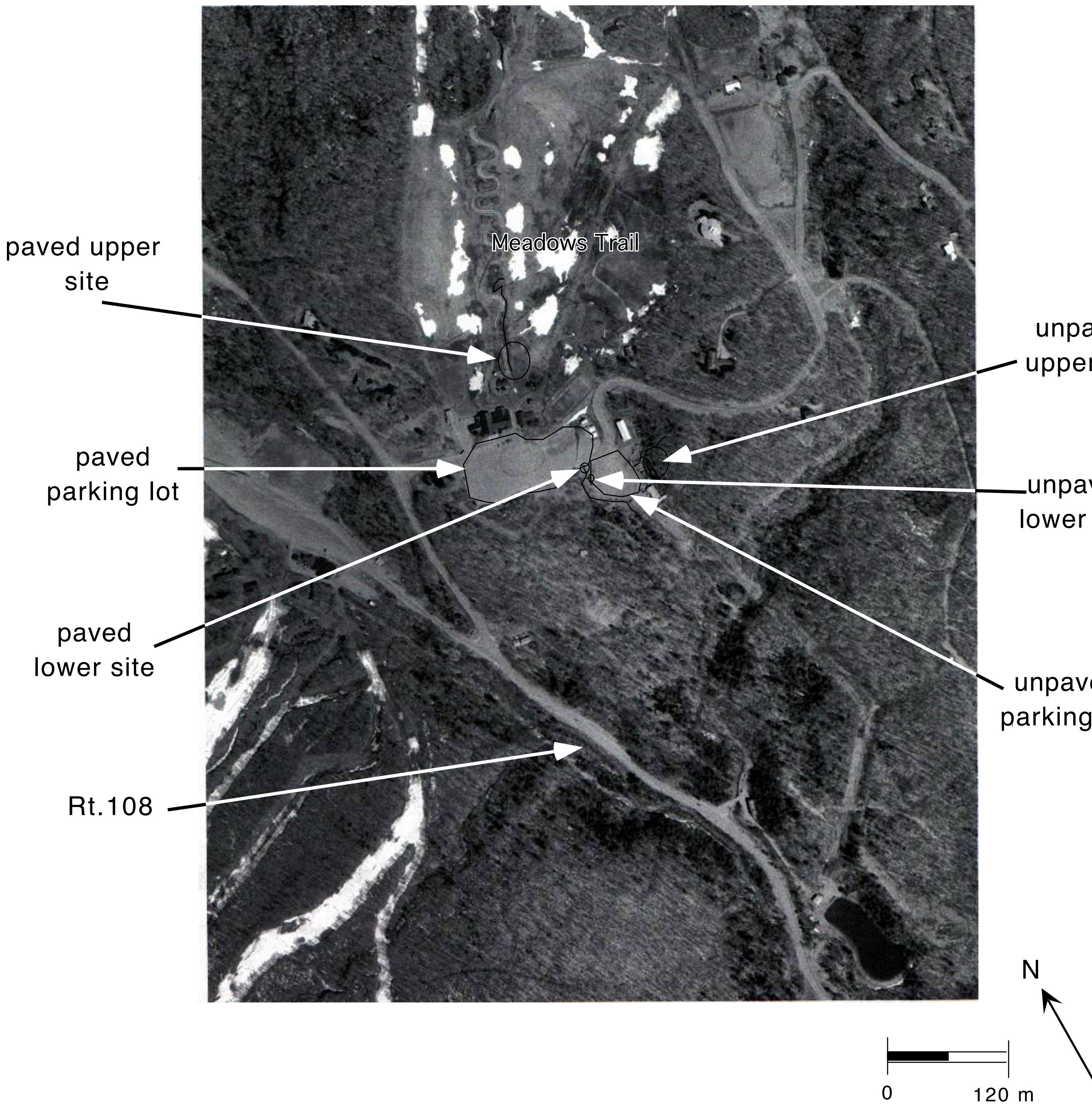

Figure 3: This is a map view of the area of the unpaved and paved Spruce Peak parking lots with respect to Rt. 108 (the mountain road). The four sites studied were the paved upper site, the paved lower site, the unpaved upper site, and the lower unpaved site, shown by arrows .

Figure 4: The two parking lots at Spruce Peak, Stowe Mountain Resort. The unpaved lot is in the foreground, and the paved lot is in the background. The boundary between the two lots is roughly marked by the pole to the left of the middle of the picture.

Figure 5a: The lower sample site for the Unpaved lot.

Figure 5b: The upper site for the Unpaved lot. The stream is difficult to see due to the poor resolution of the photograph.

Figure 6: The Rubenstein Lab, where all lab work was conducted.

Figure 7: All 30 samples, after they have been filtered. Note the large variance in color; this is actually a large difference in sediment amounts for each filter, which represents one sample bottle, with the exception of two bottles, which are represented by two filters each.

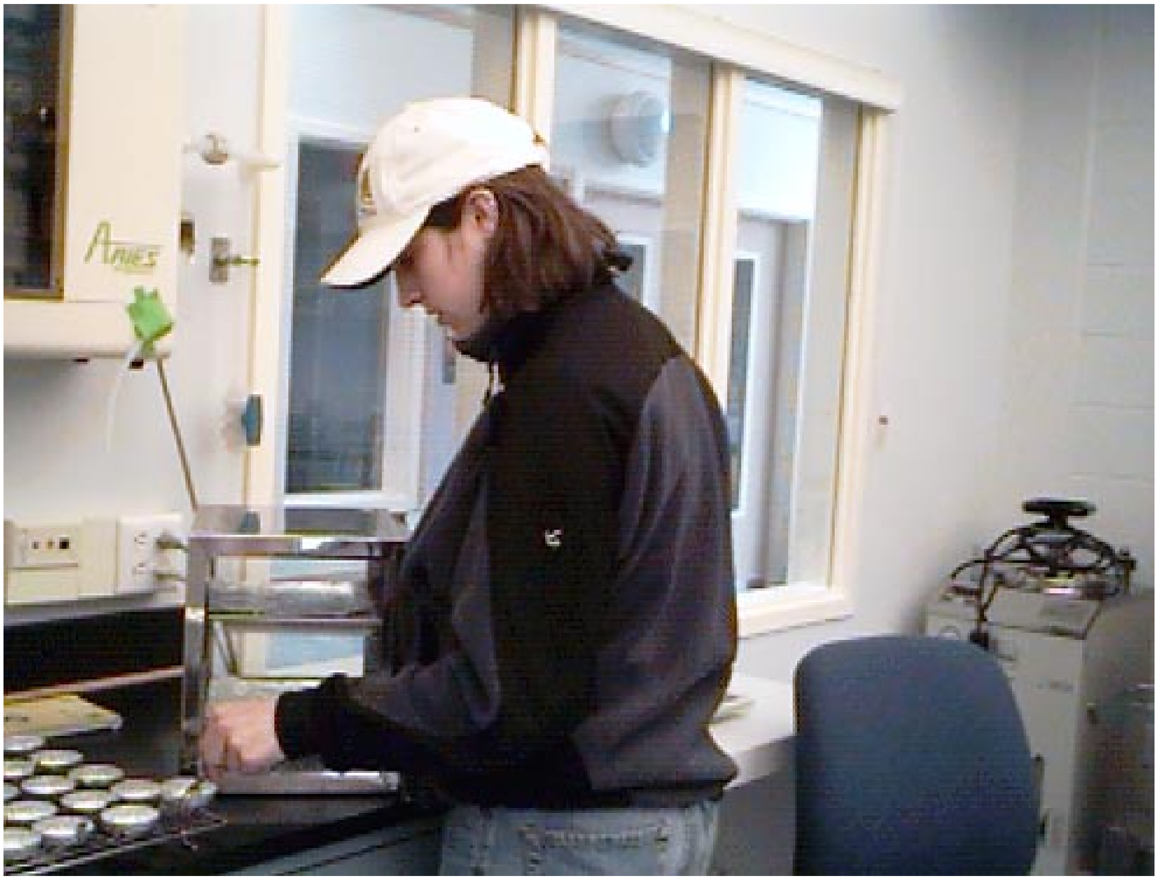

Figure 8: Marianne, placing weighed, dried samples on the oven tray for transfer to the furnace.

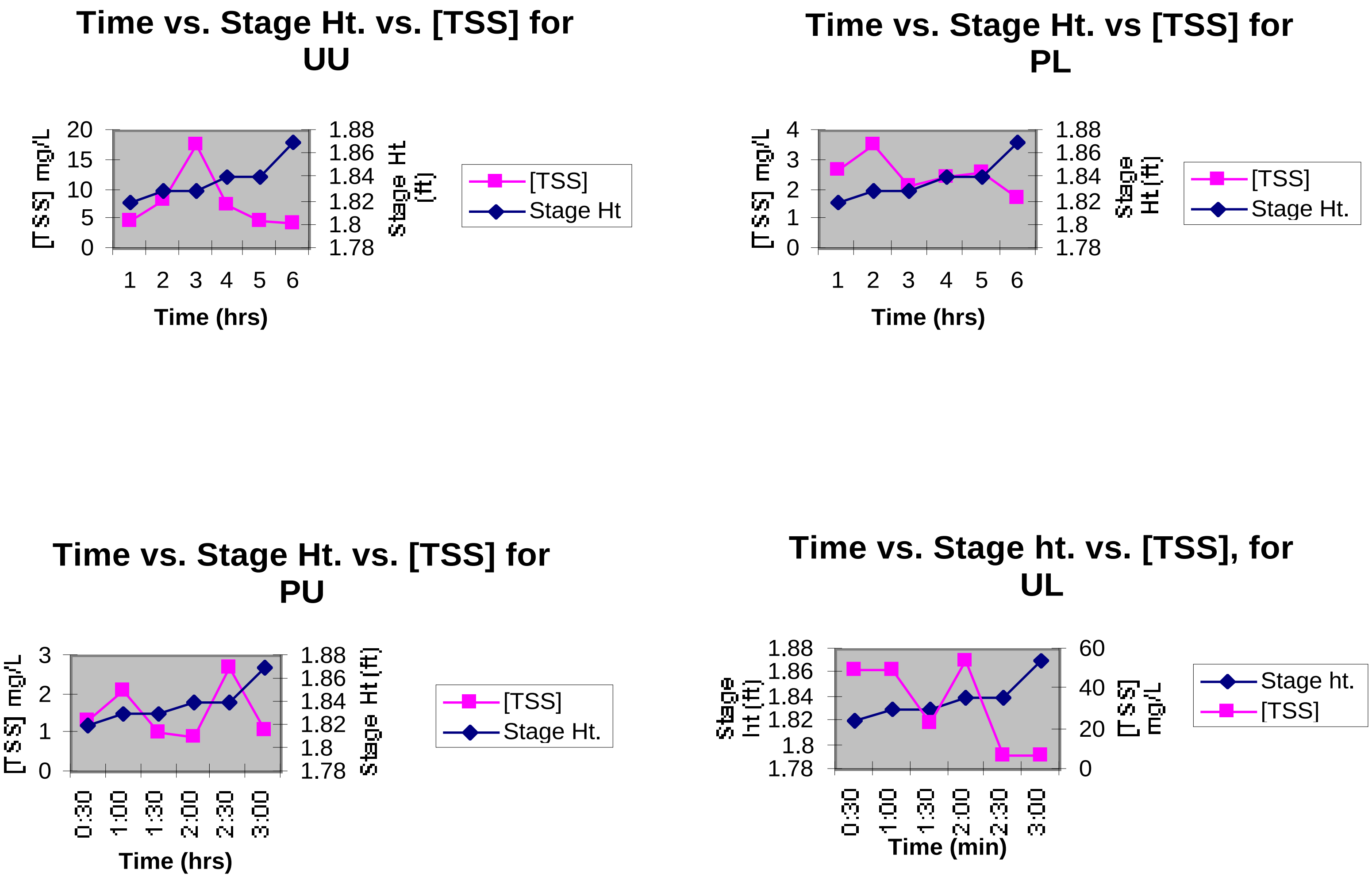

Figure 9: Graphs showing the correlation between the [TSS] and the stage height, or stream flow. Note that each graph shows the [TSS] peaking about and hour before the stage height, or flow.

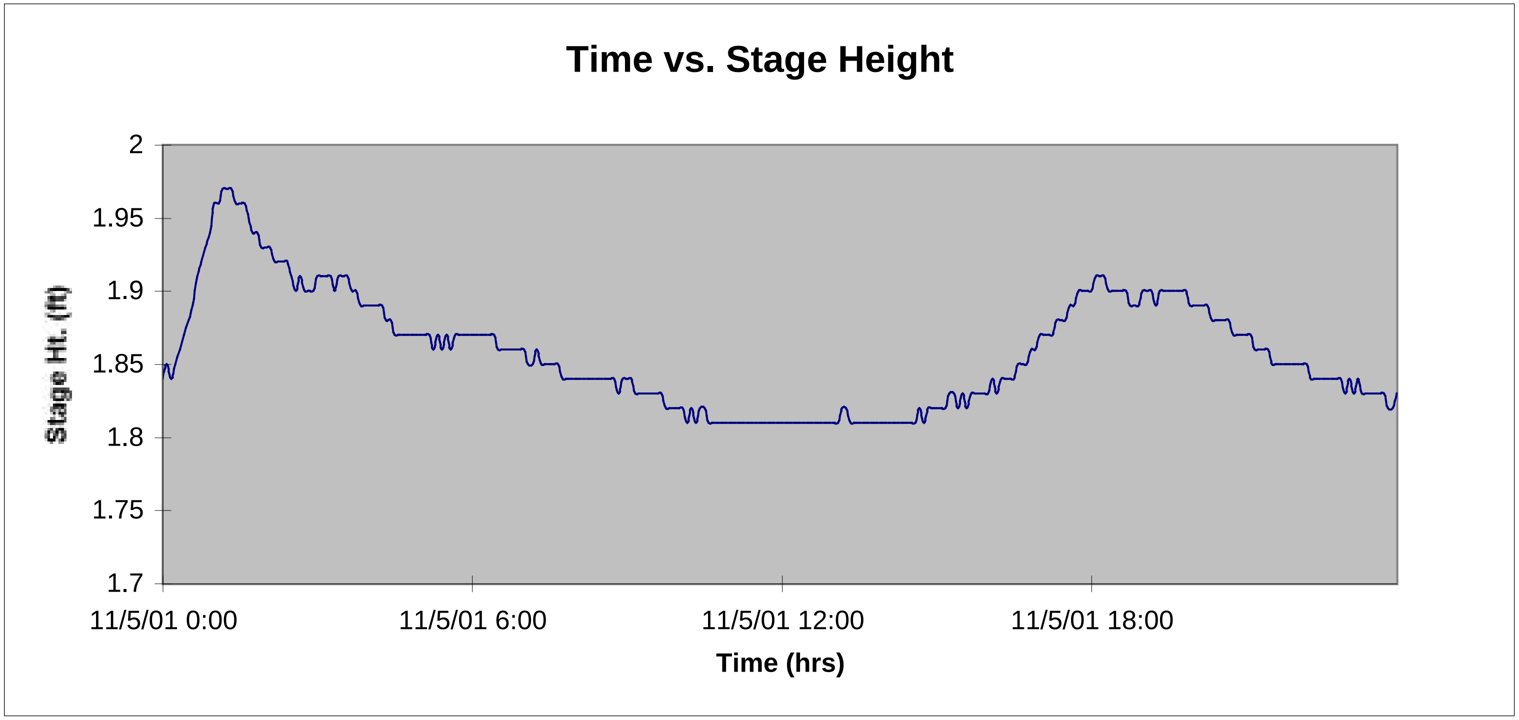

Figure 10: The Stage Height as measured by the USGS over the day that our samples were collected. This graph can be used in conjunction with Figure 9 to see the time of peak stream flow.

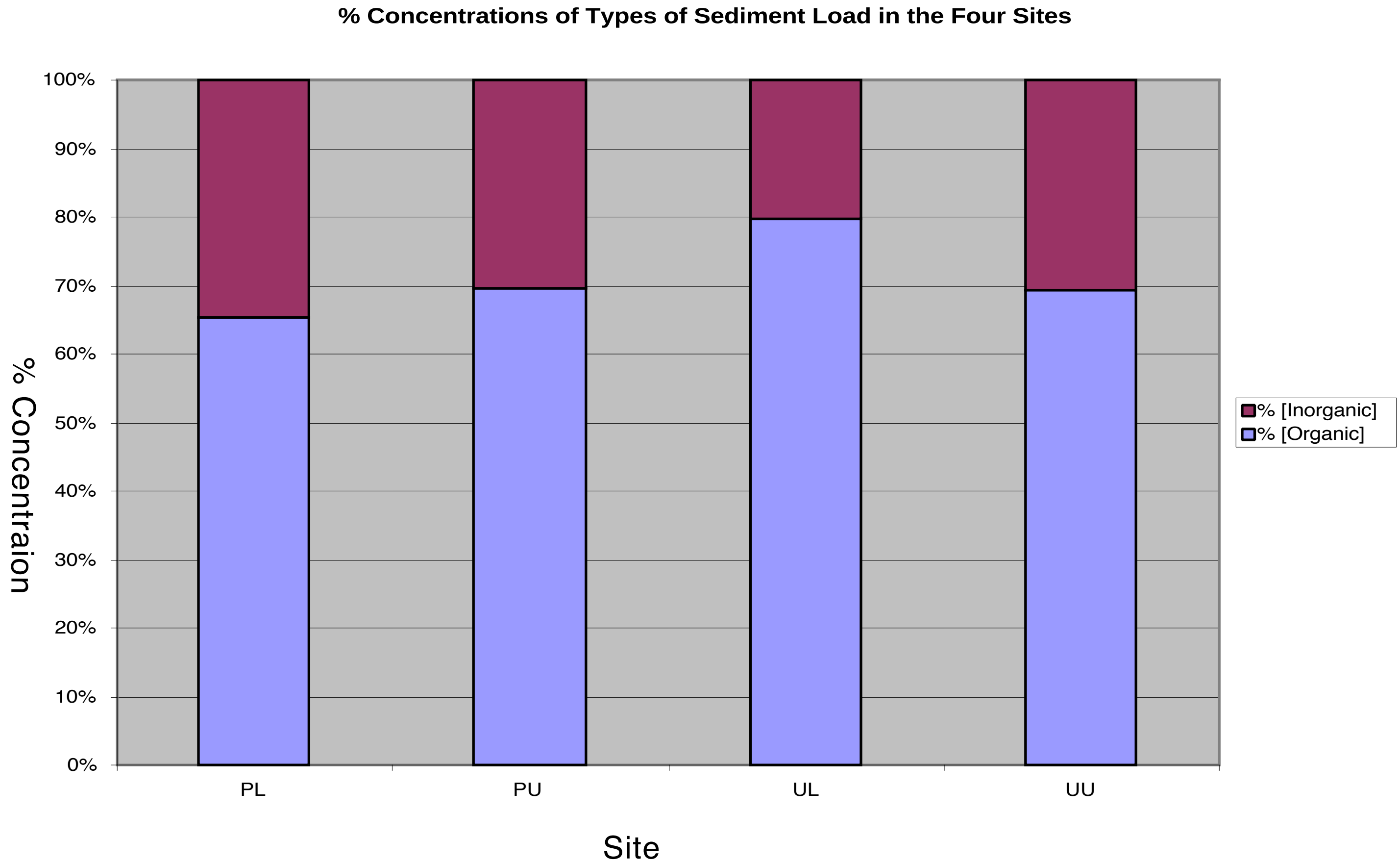

Figure 11: This graph illustrates the types of material that was running off of the parking lots. This graph shows the total amount of sediment (100%) broken into organic vs. inorganic. There is far more organic material in the runoff from the parking lots, about 70%, than there is inorganic.

Appendix 1:

The concentration of Total Suspended Solids [TSS] was calculated using the following formula:

$$[TSS]\ mg/L = \frac{TSS\ (g) * 1000}{water\ weight / 1000g}$$

Final inorganic concentration was calculated using the following formula:

$$[Inorganic]\ mg/L = \frac{(Weight\ Inorganic) * 1000}{water\ weight / 1000g}$$

T-Test for Unpaved Parking Lot:

_ = 0.05
H_o = There is no difference in the mean [TSS] between the upper and lower sites
H_A = There is a difference in the mean [TSS] between the upper and lower sites

n = 7
x_1 = 7.3921
x_2 = 29.8712
s = 19.5308
critical value = ± 2.447

$$t = \frac{x_1 - x_2}{s / \sqrt{n}}$$

$$t = \frac{7.3921 - 29.8712}{19.5308 / \sqrt{7}} = -2.959$$

T-Test for Paved Parking Lot:

_ = 0.05
H_o = There is no difference in the mean [TSS] between the upper and lower sites
H_A = There is a difference in the mean [TSS] between the upper and lower sites

n = 7
x_1 = 1.9035
x_2 = 2.4125
s = 0.6061
critical value = ± 2.447

$$t = \frac{x_1 - x_2}{s / \sqrt{n}}$$

$$t = \frac{1.9035 - 2.4125}{0.6061 / \sqrt{7}} = -2.222$$

Sample #	Date	Time (hrs)	Site	Bottle Wt. (g)	Wt. (g) b+s	Water Wt. (g)	Pan #
1	5-Nov	15:30	UL	50	989.09	939.09	54
2	5-Nov	15:30	UU	50	985.03	935.03	40
3	5-Nov	16:00	UL	50	1030.32	980.32	29*
4	5-Nov	16:00	UU	50	956.08	906.08	31
5	5-Nov	16:30	UL	50	1032.76	982.76	32
6	5-Nov	16:30	UU	50	942.37	892.37	3
7	5-Nov	17:00	UL	50	1020.39	970.39	66
8	5-Nov	17:00	UU	50	964.01	914.01	63
9	5-Nov	17:30	UL	50	1010.48	960.48	78*
10	5-Nov	17:30	UU	50	970.32	920.32	9
11	5-Nov	18:00	UL	50	976.89	926.89	1
12	5-Nov	18:00	UU	50	934.85	884.85	11
13	5-Nov	18:30	UL	50	977.36	927.36	46
14	5-Nov	18:30	UU	50	945.87	895.87	15
15	5-Nov	15:30	PL	50	867.51	817.51	49
16	5-Nov	15:30	PU	50	908.22	858.22	45
17	5-Nov	16:00	PL	50	895.09	845.09	88
18	5-Nov	16:00	PU	50	911.58	861.58	13
19	5-Nov	16:30	PL	50	792.54	742.54	28
20	5-Nov	16:30	PU	50	889.64	839.64	79
21	5-Nov	17:00	PL	50	808.4	758.4	17
22	5-Nov	17:00	PU	50	921.24	871.24	34
23	5-Nov	17:30	PL	50	910.47	860.47	35
24	5-Nov	17:30	PU	50	938.98	888.98	6
25	5-Nov	18:00	PL	50	871.51	821.51	5
26	5-Nov	18:00	PU	50	912.64	862.64	10
27	5-Nov	18:30	PL	50	920.66	870.66	43
28	5-Nov	18:30	PU	50	950.63	900.63	26
3*						980.32	41
9*						960.38	74

*indicates that there were two trays per one bottle

UL-unpaved lower parking lot
UU-unpaved upper parking lot
PL-paved lower parking lot
PU-paved upper parking lot

Wt. Clean (g)	Wt. Dirty (g)	Wt.Ignited (g)	Wt. Solids (g)	Wt. Inorganics (g)	Wt. Organics (g)
1.0858	1.1082	1.1029	0.0224	0.0053	0.0171
1.096	1.1002	1.099	0.0042	0.0012	0.003
1.0949	1.1353	1.1256	0.0404	0.0097	0.0307
1.0951	1.0994	1.0978	0.0043	0.0016	0.0027
1.0954	1.1444	1.136	0.049	0.0084	0.0406
1.094	1.1014	1.0986	0.0074	0.0028	0.0046
1.0868	1.1092	1.1051	0.0224	0.0041	0.0183
1.0828	1.0989	1.0939	0.0161	0.005	0.0111
1.0816	1.0935	1.09	0.0119	0.0035	0.0084
1.0916	1.0984	1.0962	0.0068	0.0022	0.0046
1.0863	1.0929	1.092	0.0066	0.0009	0.0057
1.0886	1.0928	1.0913	0.0042	0.0015	0.0027
1.0871	1.0933	1.0923	0.0062	0.001	0.0052
1.0904	1.0944	1.0939	0.004	0.0005	0.0035
1.0914	1.0929	1.092	0.0015	0.0009	0.0006
1.0888	1.0924	1.0913	0.0036	0.0011	0.0025
1.0771	1.0794	1.0788	0.0023	0.0006	0.0017
1.0886	1.0897	1.0892	0.0011	0.0005	0.0006
1.0926	1.0952	1.0946	0.0026	0.0006	0.002
1.0812	1.083	1.0825	0.0018	0.0005	0.0013
1.0906	1.0922	1.092	0.0016	0.0002	0.0014
1.0943	1.0952	1.0949	0.0009	0.0003	0.0006
1.0978	1.0999	1.0989	0.0021	0.001	0.0011
1.0931	1.0939	1.0936	0.0008	0.0003	0.0005
1.0898	1.0919	1.0912	0.0021	0.0007	0.0014
1.0905	1.0928	1.0924	0.0023	0.0004	0.0019
1.0927	1.0942	1.0936	0.0015	0.0006	0.0009
1.096	1.097	1.0968	0.001	0.0002	0.0008
1.0953	1.1038	1.102	0.0085	0.0018	0.0067
1.0867	1.1272	1.1199	0.0405	0.0073	0.0332

[Solids] (mg/L)	[Inorganic] (mg/L)	[Organic] (mg/L)
23.8529	5.6438	18.2091
4.4918	1.2834	3.2085
41.2110	9.8947	31.3163
4.7457	1.7658	2.9799
49.8596	8.5474	41.3122
8.2925	3.1377	5.1548
23.0835	4.2251	18.8584
17.6147	5.4704	12.1443
12.3896	3.6440	8.7456
7.3887	2.3905	4.9983
7.1206	0.9710	6.1496
4.7466	1.6952	3.0514
6.6856	1.0783	5.6073
4.4649	0.5581	3.9068
1.8348	1.1009	0.7339
4.1947	1.2817	2.9130
2.7216	0.7100	2.0116
1.2767	0.5803	0.6964
3.5015	0.8080	2.6935
2.1438	0.5955	1.5483
2.1097	0.2637	1.8460
1.0330	0.3443	0.6887
2.4405	1.1622	1.2784
0.8999	0.3375	0.5624
2.5563	0.8521	1.7042
2.6662	0.4637	2.2025
1.7228	0.6891	1.0337
1.1103	0.2221	0.8883
8.6706	1.8361	6.8345
42.1708	7.6012	34.5696

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