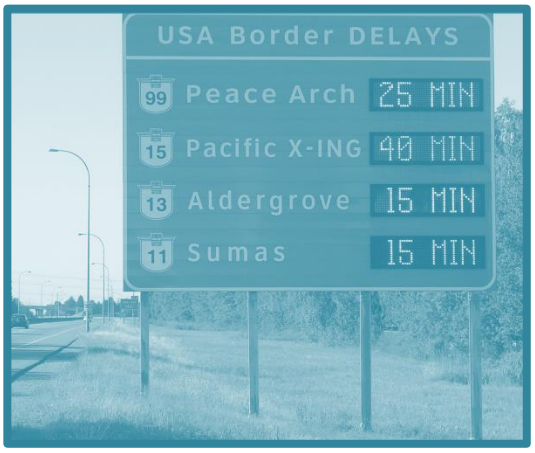
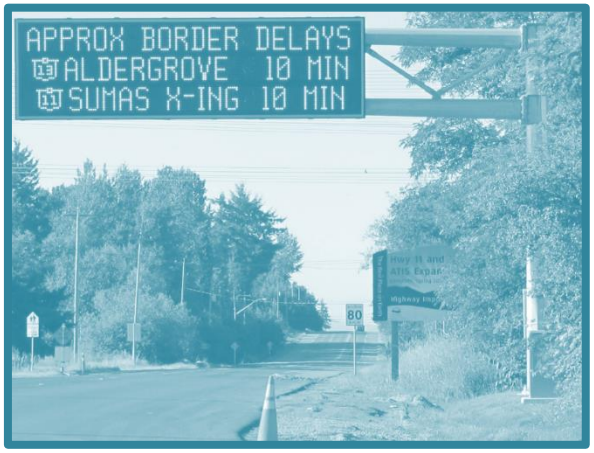
Technical Memorandum
VO-103546

CBP Data Feed to Border ATIS

Software Modification Validation Report





Prepared for BC Ministry of Transportation & Infrastructure
by IBI Group

July 12, 2017

Table of Contents

1 Introduction 1

2 Background 1

2.1 ATIS Context 1

2.2 Problem Statement 2

3 Implemented Solution 4

3.1 CBP RAD Capture and Processing Application 4

3.2 Legacy ATIS Application Enhancements 4

4 Validations and Results 6

4.1 Analysis 6

4.2 Conclusions 16

Appendix A - Sample Real-time Arrivals and Departures (RAD) XML Data 17

Appendix B - Sample Summarized Real-time Arrivals and Departures (RAD) XML Data 1

LIST of EXHBITS

Exhibit 2-1: Cross-border ATIS Web Site Home Page 1

Exhibit 2-2: ATIS Delay Calculation under Existing Assumption that Nexus Lane is Fixed 2

Exhibit 3-1 High-Level Legacy ATIS Application Enhancements Data Flow Diagram 5

Exhibit 4-1: April 1, 2017 Highway 15 Queue Length in Meters 7

Exhibit 4-2: April 1, 2017 Highway 15 Delays in Minutes and Open DCL Lane(s) 8

Exhibit 4-3: April 1, 2017 Highway 99 Queue Length in Meters 9

Exhibit 4-4: April 1, 2017 Highway 99 Delays in Minutes and Open DCL Lane(s) 10

Exhibit 4-5: April 2, 2017 Highway 15 Queue Length in Meters 11

Exhibit 4-6: April 2, 2017 Highway 15 Delays in Minutes and Open DCL Lane(s) 12

Exhibit 4-7: April 2, 2017 Highway 99 Queue Length in Meters 13

Exhibit 4-8: April 2, 2017 Highway 99 Delays in Minutes and Open DCL Lane(s) 14

Exhibit 4-9 Comparative Analysis of Error Rates 15

1 Introduction

The purpose of this technical memorandum is to present the results from integrating the newly available booth status data feed from Customs and Border Protection (CBP) into the British Columbia Ministry of Transportation and Infrastructure's (MoTI) Cross-Border Advanced Traveller Information System (ATIS).

Once reviewed and approved by MoTI, IBI Group will deploy the enhanced ATIS software which integrates the CBP status data feed to improve estimated delay accuracy.

2 Background

2.1 ATIS Context

MoTI launched the original cross-border ATIS in 2004, providing border wait time information for the southbound approach to the US border along Highways 99 and 15 (Peace Arch and Pacific Highway crossings respectively). In 2010, the system was expanded to also include Highways 13 and 11 towards the Aldergrove and Sumas crossings respectively. ATIS disseminates border wait time information through a web site accessible from MoTI's DriveBC web site, as well as through four overhead Dynamic Message Signs (DMS), four hybrid DMS and an automated phone system accessible at 604-542-4360.

Exhibit 2-1 illustrates the ATIS homepage. Over the past decade, a number of enhancements have been made to the ATIS, including the addition of historical border wait time reporting through a data feed for the Cascade Gateway Data Warehouse and commercial vehicle queues and border delay information for the Pacific Highway crossing through a redesigned web site.

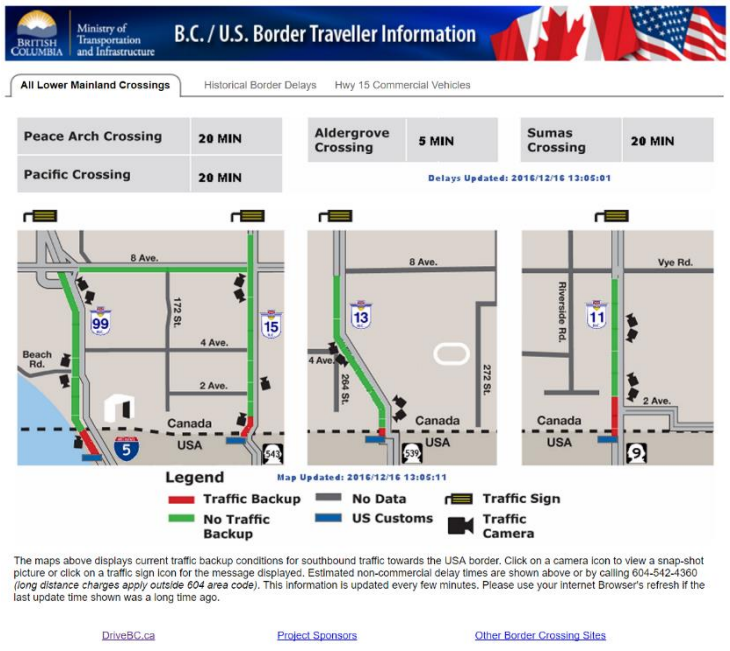


Exhibit 2-1: Cross-border ATIS Web Site Home Page

2.2 Problem Statement

The existing design of the ATIS included fundamental assumptions that were valid at the time of the launch of the system 13 years ago but are no longer valid. Specifically, when the original system was launched:

- the position of the NEXUS lane was fixed, which allowed the ATIS algorithm to exclude traffic data collected from the loops associated with the NEXUS lane in order to estimate wait times associated with General Purpose (GP) traffic; and
- there was no other category of traffic beyond GP and NEXUS, such as the recently introduced Ready Lane for travellers using an enhanced Driver's License, RFID, US passports, NEXUS etc.

Since the launch of the system, and because of a combination of high success in the NEXUS program, geometric improvements, and installation of overhead dynamic lane designation signs, CBP modifies the position and quantity of NEXUS lanes to meet advertised 15 minute maximum NEXUS user delays, improve customs officer safety and traffic flows.

Accordingly, if any of the lanes that are currently assumed by ATIS to be fixed GP lanes are designated as NEXUS, ATIS will continue to interpret traffic data from these as GP lanes. This will result in the ATIS algorithm to calculate a higher throughput or service rate (since NEXUS lanes process traffic faster) resulting in calculated delays to underestimate the actual delays experienced by GP traffic. Exhibit 2-2 and 2-3 illustrate the impact of this issue in simplified form.

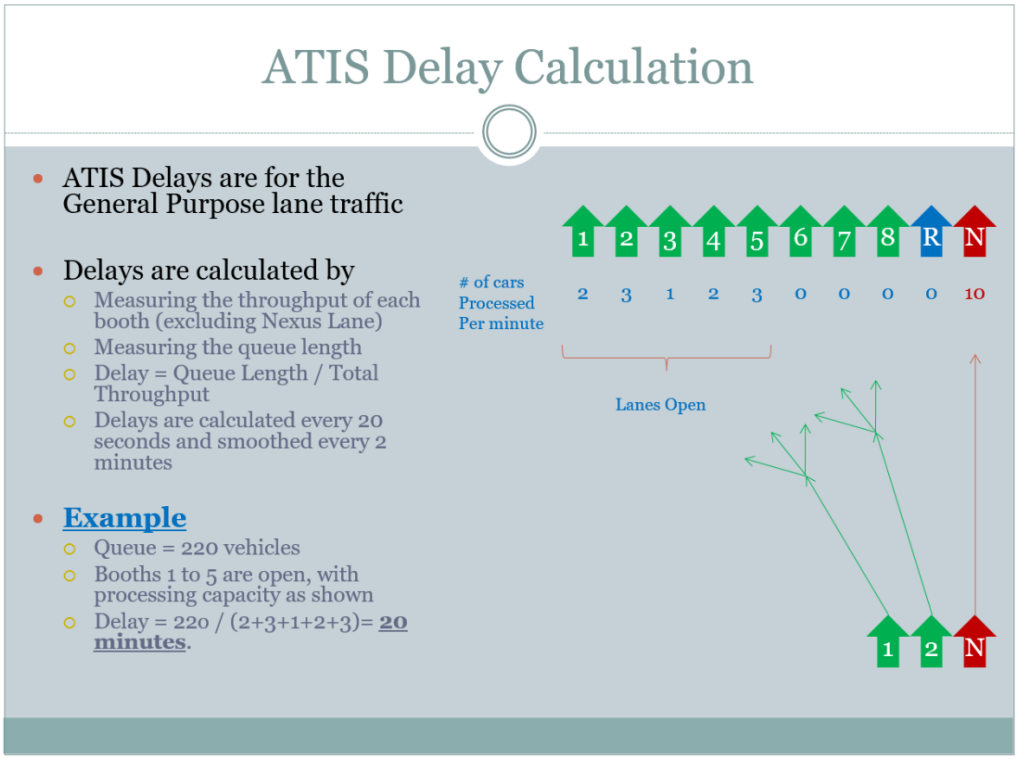


Exhibit 2-2: ATIS Delay Calculation under Existing Assumption that Nexus Lane is Fixed

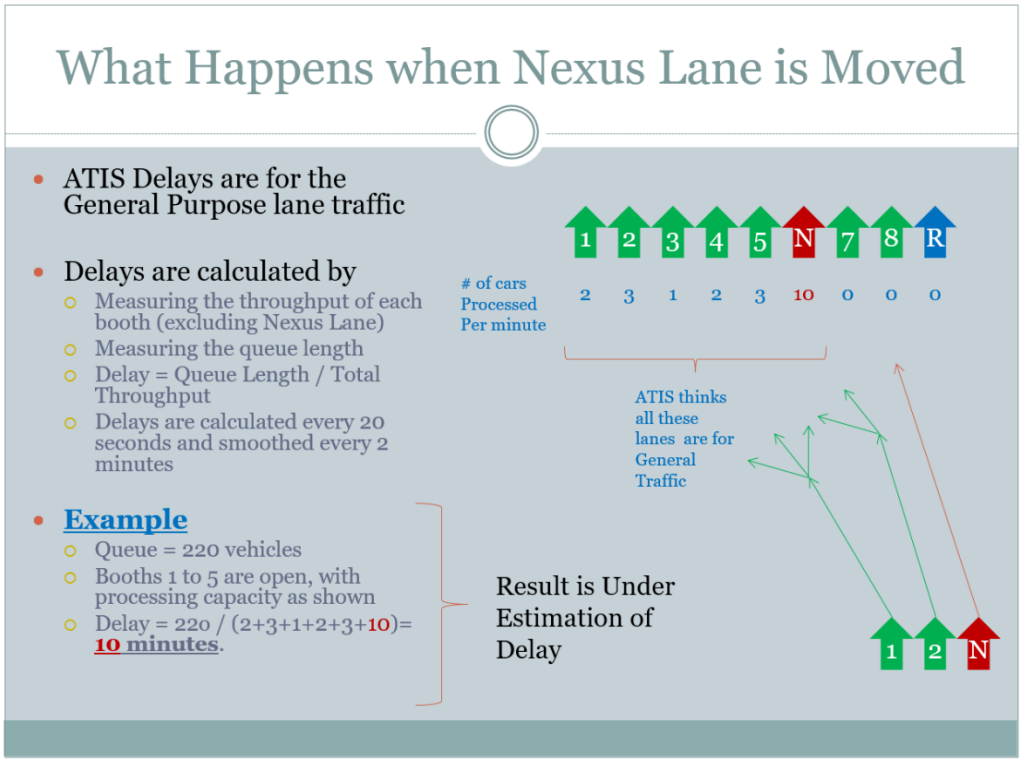


Exhibit 2-3: Impact on ATIS Delay Calculation when NEXUS Lane is Moved

3 Implemented Solution

In recognition of the problems presented in section 2.2 above, CBP initiated a project to share real time data associated with the designation of each lane, as well as vehicle arrival/departure details. Specifically, a Real-time Arrivals and Departures (RAD) application has been developed to post 10-minute data details in XML format to the following publicly accessible website: http://bwt.cbp.gov/bwtlane/lane.xml

Based upon the Software Modification Design Memo dated February 10, 2017, IBI Group has successfully completed ATIS software enhancements to integrate CBP's RAD XML data to address section 2.2 problems by enabling ATIS to accurately exclude NEXUS lanes from GP traffic estimated delay calculations.

3.1 CBP RAD Capture and Processing Application

To optimize reliability, portability and minimize legacy ATIS application modifications, a stand-alone CBP RAD application was developed. This application is autonomous from the legacy ATIS applications and has no interdependencies or required user interaction. The application simply captures, validates and prepares a CBP RAD data summary for the legacy ATIS application use. A sample RAD XML data file is included in Appendix A and the associated CBP RAD data summary file is included in Appendix B of this technical memorandum.

3.2 Legacy ATIS Application Enhancements

To leverage CBP RAD data and minimize potential legacy ATIS application performance and stability risks, the following improvements and enhancements were completed as illustrated in the high-level legacy ATIS application enhancements data flow diagram provided in Exhibit 3-1:

a. All enhancements are autonomous from the CBP RAD capture and processing application described in section 3.1. In other words, the legacy ATIS application continues to execute and perform as prior to any enhancements without any interdependencies to the CBP RAD capture and processing application or the CBP RAD data summary file.
b. Additional CBP RAD data related validation and utilization configuration parameters have been seamlessly included in the existing ATIS.cfg self-documented text configuration file. All CBP RAD data related configuration parameters are optional. In the absence of these configuration parameters, the legacy ATIS application will continue to execute and perform as prior to any enhancements.
c. Existing ATIS loop derived service rate algorithms remain and perform as prior to any enhancements to ensure uninterrupted continuance of all legacy ATIS application algorithms functions and performance in the absence of valid and current CBP data.
d. Existing ATIS delay estimation algorithms obtain CBP RAD per crossing and per traffic mode data every 20 seconds using non-blocking means, confirm validity and currency based upon user configured parameters, and then if determined to be acceptable, replace the applicable loop derived service rates with RAD derived service rates. ATIS estimated queue delays are augmented with the CBP RAD average processing time to improve accuracy by including typical interview delays.
e. Log related status/error messages to the Windows application event log.

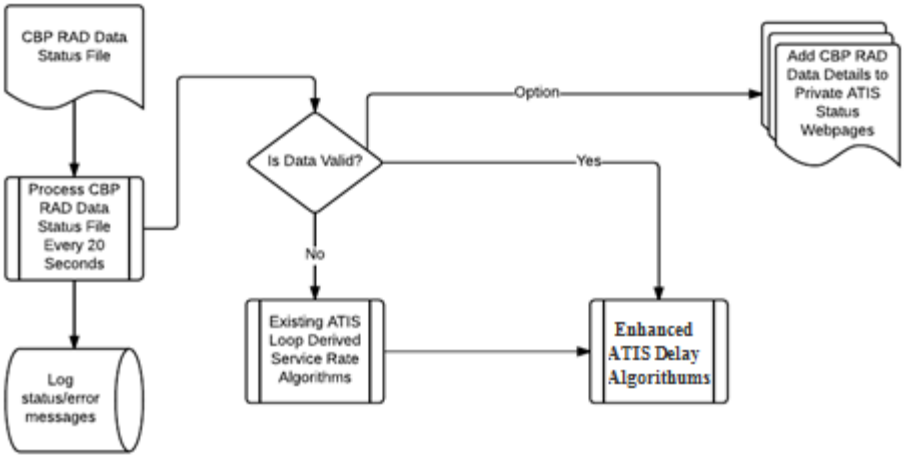


Exhibit 3-1 High-Level Legacy ATIS Application Enhancements Data Flow Diagram

4 Validations and Results

To validate estimated delay accuracy improvements for the enhanced ATIS utilizing CBP's RAD XML data, IBI Group utilized the following 3-step method:

1) Obtain ground-truth border delays and queue length by conducting on-site surveys.
2) Analyse legacy ATIS queue length and estimated delays utilizing 20-second VDS loop data and compare against survey results.
3) Conduct offline iterative calibration and validation of enhanced ATIS estimated delays utilizing captured CBP's RAD XML data files and compare against survey results.

To complete the above step 1, IBI Group retained the services of TransTech Data Services Ltd to conduct the following four on-site surveys:

- Highway 15 GP traffic from 11:00 am till 5:00 pm on April 1, 2017.
- Highway 99 GP traffic from 11:00 am till 5:00 pm on April 1, 2017.
- Highway 15 GP traffic from 11:00 am till 5:00 pm on April 2, 2017.
- Highway 99 GP traffic from 11:00 am till 5:00 pm on April 2, 2017.

To complete the above step 2, legacy ATIS queue length and estimated delays derived from loop data was plotted against survey results using Microsoft Excel as illustrated in Exhibits 4-1 to 4-8 (**Green lines**).

To complete the above step 3, IBI Group conducted offline iterative calibration and validation of enhanced ATIS estimated delays utilizing captured CBP's RAD XML data files and compared results against survey data. Based upon these efforts, the enhanced ATIS estimated delays derived from CBP's RAD XML data was plotted against survey results using Microsoft Excel and included in Exhibits 4-2, 4-4, 4-6 and 4-8 (**Purple lines**). Please note that legacy and enhanced ATIS queue lengths are identical as the algorithms were not modified and continue to utilize only loop data.

4.1 Analysis

The analysis is based upon the following two limitations which have been acknowledged and accepted by MOTi:

1) The CBP RAD XML data feed will not address ATIS delay inaccuracies under extreme queue conditions when queues extend north of the ATC loop detection limits.
2) The CBP RAD XML data feed will not improve ATIS commercial vehicle delay accuracy (i.e. only GP traffic estimated delay improvements).

Analysis considers the field measured survey delays to be ground truth values to validate ATIS delay estimates derived from both the existing looped based and enhanced CBP's RAD XML data fusion algorithms. All survey and ATIS queue length and estimated delays are plotted against time using Microsoft Excel as illustrated in Exhibits 4-1 to 4-8.

It should be noted that the legacy ATIS has lane 6 of Highway 15 and lanes 9 and 10 of Highway 99 configured as NEXUS lanes only; hence these lanes are always excluded from GP traffic discharge rates and estimated delays, while any other lanes dynamically and temporarily set as NEXUS are included for GP traffic discharge rates and estimated delays.

Exhibit 4-1: April 1, 2017 Highway 15 Queue Length in Meters

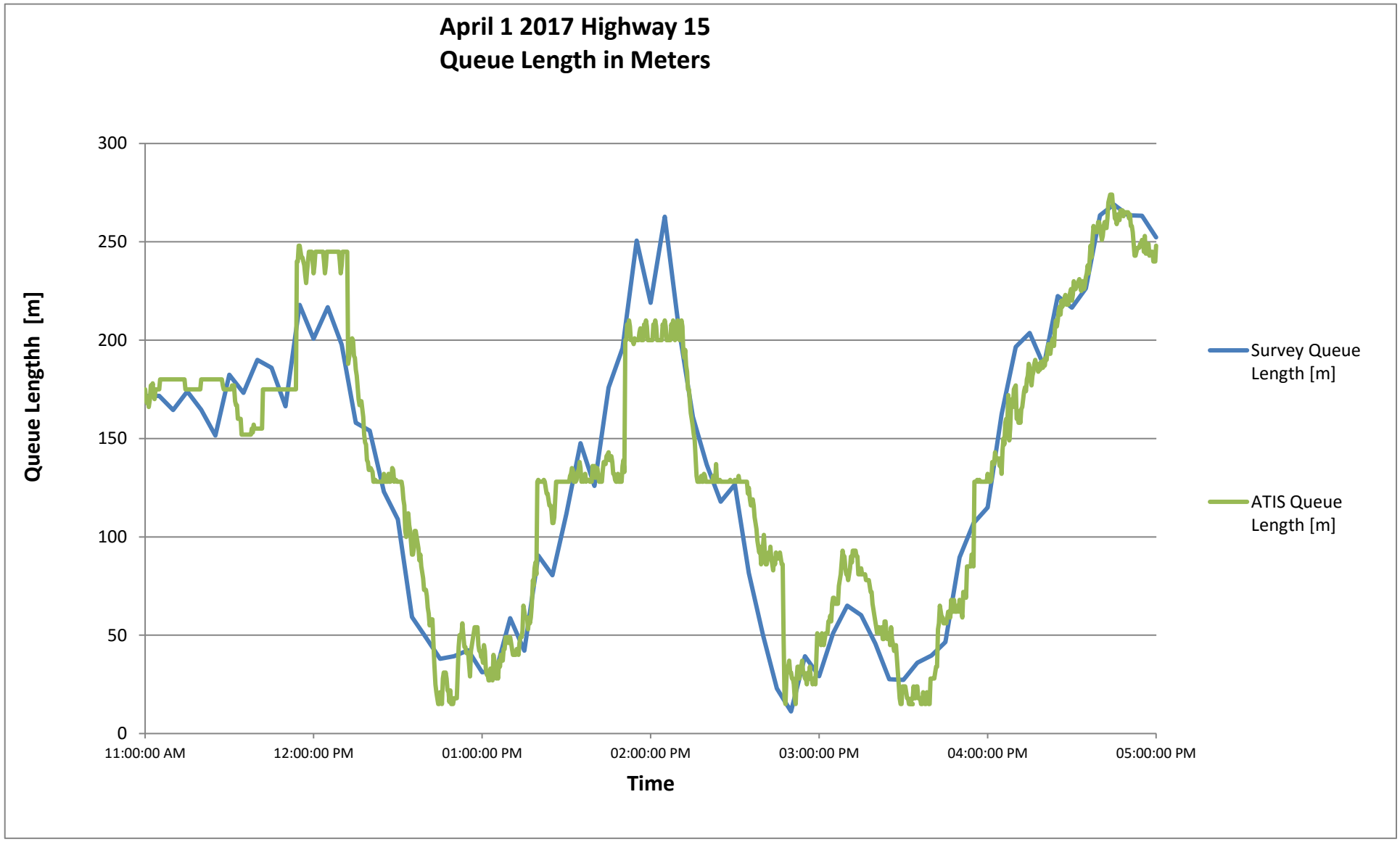


Exhibit 4-2: April 1, 2017 Highway 15 Delays in Minutes and Open DCL Lane(s)

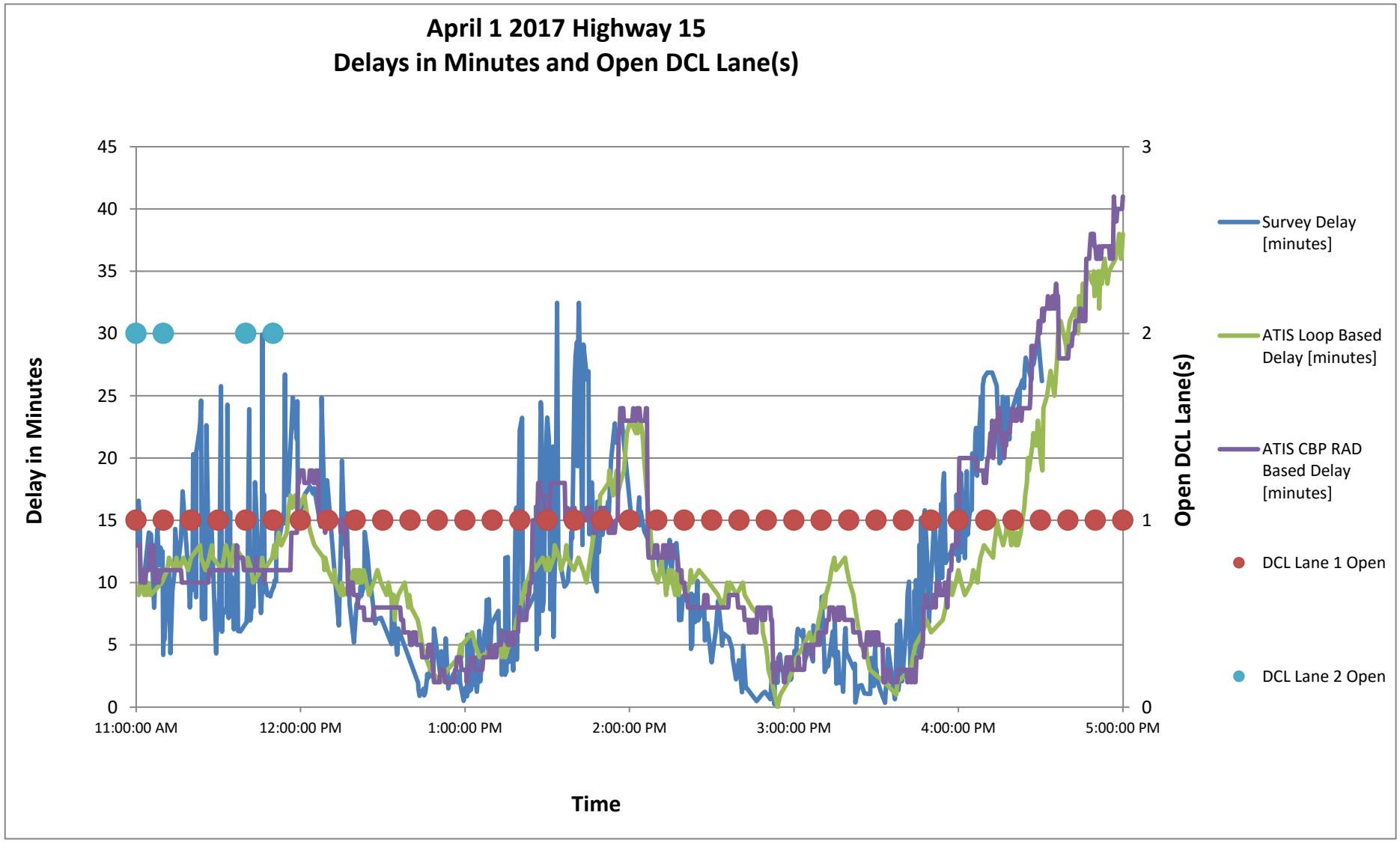


Exhibit 4-3: April 1, 2017 Highway 99 Queue Length in Meters

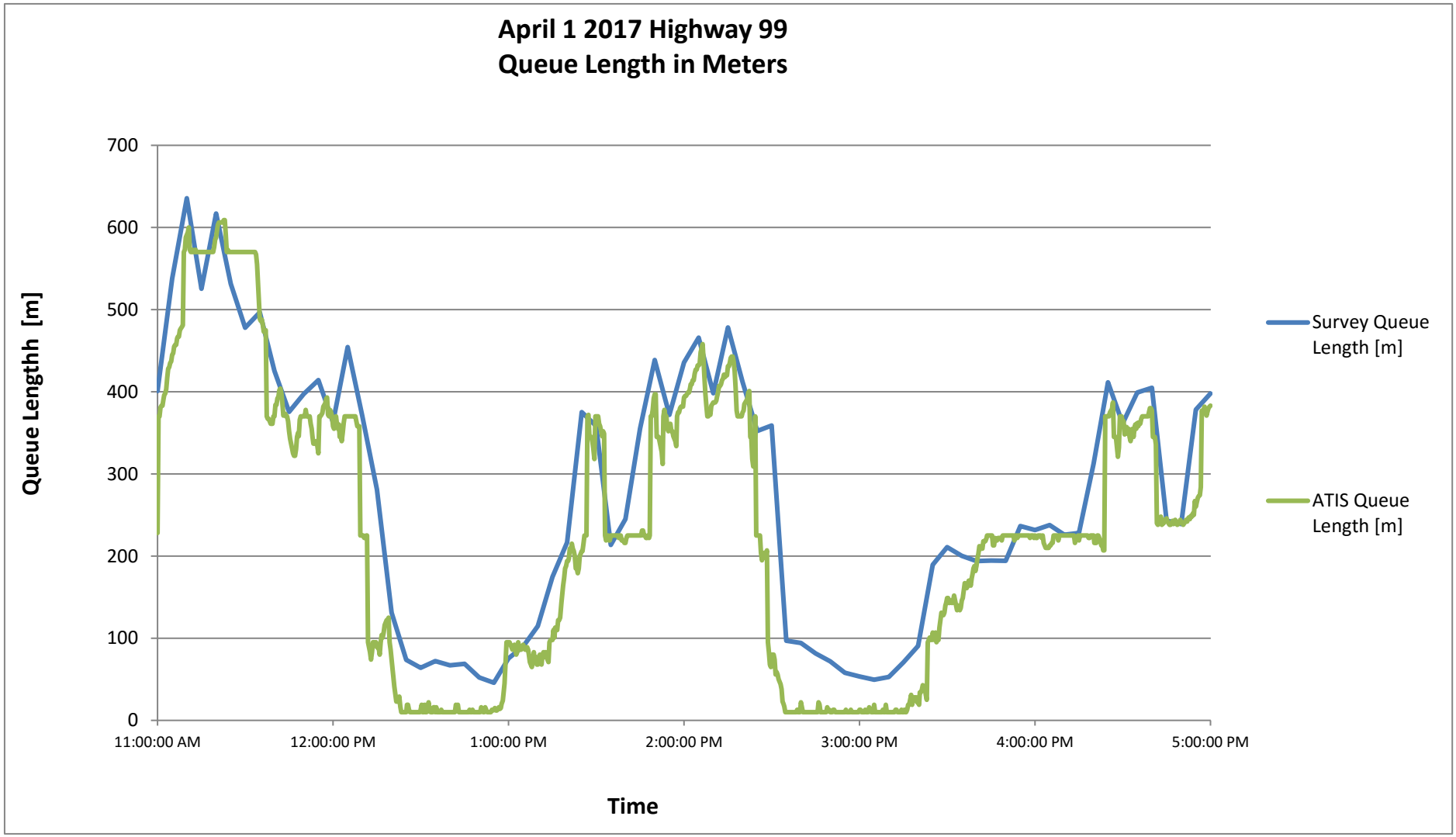


Exhibit 4-4: April 1, 2017 Highway 99 Delays in Minutes and Open DCL Lane(s)

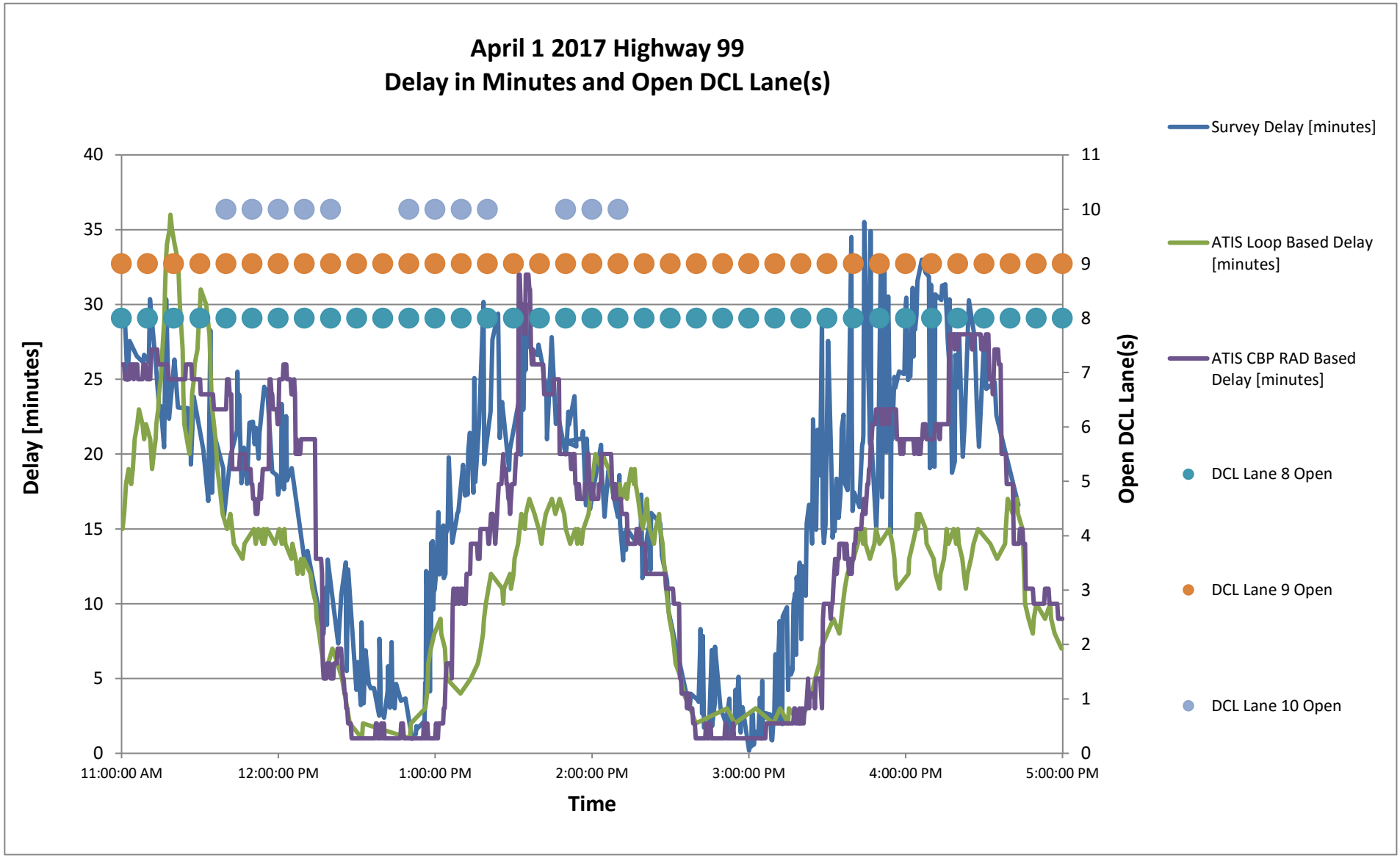


Exhibit 4-5: April 2, 2017 Highway 15 Queue Length in Meters

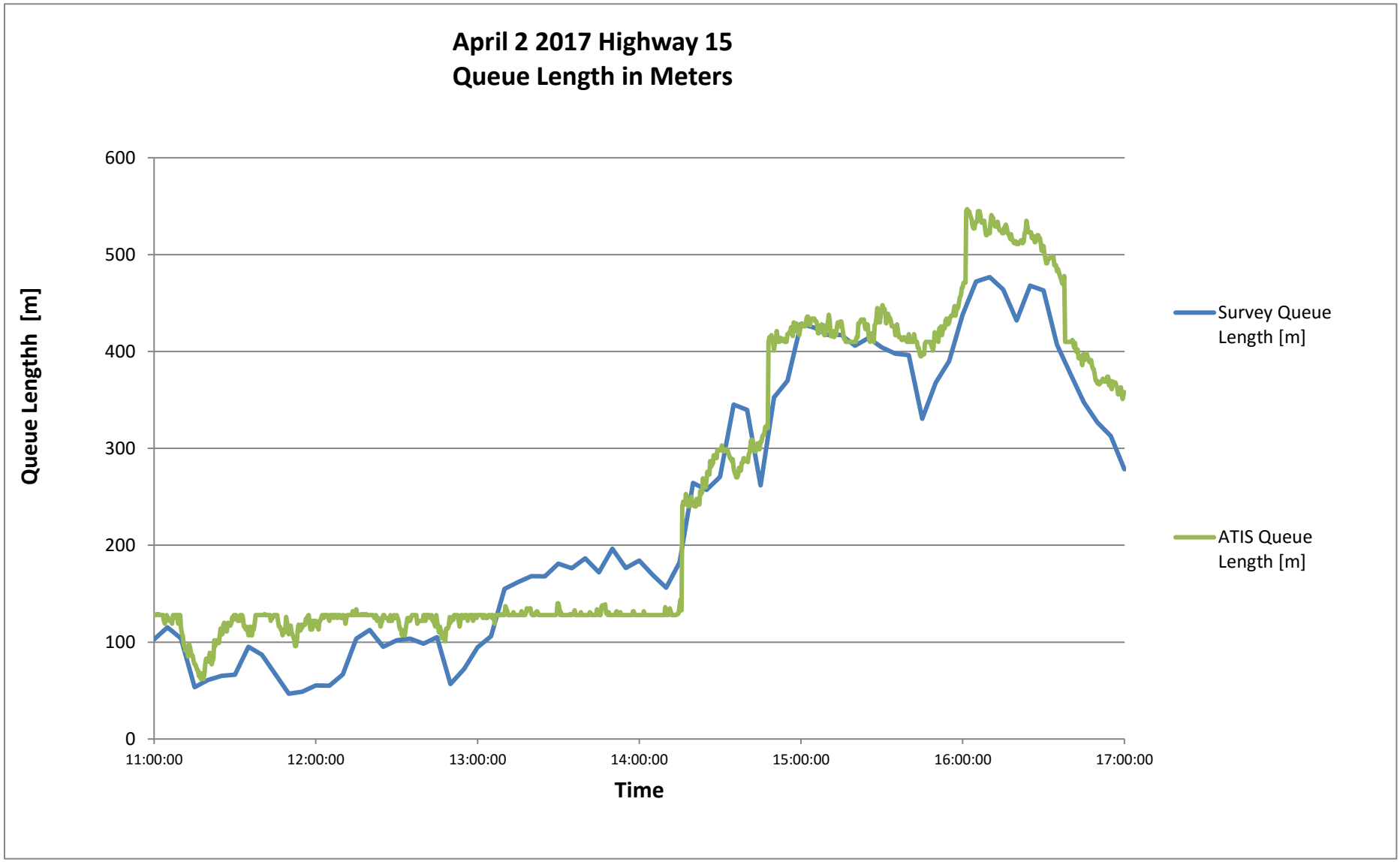


Exhibit 4-6: April 2, 2017 Highway 15 Delays in Minutes and Open DCL Lane(s)

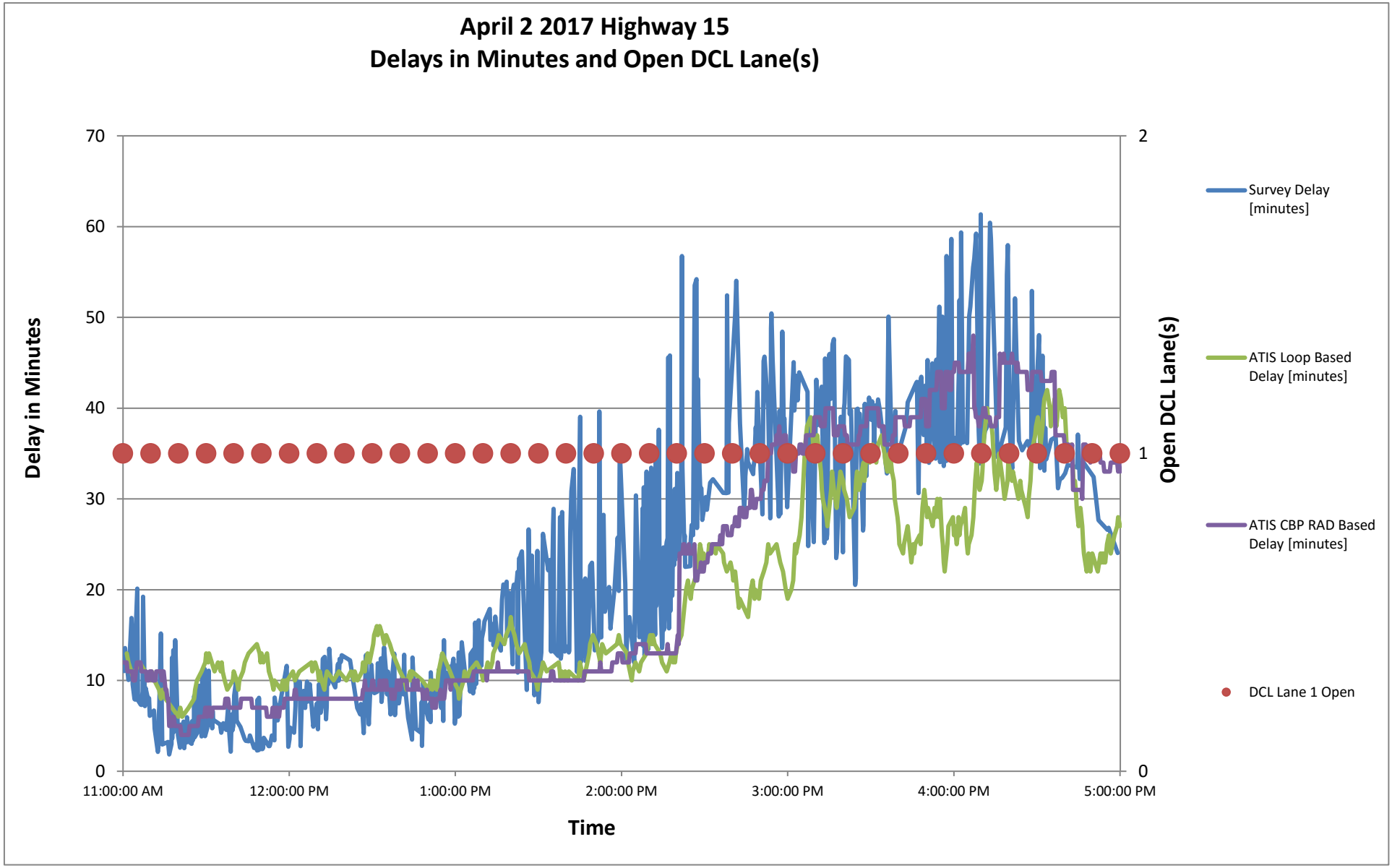


Exhibit 4-7: April 2, 2017 Highway 99 Queue Length in Meters

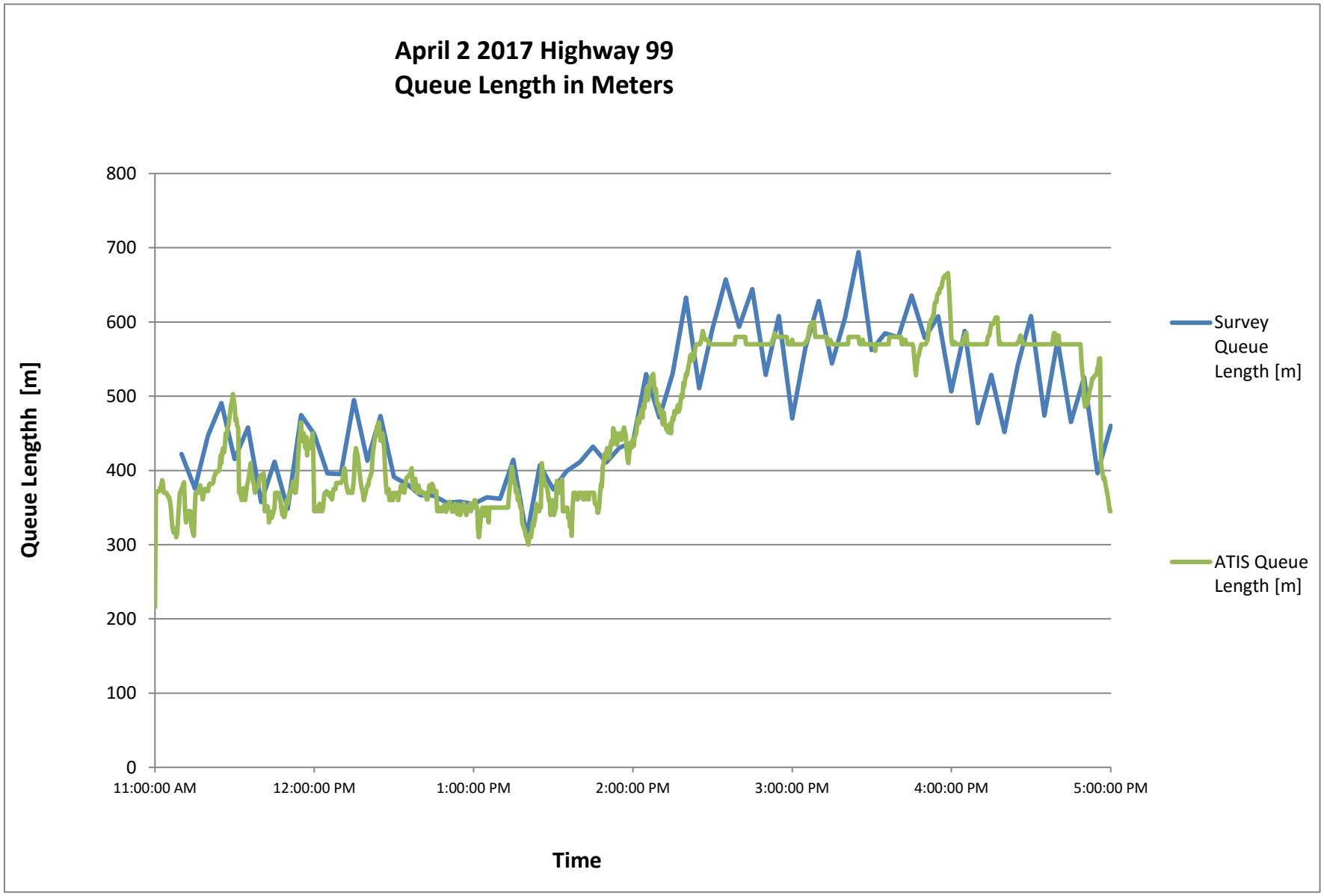
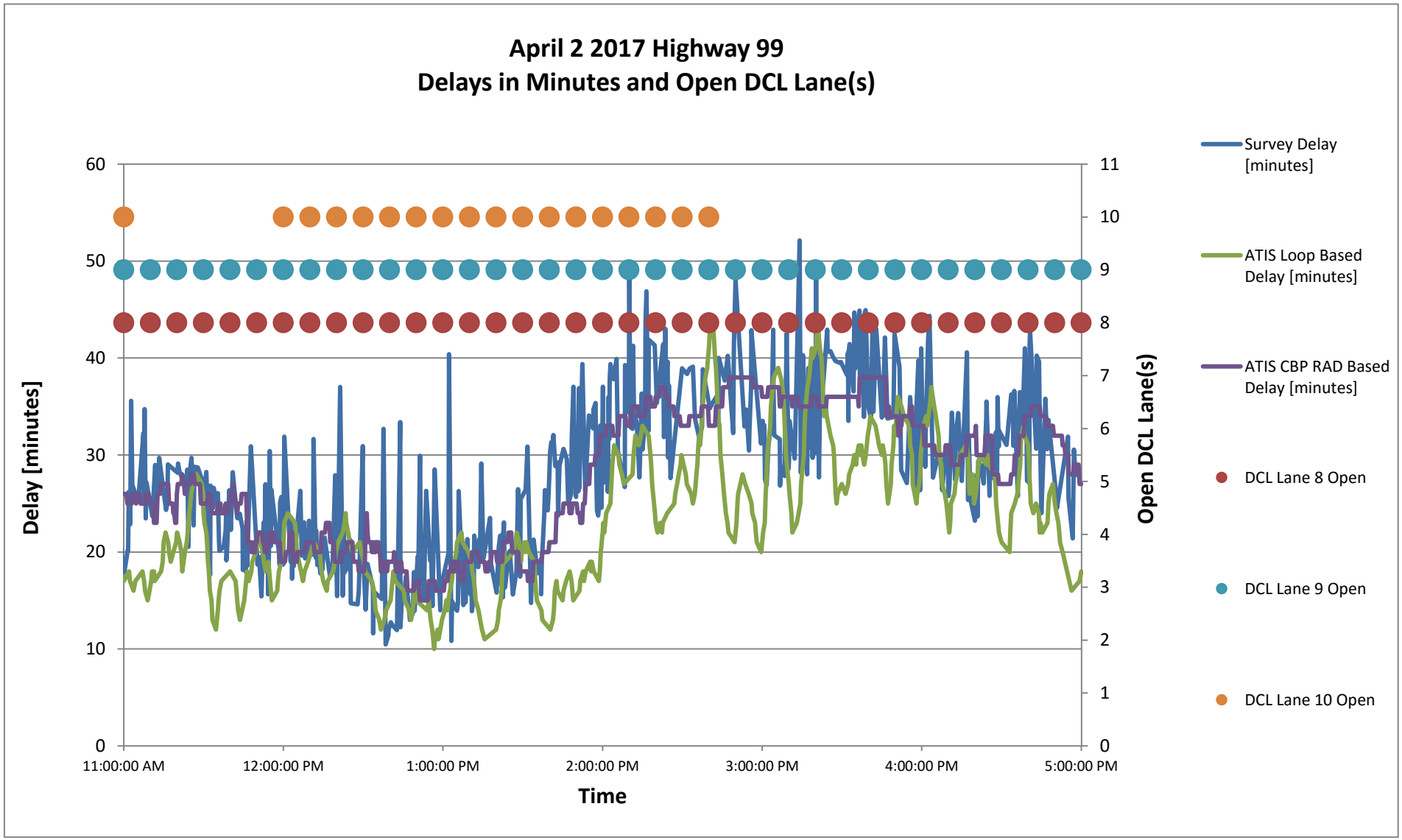


Exhibit 4-8: April 2, 2017 Highway 99 Delays in Minutes and Open DCL Lane(s)



With reference to the plots presented in Exhibits 4-1 to 4-8, the following general conclusions can be drawn:

- Queues: As before there is a good correlation between the surveyed queues and the queues detected by ATIS using the existing loop detector based approach. There is minor discrepancy between surveyed and ATIS observed queues along the Highway 15 approach; this can be attributed to a) traffic leakage (i.e., traffic exiting the network to access 1st Avenue or the Duty Free); or, b) because the occupancy at VDS 1503 was under the queue detection thresholds and possibly loop volumes determined a balanced volume of vehicles arriving at the queue tail and discharging from the queue head (i.e. ATIS determined the queue length was not growing or contracting).
- The survey delay data illustrated in Exhibits 4-2, 4-4, 4-6 and 4-8 suggests moderate delay magnitude variations over time. These variations may be related to nondeterministic external influences such as customs officer or traveler human nature or behaviour between the two GP lanes (i.e., it should be noted that past observations have shown that there are travel time variations between lanes). To determine a reasonable ground-truth delay reference, a moving average statistical analysis was applied prior to the following ATIS estimated delays validations.
- When comparing the survey delays, against the existing ATIS delay estimates (loop based) and the Enhanced ATIS (using RAD interface) it can be observed that the enhanced ATIS trends closer to the survey delays than the exiting ATIS – this is evident by noticing that the purple lines follow the blue lines much better than the green lines.

Despite the good correlation between the enhanced ATIS delay estimates and the survey delay estimates presented in the graphs, it is difficult to decipher the level of improvement introduced by the new RAD interface relative to the existing ATIS. For this reason, additional analysis was done to calculate the percentage error associated with the existing ATIS and the enhanced ATIS with the RAD interface. Exhibit 4-9 below tabulates the results of this analysis.

Exhibit 4-9 Comparative Analysis of Error Rates

		% Error			
		Delay > 10 Minutes		Delay > 30 Minutes	
		New ATIS (RAD)	Existing ATIS (Loops)	New ATIS (RAD)	Existing ATIS (Loops)
Highway 99	April 1	17%	34%	*	*
	April 2	9%	20%	5%	22%
Highway 15	April 1	13%	25%	*	*
	April 2	18%	23%	9%	24%

*Note: * indicates there were no delays in excess of 30 minutes on April 1st*

As presented in Exhibit 4-9, the results were grouped into two bins, delays greater than 10 minutes, and delays greater than 30 minutes. As illustrated, the RAD interface has introduced a significant reduction in error associated with delay estimates, especially during high-delay conditions when the implications of inaccurate information are much more critical; for example, when delays are 15 minutes, a 20% error translates to a 3 minute delay which is negligible; however, when delays are 45 minutes, a 20% delay is 9 minutes etc.

As the legacy ATIS has Highway 15 DCL lane 2 and Highway 99 DCL lanes 1 and 8 configured as GP traffic; hence during period that these lanes were open to NEXUS traffic, existing ATIS

loop based estimated delays are less than the survey measured delays due to increased queue discharge volumes. For this reason, we also considered conditions when there was more than the pre-configured DCL lanes. On April 2nd, the Highway 99 crossing had additional DCL lanes designated for the entirety the survey period, meaning that the RAD interface was supplementing the ATIS with this information for additional accuracy improvements. This is evident when comparing the April 2nd, Highway 99 error rate (5%) with the Highway 15 error rate 10%.

4.2 Conclusions

Utilizing 10-minute RAD data to derive service rates has been confirmed to improve ATIS estimated delay accuracy when compared to estimated delays utilizing loop data with a static lane usage configuration. During Periods When GP Lanes were designated as NEXUS lane, the utilization of CBP RAD data resulted in an average 17% ATIS estimated delay accuracy improvement when compared to the legacy ATIS with a static lane usage configuration.

Based upon the analysis conducted, IBI Group recommends proceeding with production deployment of the stand-alone CBP RAD application and enhanced ATIS application to utilize CBP's RAD XML data to improve estimated delays.

Appendix A - Sample Real-time Arrivals and Departures (RAD) XML Data

April 1, 2017 From 14:00:00 EDT to 14:09:59 EDT

2017-04-01T14:11:24.225399-04:00
2017-04-01T14:00:00
2017-04-01T14:09:59

L301
01
VPC
2017-04-01T14:08:52.2-04:00

2017-04-01T14:09:41.45-04:00
4
BC

L301
01
VPC
2017-04-01T14:08:17.489-04:00
2017-04-01T14:08:51.919-04:00
2
BC

L301
01
VPC
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2017-04-01T14:08:17.209-04:00
2
BC

L301
01
VPC
2017-04-01T14:06:12.468-04:00
2017-04-01T14:07:11.11-04:00
5
BC

L301
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VPC
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2017-04-01T14:06:12.188-04:00
2
BC

L301

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BC

L301
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4
BC

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L301
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2017-04-01T14:09:27.451-04:00
2
BC

L301
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02
VPC
2017-04-01T14:00:03.638-04:00
2017-04-01T14:00:50.884-04:00
4
BC

L306
03
VPC
2017-04-01T14:08:59.632-04:00
2017-04-01T14:09:43.992-04:00
2
BC

L306
03
VPC
2017-04-01T14:08:03.056-04:00
2017-04-01T14:08:47.058-04:00
2
BC

L306
03
VPC
2017-04-01T14:07:13.906-04:00
2017-04-01T14:07:52.962-04:00
1
BC

L306
03
VPC
2017-04-01T14:06:03.399-04:00
2017-04-01T14:07:01.963-04:00
2

AB

L306
03
VPC
2017-04-01T14:05:31.721-04:00
2017-04-01T14:05:52.836-04:00
1
WA

L306
03
VPC
2017-04-01T14:03:59.764-04:00
2017-04-01T14:05:06.448-04:00
1
BC

L306
03
VPC
2017-04-01T14:03:12.275-04:00
2017-04-01T14:03:47.672-04:00
2
BC

L306
03
VPC
2017-04-01T14:02:23.935-04:00
2017-04-01T14:02:58.92-04:00
1
WA

L306
03
VPC
2017-04-01T14:01:45.699-04:00
2017-04-01T14:02:07.134-04:00
3
BC

L306
03
VPC
2017-04-01T14:00:38.031-04:00
2017-04-01T14:01:25.629-04:00
1
WA

Appendix B - Sample Summarized Real-time Arrivals and Departures (RAD) XML Data

APRIL 1, 2017 FROM 11:00:00 PDT TO 11:09:59 PDT

2017-04-01T14:00:00
2017-04-01T14:09:59

L301
89
60
5
0
0
0
20
92
2

L302
0
0
0
0
0
0
0
0
0

L303
61
19
3
11
14
1
0
0
0

L306
33
22
2
0
0
0
0
0
0