Traffic Management Workshop and Technical Conference 2002

22nd – 25th September 2002
Grand Tiara Hotel–Rotorua

Title: **Monitoring Incident and Travel Behaviour Through the Use of ATMS Architecture.**

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1. Abstract

The paper highlights the initial results of a Transfund Research project being undertaken to evaluate the effectiveness of Variable Message Speed Signs (VMSS) within the Ngauranga Active Traffic Management System (NATMS).

NATMS is an incident based system whose objective is to facilitate the passage of traffic through a very demanding section of state highway just north of Wellington. Real time information is acquired through automated data collection techniques to enable traffic controllers to deal with congestion or manage incidents. The main emphasis is on the latter with a goal of reducing the effects of non-recurrent congestion (eg roadworks, breakdowns, road closures and crashes) through quicker response times to incidents and the ability to have prescribed plans in place to deal with such eventualities.

A unique feature of the NATMS is the use of VMSS which display a mandatory speed imposed by controllers in response to an incident or prevailing traffic conditions. The research intends to study response to the VMSS both under typically “normal” conditions and when an incident plan is in place.

The first stage of the research has involved an extensive data collection programme using the Video Image Processors/Incident Cameras and accompanying software to produce normalised speed profiles. The intention is to be able to show a speed profile at any instance for all camera sites within the Gorge in addition to showing how speeds vary over time at any given location.

Other data capture equipment has enabled speeds by lane, limited vehicle classification, and lane occupancy to also be evaluated.

All incidents are currently being recorded and monitored. The research team are particularly interested in how drivers respond to imposed speed reductions and how their speed varies with time and travel through the affected area.

The paper will present the initial findings from the first stage analysis of data together with some evaluation of the different types of incidents and their characteristics.

2. Overview Of System

2.1 Need For System

In February 2001 Transit New Zealand (TNZ) commissioned the operation of the Ngauranga Active Traffic Management System (NATMS) on State Highway 1, north of Wellington, New Zealand. The NATMS covers a 4km stretch of State Highway between Johnsonville and the SH1 / SH2 Interchange.

The NATMS is the first system in New Zealand to use Automatic Incident Detection (AID) and was chosen because of the challenging driving conditions which are compounded by steep terrain, numerous bends and a high degree of weaving between lanes. This in conjunction with a volume in excess of 60,000 vehicles per day and an accident rate higher than the national average were contributing factors in the introduction of the NATMS.

The NATMS is designed to reduce the number and severity of crashes, minimise driver frustration and delay on this demanding section of State Highway and improve overall traffic flow. This has been achieved by providing up to the minute traffic information to road users, emergency services and traffic controllers via the NATMS. Currently the NATMS is manned 24 hours a day to enable the implementation of faster, more appropriate traffic and emergency responses to be provided in accordance with prevailing traffic conditions or incidents, as and when they occur.

Prior to the introduction of the NATMS, there was no system whereby the Police could accurately determine the nature of an incident within the Ngauranga Gorge. Information was typically received from the public. This process often left room for error regarding the direction and location of the respective incident. Moreover, traffic would often become congested due to the incident causing further delay to emergency services in attending the scene. Reaching and isolating the incident quickly whilst providing information to drivers approaching an incident can have a major bearing on the level of congestion caused by incidents. This is where the principal benefits of the NATMS lie.

An important feature of NATMS is that it is designed for incident detection and is not a traffic management tool intended to increase efficiency and travel time.

3. General Operational Aspects

The NATMS is a sophisticated electronic system, operated by computer control stations at the following locations:

- Johnsonville Community Policing Centre (JCPC)
- The Wellington office of MWH
- ATTOMS (Auckland ATMS Control Centre)

There are also information stations situated at the Central Communications Centre of the Wellington Central Police Station and at the Transit Wellington Regional office.

It is operated on a 24-hour basis under the following regime:

- During the daytime period (0630 - 1900 hours – Monday to Friday) the system is monitored by MWH from the control station at MWH’s Wellington Office with JCPC used as a back-up facility.
- During the nighttime period (1900 - 0630 hours), weekends and public holidays, the system is monitored by ATTOMS.

The control stations operate a network of:

- 23 Variable Mandatory Speed Signs (VMSS) / Lane Control Signs;
- 6 Variable Message Signs (VMS);
- 12 Automated Incident Detection Cameras (AID);
- 3 Traffic Flow Monitoring Cameras;
- 7 Pan-tilt-zoom CCTV Cameras (PTZ)
- 2 Weathering Monitoring Stations;
- Integrated and Control Software at a number of control centres;

- 15 Video Image Processors (VIP) used to configure the information collected from the cameras. 12 are used for the AID cameras and 3 are for monitoring and collecting data relating to traffic flow.

Unlike other intelligent transport systems, the Ngauranga ATMS includes a video detection system and alarm manager that automatically alerts the operator when an incident has occurred. The detection system raises the alarm and automatically links into the appropriate video camera in order to display the relevant video image. Traditionally these systems require human operators to scan banks of video screens to visually detect incidents.

The Odyssey software developed by Philips and divested to Tyco Integrated Systems (Tyco), enables traffic ‘incidents’ (for example stationary vehicles) to be automatically detected resulting in an incident alarm being triggered and an appropriate response strategy being initiated.

3.1 Capabilities Of The System

Once incidents are detected by the system it is then the job of the operator to decide if they warrant the implementation of a predetermined response plan. There are a number of response plans which can be activated within seconds. Alternatively the operator can implement VMS messages using their own choice from a library of messages.

All of the architecture is tied together by a graphic user interface which is used as a platform to manage traffic, provide decision making facilities and to control road signs and devices. Information is collected using the 12 AID cameras (fixed cameras 1, 2, 3, 4a, 5a, 6, 7a, 7b, 8, 9, 10, 11) and processed using the VIP’s to produce information to operators. The information provided by the system to the operators contains the incident type, location of where the incident has occurred, by lane and direction. The software is capable of detecting an unlimited number of incidents at any one time. These incidents are then responded to using appropriate VMS messages and / or VMSS sign changes as necessary.

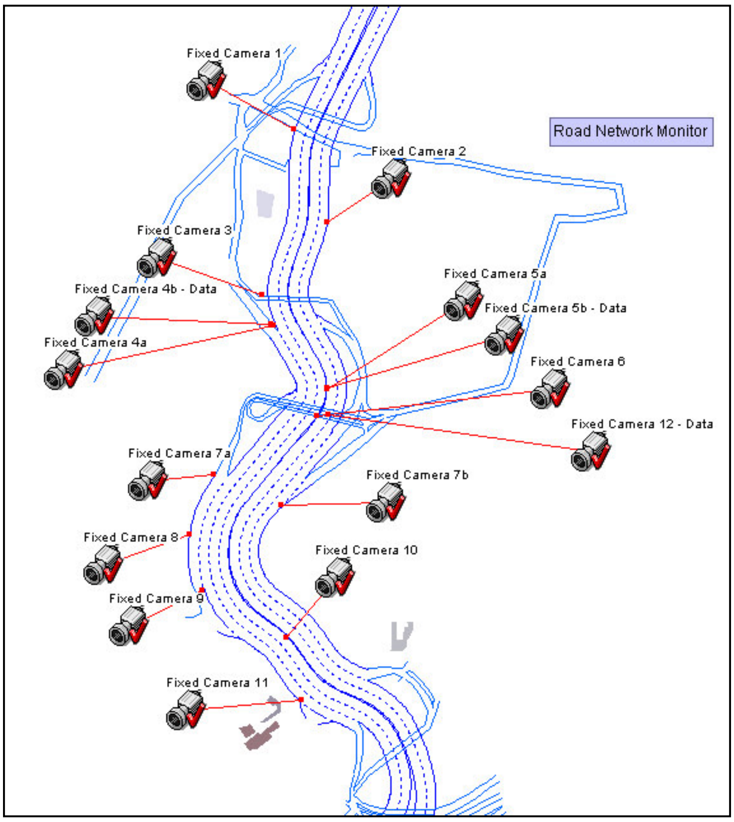

Figure 1; *Location of AID and data collection cameras*

Common incidents detected by the system are listed below;

- Deceleration (abnormal), of a group of vehicles;
- Congestion – three degrees based on high occupancy and low speed;
- Stationary vehicles – within the detection zone

There are 23 VMSS within the NATMS, 11 in the Northbound and 12 in the southbound direction.

The VMSS have the ability to display speeds between blank and 100 km/h in 10km/h increments. The unique feature about the VMSS is that these speeds are mandatory. Currently the Lane Control Signs are not used for either incidents or roadworks.

There are 6 VMS within the NATMS, 4 on the State Highway and 2 on local roads. These signs have been strategically positioned to provide information to drivers whereby a choice can be made to continue on their current path or exit, therefore avoiding the incident ahead. The VMS signs have the capacity to display multi-lined information up to 17 characters long[1].

There are 2 weather stations within the NATMS, of differing operation. One collects wetness of road (%), rainfall (mm), windspeed (m/s), wind direction and visibility (m). The second weather station only collects wind speed and direction information.

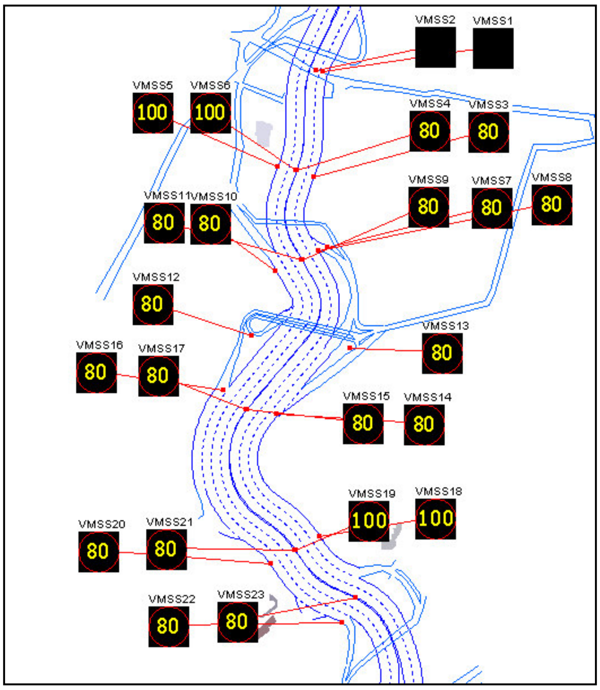

Figure 2; *Location of VMSS within NATMS*

The data is collected and processed using the AID cameras and VIP's. The only traffic data collected on the AID's and VIP's is speed and occupancy. This data is collected for all vehicles but not individual types or classes. It should be noted that the AID's do not detect a vehicle as such but a moving item on the screen. There could be instances where close moving vehicles are detected as a single data entry.

There are 3 cameras and VIP's within the NATMS that are dedicated to collecting other traffic information. They provide more information than the AID's and are intended to collect traffic volume data that can be used to monitor traffic flow. The three cameras are situated at;

[1] This is dependent on the individual letters chosen, as each has a different letter width.

- Johnsonville off-ramp covering the off-ramp and SH1 northbound.
- Johnsonville on-ramp, covering Newlands bound traffic, onramp and SH1 southbound.
- On top of Newlands overbridge collecting Newlands northbound off ramp, Newlands northbound on ramp and Newlands southbound on ramp.

The three data collection cameras collect among other things, volume, gap time, headway, speed, occupancy, and limited vehicle classification. Again this information is in 5-minute intervals.

All of the data is stored in the Wide Area Traffic Telematics Server (Watts). The information is aggregated into 5-minute timeframes. The database stores up to 30 days of data, after which data is written over and lost if not downloaded. The data is categorised by ZoneID, which is a numbering system that allocates each lane at each camera site a distinct ZoneID. In total there are 66 zones within the NATMS. Appendix A contains a plan of the location of all zones.

4. Research

4.1 Introduction

The aforementioned NATMS architecture is currently being used to obtain profiles of speeds within the Ngauranga Gorge to reflect normal flow conditions. This is the first step in a major Transfund research project aimed at evaluating the effectiveness of Variable Message Speed Signs (VMSS) within the NATMS.

Whilst it is recognised that Variable Message Signs (VMS) may convey information pertaining to an incident and therefore influence motorists to travel slower, the VMSS give the speed considered appropriate to the incident and prevailing conditions, and are, as such, mandatory, with motorists who exceed the indicated speed being liable to prosecution by the Police. It is this part of the ATMS architecture which is considered more instrumental in governing vehicle speed, although it is acknowledged that the combined effects of the VMSS, VMS and Lane Control Signs (LCS) are likely to complement each other in reducing speed.

4.2 Objectives

The research is directed towards achieving the following objectives:

4.2.1 Compliance of Vehicles with the Free Flow Speed Limit

This entails preparation of speed profiles for each camera site by lane for the time periods specified above. These base profiles assume incident free conditions, with speed of 80km/h imposed through the Gorge apart from the last sets of VMSS which are given a default setting of 100km/h. This higher speed limit effects 11 zones out of the possible 66. This also includes the morning peak, when regular recurrent congestion occurs

4.2.2 Diversionary Flow

It is also intended to quantify the amount of traffic, which elect to leave the State Highway in the event of an incident. There are two obvious locations where this can be achieved. One is at the bottom of the Ngauranga Gorge, whereby southbound vehicles can use Hutt Road off-ramp to access the Wellington CBD as an alternative to the State Highway, whilst the other is at the Johnsonville off ramp covering northbound State Highway traffic. The selection of these locations is based on the fact that there is traffic counting equipment in place enabling the monitoring of such effects.

4.2.3 Lane Use Change

The change in lane use that occurs between incident free and incident induced operations is to be quantified and evaluated. The selection of these locations is based on the fact that there is traffic counting equipment in place enabling the monitoring of such effects. Before and after comparisons are only to be made when all lanes remain open.

4.2.4 Spatial Change in Vehicle Speed

Speed data will be acquired to ascertain if drivers adjust their speed through the controlled section of highway whilst an imposed mandatory speed limit is in force as a result of an incident.

4.2.5 Types of Incident

All incidents are recorded automatically which will enable their nature (ie types, duration, response taken) to be examined and quantified. The main focus will be on breakdowns, spillages, crashes and other causes of non-recurrent congestion.

4.3 Data Capture Times

Profiles have been compiled for all sites within the NATMS with detection capabilities, covering 4 periods of the week, these being as follows;

- Monday – Thursday. Base profiles have been produced for 07:00 – 10:00 (morning peak), 10:00 – 16:00 (inter-peak), 16:00 – 19:00 (evening peak) and 19:00 – 07:00 (night period);
- Friday; Again base profiles have been produced for 07:00 – 10:00, 10:00 – 16:00, 16:00 – 19:00 and 19:00 – 07:00;
- Saturday; One base profile has been produced covering the whole day;
- Sunday; One base profile has been produced covering the whole day;

4.4 Refining The Database

Data was collected from late January to May 2002 from all AID's and VIP's with summarised printouts at 5-minute intervals. In producing the base profiles, data records were inspected visually to identify 'untypical' days or periods of time when the data appeared to be 'dubious'. Such 'abnormal' periods were removed from the database and included data acquired during incidents, roadworks, crashes and inclement weather within the Gorge.

5. Findings

The production of the base profiles was undertaken by compiling ‘clean’ days and from these producing an average base profiles for all 66 zones.

5.1 Average Speeds

5.1.1 Morning Peak

The average profiles for the AM peak indicate that the breakdown of traffic does not always occur regularly and at the same location. There are occasions when breakdown can occur at the bottom and top of the Gorge, but the road is uncongested in the middle region. This is usually due to varying lane availability and compounded by on-ramps.

The queues within the Gorge are in the southbound direction and on some days these form all the way up the Gorge, but other days may only extend half way up. Since average profiles have been produced, they represent typical conditions during traffic breakdown. The queue does not always reach the top of the Gorge where higher average speeds can be expected due to the absence of breakdown. Further down the Gorge this is not the case, as queues will form on most days due to the presence of the high volume SH1/SH2 merge. Figure 3 shows the breakdown of traffic at the top (north) of the Ngauranga Gorge.

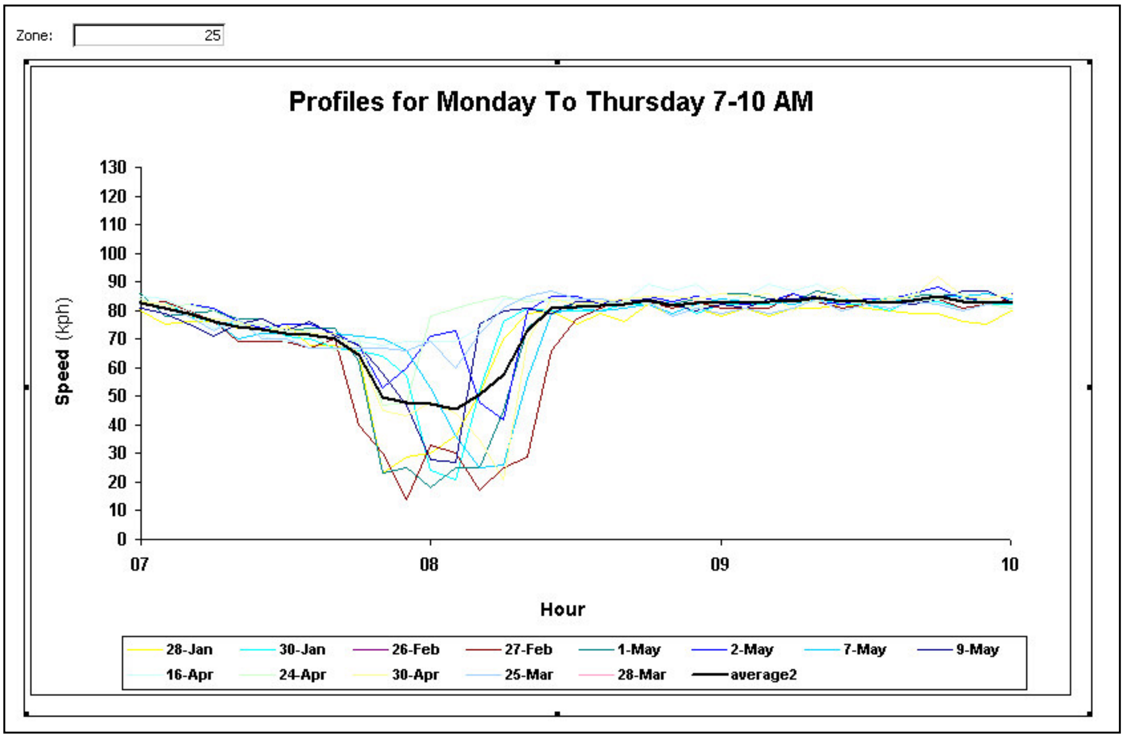

Figure 3***; Morning Peak Breakdown – Northern End of NATMS***

Figure 4 shows that the average breakdown speed at the bottom of the Gorge is significantly lower than at the top of the NATMS. The average speed of traffic during the breakdown period decreases as vehicles travel progressively south down the Gorge.

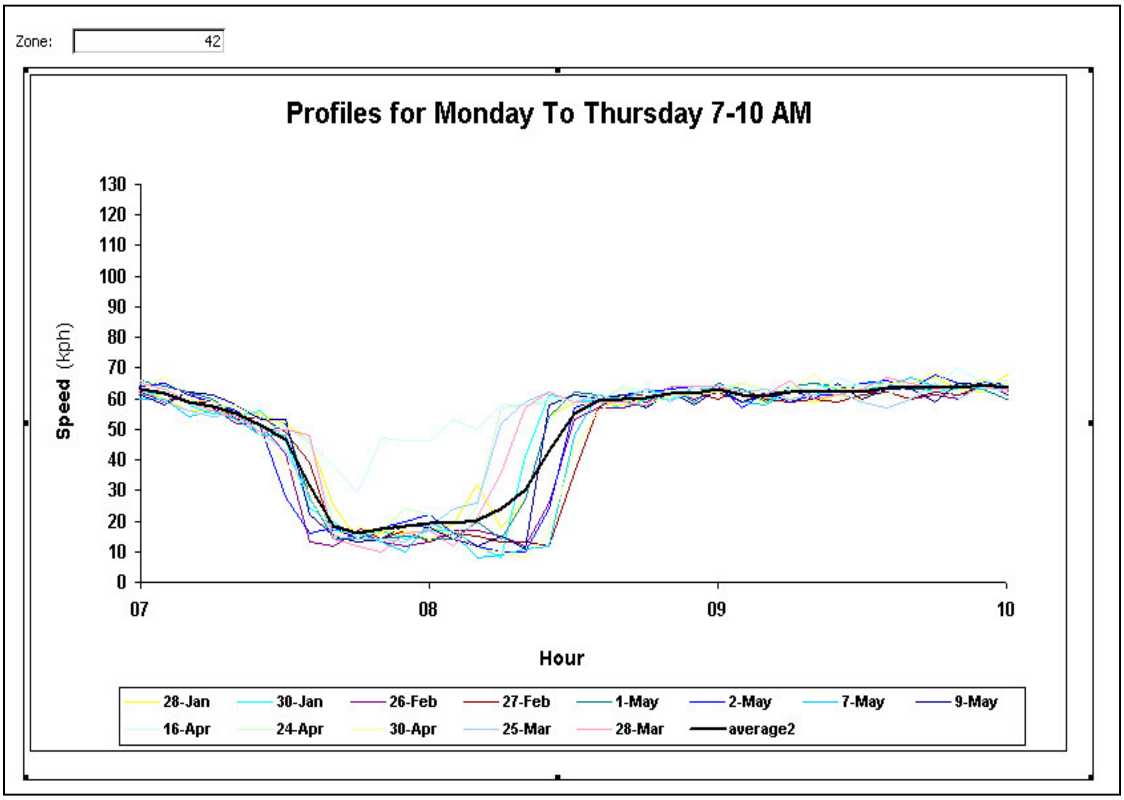

Figure 4; *Morning Peak Breakdown – Southern End of NATMS*

The recovery of the breakdown is often fast, but it should be kept in mind that the average profiles obtained represent both long and short breakdown periods. Breakdowns on differing days often recover in the same time but vary in when this occurs. This recovery speed eventually returns to approximately that prior to the breakdown. On some days the breakdown can last over an hour

5.1.2 Morning Peak Overlap

As is expected with morning AM peak traffic, queues form and extend up the Gorge. Breakdown first occurs at the bottom and as mentioned can extend all the way up on some days. Figure 5 shows three locations within the NATMS in the southbound direction. It can be seen that there is an approximate 10-minute lag between initial breakdown with the zones recording speeds as low as 25km/h. The bottom of the Gorge is the first to experience breakdown and the last to return to normal traffic flow conditions.

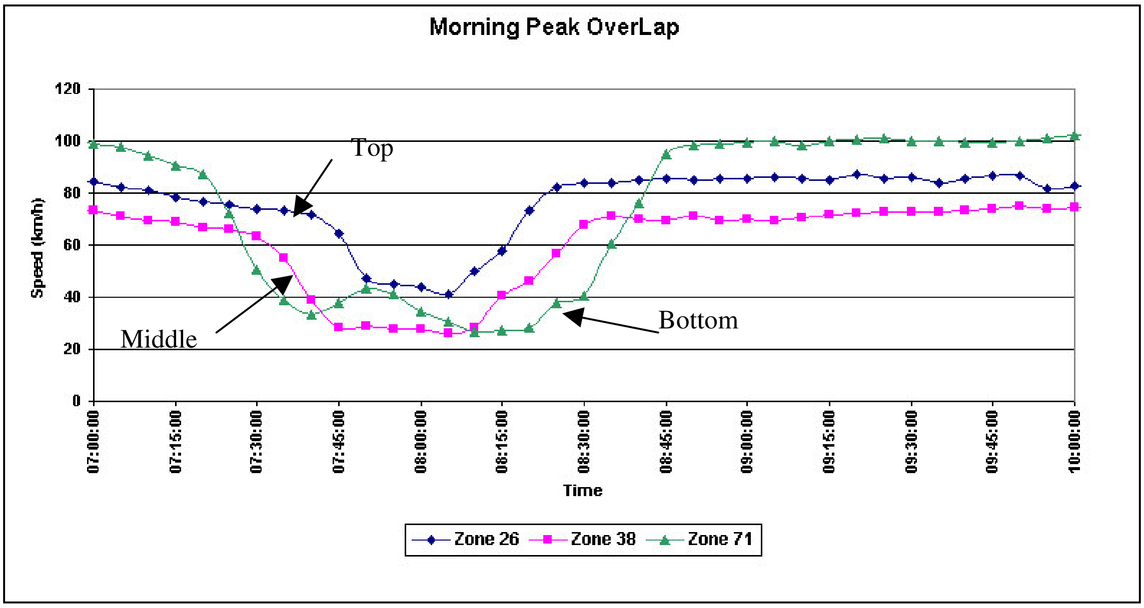

Figure 5; *Breakdown Overlap. Top, Middle and Bottom of Gorge*

5.1.3 Longitudinal Speed Profiles

Longitudinal speed profiles have been developed and encompass a snap shot of all speeds within the NATMS to be shown at anyone time instance.

A typical profile for the longitudinal speeds through the NATMS is shown in the Figure 6 below for 11:30.

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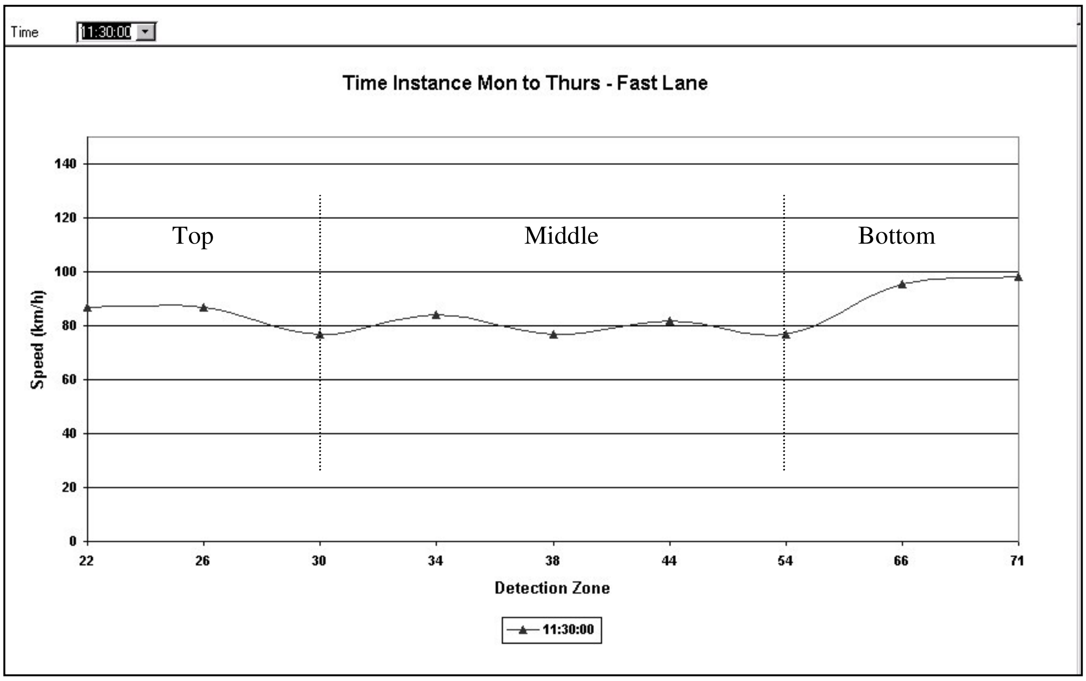


Figure 6; *Variation of Speeds within the NATMS Fast Lane Southbound*

5.1.4 Speed Profiles

It was found that the compliance with the posted speed limits varies from camera site to site. The gradient and geometry of the road (number of lanes) play a significant role from location to location. Results have shown that there is a definite speed differential between lanes at the same site. Figure 7 shows an incremental difference in speeds of approximately 10 km/h between lanes 2 to 4 with lane 1 being an entry onto the State Highway from a side road, thus providing low speed operation.

Below is a table that summarises the speeds at three locations within the NATMS. Values of average speed and standard deviation have been derived using the Monday to Thursday average profiles, in the outer (fast) lane and in the southbound direction.

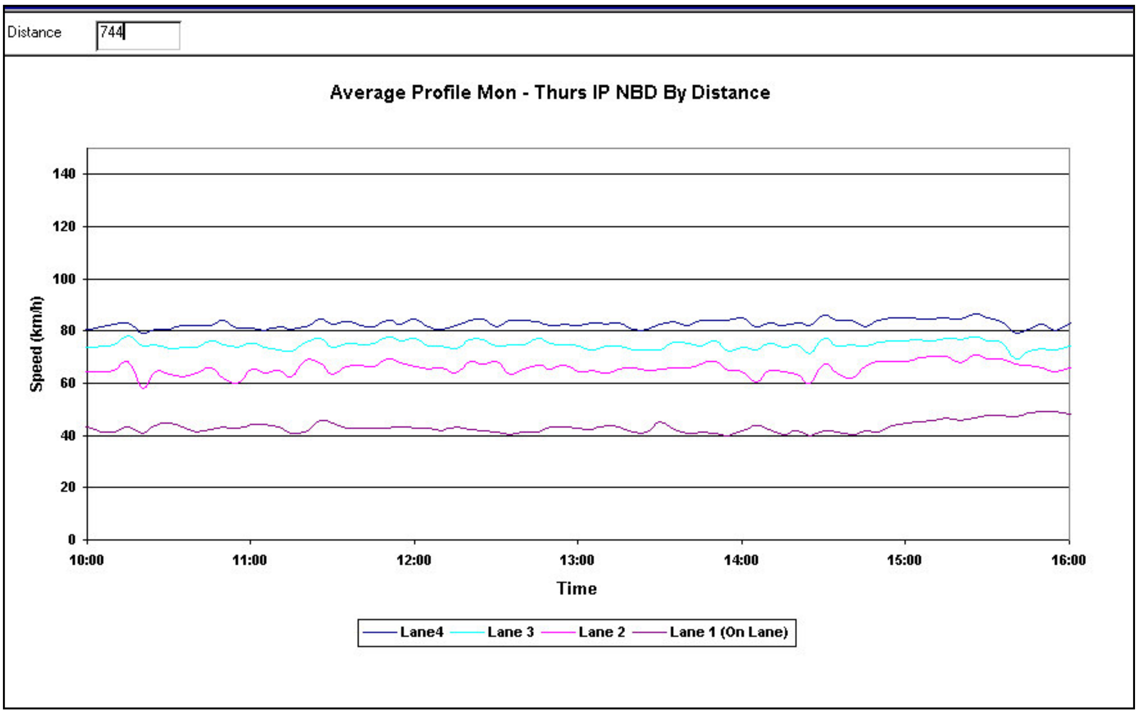


Figure 7; *Typical Lane Profiles*

Table 1; Speed Characteristics (Mon – Thurs)

	Zone					
	26 (Top)		38 (Middle)		71 (Bottom)	
Period	**Speed (km/h)**	**Std Dev (km/h)**	**Speed (km/h)**	**Std Dev (km/h)**	**Speed (km/h)**	**Std Dev (km/h)**
00:00 – 07:00	87.6	3.60	72.8	4.46	95.9	4.7
07:00 – 10:00	75.7	17.1	60.3	19.3	73.6	33.3
10:00 – 16:00	85.3	3.41	75.7	3.82	102.1	6.02
16:00 – 19:00	85.4	2.35	72.7	3.79	102.6	6.16
19:00 – 24:00	86.2	2.79	72.8	3.34	97.4	9.53

The values indicated in Table 1 suggest a lower average speed during the period 07:00 to 10:00 reflecting the additional demand experienced during morning peak.

The corresponding standard deviation is also very high indicating the varying traffic conditions likely to be experience during this time period. These can range from free flow conditions to forced flow nose to tail congested conditions. Over the other periods, there is a reasonable degree of similarity between the values of average speeds. One interesting characteristics is the drop in speed on entering the NATMS and increase when leaving. This reflects the open speed limit of 100km/h at both extremes of NATMS and 80km/h through the controlled section.

The actual differences in average speed between the derestricted sections and those zones with imposed speed controls vary between 9.6 – 14.8 km/h and 23.1 - 29.9 km/h for the top to middle and middle to bottom zones respectively. The legal difference indicated by the VMSS is 20km/h (ie difference between 100km/h and 80km/h respectively). An earlier study (1) showed that there was a 21.4 km/h reduction in speed, from 87.7 to 66.3 km/h, when VMSS were changed from 80km/h to 60 km/h. In this study 88.2% of vehicles drove above the posted 60km/h speed limit.

5.2 Speed – Flow Relationships

Preliminary work has been undertaken to investigate speed – flow relationships. Initial results suggest that the speed – flow curve follows the expected profile including a reduction in flow and speed during periods of breakdown or forced flow conditions. Maximum flow rates are around 343 veh/lane/15 min or 1372 veh/hr for the slow lane and 534 veh/lane/15 min or 2136 veh/hr for the fast lane respectively.

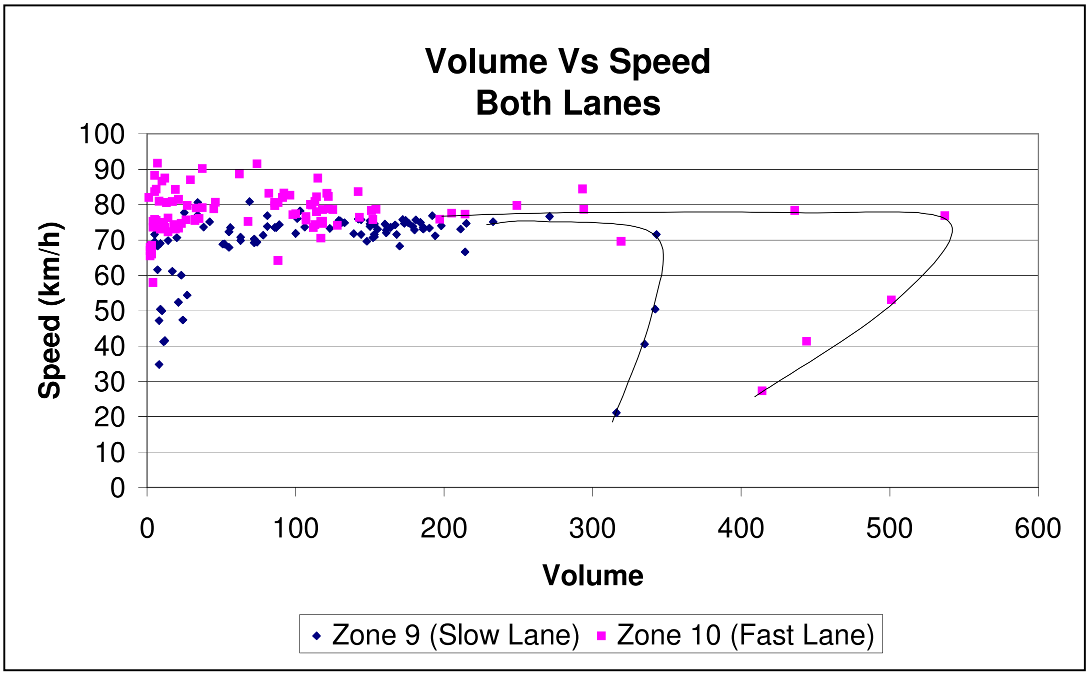


Figure 8*; Speed Flow Curve*

6. Incident Analysis

Incident monitoring has been conducted since the end of January 2002. An incident is defined as any occasion when the speed indicated by a VMSS was reduced for longer than 1 minute from its normal posted speed of 80km/h. Often there are instances where incidents occur within the confines of the Ngauranga Gorge but do not warrant the reduction in speed. An example of these would be a breakdown in the shoulder clear of the live traffic lanes.

Some days were excluded from incident analysis. These included all public holidays within the Wellington Region and school holidays. Such days were considered untypical and therefore could not be compared to the base profiles due to differing flow behaviour.

Since the end of January to 31 May 2002 there have been a total of 108 separate incidents. The tables below show information pertaining to incidents.

Period		Incidents	
Month	**Days**	**Total**	**Number / Day**
January	4	2	0.50
February	27	32	1.23
March	28	35	1.25
April	15	18	1.20
May	31	21	0.68

Table 2 Period and Incident Days.

Types				
Roadworks	Weather	Unplanned[2]	Other / Unsure	Totals
25	51	28	4	108
23%	47%	26%	4%	100%

Table 3 Overall Incident Type Breakdown

For the four months of incident data that have been collected, it can be seen that there is an approximate equal distribution between roadworks, and unplanned incidents. Weather has a higher number due to the variable nature of the climate, and the VMSS may be activated many times during an inclement day. There were four instances which did not fall under any headings and it was not known why the posted speeds were reduced.

<table>
<tr><th colspan="4">Jan - Mar</th><th colspan="6">April - May</th></tr>
<tr><td>Un-Planned</td><td>Wet Weather</td><td>Road-works</td><td>Unknown</td><td colspan="3">Un-Planned</td><td>Wet Weather</td><td>Road-works</td><td>Unknown</td></tr>
<tr><td colspan="4" rowspan="2"></td><td>Crash</td><td>Breakdown</td><td>Diesel Spill</td><td colspan="3" rowspan="2"></td></tr>
<tr><td>7</td><td>4</td><td>1</td></tr>
<tr><td>16</td><td>33</td><td>18</td><td>2</td><td colspan="3">12</td><td>18</td><td>7</td><td>2</td></tr>
<tr><td>23%</td><td>48%</td><td>26%</td><td>3%</td><td>18%</td><td>10%</td><td>3%</td><td>46%</td><td>18%</td><td>5%</td></tr>
</table>

Table 4 Incident Breakdown by Month

[2] An unplanned incident is any incident that is not planned or when the system is activated by the Automatic Incident Detector. Typically these are crashes and breakdowns.

Since April 2002, changes have been made to classification of unplanned incidents to include crashes, breakdowns or spills. This has revealed that crashes account for 58% of unplanned incidents and 18% of all incidents.

	Average Duration (hh:mm)	Average Area Affected
Roadworks	05:48	33%
Weather	03:31	7%
Unplanned	00:27	44%
Other / Unsure	00:35	29%

Table 5 Incident Duration and Area Affected

The values in Table 4 show that most changes to the VMSS were as a result of planned roadworks or inclement weather. Unplanned incidents were much shorter in duration than for speeds constraints imposed through roadworks or weather, but tended to affect a much larger area of the NATMS.

6.1 Roadworks Incidents

Figure 9 below is an example of an incident within the Ngauranga Gorge. This particular incident was a roadworks operation in the southbound direction whereby a lane closure was in place and the contractor worked in the adjacent lane.

The profile below shows the speeds in lane 2 (fast lane) alongside the closure. Table 5 shows the times when the VMSS signs were activated. The location of the incident is at the top of the Gorge where the speed limit is normally 100km/h.

Date	Description		Time	Sign Status	Signs Effected
Wed 8 May 02	Roadworks Ahead, Lane Closed	On	13:07	50 km/h	1, 2
Wed 8 May 02	Roadworks Ahead, Lane Closed	On	13:51	80 km/h	1, 2
Wed 8 May 02	Roadworks Ahead, Lane Closed	Off	17:48	Blank	1, 2

Table 6: VMSS Time Activation

As mentioned, the speed limit at his section of the Gorge is 100km/h. From the table above, the signs were raised to 80km/h and maintained at this for a substantial period of time. This was due to the continuation of roadworks being undertaken further down the Gorge. This 80 km/h speed limit it used to ensure that drivers do not experience a large speed drop whilst travelling within the confines of the Gorge. The speed was returned to its normal setting (Blank, ie 100km/h) at 17:48 PM. Recent research (2) undertaken at the University of Salford UK, indicated that the percentage of vehicles complying with the displayed speed at roadworks was 20% for the nearside and 11% for the farside lane.

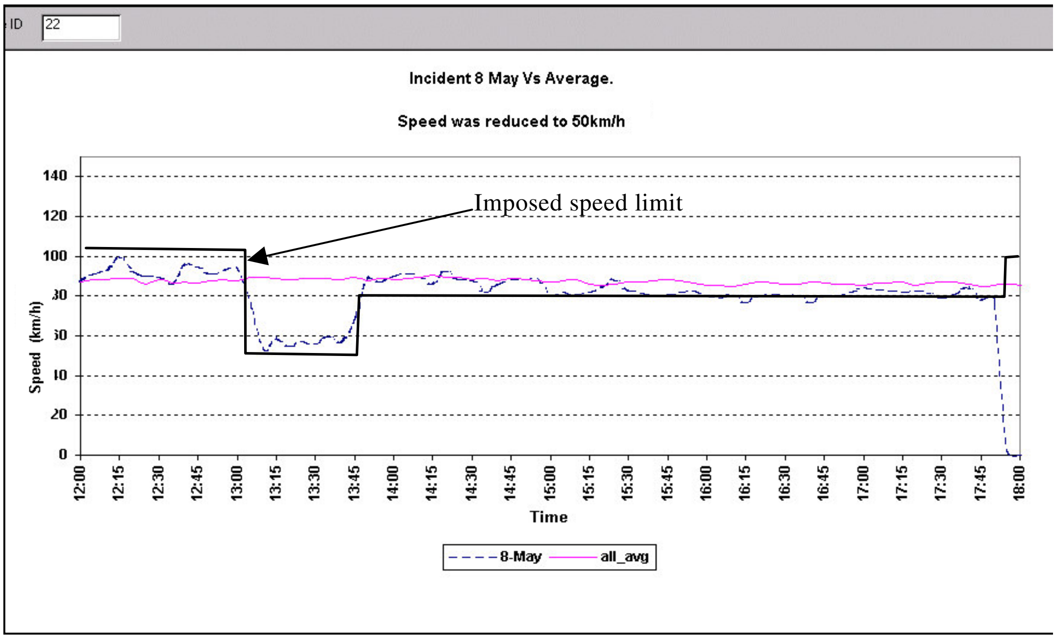


Figure 9: ***Incident profile, 8 May 2002***

Whilst the VMSS reduction is instantaneous, the slope of the reduction or eventual increase suggest a driver change of 20km/h per 5 minutes from normal conditions to speed restricted conditions and vice versa.

The average speed for the time shown prior to the incident was 92.2 km/h, and whilst the speed reduction was in place the average speed has reduced to 58.3 km/h. The average speed then rose to 83.3 km/h when the VMSS signs were increased to 80km/h.

6.2 Wet Weather Incident

Another example of an incident is provided below. This incident is a ‘wet weather’ incident, whereby the operator deemed the weather conditions extreme enough to warrant the ‘wet weather’ response plan. This plan is a predetermined plan whereby messages are displayed on the 6 VMS’s and the final two south bound VMSS’s are lowered from 100 to 80 km/h. The speeds were lowered due to the difficult driving conditions arising from the wet road surface.

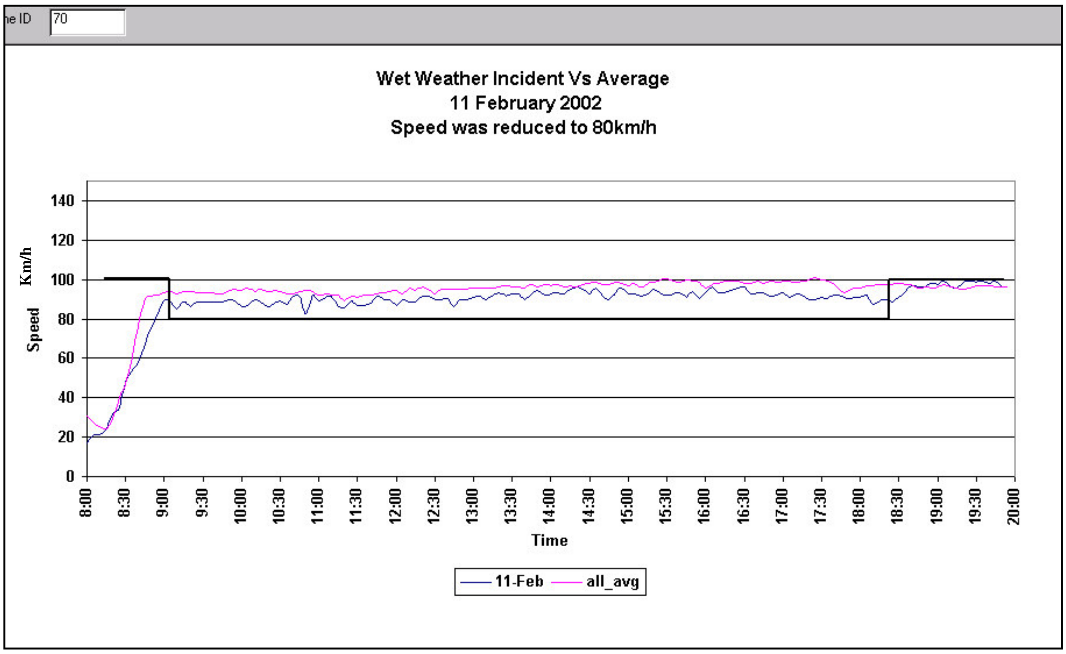


Figure 10: ***Wet Weather Incident, Zone 70 (Middle Lane)***

The above plot shows that there is a distinct drop in speed when the sign is lowered to 80km/h, but is still above the mandatory speed of 80km/h. A study undertaken in Finland in 1999 (3) showed that in winter the change of posted speed from 100km/h to 80km/h reduced the mean speed of vehicles by 3.4km/h. This was in addition to the mean speed reduction of 6.3km/h caused by adverse weather and road surface conditions. A further study (4) indicated that an estimate of speed reduction of 0.4% to 1.4% can be expected when posted speeds are dropped from 100km/h to 80km/h.

7. Future Work

The analysis of incidents is only in its infancy. Speed profiles during incidents will be produced possibly down to 1-minute time intervals. The ability to collect data at 1-minute intervals enables a more microscopic analysis of speeds and behavioural changes to be undertaken.

The effect of the imposed speed restriction on the average speed of vehicles will be undertaken at each site and then compared with the base profiles.

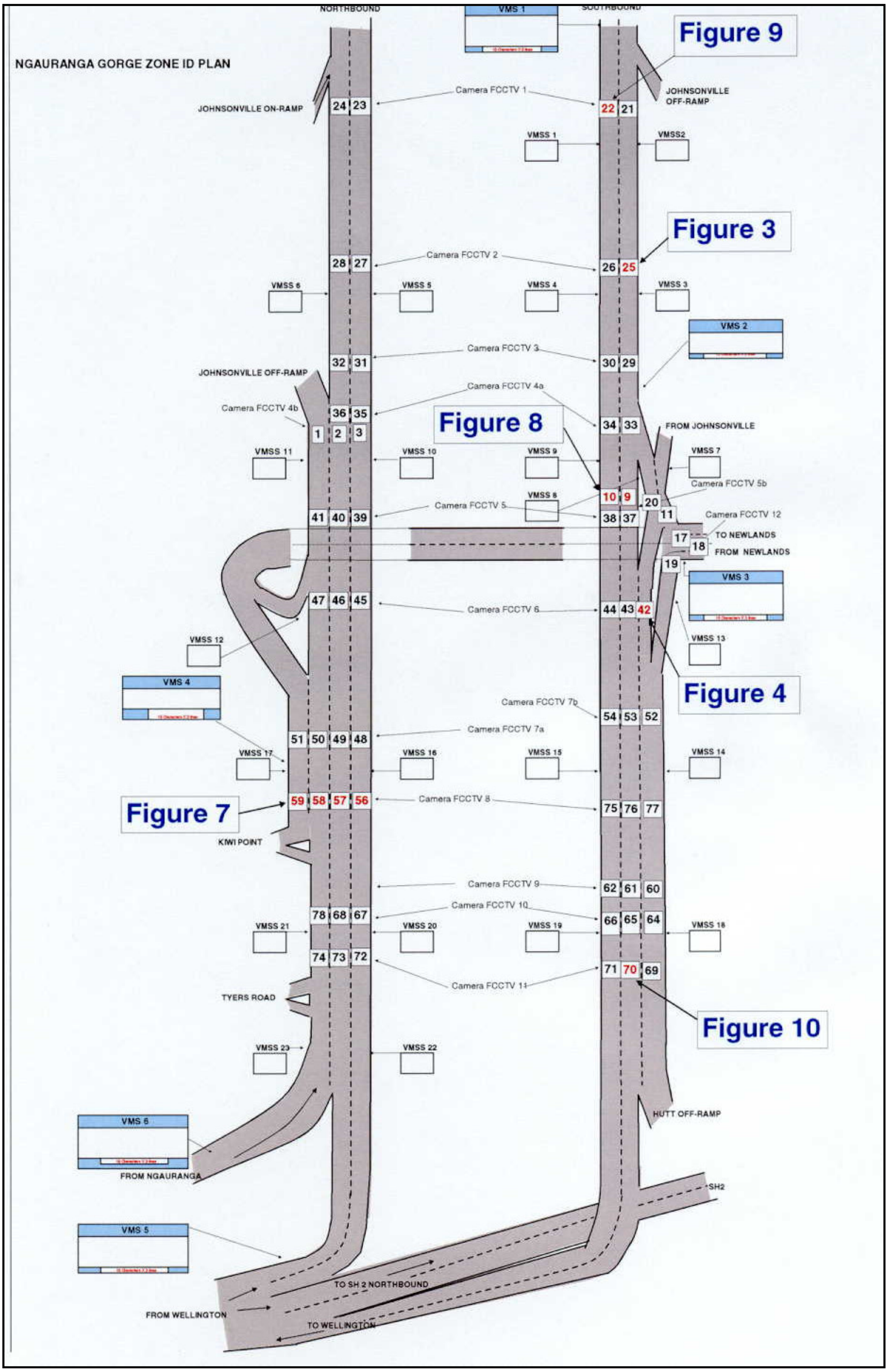
Data collected during periods containing incidents will also be examined to reveal if speed changes over time (ie as the incident continues) and also to ascertain if speeds differ spatially throughout the NATMS.

Data has already been acquired for sites offering the opportunity for diversion, and in the event of incidents (and especially lengthy ones), these locations will be monitored and the additional amounts of traffic choosing to divert will be quantified.

8. References:

1. Luomo, J., and Rama, P. (*1998)* Effects of variable speed limit signs on speed behaviour and recall of signs. In *Traffic Engineering and Control: Vol 39, No. 4 , pp 234 – 236.*
2. Yousif, S. Motorway Roadworks Effects on Traffic Operations*. In Highways & Transportation, April 2002, pp 20 – 22.*
3. Rama, P (1999). Effects of Weather-Controlled Variable Speed Limits and Warning Systems in Driver Behaviour. Transport Research Record 1689, *Proceedings of 78th Meeting of transportation Research Board*, National Research Council, Washington, D.C.
4. Pilla-Sihvila, Y., and Lahesmaa, J. (1995) Weather Controlled Road and Investment Calculations. Finnish National Roads Administration,

9. Appendix A – Zone ID Locations Within NATMS



Ngauranga Gorge Zone Plan, zones in red indicate figures presented in paper.