A Few Good Counting Stations

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ABSTRACT

Many cities use traffic counting stations. These stations sometimes do more than just count volumes – they can be used to measure vehicle speeds as well. Some large jurisdictions use these traffic monitoring stations to get congestion information, and use this data as part of a Traveller Information System.

Calgary uses traffic monitoring stations as well, but at this time has only three monitoring stations that can measure both speed and volume. Calgary also has an Advanced Traveller Information System, and would like to be able to provide congestion information through it.

This paper collects and analyses data from some of Calgary's traffic monitoring stations, in order to determine what information can be provided by the stations to a Traveller Information System, with a focus on providing congestion information. Many days worth of data has been collected and analysed in order to assess trends and find useful information.

The research done for this paper indicates that the best indication of congestion is the mean speed of traffic passing a monitoring station. As congestion grows, the mean speed will decrease. Several causes of congestion (peak period, weather and incident related) were analysed and all show a decrease in mean speed. Additionally, the standard deviation of the speed can also be used as an indicator of the reason for congestion, since accidents often cause a different distribution of speeds compared to a typical peak period.

INTRODUCTION

From the smallest hamlet to the largest metropolis, automobile traffic is a fact of life. In a small town, traffic tends to be fairly simple. There is usually not a lot, even during the peak period, and its effect on the town is not very pronounced. There is no need for major traffic studies, interchanges, or extensive systems, since a few traffic lights and some stop signs are usually enough. In a major city, a few traffic lights are not enough to handle traffic. Left unchecked, traffic could easily spiral out of control during peak times. Gridlock can become a constant reality, leading to other problems. Business traffic is slowed, hurting the economy. Pollution increases from the constantly idling vehicles and costs to average citizens increase as more gas is spent and more time is wasted. Fortunately, large cities do not ignore traffic. There are a huge variety of ways to deal with traffic. Some cities pay more attention to it than others, and every city does things differently.

One of the tools that cities can use to improve their traffic problems is a Traveller Information System. This is a fairly broad category that includes any system that provides information to travellers, as the name implies. In Calgary, there is the Advanced Traveller Information System (ATIS), which provides information about road closures, construction, detours and accidents on Calgary roads. Currently, this information is available on the internet and serves the entire city. As well, there is a radio station that provides the same information, but only serves South Calgary. (This is because the radio project is still a pilot project. It is expected that if it continues, the radio will eventually serve the entire City of Calgary.) Information on road closures, detours and construction is obtained from the Roads department at the City of Calgary, and accident information is obtained from the Calgary Police Service during peak periods.

Many other cities (and some regions) provide a similar sort of Traveller Information System to their citizens and visitors. If a large city or region has a lot of highways, sometimes it will provide a congestion map that the public can access. These can be colour coded to show how much congestion there is on any given stretch of roadway. The Puget Sound Region around Seattle is an example of a region with a colour-coded congestion map. See figure 1 for a sample of this congestion map.

In order to get such a detailed congestion map, the Washington Department of Transportation operates more than 4,000 inductive loops in the highways, giving it roughly 360 locations where it can obtain data [1]. The City of Calgary also uses induction loops for traffic monitoring. However, unlike the Washington DOT, Calgary does not have 360 volume & speed counting locations. The City of Calgary, at the time of this writing, operates only three volume, speed & classification monitoring stations. An additional 13 stations are operated by the City, but measure only volume.

PROBLEM

Despite not having many traffic monitoring stations available, the City of Calgary would like to provide congestion information as part of the Advanced Traveller Information System at some point in the future. It was decided that the first step in this plan is to assess what data could be obtained from only a small number of traffic monitoring stations, and determine how to use that data with a Traveller Information System. The focus is on getting congestion information that can be used operationally (i.e. in real-time) rather than historically (as is the case for planning data).

BACKGROUND

Congestion

In order to properly assess congestion and distribute congestion information, it is important to understand congestion. Congestion on a roadway is seen in different ways by different people, but there is one clear indicator of congestion that can easily be measured – speed. When a road is not congested, vehicle speeds will tend to hover around the speed limit, with some going faster and some going slower, but overall clustered around the limit. When a road becomes congested however, the speeds begin to drop. As more and more cars come onto the roadway, the average speed of those cars decreases. If traffic congestion gets heavy enough, eventually traffic will become stop & go (where drivers will stop and start repeatedly as the traffic moves through a heavily congested roadway). If there are many monitoring stations set up along a roadway at regular intervals, it is possible to know exactly where congestion is, and how much there is, simply by checking the speeds at several points along the roadway. When only a single station is available, an accurate picture of the whole road network cannot be given. Despite this, there is still useful data!

Causes of Congestion

There are three main causes for congestion on a roadway. The first is peak period volumes. Most people think of rush hour (peak period) traffic when they think of a congested roadway, and for good reason. The most common cause of congestion is peak period traffic, as it occurs consistently twice a day, five days a week. The amount of congestion generated by the peak period is not always the same. Fridays often see less congestion than other days of the week, and summer months see fewer vehicles on the road during peak hours than other months.

The next cause of congestion is weather conditions. At several sites studied in Calgary, many of the days with the worst congestion were those with snowfall and, to a lesser extent, rainfall. An example of this can be seen in Dataset 1, which will be introduced later. While weather effects do not cause much congestion on roadways in the off-peak, they magnify the effects of regular peak period traffic, causing heavy congestion – much worse than peak period traffic alone.

The third cause of congestion is obstructions. This is a general term that encompasses many things, such as construction, objects on the roadway, stalls and accidents. Anything that blocks or slows the regular travel on at least one lane of traffic falls into this category. Obstructions are also highly unpredictable – unless it is a scheduled event, such as construction, there is no way to know how much of an effect there will be. A minor fender-bender may close down one lane, then only slow a lane if it moves to the side. A fatality could potentially close down the entire roadway. Even knowing how long it will last is difficult. An accident could last ten minutes while the drivers get their cars off the road, or half the day if the police need to do an investigation.

Traveller Information Systems

Traveller Information Systems can provide information to drivers about many possible obstructions on the roadway. Construction and detours information can be obtained to show where there may be a problem. The police services can give out information about accidents, and sometimes stalls and other obstructions. If CCTV cameras are in place nearby, these can also be used to watch for obstructions. When inclement weather occurs, notices can be put onto the Traveller Information Systems, advising drivers that there may be slowdowns. However, it requires a traffic monitoring station to advise drivers on just how all these effects are affecting congestion on a roadway.

Using a field station for Traveller Information Systems

The first thing that was determined is that in order for a field traffic monitoring station to be useful at giving data that has operational uses, rather than historical data that can only be used for planning, it must be able to communicate in real-time with the main ATIS system. The appropriate method of communication depends entirely on what is in place in the city or region already, and what sort of budget is available. There are many options, but this paper will not go into detail about them. It is sufficient to say that some sort of communication system that can transfer data automatically (either always on, or transmitting frequently) is essential to using a traffic monitoring station with a Traveller Information System.

RESEARCH

The Locations

In this research, data from two of the three speed & volume traffic monitoring stations in the City of Calgary is analysed. The first traffic monitoring station is located on Glenmore Trail, near the interchange with 18th Street in Southeast Calgary. West of the monitoring station there are no traffic signals for over 5 km. East of the station there is a signal approximately 1.5 km away. Under typical, non peak conditions, this part of Glenmore Trail is free-flowing.

The second traffic monitoring station is located on Crowchild Trail, south of 50th Avenue in Southwest Calgary. There are no signals for more than 5.5km north of the station. South of the station is an interchange with Glenmore Trail. The vast majority of the traffic goes either west or east onto Glenmore Trail without encountering any signals for over 2 km in either direction (there are directional ramps available to go either east or west).

It should be noted that the locations for these traffic monitoring stations were not chosen in order to measure congestion, or any other operational purpose, but were instead chosen for planning needs. They are intended to be free-flow locations as much as possible, rather than locations that are particularly subject to congestion. The reason for placing the monitoring stations in free-flow locations is because traffic that stops on a loop is not counted accurately. This is still suitable, since the goal is to determine how to best use existing systems that are in place. Placing monitoring stations in areas with typically high congestion would be best for getting congestion information, but may not be appropriate for other needs (such as planning), since volume counts would not be as accurate.

The Data

There are several years worth of data available from Calgary's traffic monitoring stations. For this research, historical data was chosen in order to include some days where there was an accident reported at or near a monitoring station. Since there is less than a year's worth of accident data available from Calgary's ATIS program, the data was limited to that which is relatively recent. After choosing some days where accidents occurred, other days that were near to the ones chosen were also analysed, in order to have some 'control' days for comparison. Sometimes it turned out that the 'control' days actually had other unusual events that were not accidents, such as snow or heavy rain. Some monthly averages were analysed as well in order to get a baseline that was least affected by unusual conditions. Most of the data analysed is from the Glenmore Trail station because there were more accidents found that had an obvious impact on traffic at the station.

Calgary's traffic monitoring stations have a standard method of operation, which saves data in 15 minute intervals. In order to get some more varied data, the Glenmore Trail monitoring station was reprogrammed to save data in 5 minute intervals for seven full weekdays (as well as two partial weekdays and one weekend, which were discarded). No accidents were reported during the peak period over the seven weekdays, and weather effects were limited to the last two days. Therefore, the data should be a good comparison to average days.

Speed data for the traffic monitoring stations is grouped into bins and stored in that way – individual speeds are not recorded (in order to keep data sizes down). Calgary's standard speed bins (and thus the ones used for the 15 minute interval data) are (in km/h): 0 – 42; 42 – 50; 50 – 58; 58 – 66; 66 – 74; 74 – 82; 82 – 90; 90 – 98; 98 – 106; 106 – 114; 114 – 122; 122 – 129; 129 and up.

Because speeds are stored in bins, rather than as exact values, the analysis of mean speed and standard deviation of speed are not 100% accurate. For analysis purposes, the mid-point value for each bin is assigned to every vehicle in the bin (i.e. all vehicles in the 66 – 74 bin are assigned a speed of 70). This is normally a fair approximation, and so does not adversely affect the data.

However, when there are many vehicles falling into the 0 – 42 km/h speed bin, such as during heavy congestion, treating all their speeds as 21 km/h may not be a close approximation. The effect of this approximation depends on how many vehicles are in the lowest speed bin, and what their actual speeds are. If there are few vehicles in the bin, relative to the total number of vehicles, the effects on the overall speed will be minimal. Additionally, even if there are many vehicles counted in the bin, if the real vehicles were driving at an average speed close to 21 km/h, the effects of the approximation will also be minimal.

The two cases where the low speed bin approximation could cause a significant effect on the mean speed, are if there are many vehicles and they were driving at close to 35 or 40 km/h, or if there were many vehicles and they were all driving quite slowly (such as at 10 km/h or so). These conditions will artificially lower or raise the mean speed, respectively. Fortunately, if a significant number of vehicles are placed in the lowest speed bin, there will definitely be a very visible effect on the mean speed, so no valuable data will be missed. For the purposes of this research, it will be assumed that these effects are negligible.

The Analysis

The data analysed can be placed into several groups, based on date and location. Each group will be briefly discussed, including information on accidents, weather, and any results that can be taken from the data. Accident data is obtained from Calgary ATIS accident logs which record some basic information about that accident, as well as the time it is reported by the Calgary Police Service to the ATIS technician (there is potential for a delay of several minutes between the time the accident occurs and the time it is reported to the technician). Weather data is obtained from Environment Canada's historical climate information database [2] for conditions at the Calgary Airport.

Dataset 1: August

This dataset was taken from the Crowchild Trail monitoring station, using traffic travelling in the southbound direction. Thus, traffic was approaching an interchange where the bulk of the movements were onto ramps going to either eastbound or westbound Glenmore Trail. Dates analysed are August 3^{rd}, 8^{th}, 9^{th} and 10^{th}, 2006. The average of all of August was analysed as well.

The average values over the month of August (see figure 2) show a clear drop in mean speed and an increase in the standard deviation of speed during the afternoon peak period at this monitoring station. The data for August 8^{th} and August 10^{th} are similar, as they both show a decrease in mean speed (see figures 3 & 4). The decreases are different each day, but are not significantly far from the averages. The mean speed decrease on August 10^{th} is a bit sharper and more pronounced than that of August 8^{th} or the August averages. This may be due to the rainfall that occurred near the end of the afternoon peak period on that day, or simply daily variations.

The significant results come on August 3^{rd} and August 9^{th}. Both of these days show a relatively large and long-lasting decrease in mean speed. August 3^{rd} has the most dramatic effect (see figure 5). At roughly 3:45pm there was a 4 vehicle accident downstream of the monitoring station. Mean speed shows an immediate and sharp decrease, and stays at roughly the same low value until after 7:30pm, where it quickly goes back up to a normal value for the location (presumably the accident was cleared at this point). On August 9^{th}, there were thunderstorms and rain showers in the afternoon peak (see figure 6). On this day, a similar pattern to what happened on August 3^{rd} occurs with mean speed, although it does not stay low for as much time as it did after the accident.

Another thing that is interesting to note is how the standard deviation of the speed behaved. During the heavy rainfall, the standard deviation remained above the daily average during the time of reduced mean speed. This implies a high variability in the speeds – some drivers were still able to travel at a near average rate of speed, while others were forced to (or chose to) slow down significantly. Higher than normal standard deviations are shown during the monthly average as well, so this appears to be a typical peak period behaviour.

During the accident on August 3^{rd} however, the standard deviation is quite variable (see figure 7). Sometimes it is above average, sometimes it is actually below average! This implies that most drivers were forced to slow down and very few were able to continue at a regular pace.

Also of note is that the overall traffic volumes for August 3^{rd} are lower than both the monthly average and the volumes for August 9^{th} during the period of the accident (see figure 8). This may be a result of drivers hearing about the accident on the radio or Calgary's Advanced Traveller Information System, and avoiding the area. Another possibility is that fewer vehicles were able to pass through the monitoring station due to the accident. Since there was not a corresponding increase in volumes over the averages after the accident cleared, this seems less likely than drivers simply avoiding the area.

Dataset 2: December

The second dataset analysed was taken from the Glenmore Trail monitoring station in the westbound direction. It covers December 13^{th} and 15^{th}, as well as the average for January (this month was chosen as a baseline because it had few heavy weather events). December 15^{th} was an average day, with no snow or rain and no peak period accidents. Comparing the mean speed and standard deviation of speed between December 15^{th} and the January Average shows nothing significant at all (see figures 9 & 10). Mean speeds tend to float around the 80km/h mark over the entire day, and standard deviation is relatively flat.

December 13^{th} is different (see figure 11). An accident was reported near the site of the monitoring station in the westbound direction at roughly 6:30am and clearing roughly an hour later. The mean speed drops quickly around 6:15am, and holds at the low point for an hour before returning towards the average mean speed for the morning peak. The fact that the mean speed decreased earlier than the accident was reported is likely due to a delay between the accident occurrence, and the information reaching the ATIS technician.

The standard deviation of the speeds does not show anything remarkable. There is a small spike as the accident is clearing, but the standard deviation alone does not give enough indication of an accident in this case.

Dataset 3: January

The third dataset analysed was also taken from the Glenmore Trail monitoring station, but in this case it is from the eastbound direction. Dates covered are January 10^{th}, 11^{th}, 17^{th} and 31^{st}, as well as the January Average. Comparing January 10^{th} and 11^{th} to the January average shows them as being fairly average and uneventful days (see figures 12, 13 & 14). The January average shows a small drop in mean speed during the morning peak period, as well as a noticeable increase in the standard deviation. This does not appear at all on January 11^{th}, and only a small decrease in mean speed can be seen on January 10^{th}, but this is not significant (and could possibly be a result of random variance as opposed to peak period traffic).

January 17^{th} is a different situation (see figure 15). An accident was reported at roughly 6:45am that day, and the mean speed shows a drop at that time, while the standard deviation increases as well. The accident lasts about an hour, and the overall drop in mean speed lasts a similar amount. There is one time period during the accident where the mean speed and standard deviation both return to close to their usual values, before jumping back to typical accident values. The reason for this is unclear. It is possible that there was a lull in the amount of vehicles trying to use that roadway which allowed the congestion to clear briefly. Regardless, aside from the one time period, the accident on January 17^{th} causes the mean speed to behave as it typically does when an accident is present near a monitoring station.

January 31^{st} is an interesting case (see figure 16). There was another accident reported during the morning peak period, but it was quickly moved to the side of the road and had only a brief and small effect on mean speed. In the afternoon however, there is a long and large effect on mean speed and standard deviation. Investigation into this found that a section of Deerfoot Trail, a nearby roadway, had been closed in the southbound direction due to several accidents that day, and traffic was being detoured onto Glenmore Trail. The average daily traffic on that section of roadway is nearly 56,000 vehicles, with approximately 11,500 coming in the afternoon peak period alone. This detour resulted in volumes at the Glenmore Trail monitoring station during the afternoon peak period that were significantly above average that day, which in turn caused congestion and a decrease in mean speed for roughly two hours (see figure 17). The effect on mean speed and standard deviation was similar to that of an accident on the roadway itself. Additionally, there was an unusual spike of higher mean speeds in the middle of the detour, much like there was during the accident on January 17th.

Dataset 4: April

The fourth dataset that was analysed was again from the Glenmore Trail monitoring station, in both the eastbound and westbound directions. This data was stored over 5 minute intervals however, instead of the standard 15 minute intervals. Additionally, the speed bins that were used were different from the standard ones, in order to better analyse those vehicles that are driving slowly past the monitoring station. The new speed bins for this dataset are (in km/h): 0 – 8; 8 – 16; 16 – 24; 24 – 32; 32 – 40; 40 – 48; 48 – 56; 56 – 64; 64 – 72; 72 – 80; 80 – 88; 88 – 96; 96 – 104; 104 km/h and above.

The mean speed of traffic in the westbound direction did not experience any unusual effects, nor did the standard deviation of the same speeds (see figures 18 & 19). There were some significant fluctuations in the mean speed and standard deviation in the late night and early morning, but this is most likely caused by a combination of low night-time volumes and small time intervals. This shows that on a typical day, there is no significant congestion in the westbound direction at Glenmore Trail. This is logical, since the nearest signal is over five kilometres away. There is nothing else of note in the westbound data.

The eastbound data has many unusual effects (see figures 20 – 26). Each of the days analysed has at least one time when the mean speed shows a decrease over average values (and the standard deviation increases). The magnitudes are variable, which is not uncommon with peak period variation. As well, most of the mean speed decreases occurred during one of the peak periods, which is also not uncommon. However, there were some decreases that occurred during off-peak times, which is unusual. Additionally, after viewing the number of vehicles driving at low speeds during those speed decreases and comparing that with average values for previous months, it turned out that there was an unusually high number of slow-moving vehicles recorded. The reasons for this are unclear. There is an at-grade rail crossing approximately two kilometres downstream from the monitoring station. It is possible that particularly long trains blocked the roadway for a time and forced some drivers to slow down and wait for the train to pass. There is no way to be certain. More research is needed in order to determine exactly what happened during the unusual events. No accidents were reported during the peak periods, nor was there any construction in that area reported to ATIS any of those days. Nevertheless, there was clearly some sort of slowdown on the road, and they could be detected and reported to a Traveller Information System as needed.

RESULTS

Information from Mean Speed

Clearly it is possible to use data from even a single traffic monitoring station in a Traveller Information System. Regardless of the cause of the congestion, mean speed is a good indicator of its presence. The amount of different levels of congestion to be reported is dependent on the administrator of the Traveller Information System. Various mean speed threshold levels can be established. As long as the monitoring station is continually reporting mean speeds, there is no limit to how it can be done. The most important thing is to use historical data to find a good threshold for when the first congestion warning should be issued. If the system is going to be automated, there will be no human to notice that the system is putting out a congestion warning several times at night when the mean speed is fluctuating because there are few cars on the road, and some are driving slowly. It also must be remembered that knowing the actual cause of the congestion is difficult. A lane being closed down for road construction will cause a similar decrease in mean speed to a highly congested peak period, or a minor accident, or it may cause nothing at all if the remaining lanes are still able to handle all the traffic. As long as the congestion warnings are sufficiently generic, there should be no trouble. Regardless of the reason for it, drivers will want to know that traffic is moving slowly on a certain section of roadway.

Another use for the mean speed that is obtained from a single traffic monitoring station was shown in Dataset 2, where there was a clear delay between the time of an accident occurring, and the time it was finally reported to Calgary's ATIS technician. If the ATIS technician had access to a real-time update on the mean speed at the Glenmore Trail monitoring station, the technician could have become aware even earlier that there was a problem, and could have made a note on the ATIS website immediately, warning drivers of a possible incident. Once the police service confirmed the accident, more details could have been posted. For traveller information, the sooner an incident is posted, the more drivers will be able to avoid it and the better the situation will be.

Information from Standard Deviations of Speed

If more information is desired, there is one extra thing that can be done. During the initial research, an attempt was made to see if traffic monitoring stations could be used for incident detection. Unfortunately, it was determined that an accident has a very similar effect on mean speed as heavy snowfall, heavy rain, or increased traffic after a nearby major road was closed and traffic was detoured, as was the case on January 31st at the Glenmore Trail monitoring station. However, one thing was noticed when analysing data from the Crowchild Trail monitoring station. When an accident occurred on the roadway close to the monitoring station, the mean speed decreased as usual, but the standard deviation increased only briefly, at the start of the incident. Afterwards it became inconsistent, and even dropped below the average of the entire day. Examining the speed breakdown showed that during the incident, nearly all drivers were going very slowly. See tables 1, 2 & 3 for examples of the speed breakdowns for an accident event, a heavy rainfall event and a regular peak period congestion event. This would seem logical, except that it must be remembered that most of the peak period congestion events analysed only had some vehicles going slowly, while others were going much faster (not at the speed limit, but noticeably faster than those that are barely moving past the station). Whether this particular information is useful depends on whether someone wants to know the cause of congestion, or simply wants to report the congestion itself. For a Traveller Information System, it would be more reliable to contact the police service to determine if there is an accident than to check the standard deviation. Additionally, the police service would likely be aware of the accident before enough data had been collected to determine the behaviour of the standard deviation. Checking the standard deviation of speeds may be useful in notifying a Traveller Information System operator of times when they should phone the police to check for an accident, particularly if the Traveller Information System operator phones the police infrequently. Beyond notifying an operator that there may be a problem, the standard deviation may be more useful in analysing historical data, where all the information for the entire day is visible at once.

CONCLUSION

The mean speed on a roadway is a very good indication of congestion. Congestion is inversely related to the speed of traffic, and when it occurs, the drop in mean speed is quite obvious. Therefore, if mean speeds can be constantly monitored by a traffic monitoring station, it is possible to use this data for a Traveller Information System. The mean speeds can indicate a level of congestion, which can be passed on to drivers. There will be accuracy and certainty for that particular stretch of roadway. The congestion information can be applied along the roadway in either direction if desired, but the certainty of the information decreases the farther the distance from the monitoring station. Historical data can be analysed to find patterns between the mean speed at a monitoring station, and the mean speed at another area, but there is always the possibility of an unusual situation causing the historical correlation to change (such as in Dataset 3, when Deerfoot Trail was closed and caused a large increase in traffic past the Glenmore Trail monitoring station).

Additionally, standard deviations of speeds can be used to get information on the type of congestion – typical stop & go congestion, or gridlock congestion (as is common at accidents, where many vehicles come nearly to a stop). This information may be less useful to drivers than the actual amount of congestion, but it is up to each Traveller Information System administrator to decide if that information should be included or not.

In the end, a single traffic monitoring station can provide useful information for a Traveller Information System. It can easily determine the level of congestion at that given spot, which is useful information to those who travel along that route. Ideally, there would be more monitoring stations along the alternate routes, so that drivers could determine which route is least congested and pick that (if it improves their drive). Since it is not always practical to have that many traffic monitoring stations, at least some information can be made available to drivers. Three monitoring stations will never give the same amount of detail as 360, but for many, some information is better than nothing. Additionally, the City of Calgary is working towards building more traffic monitoring stations on key corridors that will meet both planning and operations needs. It never hurts to have a few good counting stations.

REFERENCES

[1]: Washington State Department of Transportation, “WSDOT’s Congestion Measurement Approach: Learning from Operational Data”, referenced April 24, 2007, http://www.wsdot.wa.gov/publications/folio/MeasuringCongestion.pdf

[2]: Environment Canada, “Canadian Climate Data”, referenced April 24, 2007, http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

TABLES

Speeds (km/h)	0 - 42	42 - 50	50 - 58	58 - 66	66 - 74	74 - 82	82 - 90	90 - 98	98-106	106-114	114-122	122-129	129-999	Total	Mean	Std.Dev.
15:15	1	0	3	14	98	230	167	53	13	2	1	1	0	583	81	9
15:30	3	0	6	66	177	243	107	35	7	3	0	0	0	647	76	10
15:45	171	59	75	72	98	112	42	12	1	1	0	0	0	643	55	23
16:00	343	126	76	20	4	0	0	0	0	0	0	0	0	569	33	15
16:15	378	77	41	12	3	0	0	0	0	0	0	0	0	511	29	13
16:30	387	57	6	1	0	0	0	0	1	0	0	0	0	452	25	10
16:45	414	45	18	0	0	0	0	0	0	0	0	0	0	477	25	9
17:00	549	9	2	0	0	0	0	0	0	0	0	0	0	560	22	4
17:15	437	42	7	1	0	0	0	0	0	0	0	0	0	487	24	8
17:30	659	83	22	9	2	0	0	0	0	0	0	0	0	775	25	10
17:45	617	62	20	5	1	0	0	0	0	0	0	0	0	705	24	9
18:00	461	16	25	5	1	0	1	0	0	0	0	0	0	509	24	10
18:15	386	26	52	52	26	3	1	1	0	0	0	0	0	547	32	18
18:30	421	76	22	3	0	0	0	0	0	0	0	0	0	522	26	11
18:45	345	19	1	0	0	0	0	0	0	0	0	0	0	365	22	6
19:00	286	14	2	0	0	0	0	0	0	0	0	0	0	302	22	6
19:15	356	55	8	2	0	0	0	0	0	0	0	0	0	421	25	10
19:30	287	143	65	46	37	11	5	0	0	0	0	0	1	595	39	19
19:45	2	20	65	93	117	77	10	4	1	1	0	0	0	390	66	11
20:00	0	1	1	9	49	151	120	33	9	1	0	0	0	374	81	8

Table 1: Distribution of Vehicle speeds by bin per 15 minute interval (time noted is interval end time) in afternoon of August 3, 2006 (Date when an accident occurred)

Speeds (km/h)	0 - 42	42 - 50	50 - 58	58 - 66	66 - 74	74 - 82	82 - 90	90 - 98	98-106	106-114	114-122	122-129	129-999	Total	Mean	Std.Dev.
15:15	0	1	2	18	137	235	148	34	9	1	1	0	0	586	79	8
15:30	2	0	0	6	98	283	173	39	13	8	0	0	0	622	81	9
15:45	4	7	16	38	146	285	136	38	8	3	0	0	2	683	77	11
16:00	4	0	13	14	123	250	159	39	20	3	1	0	0	626	79	10
16:15	1	0	4	43	170	310	145	38	15	2	1	0	0	729	78	9
16:30	4	0	3	52	226	246	145	51	10	5	0	1	0	743	77	10
16:45	136	68	87	125	234	157	52	11	1	3	0	0	0	874	61	20
17:00	233	67	61	70	98	127	65	12	6	1	0	0	0	740	54	25
17:15	18	16	54	85	148	250	158	40	14	2	0	0	0	785	74	14
17:30	50	41	79	142	191	172	57	13	2	0	0	0	1	748	66	16
17:45	3	0	0	46	127	271	179	53	13	2	1	1	0	696	79	10
18:00	1	0	0	8	62	231	187	76	24	2	0	0	0	591	83	9
18:15	3	0	0	5	68	275	196	51	15	1	1	0	0	615	81	9
18:30	0	0	1	8	91	228	216	44	23	6	1	0	0	618	82	9
18:45	1	0	0	4	41	178	191	57	23	5	1	0	0	501	83	9
19:00	2	0	1	0	42	163	190	54	17	2	1	0	2	474	83	9
19:15	1	0	0	3	58	180	155	46	17	2	2	0	0	464	82	9
19:30	1	0	0	1	23	153	169	57	25	7	0	1	0	437	85	9
19:45	0	0	0	2	18	133	142	45	27	2	1	0	1	371	85	9
20:00	1	0	0	0	28	149	158	49	17	4	0	0	0	406	84	8

Table 2: Distribution of Vehicle speeds by bin per 15 minute interval (time noted is interval end time) in afternoon of August 8, 2006 (Date when no unusual events occurred)

Speeds (km/h)	0 - 42	42 - 50	50 - 58	58 - 66	66 - 74	74 - 82	82 - 90	90 - 98	98-106	106-114	114-122	122-129	129-999	Total	Mean	Std.Dev.
15:15	2	1	21	42	179	233	132	39	5	2	2	0	1	659	77	10
15:30	3	0	2	34	119	286	145	42	8	3	0	0	0	642	79	9
15:45	2	4	14	48	178	270	137	38	6	0	1	0	0	698	77	10
16:00	287	67	90	69	55	53	21	5	1	0	0	0	0	648	44	23
16:15	87	84	157	175	137	88	35	11	0	0	0	0	0	774	59	17
16:30	64	84	86	151	175	135	64	11	3	0	1	0	0	774	63	17
16:45	200	114	133	142	118	77	31	4	1	0	0	0	0	820	52	21
17:00	559	51	14	22	23	21	0	0	0	0	0	1	0	691	28	16
17:15	419	68	79	66	68	39	20	4	0	0	0	0	0	763	40	22
17:30	506	29	33	63	34	36	5	0	0	0	0	0	0	706	33	20
17:45	487	41	76	65	25	7	0	0	0	0	0	0	0	701	32	17
18:00	550	26	48	29	13	4	2	0	0	0	0	0	0	672	28	14
18:15	437	26	53	45	37	19	2	2	0	0	0	0	0	621	33	19
18:30	257	45	39	48	73	95	59	25	4	1	1	0	0	647	51	27
18:45	0	0	5	40	112	248	139	34	3	0	0	1	0	582	78	8
19:00	3	2	2	13	82	187	144	55	8	1	1	1	0	499	80	10
19:15	1	1	0	3	45	177	175	59	13	0	0	1	0	475	83	8
19:30	1	0	0	6	40	162	152	78	10	1	1	0	0	451	83	9
19:45	0	0	0	4	17	132	141	82	16	7	1	0	0	400	85	9
20:00	1	0	4	7	34	136	130	68	20	4	0	0	0	404	83	10

Table 3: Distribution of Vehicle speeds by bin per 15 minute interval (time noted is interval end time) in afternoon of August 9, 2006 (Date when heavy rainfall occurred)

FIGURES

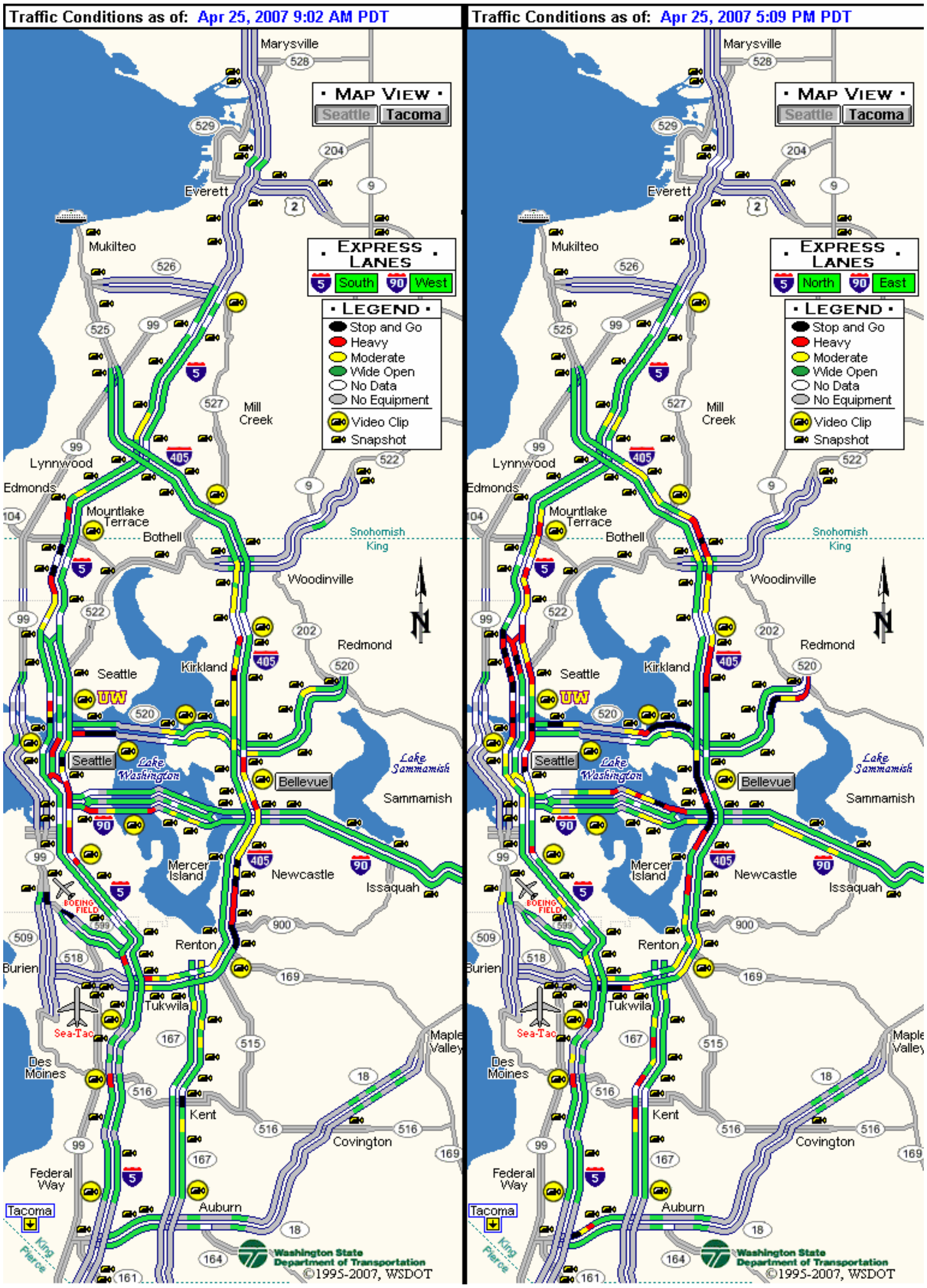


Figure 1: Two versions of the Washington Department of Transportation's Seattle Area Traffic map. Both images are time-stamped at the top.

Figure 2: Crowchild Trail Monitoring Station, Southbound Direction
August 2006 Average Values

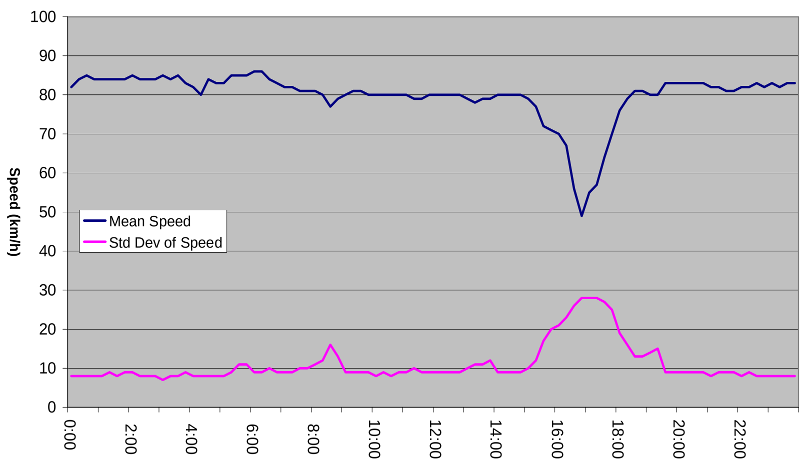


Figure 3: Crowchild Trail Monitoring Station, Southbound Direction
August 8, 2006

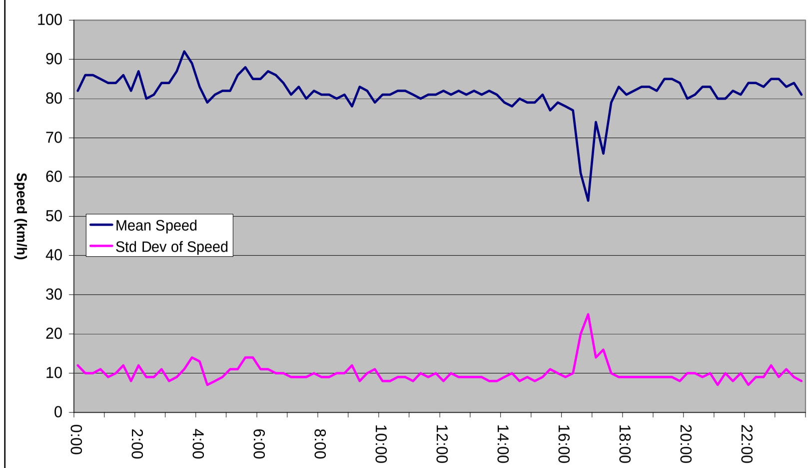


Figure 4: Crowchild Trail Monitoring Station, Southbound Direction
August 10, 2006

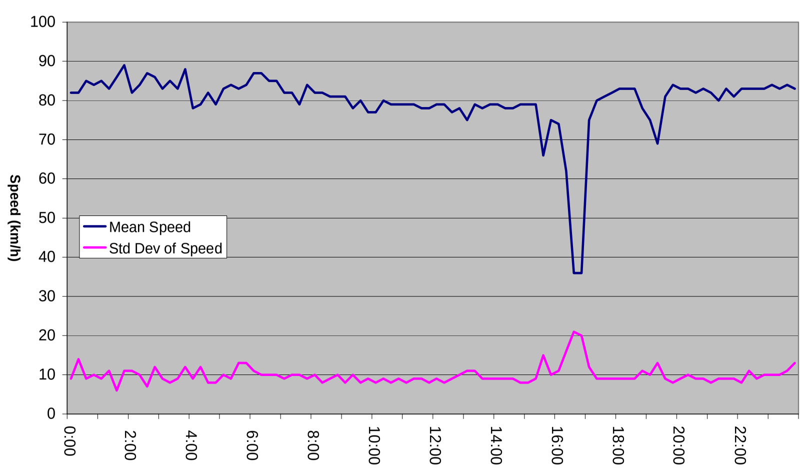


Figure 5: Crowchild Trail Monitoring Station, Southbound Direction
August 3, 2006

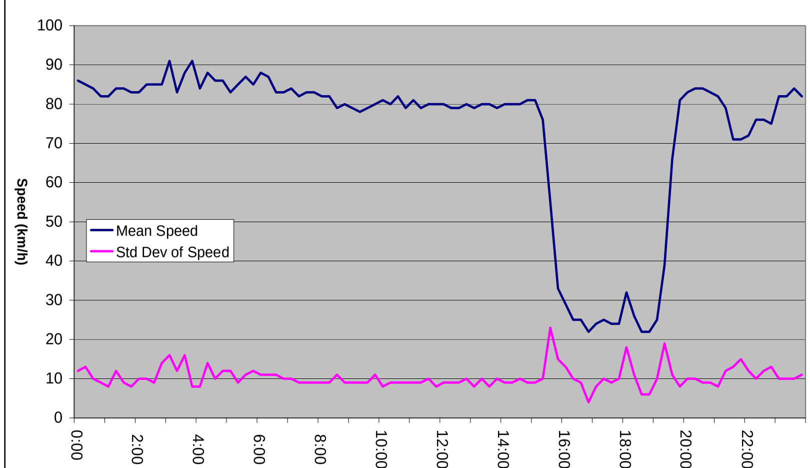


Figure 6: Crowchild Trail Monitoring Station, Southbound Direction August 9, 2006

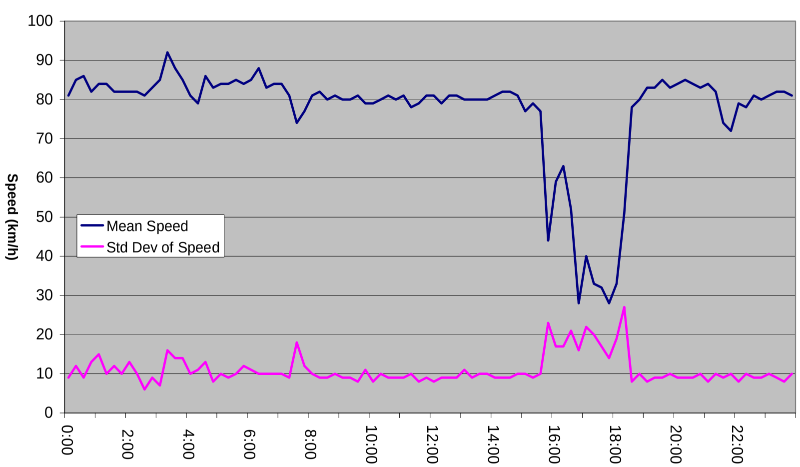


Figure 7: Crowchild Trail Monitoring Station, Southbound Direction August 3, 2006 (Standard Deviation Only)

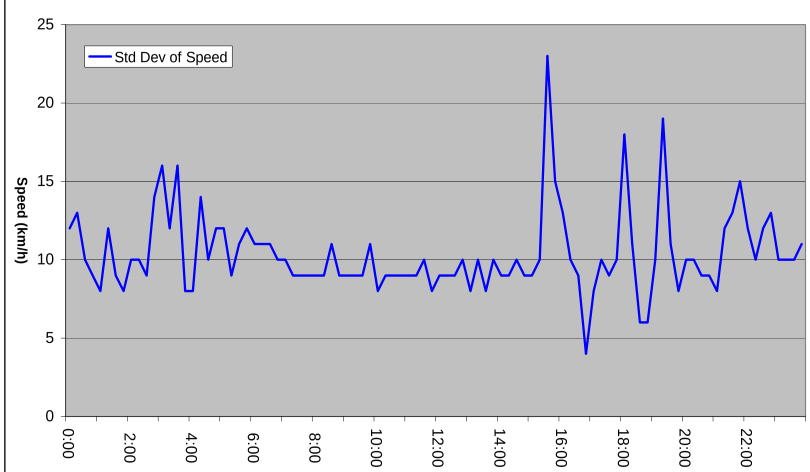


Figure 8: Crowchild Trail Monitoring Station, Southbound Direction Traffic Volume Comparison

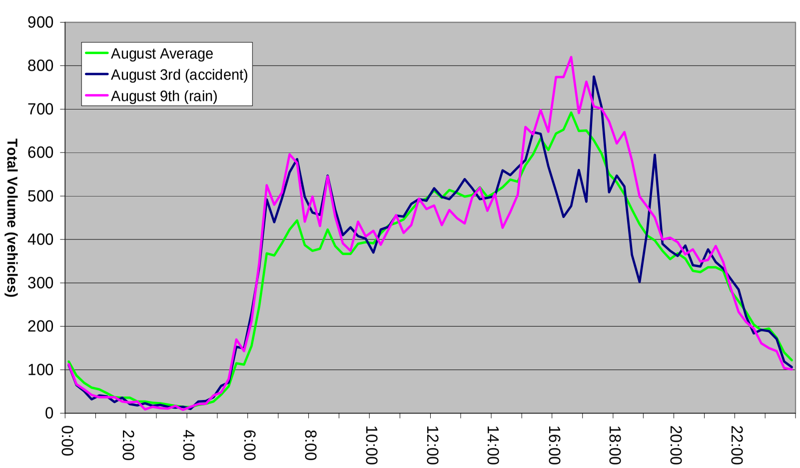
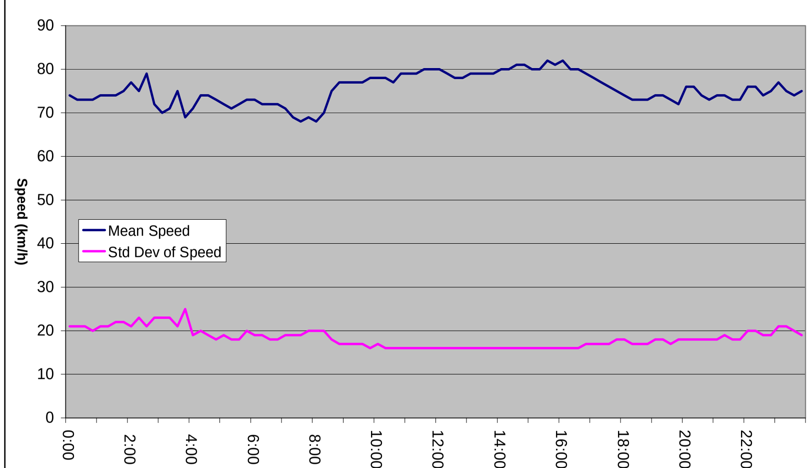


Figure 9: Glenmore Trail Monitoring Station, Westbound Direction January 2007 Average Values



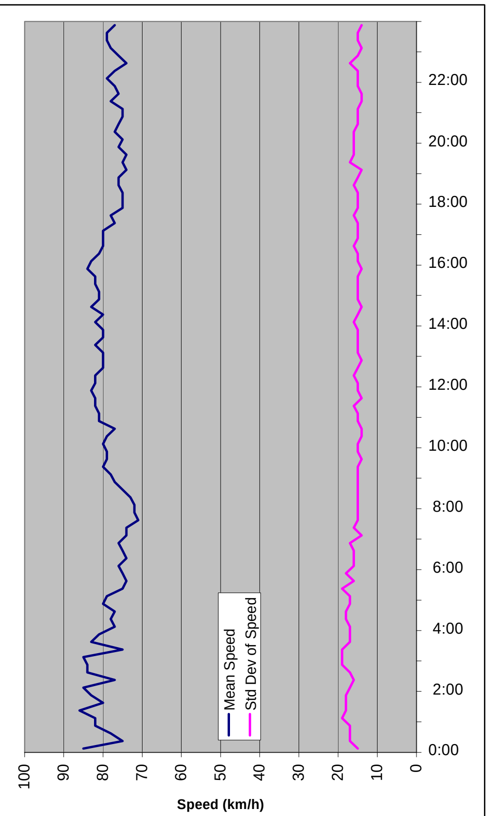


Figure 10: Glenmore Trail Monitoring Station, Westbound Direction
December 15, 2006

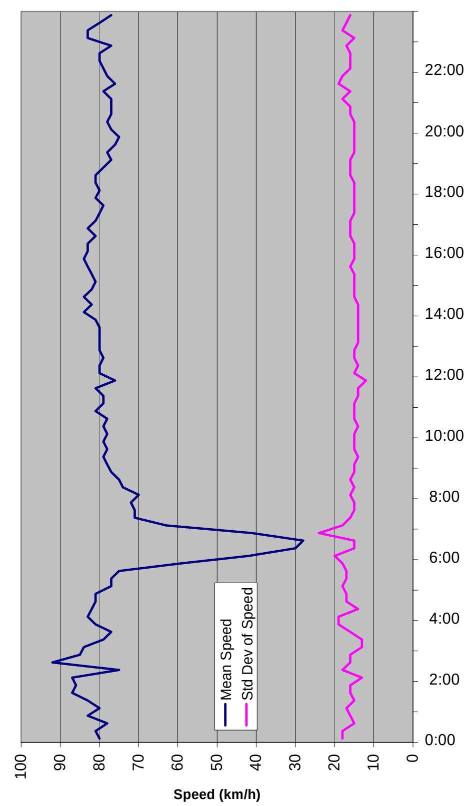


Figure 11: Glenmore Trail Monitoring Station, Westbound Direction
December 13, 2006

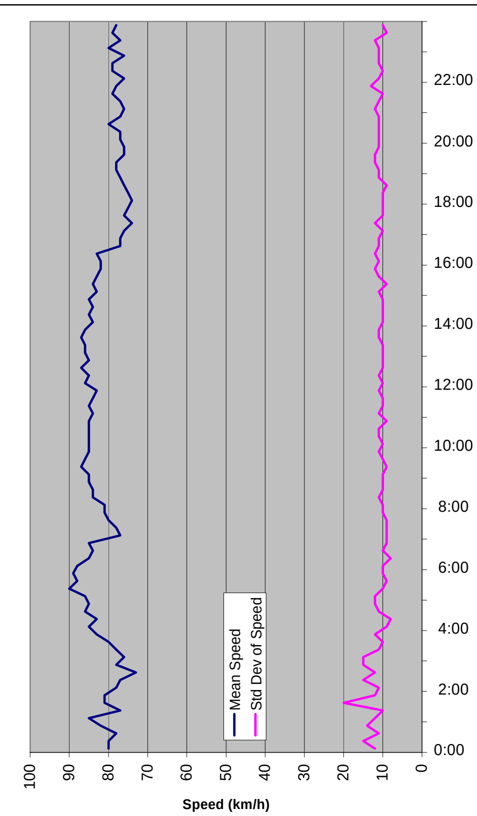


Figure 12: Glenmore Trail Monitoring Station, Eastbound Direction
January 10, 2007

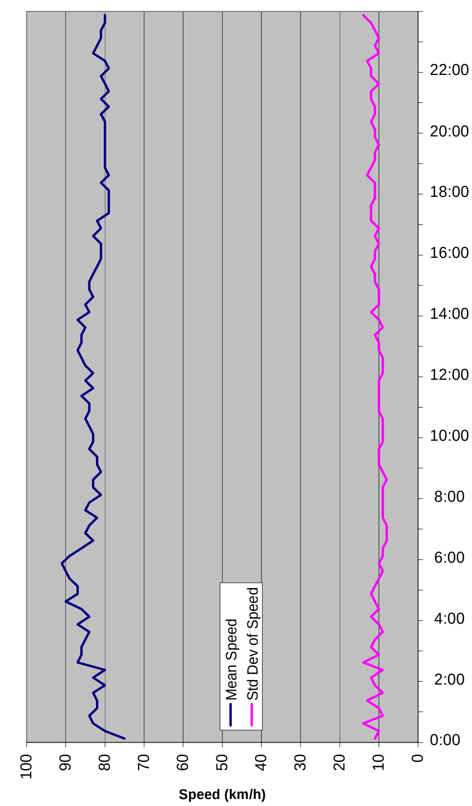


Figure 13: Glenmore Trail Monitoring Station, Eastbound Direction
January 11, 2007

Figure 14: Glenmore Trail Monitoring Station, Eastbound Direction
January 2007 Average Values

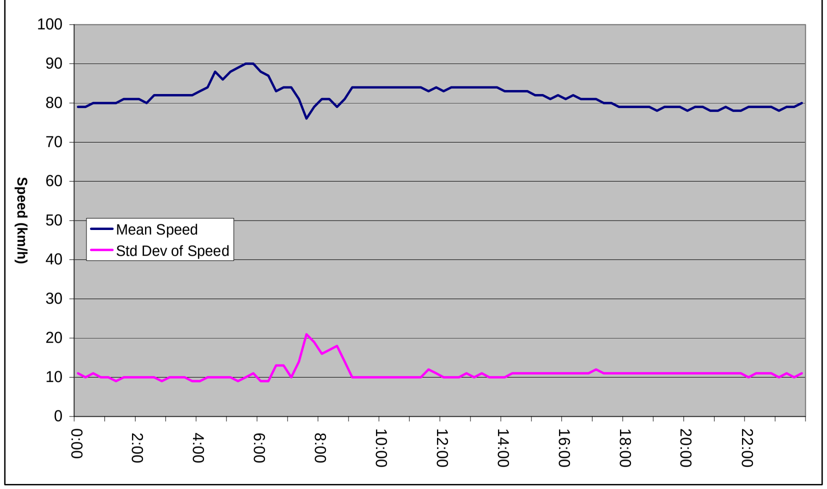


Figure 15: Glenmore Trail Monitoring Station, Eastbound Direction
January 17, 2007

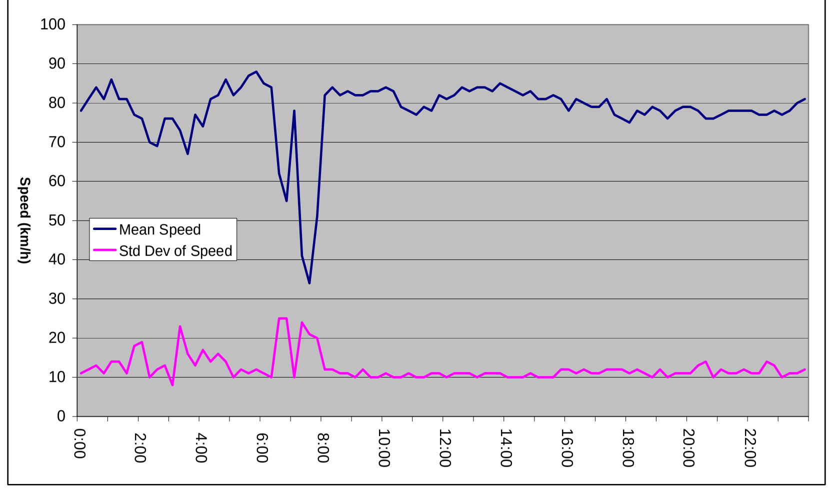


Figure 16: Glenmore Trail Monitoring Station, Eastbound Direction
January 31, 2007

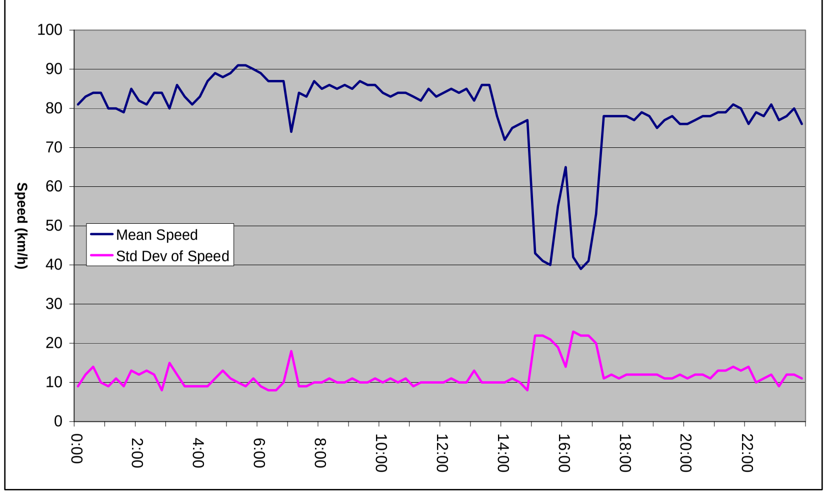
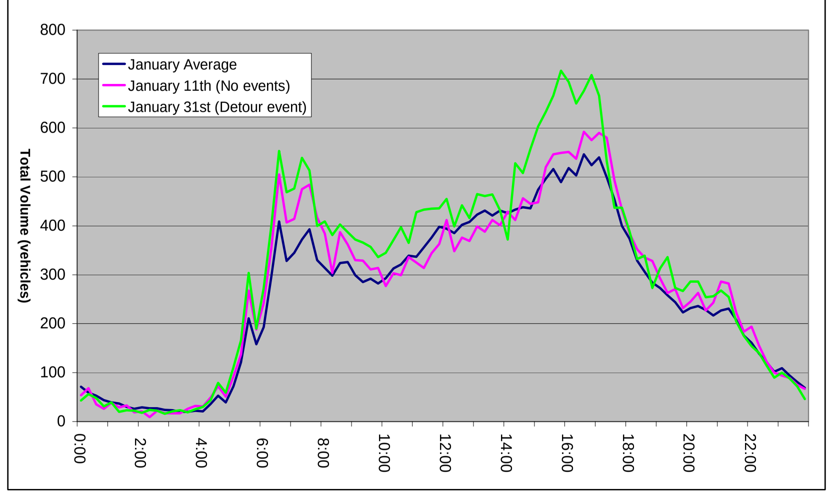


Figure 17: Glenmore Trail Monitoring Station, Eastbound Direction
Traffic Volume Comparison



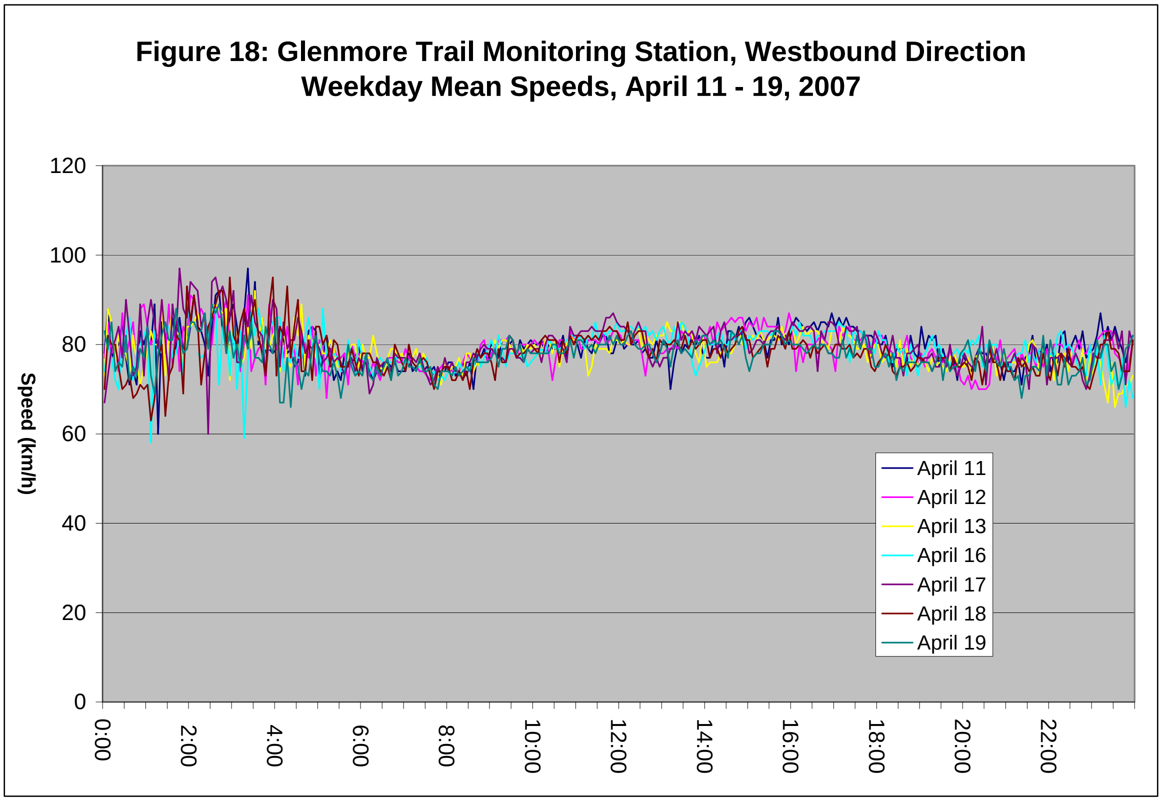


Figure 18: Glenmore Trail Monitoring Station, Westbound Direction
Weekday Mean Speeds, April 11 - 19, 2007
Speed (km/h)
120
100
80
60
40
20
0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
April 11
April 12
April 13
April 16
April 17
April 18
April 19

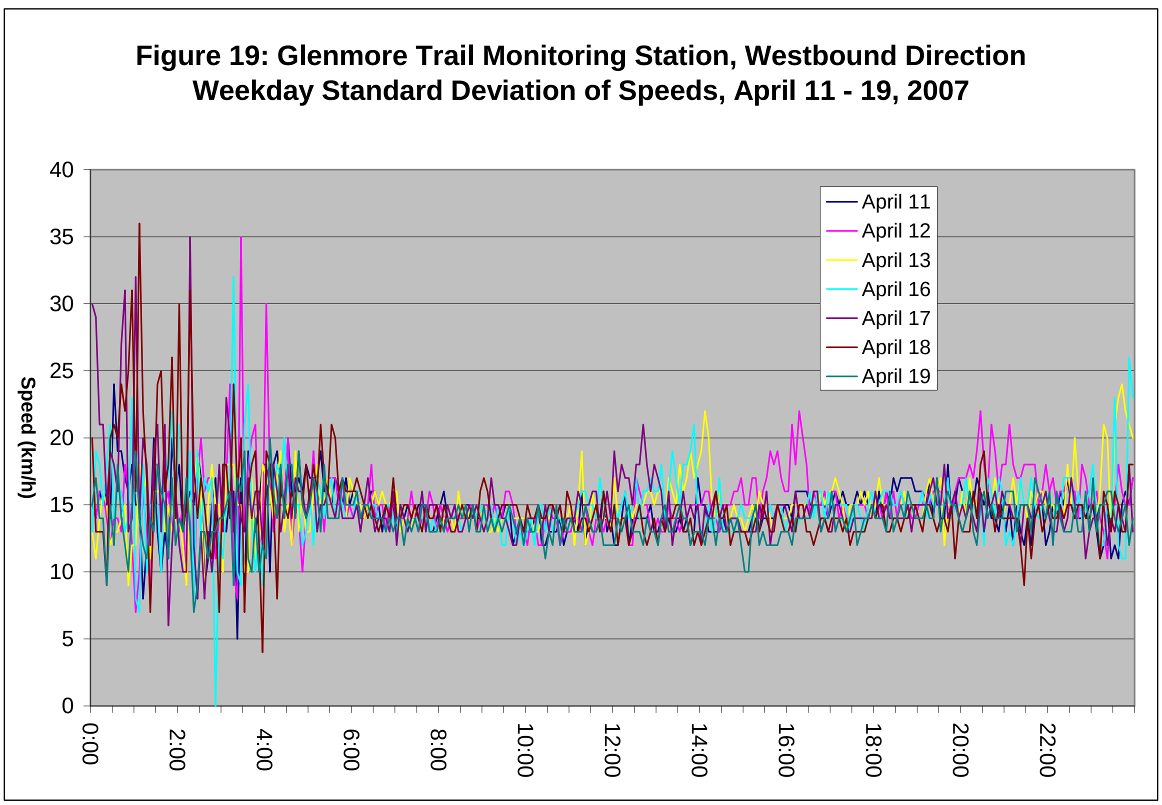


Figure 19: Glenmore Trail Monitoring Station, Westbound Direction
Weekday Standard Deviation of Speeds, April 11 - 19, 2007
Speed (km/h)
40
35
30
25
20
15
10
5
0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
April 11
April 12
April 13
April 16
April 17
April 18
April 19

Figure 20: Glenmore Trail Monitoring Station, Eastbound Direction April 11, 2007

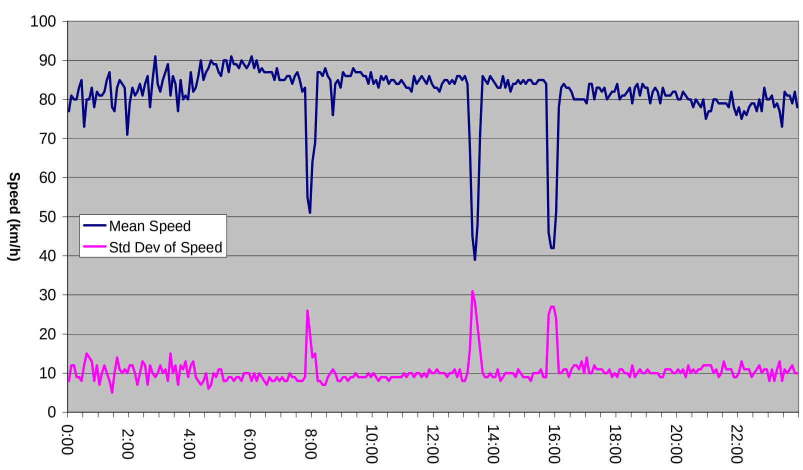


Figure 21: Glenmore Trail Monitoring Station, Eastbound Direction April 12, 2007

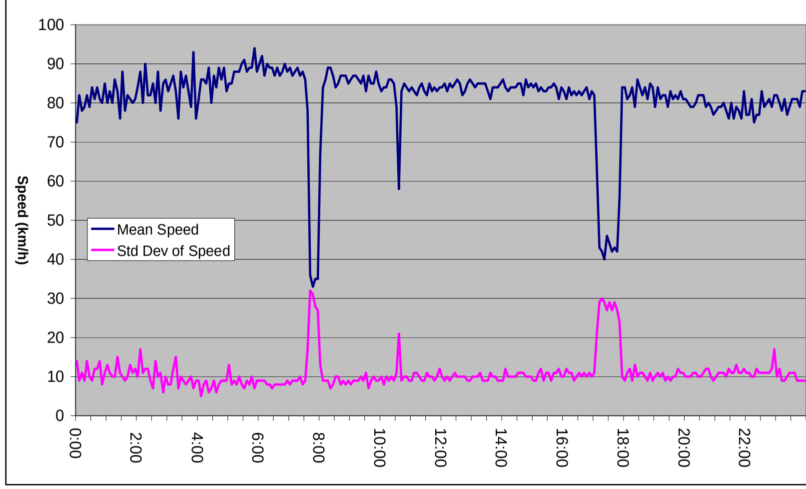


Figure 22: Glenmore Trail Monitoring Station, Eastbound Direction April 13, 2007

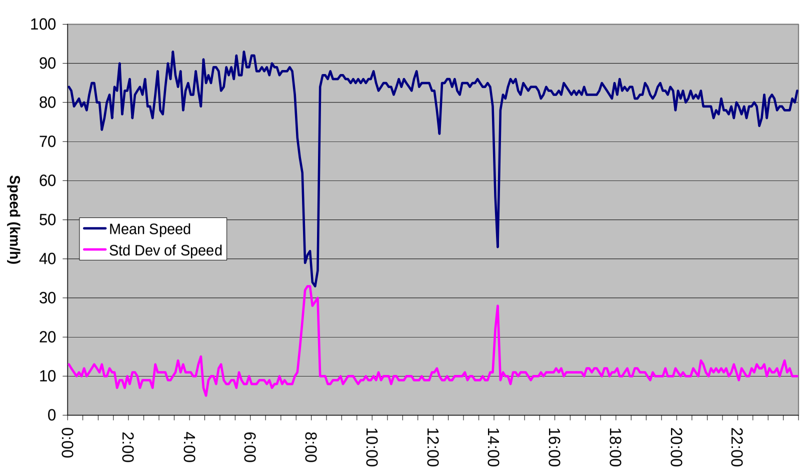


Figure 23: Glenmore Trail Monitoring Station, Eastbound Direction April 16, 2007

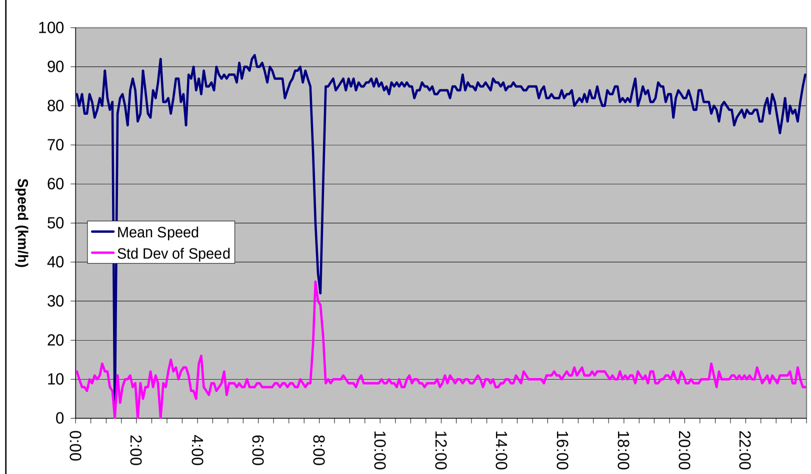


Figure 24: Glenmore Trail Monitoring Station, Eastbound Direction
April 17, 2007

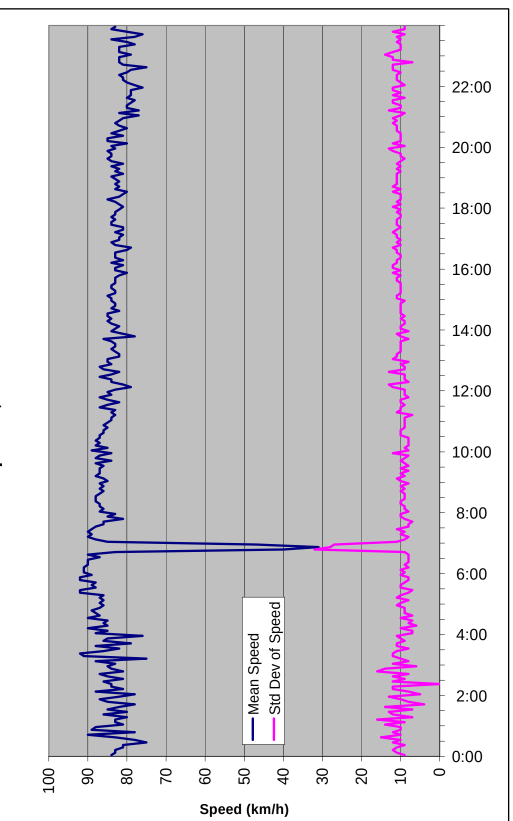


Figure 25: Glenmore Trail Monitoring Station, Eastbound Direction
April 18, 2007

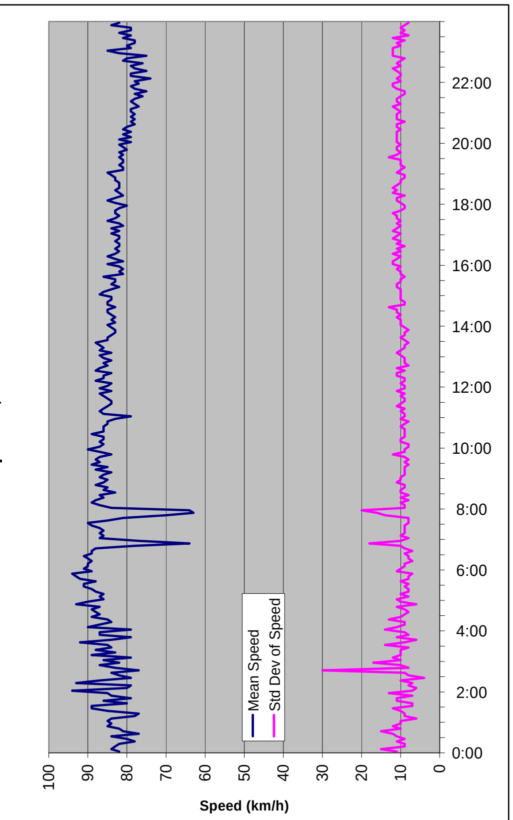


Figure 26: Glenmore Trail Monitoring Station, Eastbound Direction
April 19, 2007