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IMPLEMENTATION OF AERIAL LIDAR TECHNOLOGY TO UPDATE HIGHWAY FEATURE INVENTORY

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16. Abstract

Highway assets, including traffic signs, traffic signals, light poles, and guardrails, are important components of transportation networks. They guide, warn and protect drivers, and regulate traffic. To manage and maintain the regular operation of the highway system, state departments of transportation (DOTs) need reliable and up-to-date information about the location and condition of highway features. Different methodologies have been employed to collect road inventory data. Currently, ground-based technologies are widely used to help DOTs continually update their road database, while air-based methods are not commonly used. The focus of this project is to analyze the capability and strengths of an airborne data collection system in highway inventory data collection.

In this study, a field experiment was conducted to collect both light detection and ranging (LiDAR) point cloud data and high-resolution aerial imagery data. A comprehensive introduction to highway inventory methodologies, especially airborne LiDAR technology, was provided to relevant departments and personnel to promote their understanding of the pros and cons of different inventory techniques. An ArcGIS-based algorithm was developed to analyze and process LiDAR data as well as extract desirable features from raw LiDAR point clouds. In addition, a MATLAB-based drainage grate detection algorithm was proposed to demonstrate the effectiveness and economic efficiency of the airborne data collection system. The detection results were provided and compared with a Mandli dataset. Economic comparison between airborne LiDAR and mobile LiDAR was also provided. From the results of this project, we can conclude that airborne LiDAR technology is a promising method for road inventory data collection.

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1.0 INTRODUCTION

1.1 Problem Statement

The main focus of this research project is to evaluate the application of the airborne light detection and ranging (LiDAR) system when updating the highway inventory database. Highway assets, such as traffic signs and signals, directional signs, mile markers, streetlights, guardrails, and culverts, play a vital role in regulating traffic and guiding and warning drivers as well as pedestrians. Therefore, it is helpful for state Departments of Transportation (DOTs) to have up-to-date inventory data to establish the condition of the road networks within their states, prioritize reconstruction and repair work, and value their highway assets. DOTs also use road inventory data for traffic engineering studies, planning, and meeting federal data reporting requirements. Because of the importance of collecting highway inventory data, many methodologies have been proposed to gather the data. The techniques range from the simplest manual inventory method to methods that involve advanced technology, such as aerial photography and LiDAR. In the past few years, various state DOTs have conducted inventory data collection using a number of methods. Among these methods, photo/video log and integrated global positioning system (GPS)/global information system (GIS) mapping are popular because of their low initial cost and ease of operation. For example, Washington DOT has adopted photo log and integrated GPS/GIS mapping for roadway data collection. Michigan DOT has utilized the integrated GPS/GIS mapping method and field inventory, and Idaho DOT has used video log. On the other hand, mobile LiDAR and airborne LiDAR, even though they involve higher equipment costs and are relatively new technologies, are being employed by more and more state DOTs and transportation agencies.

A substantial amount of work has been done to analyze different methodologies for road inventory. For example, Khattak et al. (2000) conducted four experiments to compare the traditional manual method with the integrated GIS/GIS mapping systems. Jeyapalan (2004) developed a method to obtain the three-dimensional locations of road features with data captured from a video logging system. Landa and Prochazka (2014) compared RGB (red, green, and blue) image-based road inventory and LiDAR-based road inventory, finding that road sign detection from RGB data is much cheaper and can include color information, while more precise position and height information can be obtained from LiDAR data. They also provided a traffic sign detection method based on point clouds obtained by a mobile laser scanning system, and tested their method on a road section in Brno, Czech Republic. The results showed relatively high precision in their proposed LiDAR-based method. Jalayer et al. (2015) evaluated the capability of the photo/video log to collect geospatial highway inventory data required by the Highway Safety Manual (HSM). The authors conducted a Web-based nationwide survey to analyze the advantages and disadvantages of photo and video logs as well as a field trial that recorded the data-collected time and data-reduction time for three different types of roadway segments (rural two-lane highway, rural multilane highway, and urban and suburban arterial segments) using the photo and video logging method. Based on the survey and the trial, the authors concluded that geo-tagged photo and video log technology is one of the most economical and efficient methods for DOTs.

Despite LiDAR becoming increasingly popular across the United States, and state DOTs and transportation agencies adopting LiDAR technology to deal with transportation-related applications, to date, airborne LiDAR is still not as popular as other inventory techniques because of its expensive initial investment and limitations in identifying small objects. The main purpose of this research is to analyze the advantages and disadvantages of airborne LiDAR technology in collecting and recording highway assets. Furthermore, because aerial imagery data are relatively easy to acquire when the aircraft is flying, imagery data were also collected along with the LiDAR data for a joint analysis.

1.2 Research Objectives

To achieve the goal of this research project, the following objectives were identified:

- Conduct a literature review covering the existing road inventory technologies, especially for airborne LiDAR technology.
- Carry out a field trial to collect both airborne LiDAR data and high-resolution aerial images of four highway sections in Utah: two on Interstate 15 (I-15), one on Interstate 84 (I-84), and one on US-191.
- Develop a GIS-based algorithm to process the raw LiDAR point clouds to extract candidate highway assets, and then apply the manual recording method to assess the location and structure information of the assets.

- Propose a MATLAB-based method to process the imagery data. Detect drainage grates with high accuracy.
- Investigate the feasibility of using airborne LiDAR to supplement mobile LiDAR by identifying assets that mobile LiDAR cannot.
- Compare the pros and cons of the airborne LiDAR technology with the mobile counterpart.

1.3 Expected Contributions

Highway inventory data collection should be conducted periodically to check the completeness of road infrastructure and assets to ensure safety. This is a very costly project for most transportation agencies; not only a large number of crews are sent out for a long time, but the crews are also exposed to traffic, which is not safe. The airborne mapping technique is often more cost-effective than conventional surveying methods and has other additional values, such as no disruption to traffic and improved safety. Thus, proving that data collected through airborne mapping can also provide effective information about road assets will help state DOTs and transportation agencies save large amounts of resources on road inventory in the future. Our research project assessed an aerial mapping technology, airborne LiDAR, in highway assets detection, demonstrating that airborne LiDAR is a promising technique for relevant agencies to collect road inventory data in the future.

1.4 Outline of the Report

Chapter 1 has provided a brief introduction to the research. Chapter 2 introduces different kinds of existing technologies for road surveying. Chapter 3 focuses primarily on the introduction of LiDAR, especially the advantages and applications of airborne LiDAR. In Chapter 4, the field experiment and data collection will be presented. Chapter 5 develops an ArcGIS-based algorithm to analyze LiDAR data, and provides the data analysis results. Chapter 6 proposes an image processing method based on MATLAB to detect highway drainage grates. Chapter 7 concludes the report.

2.0 INTRODUCTION OF ROAD SURVEYING METHODOLOGIES

Road surveying/inventory is a compilation of components and conditions of road system. Collecting and storing roadside assets data such as lane width, traffic sign height, location, and condition, help transportation agencies make future safety and maintenance investment decisions and provide program managers with better information for program prioritization. For example, the recently published Highway Safety Manual (HSM) (2010) has assisted many state DOTs to evaluate the highway safety performance at different construction stages and operation stages. However, some state DOTs are still in the awkward position of lacking HSM-required highway inventory data (HID). Given the importance of the information of roadside features to the management of roadways, finding effective and economic methods to enrich the inventory data system is fairly urgent.

State DOTs and local transportation agencies have employed different types of HID collection techniques, such as field inventory, photo/video log, integrated global positioning system (GPS)/ global information system (GIS) mapping systems, aerial/satellite photography, terrestrial light detection and ranging (LiDAR), mobile LiDAR, and airborne LiDAR. These techniques vary in time consumption, costs, effectiveness, and accuracy. In this section, we provide a brief introduction to each of these techniques, and focus mainly on their advantages and disadvantages in the application of road inventory data collection.

Table 2.1 Classification of Existing Road Inventory Data Collection Methods

	GPS	**GPS and Image**	**GPS, Image and LiDAR**
Land-based	• Field Inventory • Integrated GPS/GIS Mapping Systems	• Photo/Video log	• Terrestrial LiDAR • Mobile LiDAR
Air- or Space-based		• Aerial/Satellite Photography	• Airborne LiDAR

Existing roadway inventory data collection methods can be roughly divided into two categories: ground-based and air- or space-based methods (Zhou et al., 2013). Based on the equipment of these systems, they can also be divided into three categories: based on GPS, based on GPS and image, and based on GPS, image and LiDAR. The classification of existing road inventory data collection methods is given in Table 2.1.

2.1 Manual/Field Inventory

The first proposal and implementation of collecting roadway inventory data dates back to the mid-1890s (Degray and Hancock, 2002). At that time, road inventory mainly relied on manual collection, which is also known as field inventory. Typically, as shown in Figure 2.1, manual inventory needs data collectors, a vehicle, a distance measuring instrument (DMI), and paper and pencils or a laptop for collecting and recording georeference (i.e., latitude, longitude and altitude) and descriptive (i.e., length, width, height and condition) data (Khattak et al., 2000). Although this method is time consuming, loosely organized and unsafe because crews need to be exposed to traffic and field, its capability of collecting rich and accurate data and its low initial cost still make it quite a competitive method.

As the nation's road network rapidly and continuously grew, manual collection could no longer satisfy the huge and sophisticated needs for roadway data. New technologies emerged, allowing for more efficient data collection and recording. However, field inventory is still required and cannot be completely replaced by later technologies, as new technologies may not be able to collect data on all kinds of assets.

The advantages and disadvantages of manual inventory are summarized as follows:

Advantages

- Low equipment cost
- Minimal training requirements for personnel
- Low data reduction efforts
- Capable of collecting rich road inventory data
- Capable of collecting feature conditions

Disadvantages

- Personnel exposed to dangerous traffic environment
- Hinder the traffic to some extent
- Long collection time

- Labor intensive
- Less accuracy

Figure 2.1 Field Inventory

2.2 Photo/Video Log

Image inventory, also known as photo logging, is based on cameras taking images of a roadway at constant intervals along the road. The primary difference between the photo log and video log is that they use different recording mediums. A photo log is obtained by automatically recording pictures while the vehicle is moving along the roadway, whereas a video log records continuous images.

Equipped with a high-resolution digital camera, a GPS receiver, and an inertial navigation system (INS), the mobile photo/video logging system has been widely used for capturing roadway features in recent years. For example, approximately 27,000 miles of roadway in Tennessee were mapped by photo log (Tao, 2000). Jeyapalan and Bhagawati (2000) used the video logging method (Figure 2.2) to collect roadside assets at a scale of 25 feet or less, in order to create a geographic information system. Then in 2002, Jeyapalan and Jaselskis used video logs for their study (Jeyapalan and Jaselskis, 2002), testing three sites with video logging van-captured images: Grand Avenue, EDM baseline, and US-30. A few years later, the video logging technique was once again used by Jeyapalan, who developed a method for determining the three-dimensional (3D) locations of road features by using images obtained from a video logging system (Jeyapalan, 2004).

Compared with field inventory, most of the work of a photo/video log can be done indoors, thereby reducing potential hazards to data collection personnel. Only one or two personnel are required, and they ride inside the vehicle without direct exposure to traffic. Therefore, the photo logging method is more efficient and safer. In addition, the data collected by a photo log is more accurate and uniformly recorded, because field inventory is generally conducted by several different crews whose operating levels toward measurement equipment and degree of carefulness may be remarkably diverse. Thus, there tends to be more errors in field inventory.

But this method collects lots of useless information, hence, it needs large data reduction efforts. It is also not able to measure feature dimensions. Another disadvantage of a photo log or video log is that the collected data quality is subject to weather conditions.

Figure 2.2 Video Logging (Jeyapalan and Bhagawati 2000)

2.3 Integrated GPS/GIS Mapping System

An integrated GPS/GIS mapping System is commonly used technology among DOTs and transportation agencies for roadside inventory. Most integrated GPS/GIS mapping systems are also equipped with an INS. INS is the backup system when GPS loses its lock due to signal obstruction so that the mapping system can obtain continuous position information (Figure 2.3).

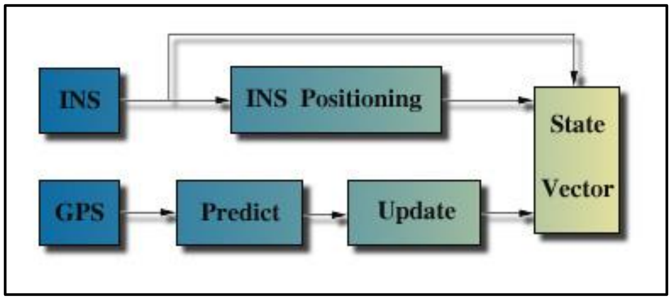


Figure 2.3 The GPS/INS Integration Procedure

(Source: http://www.lambdatech.com)

Figure 2.4 Integrated GPS/GIS Mapping

(Source: http://www.irmforestry.com/habitat-restoration-services/ restoration-management - planning/gis-mapping/ http://www.waypointtech.com/rentals/gps-mapping-systems/)

The advantages of the integrated GPS/GIS method are that it needs relatively low initial cost and low data reduction efforts, and it improves data accuracy. However, crews have to be exposed to the traffic and field during long data collection periods (Figure 2.4).

2.4 Aerial/Satellite Photography

High-resolution images taken from an aircraft or satellite can be used for analyzing road networks. Hallmark et al. (2001) tested the use of remotely sensed images with different resolution levels (2-inch resolution, 6-inch resolution, 24-inch resolution, and 1-meter resolution) on road inventory feature detection. They found that most features could be successfully identified in the 2-inch and 6-inch datasets, while only large features, such as intersections and railroad crossings, had relatively higher identification rate in the 24-inch or 1-meter datasets.

Because photos are obtained from the air with a panoramic view, they can display the entire road network (Figure 2.5 and Figure 2.6). Such a display can provide researchers with a better understanding of how the transportation network interacts with the environment around it. The aerial/satellite photography method can collect inventory data efficiently, and there is no traffic exposure so collection personnel do not need to face dangerous traffic, and the collection process will not distract motorists on the road. However, this method requires crews with professional skills and the latter data processing part could be quite complicated. In addition, the quality of the collected data is greatly affected by the weather conditions during the collection period.

Figure 2.5 Aerial Photography No.1

Figure 2.6 Aerial Photography No.2

2.5 LiDAR

LiDAR or 3D laser scanning is a remote sensing technology that uses laser light to densely sample the surface of the earth. Three types of LiDAR can be used to collect road inventory data, namely, terrestrial LiDAR, mobile LiDAR, and airborne LiDAR. Recent dramatic advances in LiDAR technology have made it quite competitive in science and engineering applications. A detailed description of LiDAR will be presented in Chapter 3.

2.6 Summary

In conclusion, many methods are available to perform road inventory data collection. These methods include field inventory, photo/video logs, integrated GPS/GIS mapping, aerial/satellite photography, terrestrial LiDAR, mobile LiDAR, and airborne LiDAR. Each method has its advantages and disadvantages and scope of application. Road inventory data collection is costly and time-consuming, and should be conducted periodically. Therefore, choosing an appropriate method to survey the road in order to get accurate statistics on road features is critical for enabling state DOTs as well as the transportation agencies to save maintenance costs.

This chapter has mainly introduced different road inventory methodologies, except for the LiDAR technology, which will be discussed in details in Chapter 3. The equipment needed for each technique is described, as well as the strengths and weaknesses.

3.0 LiDAR

3.1 What Is LiDAR

LiDAR is a remote sensing technology that collects geometric and geographic information from targets on the earth's surface in the form of point clouds (Figure 3.1). A LiDAR system principally consists of a laser scanner, a specialized GPS receiver, and an IMU system. It uses a similar principle as radar, a better-known technology. The main difference is that, instead of using radio waves or microwaves, LiDAR sends out intense, focused beams of light to measure the distances to the objects. Depending on the wavelength laser used, LiDAR can map a wide range of objects, such as rocks, vegetation, chemical compounds, clouds, and even single molecules. Recent advancements in the LiDAR mapping technique have enabled researchers and mapping professionals to efficiently map large-scale areas with improved accuracy and flexibility.

The history of LiDAR dates back to the early 1960's, shortly after the invention of laser. LiDAR was first used in meteorology by the National Center for Atmospheric Research (Goyer and Watson, 1963). In the early 1970s, early models of LiDAR were successfully used in the United States, Australia, and Canada. The Ohio Department of Transportation was one of the earliest agencies to employ LiDAR systems in engineering operations (Grejner-Brzezinska et al., 2005). By the end of the 1990s, this technology was occupying a leading position in high-precision spatial data. Compared with other remote sensing technology, LiDAR is more automatic, efficient, and accurate, and can work both during the daytime and at night because laser scanning is relatively independent of sunlight. Since the introduction of LiDAR, this technology has been used for a wide range of applications, including high-resolution topographic mapping (Hill et al., 2000), archaeological sites detecting (Doneus et al., 2013), 3D surface modeling (Zhao et al., 2008), and infrastructure and biomass studies (Chen et al., 2012).

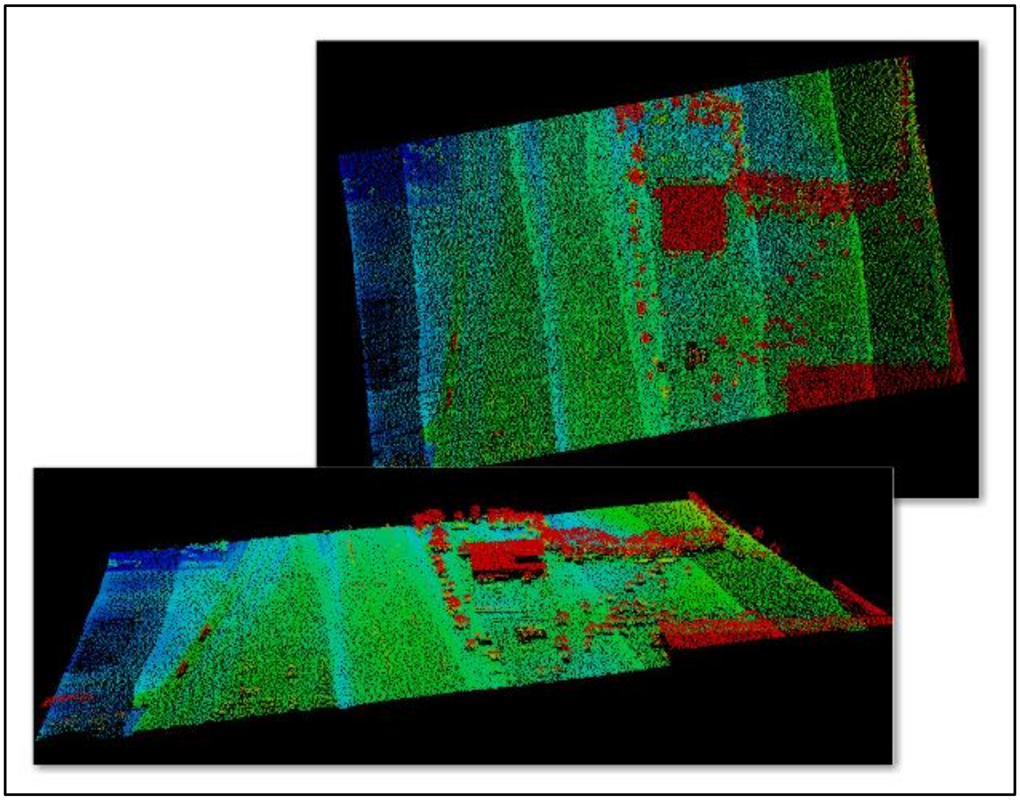


Figure 3.1 LiDAR Point Cloud

3.2 How LiDAR Works

There are two methods to estimate the distance between the LiDAR unit and the target objects: time-of-travel and phase-shift. Time-of-travel scanners transmit pulses and record the time interval between an initial transmission of individual laser pulses and the returning detection of reflected signals to calculate distance values.

$$\text{Distance} = (\text{Speed of Light} \times \text{Time Interval}) / 2 \quad (1)$$

On the other hand, phase-shift scanners calculate distance using the phase shift principle. A sinusoidally modulated laser pulse is sent out as the laser beam reaches a surface, a shift in the signal is detected and registered as a point in the space.

Compared with phase-shift scanners, time-of-travel scanners are rated at much longer ranges, so they are usually used for long-range applications. Phase-shift scanners, however, are limited in range and are generally utilized for indoor or short-range applications, despite being faster and more accurate.

The measured distance is then combined with the position and orientation information obtained from integrated GPS and IMU systems to generate the 3D (i.e., latitude, longitude, and altitude, which are also known as the x, y, z coordinates) information about the targeted objects. The x, y, z coordinates of the objects are computed based on:

1. the distance between the object and the scanning LiDAR sensor;
2. the angle at which the laser pulse was "fired"; and
3. the absolute location of the sensor.

3.3 LiDAR Classification

Generally speaking, there are three types of LiDAR systems: (1) airborne laser scanning (ALS), (2) mobile laser scanning (MLS), and (3) terrestrial laser scanning (TLS). Each system varies in application, data collection time, cost, and accuracy.

3.3.1 Airborne Laser Scanning (ALS)

ALS is an aerial mapping technology that uses reflected laser returns from the earth's surface with on-board GPS and IMU sensors to generate precise 3D information about terrestrial objects.

Airborne LiDAR is the most commonly available LiDAR, and most airborne LiDAR systems can cover more than 19.3 square miles (50 square kilometers) per hour while the collected data still meet the requirements for high-accuracy data.

As shown in Figure 3.2, airborne systems are capable of scanning perpendicularly to the airplane's flight direction to capture segments of the earth's surface. The laser ranging device sends out millions of pulses to determine the distance between the aircraft and the targets. The GPS provides the location of the instrument holding the LiDAR sensor, and the IMU is used to measure the pitch, roll, and heading of the aircraft, which are important for accurate elevation measurements.

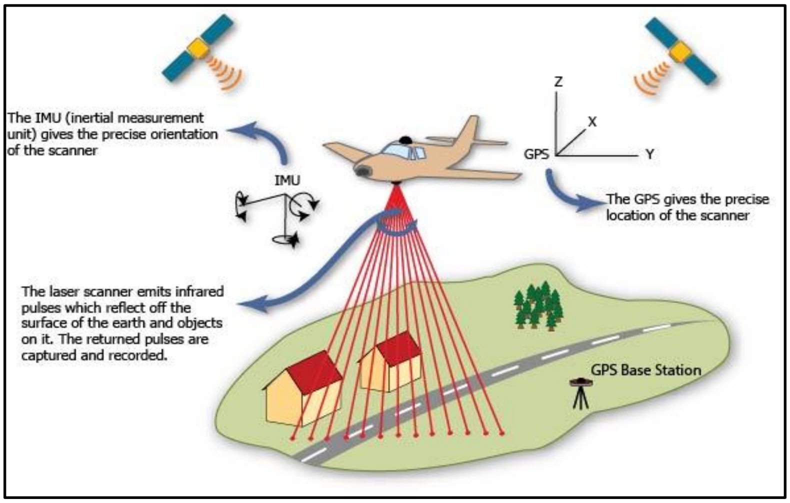


Figure 3.2 Airborne LiDAR System Schematic

(Source: http://gmv.cast.uark.edu/scanning-2/airborne-laser-scanning/**)**

Figure 3.3 Mobile LiDAR System (Topcon IP-S2 HD system operated by Oregon DOT)

3.3.2 Mobile Laser Scanning (MLS)

MLS is essentially the same as ALS, except that the LiDAR set up is integrated on a ground-based vehicle, as shown in Figure 3.3. Depending on the range requirement, MLS can use either the time-of-travel or phase-shift method. Current MLS systems are capable of collecting up to one million points per second while driving at highway speeds, including digital imagery and other geospatial data (Williams et al., 2013). This enables MLS systems to provide a dense, geospatial dataset as a 3D virtual world. MLS is efficient in collecting data, and it can minimize traffic disruption as well as safety hazards.

3.3.3 Terrestrial Laser Scanning (TLS)

The fundamentals of laser distance measurement and scanning of TLS are similar to ALS and MLS. TLS is usually operated on a tripod, as shown in Figure 3.4. Because it generally has a relatively smaller range requirement, a TLS system mainly uses phase-shift measurement systems. An ALS system needs only one scanning direction (the other one is accomplished by the moving aircraft), while a terrestrial laser scanner needs a 2D scanning device (Vosselman and Maas, 2010). Because TLS refers to tripod-based measurements, it is stationary and does not need a GPS or INS for direct georeferencing; furthermore, it is able to achieve the highest accuracy among the three types of LiDAR systems.

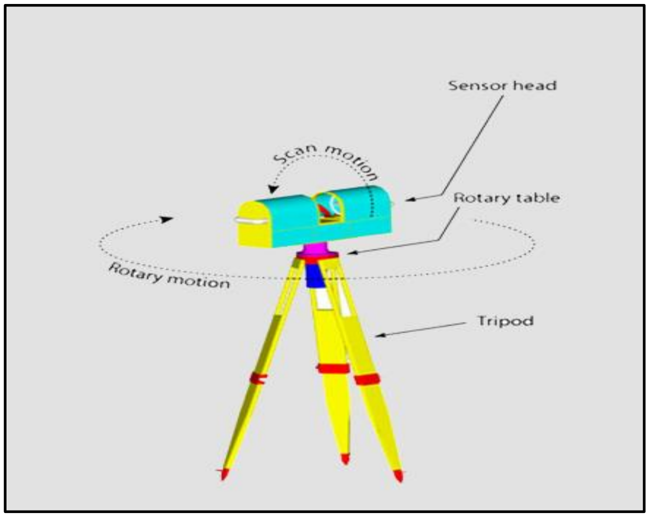


Figure 3.4 Terrestrial LiDAR System

(Source: http://www.bu.edu/tech/support/research/visualization/gallery/lidar/)

3.4 Comparison of LiDAR

The advantages and disadvantages of the three types of LiDAR are summarized in Table 3.1.

Table 3.1 Advantages and Disadvantages of Different Types of LiDAR

	Airborne LiDAR	**Mobile LiDAR**	**Terrestrial LiDAR**
Advantages	High degree of automation Safe operation Less affected by atmospheric conditions Efficient Direct view of pavement and building tops Faster coverage Larger footprint Point density is more uniform High post-processing efficiency	Safe Good view of pavement Direct view of vertical features Higher density Cost-effective	Higher flexibility Higher resolution Higher accuracy Easy to use Highest level of detail
Disadvantages	Poor view of vertical features Lower point density More horizontal positioning uncertainty Could be obstructed by high trees	Cannot capture building tops Cannot detect lower level objects blocked by road surface Slower coverage Small footprint Could be blocked by adjacent large vehicles	Inefficient Lowest cost efficiency Limited to project size

3.5 Airborne LiDAR

3.5.1 Background and History

As early as the beginning of the 1970s, airborne LiDAR systems could reach the precision of less than 3.28 feet (one meter) when measuring distances between aircraft and the earth's surface. However, they were not widely used at that time for their limited accuracy and measurement range. With the introduction of differential GPS at the end of the 1980s, the position of the scanners could be determined in sub-decimeter range. After that, airborne LiDAR developed very rapidly and became widely used (Vosselman and Maas, 2010).

Many studies and applications have been conducted since the introduction of airborne LiDAR. Baltsavis (1999) provided us with a comprehensive overview of existing systems, vendors, and resources of airborne laser scanning through extensive research. Vosselman and Maas (2010) introduced the principles of airborne and terrestrial laser scanning technology as well as the applications of 3D point clouds collected by laser scanners. This technology is being used for a wide range of applications, including high-resolution topographic mapping and 3D surface modeling as well as infrastructure and biomass studies. Airborne LiDAR data were successfully used by Bernardini et al. (2013) in the mapping of Karstic areas (north eastern Italy), which demonstrates the value of airborne LiDAR technology in landscape archaeology and archaeology. Swetnam and Falk (2014) used airborne LiDAR to identify individual trees across large forested landscapes. Doneus et al. (2013) demonstrated the potential of this novel technique to map submerged archaeological structures over large areas in high detail in 3D, providing unique means for underwater heritage management.

3.5.2 Components

The basic components of the airborne laser scanners include the following five parts:

1. Flight management system
2. Airborne platform
3. Laser scanner
4. Position and orientation system
5. Control and data recording unit (computer)

Flight Management System

The flight management system serves as a means for mission planning, and various stages of processing. For example, the pilot can display the preplanned lines through this system, which will give support in completing the mission (Vosselman and Maas, 2010).

Airborne Platform

An airborne platform is a platform for mounting all of the data collection hardware. Airplanes and helicopters are the most commonly used platforms for acquiring LiDAR data over broad areas. Helicopters are typically used in the following applications: (1) small width, elongated areas (e.g., power lines, corridor mapping, and topographic and bathymetric mapping along coastlines), (2) small areas (e.g., airports, open pit mines), (3) conditions at very low altitudes (for higher accuracy and denser point measurements) or where low flying speeds are needed (flood mapping), (4) conditions when high maneuverability and many high-curvature turns (e.g., following roads in 3D city modeling) are required, and (5) difficult terrain with abrupt height discontinuities (mountains) (Baltsaias, 1999).

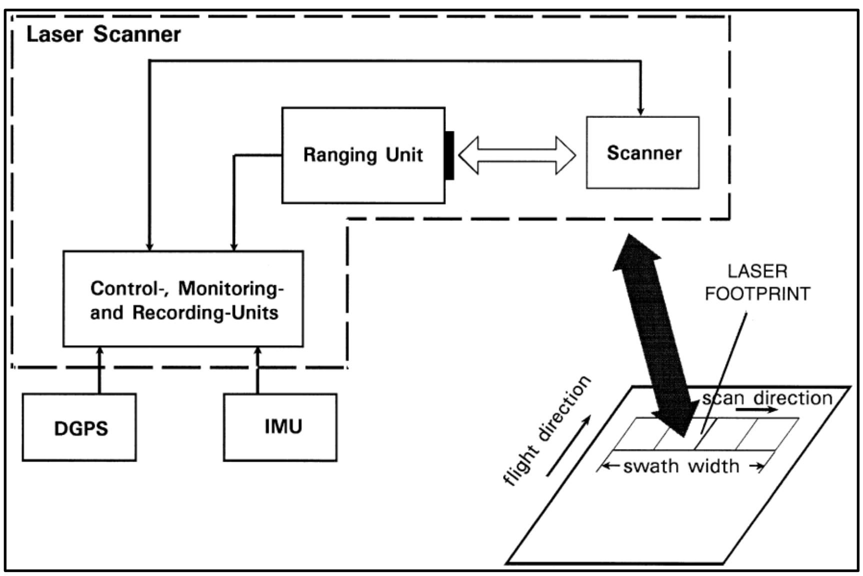


Figure 3.5 Laser Scanner Schematic Unit (Wehr and Lohr, 1999)

Laser Scanner

The airplane uses a laser beam to scan the earth from side to side as the plane flies. As shown in Figure 3.5, a typical laser scanner can be subdivided into the following key units: laser ranging unit, opto-mechanical scanner, and control and processing unit (Wehr and Lohr, 1999). A medium-sized digital camera that provides image data often works together with laser scanners because it is difficult to recognize objects using only the range data provided by laser scanners (Vosselman and Maas, 2010). Powerfully pulsed lasers are needed for the measurement of the range because of the relatively large distance between the aircraft and the objectives.

Position and Orientation System

The laser scanner measures only the line-of-site vector from the laser scanner aperture to a point on the earth's surface (Wehr and Lohr, 1999). In order to obtain the 3D position of the target point, the laser scanner system should be supported by a position and orientation system. GPS and IMU are usually used together as the position and orientation system. The GPS antenna is always installed on top of the aircraft to provide an undisturbed view for the GPS satellites, and the IMU is either fixed directly on the laser scanner or close to it (Vosselman and Maas, 2010).

Control and Data Recording Unit

A computer equipped with a display and an operator should be included to provide the control and processing functions for the overall system. The onboard computer also records and stores all of the important information that the LiDAR collects as it scans the earth's surface. By technically using this unit, the operator can set up mission parameters and monitor the performance of the system (Vosselman and Maas, 2010).

Airborne LiDAR systems are always composed with a GPS ground station, serving as a reference station for achieving decimeter accuracy. During the data collecting process, two GPS ground stations are usually operated, one as the base station and the other as a backup. In recent years, several countries have installed permanent GPS ground stations; thus, normally there is no need to operate their own GPS stations.

3.6 Applications of ALS in Transportation

Traffic Flow Estimation

Grejner-Brzezinska et al. (2005) conducted a project using airborne LiDAR data for traffic flow estimates. The study presented theoretical and practical studies on the feasibility of using LiDAR data and airborne imagery collected over the transportation corridors for the estimation of traffic flow parameters. They proved that high-point density airborne LiDAR can effectively support traffic monitoring and management by delivering a variety of traffic flow data.

Highway Corridor Mapping

Uddin and Al-Truk (2001) presented the application of airborne LiDAR technologies for the cost-effective management of highway corridors, airports, and related transportation infrastructure assets. They produced digital terrain models, generated digital mapping databases, and linked various data sources through user-friendly GIS software. In their study, they introduced a real case study of the Raleigh bypass highway alignment project. The study also carried out a high resolution and accurate digital terrain mapping for Oxford and surrounding areas in northern Mississippi by applying the airborne LiDAR technology to illustrate the data accuracy, efficiency, and cost-effectiveness of the airborne laser technology.

Integrated Uncertainties of Traffic Island Modeling

Affecting traffic behavior safety, air pollution, and transport decision support, traffic islands play a major role in transport studies. Zhou and Stein (2013) used airborne laser scanning data to develop a random set approach to determine the locations of traffic islands. The study showed that point spacing makes the largest contribution to the positional accuracy of a traffic island.

Collecting and Recording Highway Inventory

Zhou et al. (2013) compared various technologies of collecting highway inventory data to determine the most cost-effective method. These technologies include field inventory, photo/video logs, integrated GPS/GIS mapping systems, aerial photography, satellite imagery, virtual photo tourism, terrestrial laser scanners, and mobile mapping systems (i.e., vehicle-based LiDAR, and airborne LiDAR). They concluded that mobile LiDAR can collect all required feature data in a short period of time, but it requires an extensive data reduction effort and has the ability to collect data valuable for multiple DOT programs.

Expanding Highway Projects

The application of airborne laser technology in Uddin's paper demonstrated that ALS is an efficient and economical way of collecting data (Uddin, 2008). They compared the elevation data accuracy, efficiency, and cost-effectiveness with the traditional aerial photogrammetry and ground-based total station survey methods. This research recommended that traditional methods should be combined with low-altitude airborne laser technology to save money and time for highway projects.

3.7 Summary

This chapter provides a detailed description of LiDAR technology and places more emphasis on airborne LiDAR. LiDAR is a remote sensing technology that can generate accurate 3D information of target objects. It has been widely used in road inventory data collection in recent years. Based on different carrying platforms, there are three kinds of LiDAR: terrestrial LiDAR mounted on a tripod, mobile LiDAR in a mobile vehicle, and airborne LiDAR in a plane or aircraft.

Compared with terrestrial LiDAR and mobile LiDAR, airborne LiDAR has significantly high mapping efficiency; it can also map a wide range of highways without affecting highway traffic. Although airborne LiDAR produces data with lower point density, the data resolution is sufficient for us to identify the location of many features on highways. The attractive advantages of airborne LiDAR make it a very promising technology in transportation.

4.0 FIELD EXPERIMENT AND DATA COLLECTION

4.1 Methodology

The object of this project is to evaluate the pros and cons of the airborne LiDAR system in gathering road inventory data. Remote Sensing Service Laboratory (RSSL) at Utah State University (USU) carried out the data collection campaign.

The USU airborne LiDAR system is mounted in a single engine Cessna TP206 aircraft (Figure 4.1). The system consists of a LiDAR scanner, IMU, and flight navigation unit (Figure 4.2). The LiDAR instrument consists of a Riegl Q560 transceiver and Novatel SPAN LN-200 GPS/IMU positioning and orientations system. Depending on the flight height, the LiDAR scanner is able to collect data at a pulse rate of 250,000 shots/seconds. Together with the LiDAR system, the USU airborne system is also equipped with multispectral and thermal infrared cameras, which can be used for aerial photos. The camera system is composed of four ImperX 4820 Monochrome cameras with 4872 x 3248 pixels per camera. They are also equipped with interface filters in the blue, green, red, and near-infrared (NIR) centered at 0.472 μm, 0.562 μm, 0.655 μm, and 0.80 μm, respectively.

Figure 4.1 The USU Cessna TP206 Research Aircraft

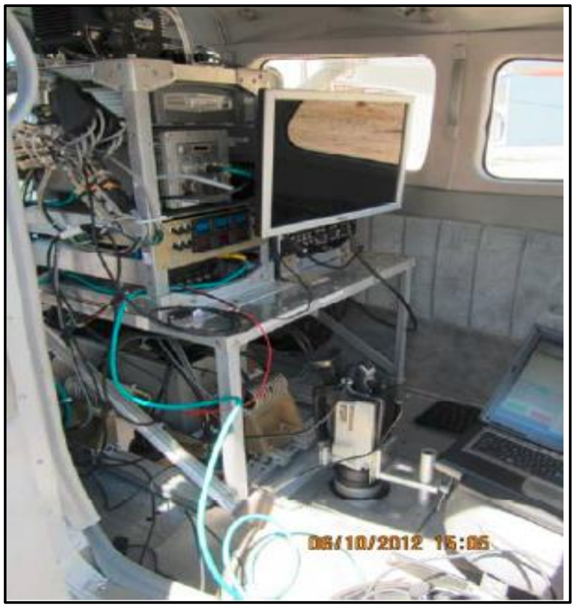


Figure 4.2 The Onboard Integrated Remote Sensing System

4.2 Data Collection

This part of the study summarizes the field experiments conducted by the RSSL at USU. Prior to data acquisition the flight lines were planned and stored in the onboard GPS system to be followed during the actual flight. The flight campaign was conducted on June 4, 2015, and can be divided into two separate parts. The first part was from 11:20 am to 12:45 pm and covered three road sections: I-84, I-15 North, and I-15 South. The second part was from 3:20 pm to 4:20 pm and mapped section US-191. The weather conditions were a partially cloudy sky and a clear sky during the first and second parts of the flight, respectively.

Each section of the roads of interests was divided into multiple subsections with each covered by a single flight line. The data acquisition includes LiDAR and colored high resolution images. This study covers four road sections in Utah, one on Interstate 84 (I-84), two on Interstate 15 (I-15), and one on US-191 (Figures 4.3-4.4). The exact location of these sites can be described by the distance between two mileposts (MP) as follows:

1. I-84 from Mountain Green to Morgan County/Summit County (MP 97 to 113)
2. I-15 North from Lehi to Salt Lake City (MP 284 to 307)
3. I-15 South from Santaquin to Springville (MP 241 to 260)
4. US-191 from MP 84 to 112 (MP 84 to 112)

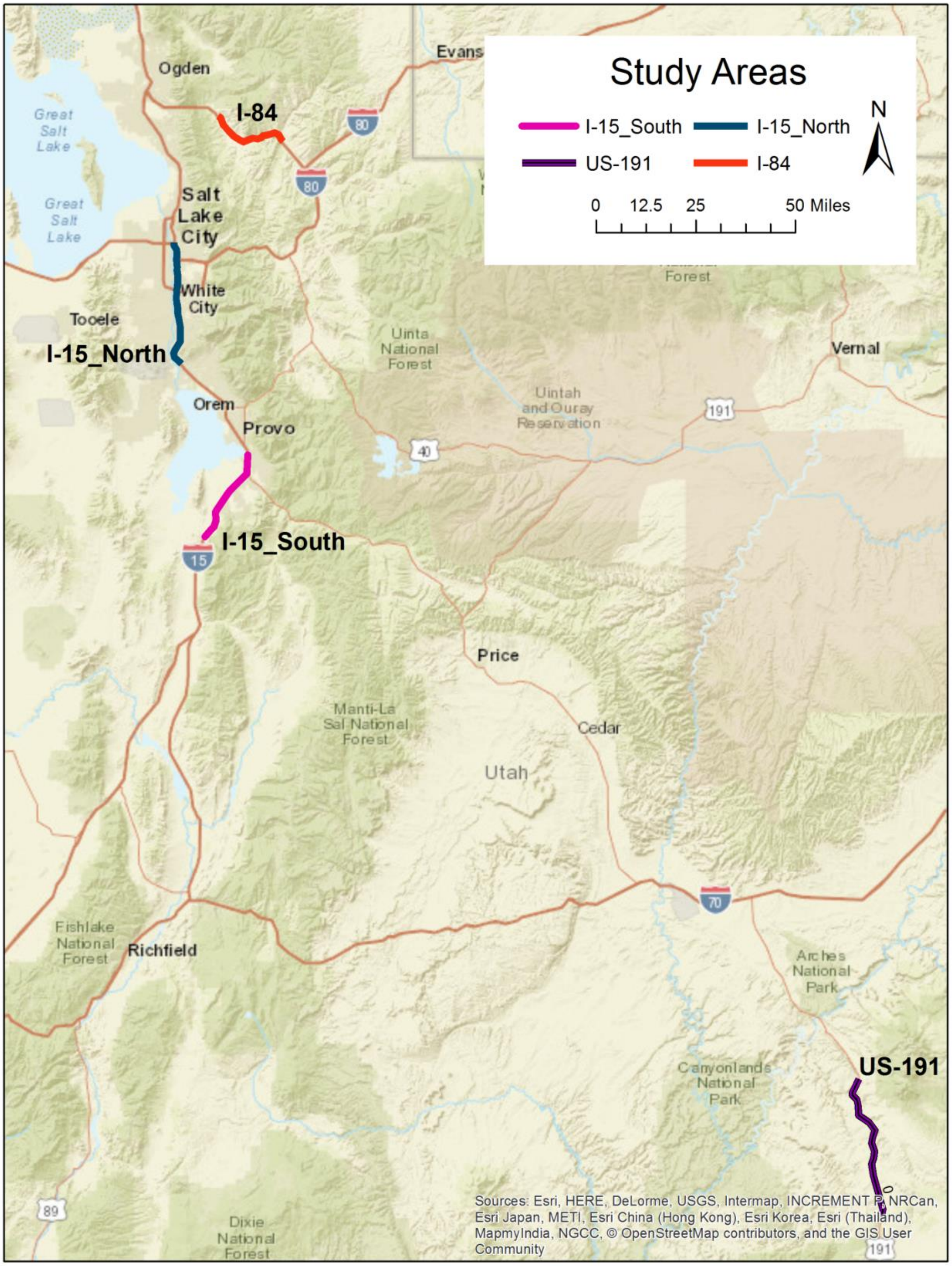
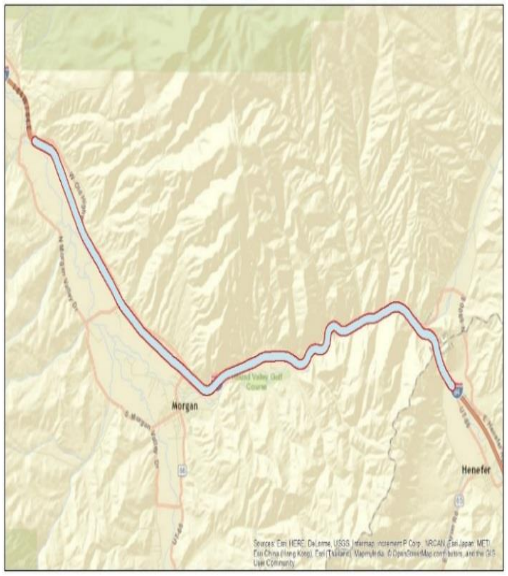
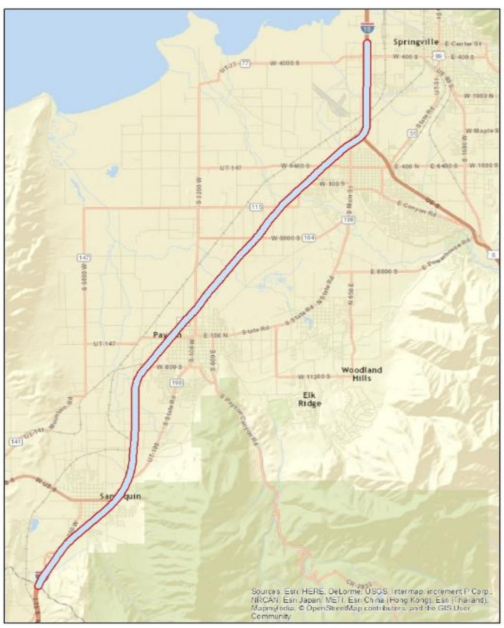


Figure 4.3 Layout of the Mapping Areas

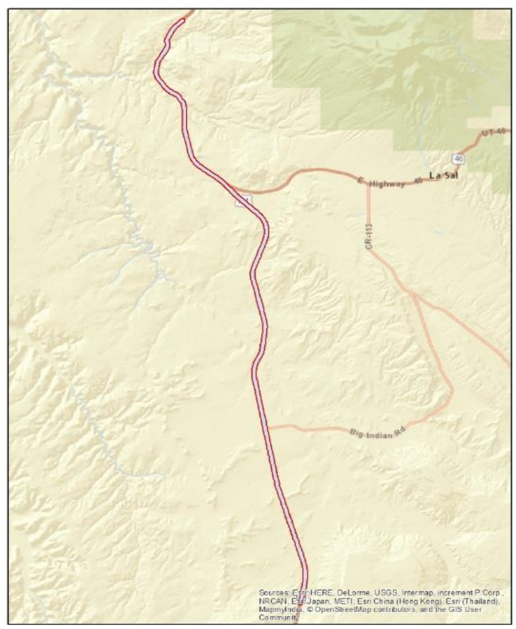


Site 1: I-84 from Mountain Green to Morgan County/Summit County

Site 2: I-15 North from Lehi to Salt Lake City



Site 3: I-15 South from Santaquin to Springville



Site 4: US-191 from MP 84 to 112

Figure 4.4 Layout of the Surveyed Road Sections

The data were acquired at an average flight height of approximately 1640 feet (500 meters) above ground level (AGL) or lower. The LiDAR scan rate was about 125 Hz, the pulse rate was 200,000 shots/second, and average flight speed was about 112 mph (180 km/h). In these settings, the point density can be up to 0.6 points/ft^2. In total, four bands of multispectral data were acquired by the cameras, red, green, blue, and NIR. The lists of raw LiDAR data for I-84, I-15 North, I-15 South, and US-191 are given in the following two tables. Because there are a large number of imagery data files, we decided not to list them here.

Table 4.1 Raw LiDAR Data Files for I-84, I-15 North, and I-15 South

No	File name	No	File name	No	File name
1	150604_172316.las	**12**	150604_181243.las	**23**	150604_184006.las
2	150604_172716.las	**13**	150604_181603.las	**24**	150604_184249.las
3	150604_173001.las	**14**	150604_181830.las	**25**	150604_185420.las
4	150604_173255.las	**15**	150604_182123.las	**26**	150604_185716.las
5	150604_173438.las	**16**	150604_182332.las	**27**	150604_190007.las
6	150604_173631.las	**17**	150604_182545.las	**28**	150604_190536.las
7	150604_174345.las	**18**	150604_182708.las	**29**	150604_190838.las
8	150604_174737.las	**19**	150604_183024.las	**30**	150604_191047.las
9	150604_174928.las	**20**	150604_183259.las	**31**	150604_191329.las
10	150604_175150.las	**21**	150604_183538.las		
11	150604_181046.las	**22**	150604_183745.las		

Table 4.2 Raw LiDAR Data Files for US-191

No	File name	No	File name
1	150604_220311.las	**12**	150604_213710.las
2	150604_220453.las	**13**	150604_213816.las
3	150604_220648.las	**14**	150604_214020.las
4	150604_221114.las	**15**	150604_214252.las
5	150604_221513.las	**16**	150604_214525.las
6	150604_212453.las	**17**	150604_214900.las
7	150604_212659.las	**18**	150604_215123.las
8	150604_212904.las	**19**	150604_215407.las
9	150604_213115.las	**20**	150604_215759.las
10	150604_213324.las	**21**	150604_220028.las
11	150604_213516.las		

4.3 Data Preprocessing

The raw airborne LiDAR data and imagery data were preliminarily processed and evaluated by the RSSL at USU. They used the Waypoint Inertial Explorer software (www.novatel.com) to process the raw GPS/IMU data and the GPS data, which were obtained from the onboard navigation system and the international global navigation satellite system (GNSS) (https://igscb.jpl.nasa.gov/) service (IGS) base stations, respectively. From these datasets, they could get the position and the altitude of the aircraft. Four IGS base stations were chosen based on their proximity to the four highway segments. The coordinates of the IGS base stations established a geo-position relative to the WGS84 datum during the data collection process, and generated the navigation message.

The flight trajectory data were transformed to the WGS84 datum. Figure 4.5 presents the whole flight trajectory for the entire data collection. Figure 4.6 presents the separate flight trajectories for each highway segment.

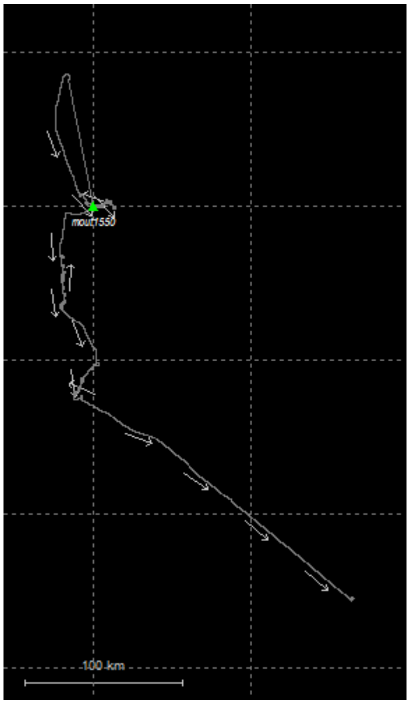
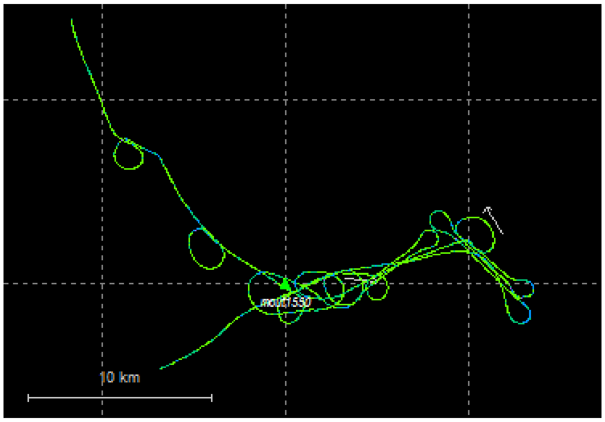
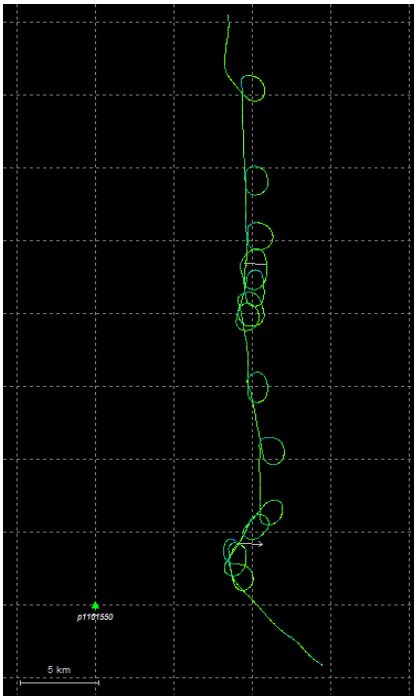


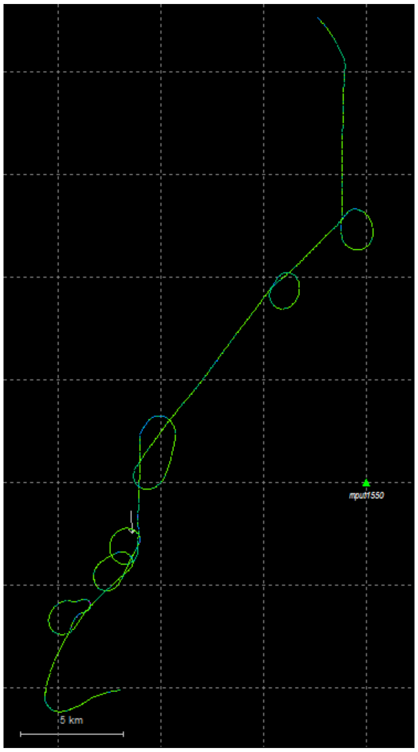
Figure 4.5 The Whole Flight Trajectory for the Entire Data Collection



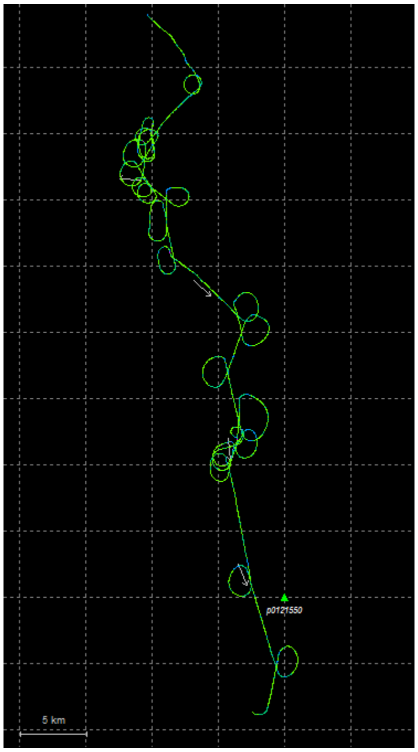
Site 1: I-84



Site 2: I-15 North



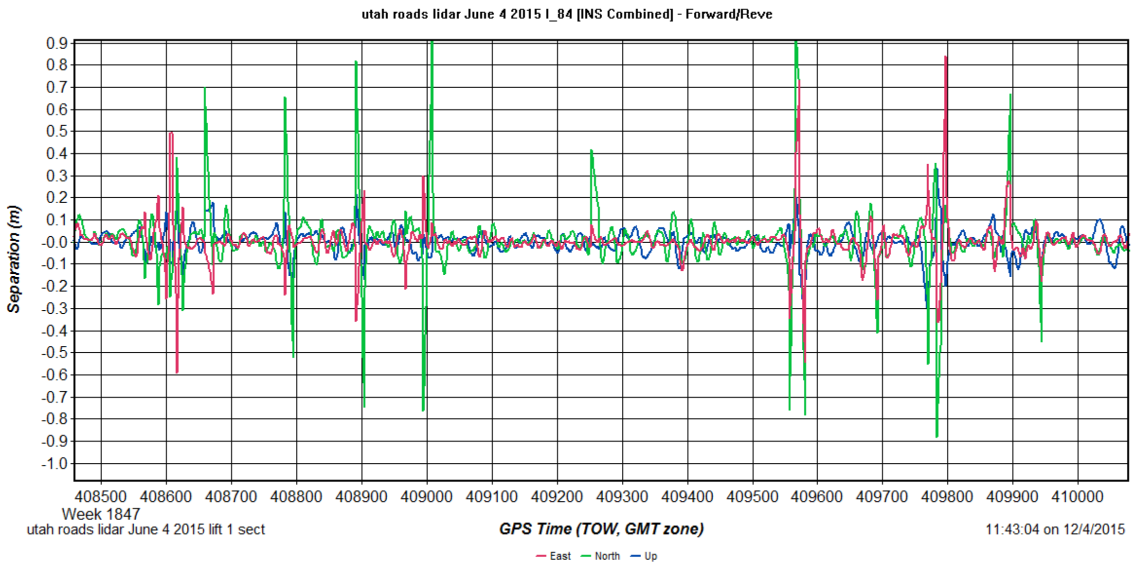
Site 3: I-15 South



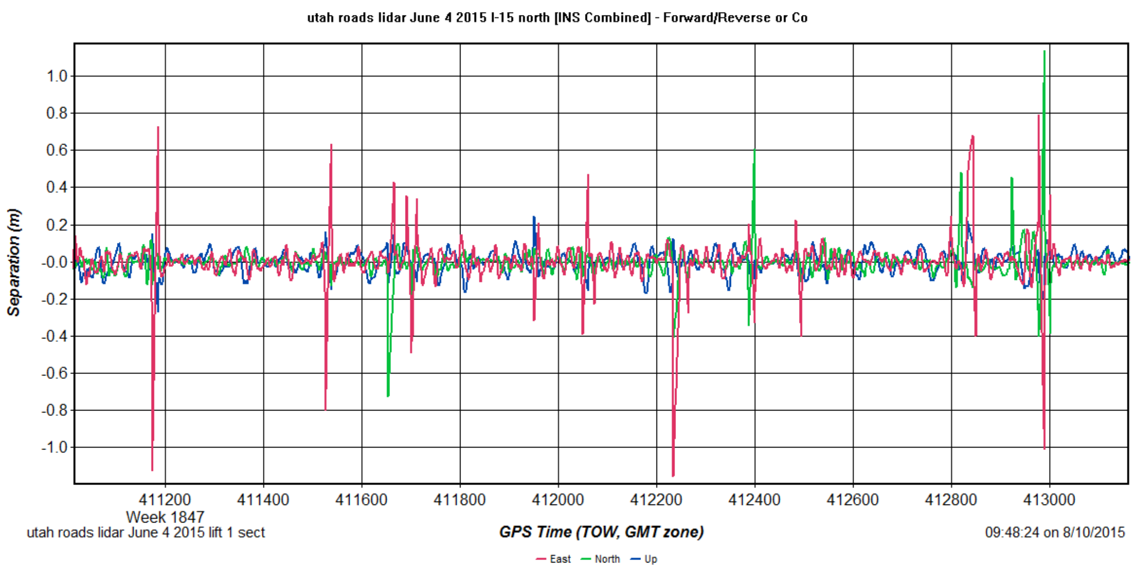
Site 4: US-191

Figure 4.6 The Separate Flight Trajectories for Four Sections

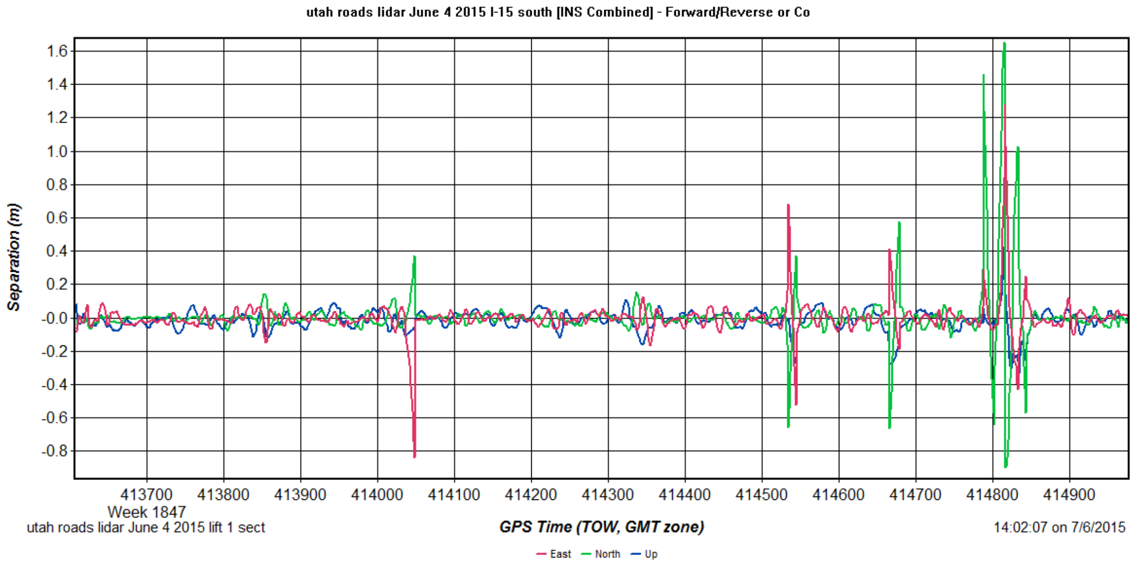
The aircraft trajectories were also processed in time. The separations of the aircraft trajectories are shown in Figure 4.7, where the east, north, and up directions (x, y, and z coordinates) were presented by red, green, and blue colors, respectively, and the peak/high separation values respected the direction changes or turns.



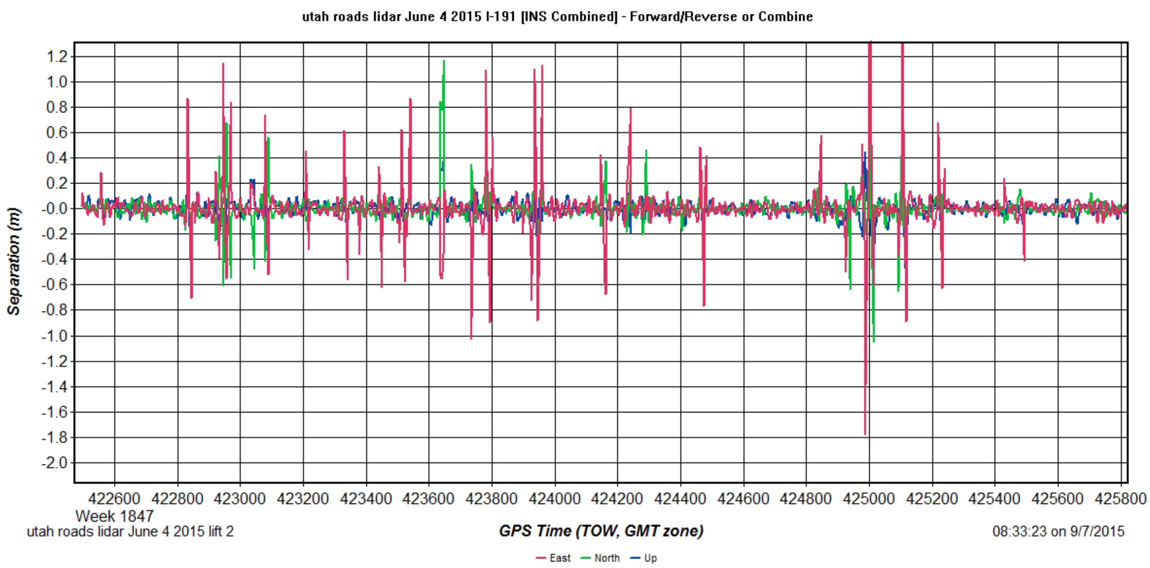
Site 1. I-84



Site 2. I-15 North



Site 3. I-15 South



Site 4. US-191

Figure 4.7 Flight Trajectory Separation in Time

The RiAnalyze software was used to analyze the collected LiDAR data and transform the LiDAR full waveform data to point cloud data. Then the RiProcess software was used to add the x, y, z coordinates to the point cloud data. The RiProcess software was also used to perform data calibration and strip (single scan line) adjustment to improve data accuracy. Because each flight line was processed individually, it was possible for the data analyst to ensure quality control (QC) for the overlap between lines.

4.4 Accuracy of LiDAR Data

We used the U.S. Geological Survey (USGS) National Geospatial Program (NGP) standard to evaluate the LiDAR data accuracy. This standard places unprecedented emphasis on LiDAR point cloud data. The basic requirements for LiDAR point cloud data according to the USGS NGP standard are shown in Table 4.3.

Table 4.3 Summary of USGS NGP Guidelines v.13 for LiDAR Data Quality

RMSE	Condition	Source
4.9 in (12.5 cm)	Fundamental vertical accuracy (in the clear)	USGS
3.9 in (10.0 cm)	Within swath overlap regions	USGS
2.8 in (7.0 cm)	Relative accuracy within individual swaths	USGS

Two methods are used to evaluate the accuracy of the LiDAR data. One evaluates the differences between the flight trajectory obtained from the onboard GPS/IMU system and the flight trajectory obtained from the ground-based IGS station. The other one evaluates the elevation differences of different flight strips within their overlapping areas. However, during the data acquisition process, no ground control point information was collected. Hence, we cannot use the flight trajectory solution to estimate data accuracy. But according to Figure 4.7, the average forward/reverse or combined separation is less than 2.0 in (5 cm), which generally means that fundamental vertical accuracy (in the clear) of 4.9 in (12.5 cm) can be achieved.

The error within swath overlap regions can be calculated by comparing the differences between flight lines in their overlapping areas. Figures 4.8 through 4.11 show the flight lines for one highway section and use one overlapping area for error evaluation; the evaluation result is provided in a histogram.

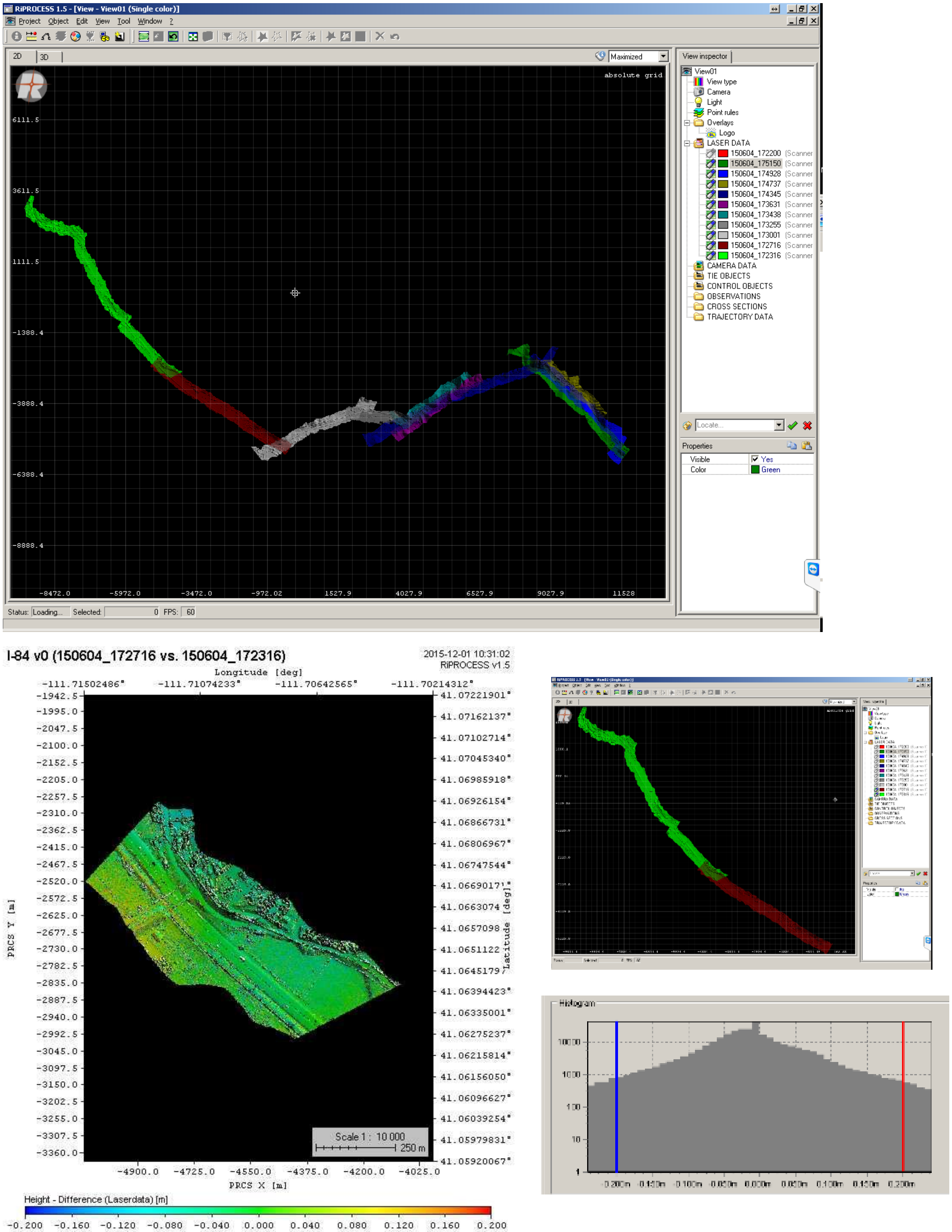


Figure 4.8 Site 1. I-84

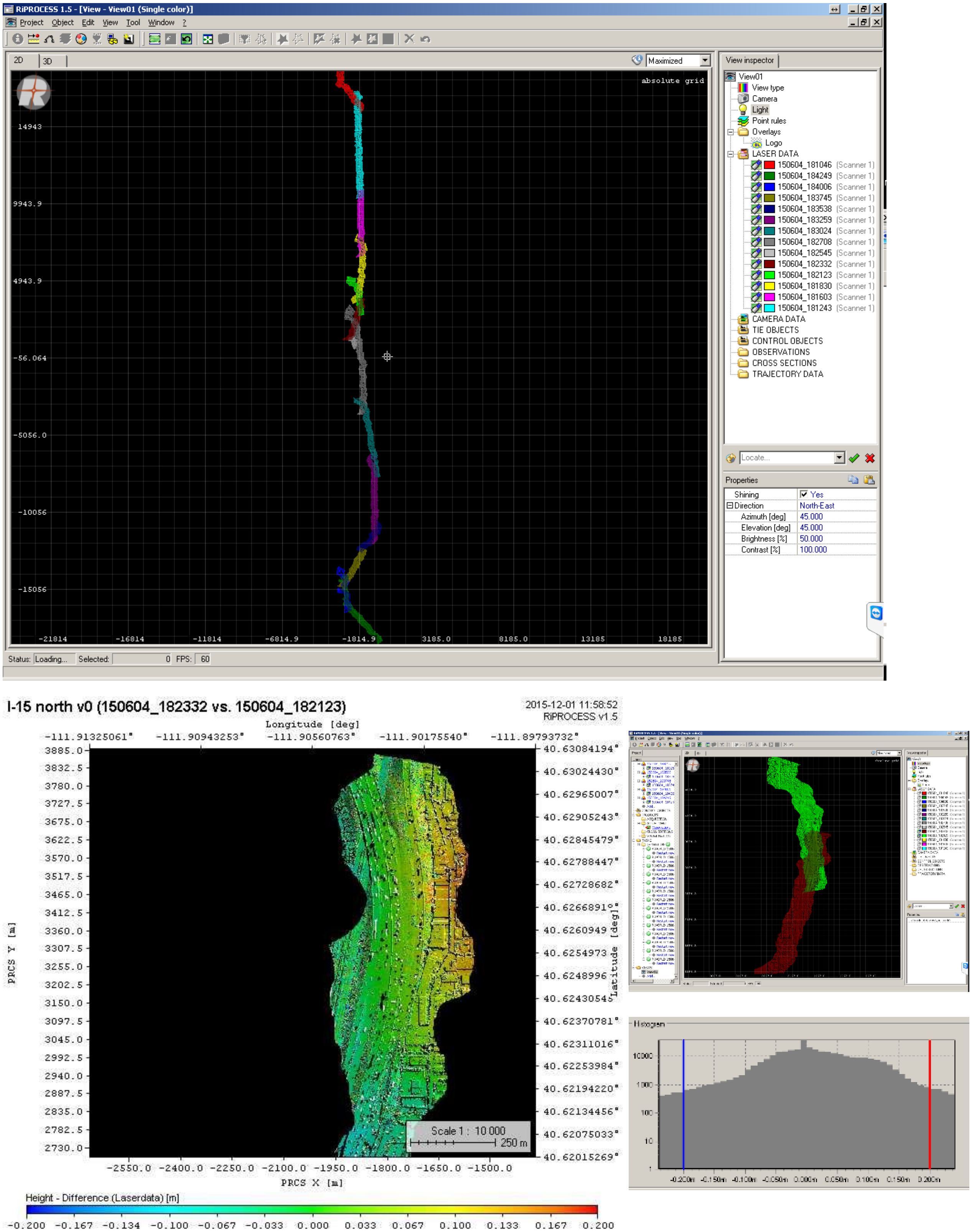


Figure 4.9 Site 2. I-15 North

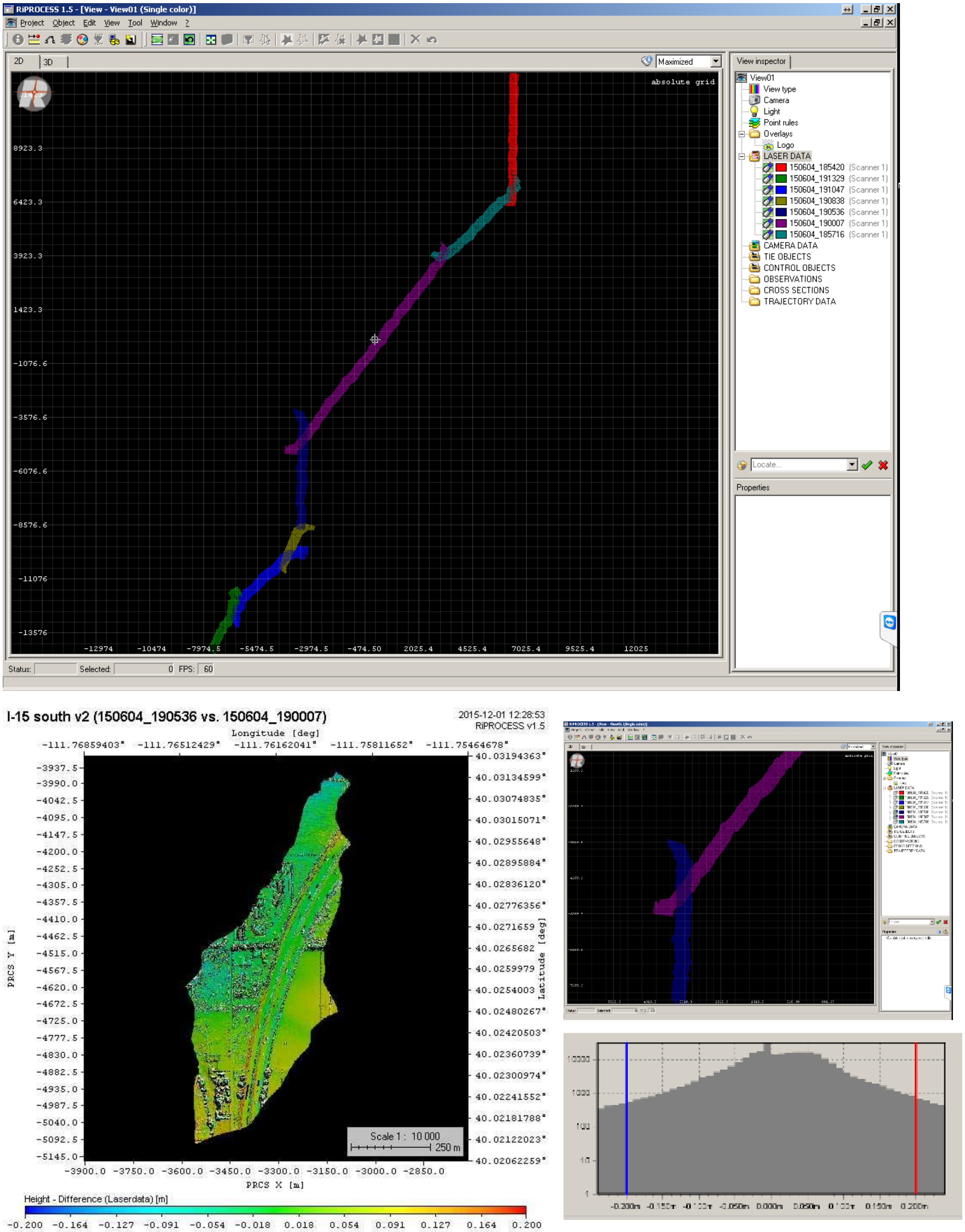


Figure 4.10 Site 3. I-15 South

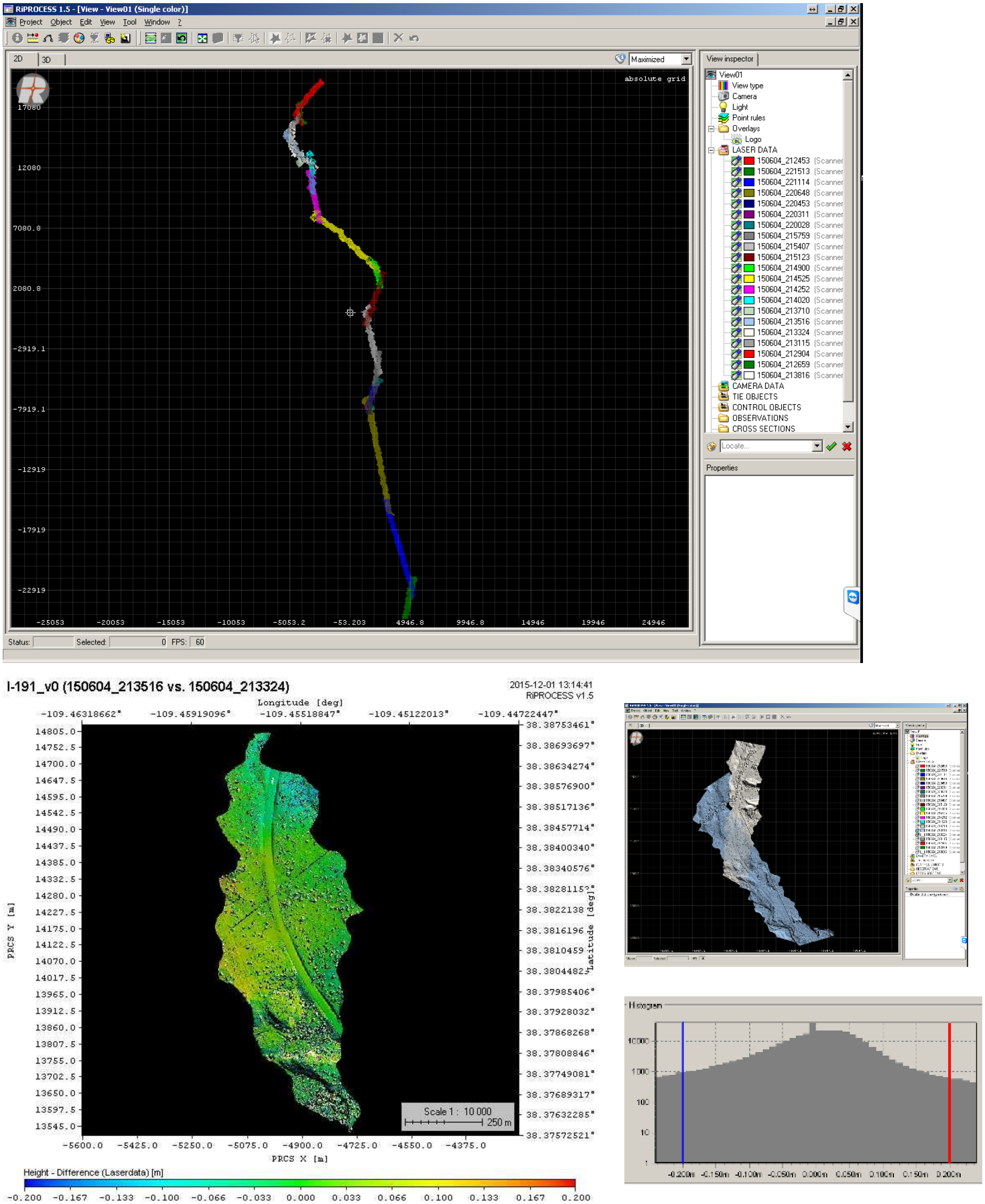


Figure 4.11 Site 4. US-191

The associated RMSE for each of the road sections (i.e., I-84, I-15 North, I-15 South, and US-191) was calculated to be 3.3 in, 3.0 in, 3.2 in, 2.4 in (8.3, 7.6, 8.2, and 6.2 cm), respectively. The average RMSE was 3.0 in (7.6 cm), which is smaller than 3.9 in (10 cm) as required by the USGS standard. Thus, the accuracy standard within the swath overlap regions was achieved.

Generally speaking, the relative accuracy within individual swaths will not be greater than the overlap regions' accuracy. Hence, the relative accuracy within the swath can be estimated to be less than the RMSE of 3.0 in (7.6 cm) on average.

A summary of the LiDAR data accuracy assessment is shown in Table 4.4.

Table 4.4 Summary of LiDAR Data Accuracy Assessment

RMSE Requirement	Condition	Estimated RMSE Achieved
2.8 in (7.0 cm)	Relative accuracy within individual swaths	Less than 3.0 in (7.6 cm) estimated
3.9 in (10.0 cm)	Within swath overlap regions	3.0 in (7.6 cm) average measured
4.9 in (12.5 cm)	Fundamental vertical accuracy (in the clear)	Not assessed but was likely achieved

4.5 Summary

In this chapter, the data collection process as well as the airborne LiDAR data preprocessing was introduced. Both LiDAR data and aerial imagery data were collected by the RSSL at USU. In total, four highway sections in Utah were mapped, including one section on Interstate 84 (I-84), two on Interstate 15 (I-15), and one on US-191. The collected raw LiDAR data were preprocessed through specific software, and accuracy was evaluated according to the USGS NDP standard. The results showed that the collected data generally met the accuracy requirement.

5.0 AIRBORNE LIDAR DATA PROCESSING USING ARCGIS

5.1 Introduction

After preprocessing, LiDAR data can be used to extract information, such as the height and location of various highway assets. Several kinds of software can process LiDAR data, including FugroViewer and ArcGIS. FugroViewer is a 3D geodata viewer; it can read LiDAR data and provide some basic tools to extract information from the data. ArcGIS is developed by Esri for working with maps and geographic information. Once the data have been acquired as a vector file, a raster file, or a LAS file, they can be viewed and operated in ArcGIS. In this chapter, we developed an ArcGIS-based algorithm to detect highway assets from the obtained LiDAR data.

Highway assets include traffic signs, traffic signals, billboards, light poles, guardrails, bridges, culverts, and more. As previously mentioned, LiDAR is a remote sensing technology that collects geometric and geographic information of targets on the earth's surface in the form of point clouds. In LiDAR data, an object can only be identified based on its corresponding points. Thus, if an object has no or very few corresponding points, we cannot properly identify it. The point density of the obtained LAS files is around 0.6 points/ft^2 (6 points/m^2). For small traffic signs, such as speed limit signs and instruction signs (Figures 5.1-5.2), their areas are usually less than 10 ft^2 (1 m^2). Moreover, there is an angle (less than 90 degrees) between the laser beams and the signs during scanning. Therefore, there may be only one or two points representing a sign. We can hardly identify an object based on one or two points, thus it is impossible for us to detect those small signs simply by using airborne LiDAR data. However, large traffic signs, especially those with large assemblies, are fairly conspicuous in LiDAR data. Figure 5.3 shows a picture of an overhead traffic sign and, Figure 5.4 shows its corresponding LiDAR data. We can observe that, although the sign's face cannot be clearly seen in LiDAR data, the large sign assembly represented by a series of points and can be easily identified. Similarly, small traffic signals are not clear in LiDAR data (as shown in Figure 5.5 and Figure 5.6), while traffic signals with large assemblies can be identified in LiDAR data (as shown in Figure 5.7 and Figure 5.8). In addition, light poles usually are vertical structures; they can also be identified in LiDAR data (as shown in Figure 5.9 and Figure 5.10). Billboards usually have large faces and assemblies, making them very conspicuous in LiDAR data (as shown in Figure 5.11 and Figure 5.12). Since airborne LiDAR technology maps target objects from the air, highway structures including bridges and culverts can also be seen in airborne LiDAR data. Figure 5.13 and Figure 5.14 show a picture of a bridge and its profile in LiDAR data, respectively. Figure 5.15 and Figure 5.16 show a culvert and its profile in LiDAR data, respectively. Barriers are also very important subsidiary facilities for highways. Different types of barriers exist, such as cable barriers, box beam barriers, and constant slope concrete barriers. In the collected airborne LiDAR data, all kinds of barriers can be easily identified, except for cable barriers with a small surface area. Figure 5.17 shows a section of cable barriers, and Figure 5.18 shows its profile in collected LiDAR data. Cable barriers can hardly be seen in LiDAR data. As shown in Figure 5.19 and Figure 5.20, a segment of W-beam barriers corresponds to a long string of points above ground in LiDAR data.

Figure 5.1 Speed Limit Sign

Figure 5.2 Instruction Sign

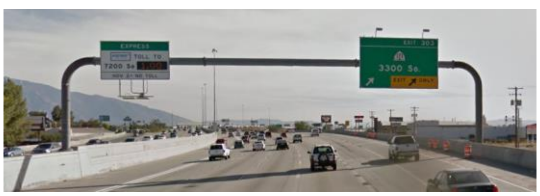


Figure 5.3 Overhead Traffic Sign

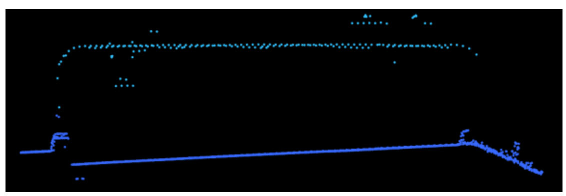


Figure 5.4 Overhead Traffic Sign in LiDAR Data

Figure 5.5 Small Traffic Signal

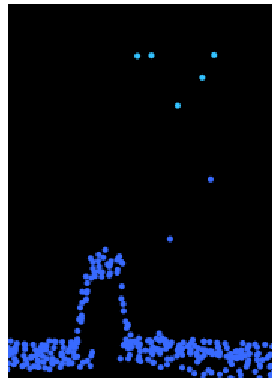


Figure 5.6 Small Traffic Signal in LiDAR Data

Figure 5.7 Large Traffic Signal

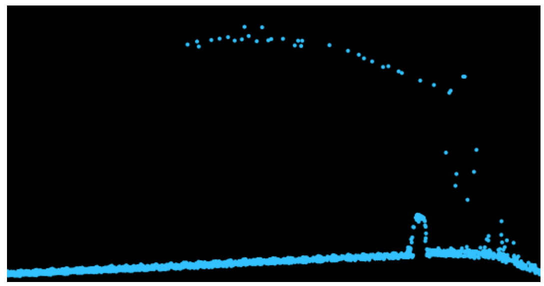


Figure 5.8 Large Traffic Signal in LiDAR Data

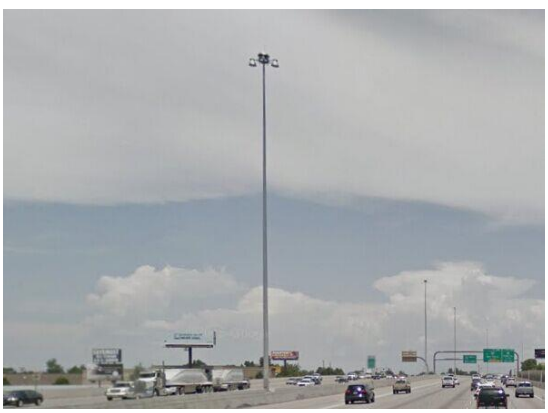


Figure 5.9 Light Pole

Figure 5.10 Light Pole in LiDAR Data

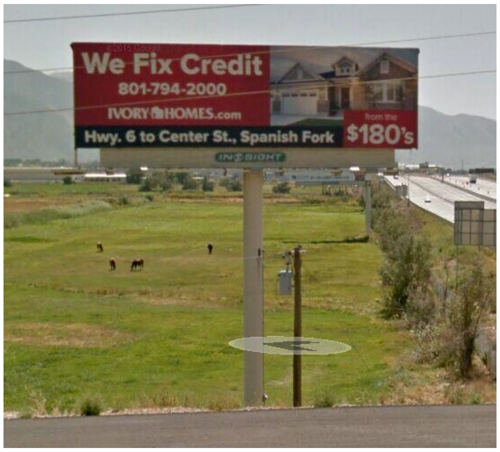


Figure 5.11 Billboard

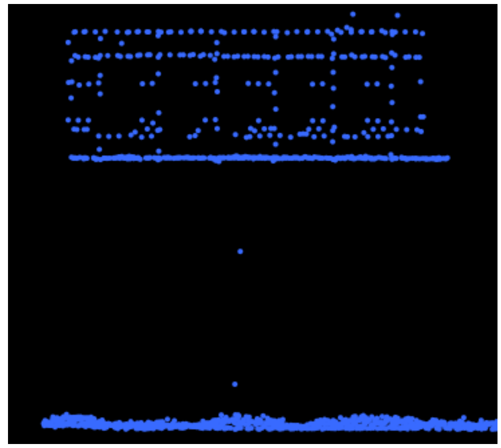


Figure 5.12 Billboard in LiDAR Data

Figure 5.13 Bridge

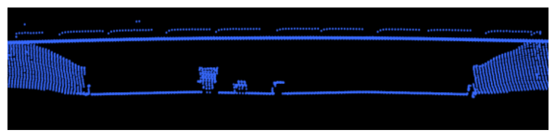


Figure 5.14 Bridge in LiDAR Data

Figure 5.15 Culvert

Figure 5.16 Culvert in LiDAR Data

Figure 5.17 A Section of Cable Barrier

Figure 5.18 Cable Barrier in LiDAR Data

Figure 5.19 W-beam Barrier

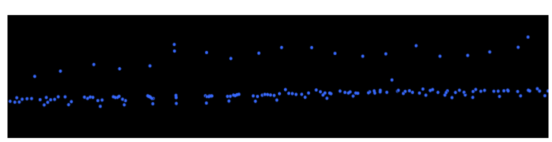


Figure 5.20 W-beam Barrier in LiDAR Data

For all the above-mentioned road assets that can be identified in airborne LiDAR data, their specific location information and structure characteristics can be manually measured and recorded in the LiDAR data. However, manually identifying all the road features requires a great deal of time and effort; meanwhile, it may lead to some omission due to human error. Therefore, we developed an ArcGIS-based algorithm to extract certain types of road features from airborne LiDAR data. Based on the algorithm, we first used ArcGIS to automatically find all specific road assets, and then measured and recorded their location and structure information.

5.2 ArcGIS-based Feature Extraction Algorithm

The algorithm we developed for extracting road assets is based on the elevation difference between the assets and the bare ground. The algorithm consists of the following steps:

1) Load LAS files (airborne LiDAR data) to ArcGIS. Divide the LAS data into small square cells of a certain size. For each small cell, calculate the elevation difference between the highest point and the lowest point within that cell. This procedure can be done using the LAS Point Statistics as Raster tool in ArcGIS. The result will be raster data, within which each cell has a particular value: the elevation difference.
2) Evaluate the range of elevation difference between a certain type of road asset and the bare ground. Delete all the cells that are out of the range from the obtained raster data.
3) Determine a road boundary and clip the raster data from step (2) according to the boundary to remove the cells beyond the road.
4) Further convert the raster data from step (3) into feature data.

Figure 5.21 shows the flowchart of this algorithm.

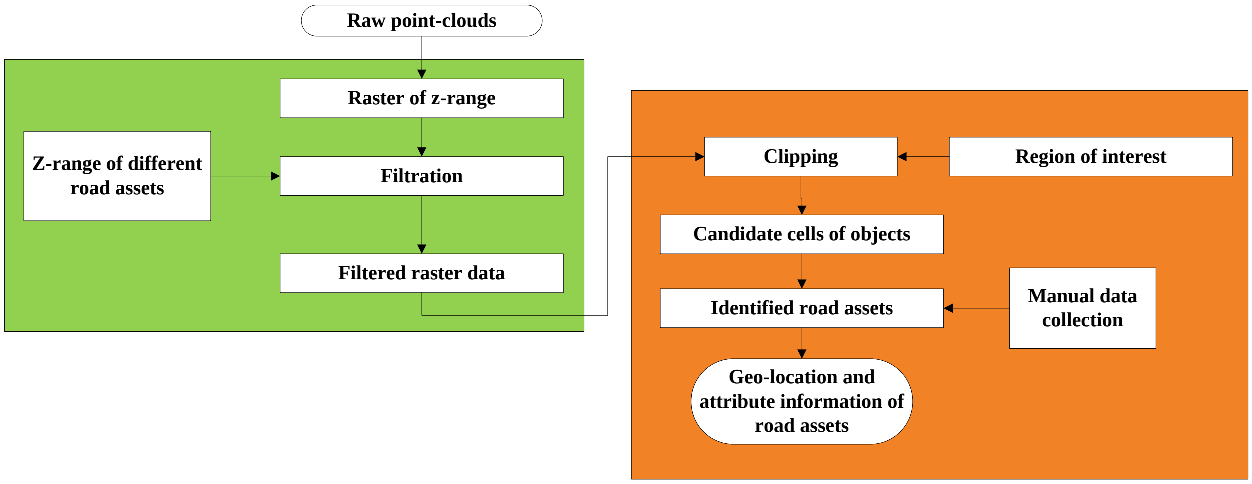


Figure 5.21 Flowchart of ArcGIS-based Algorithm

In this report, we used a large traffic sign as an example to show the effectiveness of the proposed algorithm. Figure 5.22 shows a section of the original LAS data in ArcGIS. We can hardly identify anything from the raw data. We then transformed the LAS data into raster data using the LAS Point Statistics as Raster tool (step 1). The obtained raster data are shown in Figure 5.23. Then we can use the raster-based tools in ArcGIS to deal with the raster data. In this research, we chose 1 as the cell size of the raster data (i.e., each cell of the raster data has an area of 1 m^2). It can be seen from Figure 5.23 that most cells have values near zero. As previously mentioned, the value of a cell represents the elevation difference between the highest point and the lowest point within that cell; thus, a cell with a value near zero means all the LAS points within that cell have a similar elevation. For the cells that contain points representing a large traffic sign, the values should be near the height of the traffic sign. The height of traffic signs can be directly measured from LAS data, or can be estimated based on highway design specifications. If we remove all the cells whose values fall into a certain range (e.g., smaller than the height value of the traffic sign), the remaining cells should be the candidate cells that may contain points representing the traffic sign (Figure 5.24). We then clipped out all the cells that were within the range of the road surface as traffic signs should be in the range of the road surface (Figure 5.25). From Figure 5.25, we can easily detect the traffic sign and then record the location and structure information of the traffic sign.

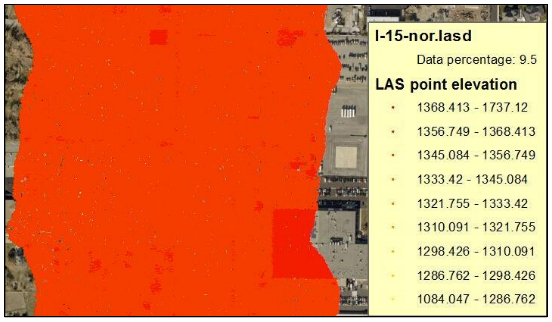


Figure 5.22 LAS Data

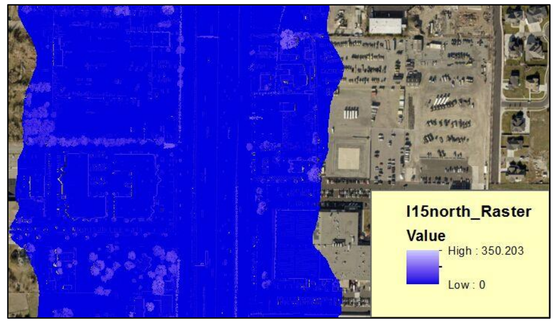


Figure 5.23 Raster Data

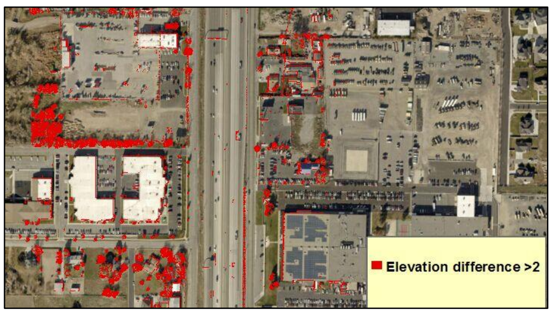


Figure 5.24 Filtered Raster Data

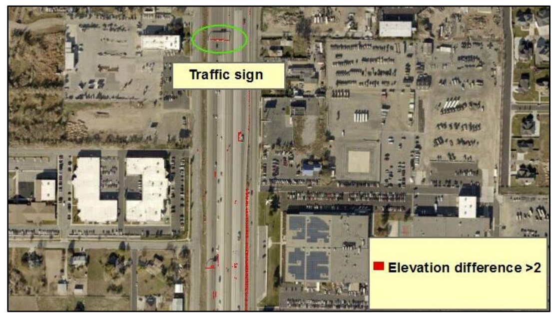


Figure 5.25 Clipped Raster Data

5.3Road Assets Inventory

With the proposed ArcGIS-based algorithm, we can easily identify different kinds of road assets. However, this algorithm can only help us find road assets. The specific location and structure information of the road assets still need to be collected manually. In this section, we provided our collected information of all the assets that can be identified from airborne LiDAR data and compared them with the Mandli dataset.

5.3.1 I-84

In total, 10 raw airborne LiDAR data files were obtained for the mapping section on I-84: No.1-No.10 (Chapter 4, Table 4.1). Among them, No. 8 was a duplication of No. 7, and both No. 9 and No. 10 missed some part of the highway. Therefore, in our project, the total valid length of the mapping section was around 15.5 miles, crossing Peterson and Morgan.

With the proposed feature extraction algorithm, we found 2 overhead traffic signs, 19 light poles, 5 billboards, 27 bridges and culverts on the mapping section of I-84. In addition, barriers (excluding cable barriers) were identified. Figure 5.26 shows all road assets detected on I-84. The geo-location information and structure characteristics of these identified road assets were manually recorded and are provided in Table 1−Table 6 in the Appendix.

5.3.2 US-191

Fourteen raw LiDAR data files were collected for US-191: No. 1-No. 21 (Chapter 4, Table 4.2). The total effectively mapped highway length was about 28 miles. On the mapping section of US-191, we did not find any recognizable traffic signs, signals or light poles. We identified 1 billboard, 6 bridges and culverts, and all barriers. All road assets we detected on US-191 are shown in Figure 5.27. Detailed geo-location information and structure attributes of these road assets were collected manually and are given in Tables 7−9 in the Appendix.

5.3.3 I-15 North

As introduced in Chapter 4, I-15 North refers the section from MP 284 to 307 on I-15. In total, 14 raw airborne LiDAR data files were obtained for the mapping section of I-15 North: No. 11-No. 24 (Chapter 4, Table 4.1). Among them, No. 17 and No. 23 were redundant because their mapping sections were also covered by other LAS data. The total length of the mapping section was around 23 miles.

On I-15 North, we found 192 overhead traffic signs, 178 light poles, 124 billboards, 54 bridges and 1 culvert on the mapping section of I-15 North. In addition, barriers (excluding cable barriers) were identified using the ArcGIS-based algorithm. Figure 5.28 shows all the road assets we identified on I-15 North. We manually collected the geo-location information and structure characteristics of these identified road assets. Detailed information is given in Tables 10−15 in the Appendix.

5.3.4 I-15 South

On I-15, we also collected airborne LiDAR data from Santaquin to Springville (MP 241 to 260), which is referred to as I-15 south. In total, 7 raw airborne LiDAR data files were obtained for the mapping section on I-15 South: No. 25−No. 31 (Chapter 4, Table 4.1). These

LiDAR data were all valid and were used to extract information for the road assets. The total length of the mapping section was around 19 miles.

On I-15 South, 34 overhead traffic signs, 103 light poles, 56 billboards, 33 bridges and 4 culverts were detected. We also identified all barriers (excluding cable barriers) using the proposed ArcGIS-based algorithm. Figure 5.29 shows all road assets identified on I-15 South. Specific geo-location information and structure attributes about these identified road assets were collected manually. Detailed information is given in Tables 16−21 in the Appendix.

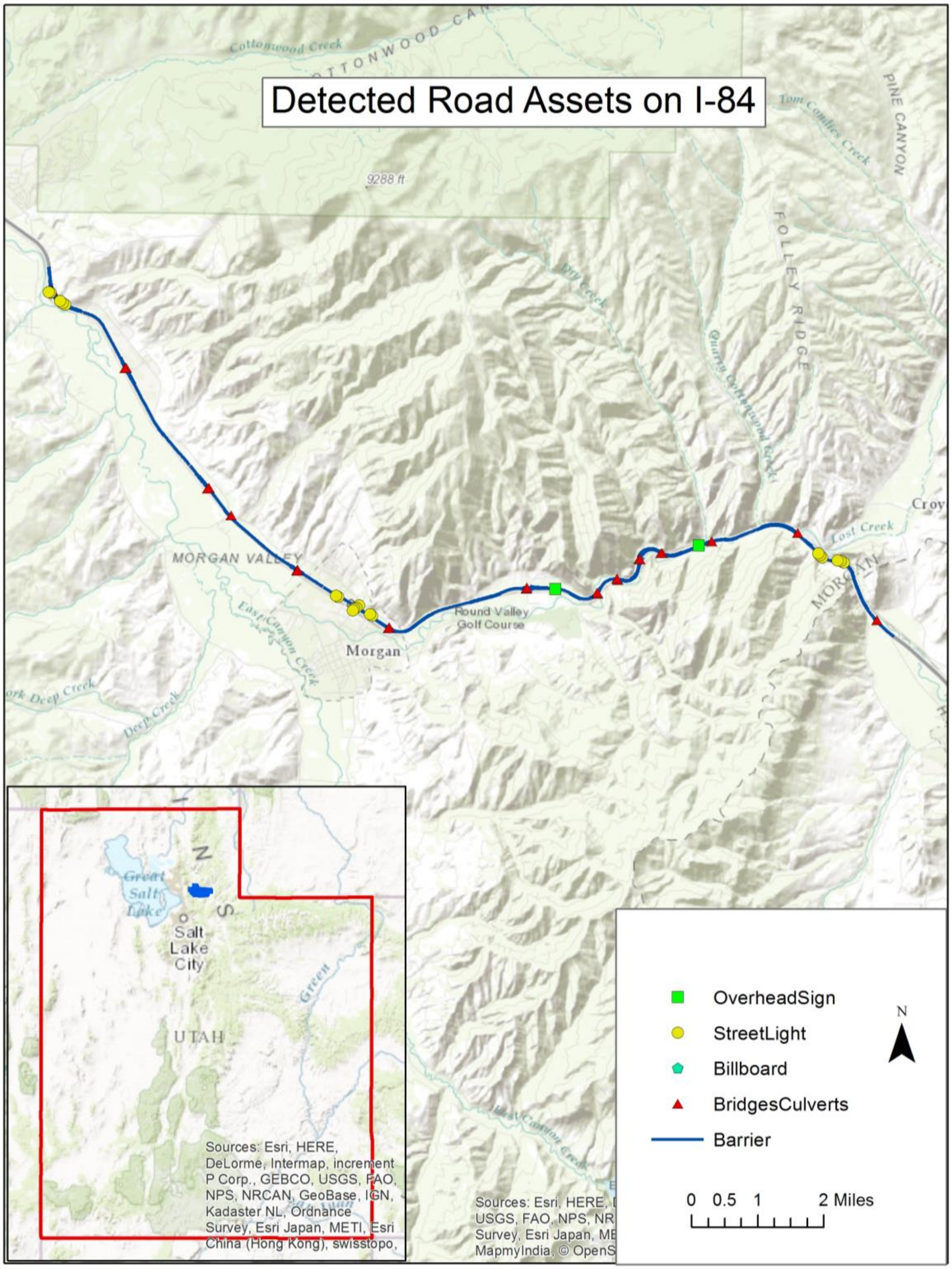


Figure 5.26 Detected Road Assets on I-84

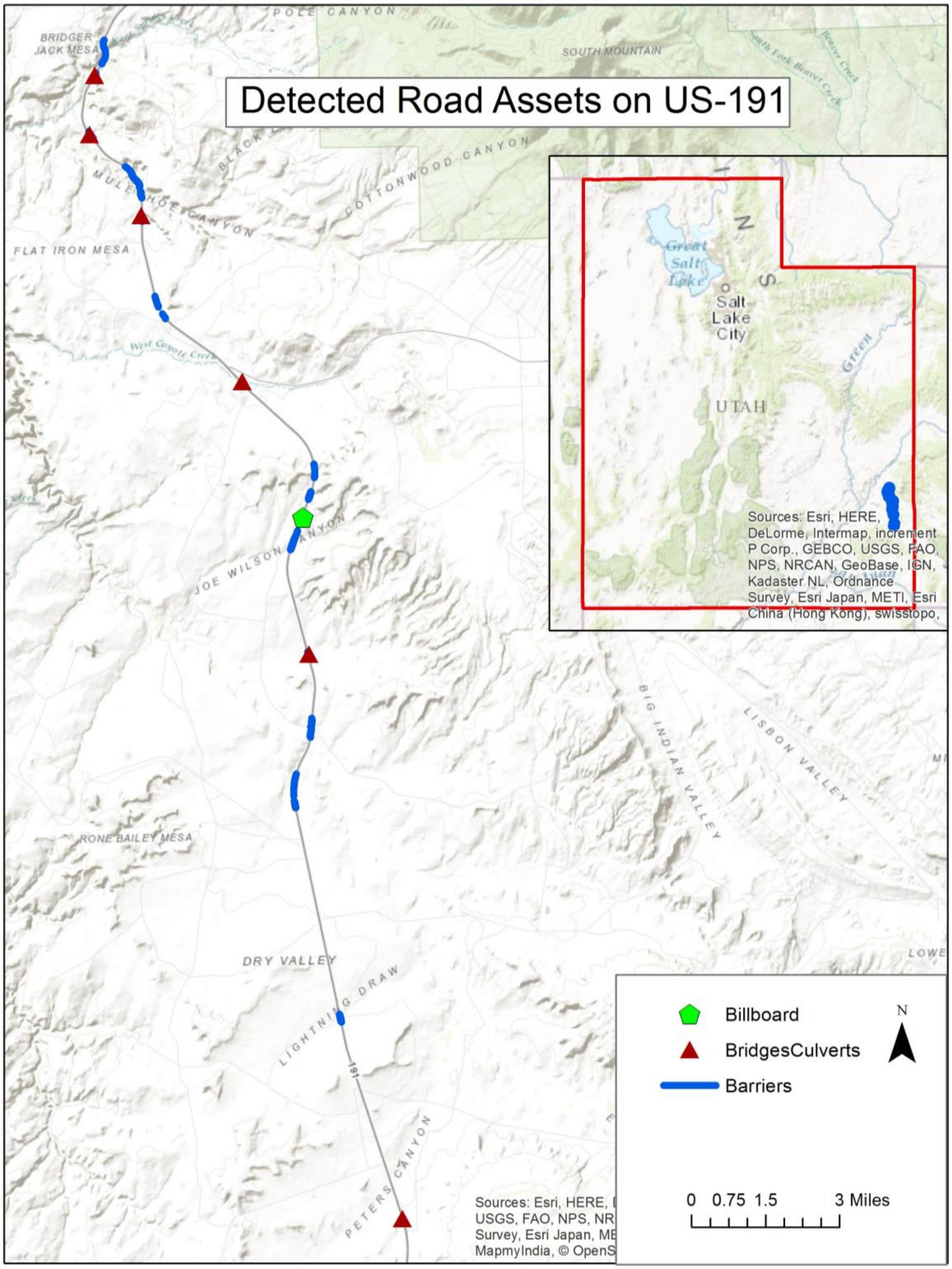


Figure 5.27 Detected Road Assets on US-191

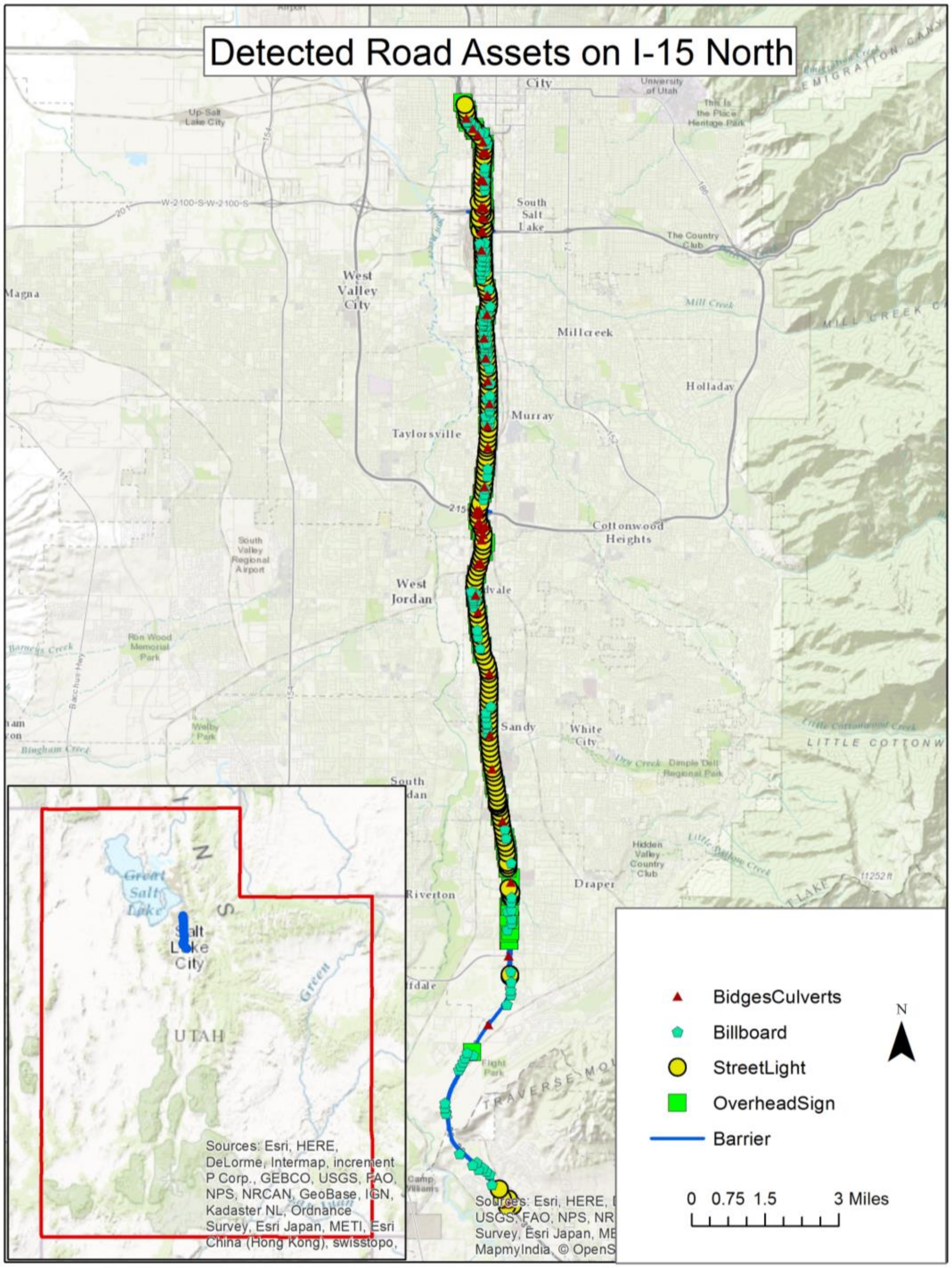


Figure 5.28 Detected Road Assets on I-15 North

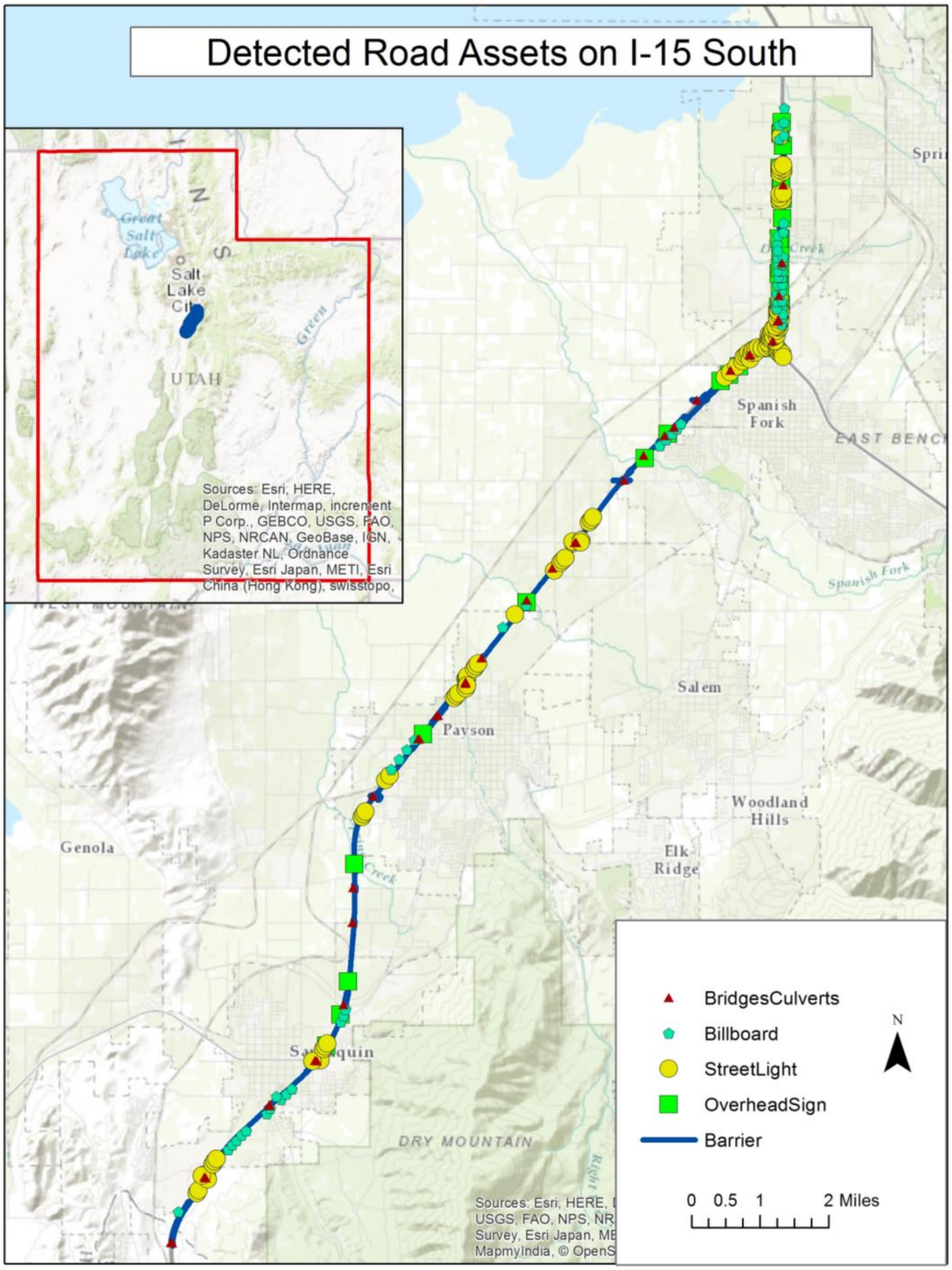


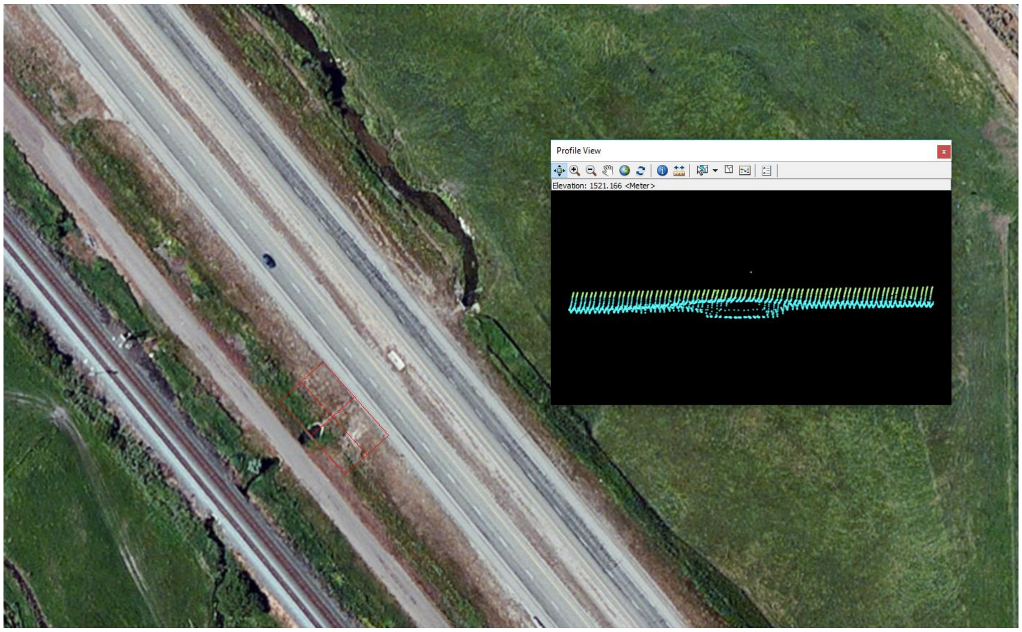
Figure 5.29 Detected Road Assets on I-15 South

5.4 Comparison with Mobile LiDAR

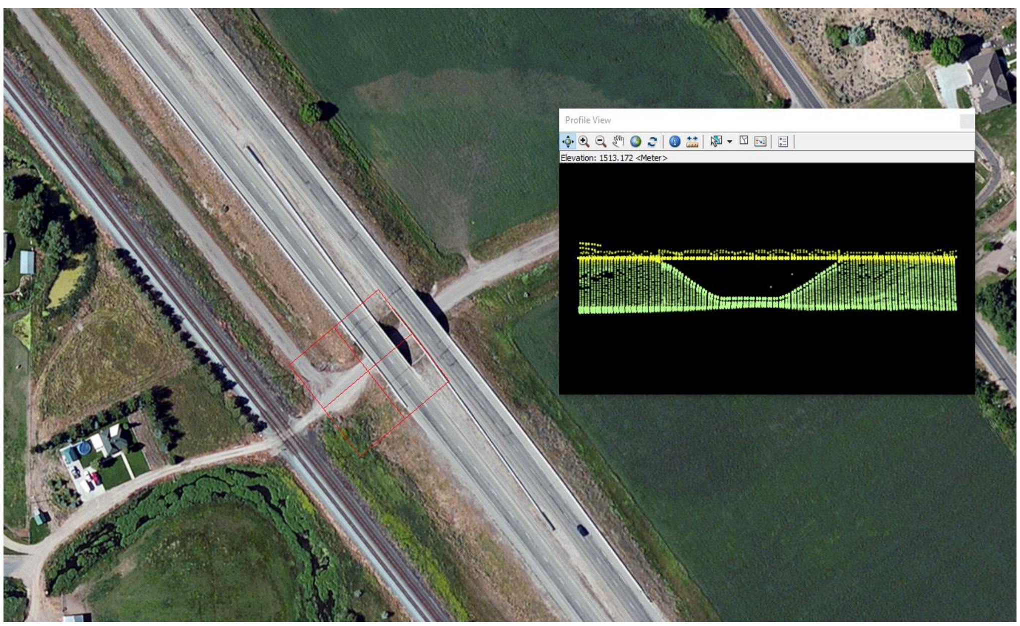
5.4.1 Effectiveness Comparison with Mobile LiDAR

To verify the collected information of road assets from airborne LiDAR data, we compared our results with the existing highway inventory dataset of UDOT, which was collected by Mandli in 2014. The latest Mandli dataset was collect via mobile LiDAR and Photolog imagery. Traffic signs, including small signs and large overhead signs, traffic signals, billboards, and barriers, were all included in the Mandli dataset. Because of the sparseness of the airborne LiDAR points, we could not extract small signs in this research. However, all other assets included in the Mandli dataset were successfully explored. Moreover, we were able to detect bridges and large culverts that cannot be mapped from the mobile platform because of the broad view and different perspective of the aircraft. As shown in Figure 5.30, culverts (a) and bridges (b) are very distinctive in airborne LiDAR data. We also explored the light poles that may be useful to state DOTs but were not detected by Mandli since light poles were not included in the contract. Note that in this study, we only collected the location and size information of assets, the specific contents (e.g., the advertisement details of the billboards, the instruction information of the signs, etc.) with the assets could not be identified. Nevertheless, this kind of information, if deemed important for highway maintenance and asset management, can be easily obtained if we combine LiDAR data with imagery data in the future.

For simplicity, here we used the detection results of billboards as an example to make the comparison. Figure 5.31 shows the comparison between the billboards detected in our research and by Mandli. The billboards in Mandli dataset are marked with green hexagons, and the billboards detected in our research are marked with black triangles. It can be observed that our detection results match Mandli dataset well, both in quantity and location.



(a)



(b)

Figure 5.30 3D View of Culvert and Bridge in Airborne LiDAR Data (a) Culvert (b) Bridge

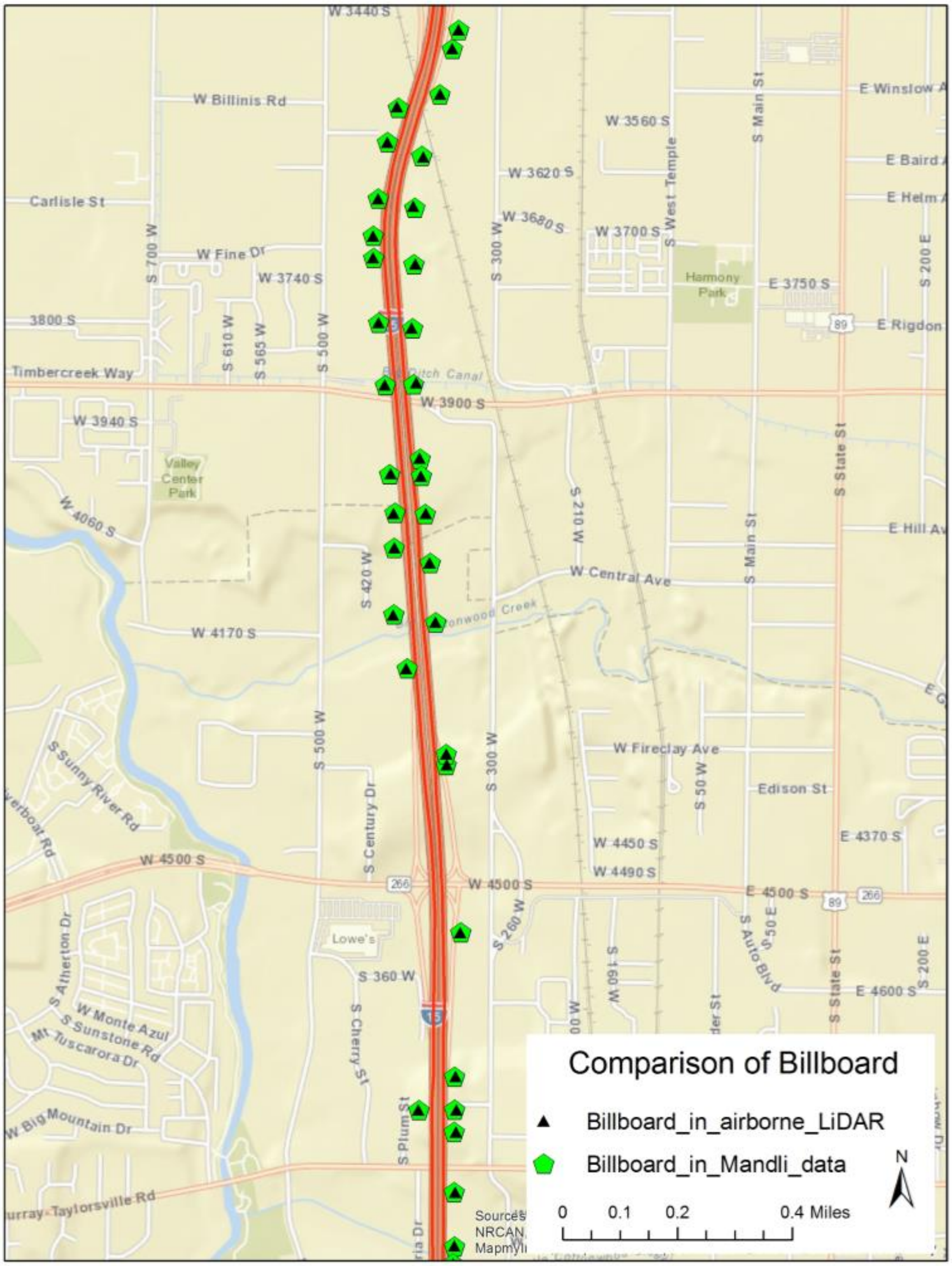


Figure 5.31 Billboards in Mandli Datasets versus Billboards Detected in Our Project

5.4.2. Economic Comparison with Mobile LiDAR

Jayaler et al. (2014) conducted a field trail to evaluate five highway inventory data collection methods: GPS data logger, robotic total station, GPS enabled photo/video log, satellite/aerial imagery, and mobile LiDAR. They provided a detailed summary about the five methods. The cost and time information of mobile LiDAR were adopted in this paper for comparison purpose. In our study, we did not detect any small signs due to the insufficient point density of airborne LiDAR data. However, small signs could account for a substantial proportion of the total number of assets (about 50% according to Mandli dataset). Therefore, for fair comparison, we halved the total data reduction time provided by Jayaler et al. (2014) (i.e., the actual total data reduction time of the mobile LiDAR field trail was 70 man-hr, but was assumed to be 35 man-hr in this paper). For cost analysis, the unit labor cost in this study is assumed to be the same amount as which adopted by Jayaler et al. (2014): $130 per hour. Regarding the data collection cost, Jayaler et al. (2014) estimated the average cost per mile for mobile LiDAR to be $200, while the total mapping cost of the airborne LiDAR in this study is about $5000. Note that if a larger area was surveyed with the airborne platform the unit data collection cost for airborne LiDAR could be even lower due to the economy of scale. Table 5.1 shows the comparison between the mobile LiDAR field trail conducted by Jayaler et al. (2014) and the field trail in this study.

Based on Table 5.1, the data collection efficiency of airborne LiDAR is much higher than mobile LiDAR. The difference in data reduction speed between the two methods demonstrates that the proposed ArcGIS-based algorithm can reduce the data reduction time to some extent. Furthermore, the average cost per mile for airborne LiDAR and mobile LiDAR methods are $292.1 and $590.0, respectively. Thus, we can conclude that the airborne LiDAR method is more economical than mobile LiDAR in highway asset inventory.

Table 5.1 Economic Comparison Between Airborne LiDAR and Mobile LiDAR.

Methods	Total mapping length (mi)	Total data collection time (man-hr)	Total data reduction time (man-hr)	Data collection cost ($/mi)	Labor cost ($/man-hr)	Average time (man-hr/mi)	Average cost ($/mi)
Mobile LiDAR	14.2	8.0	35.0	200.0	130.0	3.0	590.0
Airborne LiDAR	86.0	4.8	150.0	58.1	130.0	1.8	292.1

5.5 Summary

In summary, we developed an ArcGIS-based algorithm to semi-automatically detect and record highway assets from the collected LiDAR data. According to the point density of the airborne LiDAR data and the characteristics of different highway features, we successfully extracted large overhead traffic signs, traffic signals, billboards, barriers, bridges and large culverts. For these highway features, their height above the ground was the main characteristic distinguishing them. Therefore, we used the elevation difference within a certain area of the point cloud as a criterion for determining whether an object was the target feature or not. We then manually recorded the location and structure information of those assets. With the information, we created a series of shape files of the highway features, which can be added to UDOT's current dataset to update the database of highway inventory. The detection results showed that the ArcGIS-based algorithm proposed in this report is effective and efficient, and airborne LiDAR technology is applicable for highway inventory.

6.0 DRAINAGE GRATE DETECTION USING MATLAB

This section presents an automatic highway drainage grate detection and recognition algorithm based on aerial images. Drainage systems that remove storm water from highways are very important factors for maintaining highway safety. The statistics of drainage assets on highway systems is essential for the state DOTs or local agencies to manage and upgrade drainage features. However, the significant number of these drainage grates along US highways can make their manual detection and analysis laborious. To address these challenges, this chapter proposes a method to directly extract drainage grates from aerial photos of highways.

Drainage grates, unlike traffic signs that are brightly painted and particularly shaped, usually have a dark color and small size, making them hard to recognize in ground-based photos or videos. But aerial images obtained from flights can clearly show the shape and color of drainage grates (Figure 6.1). Thus, in this chapter, our goal is to formulate a general framework of detecting and recognizing highway drainage grates based on aerial image processing.

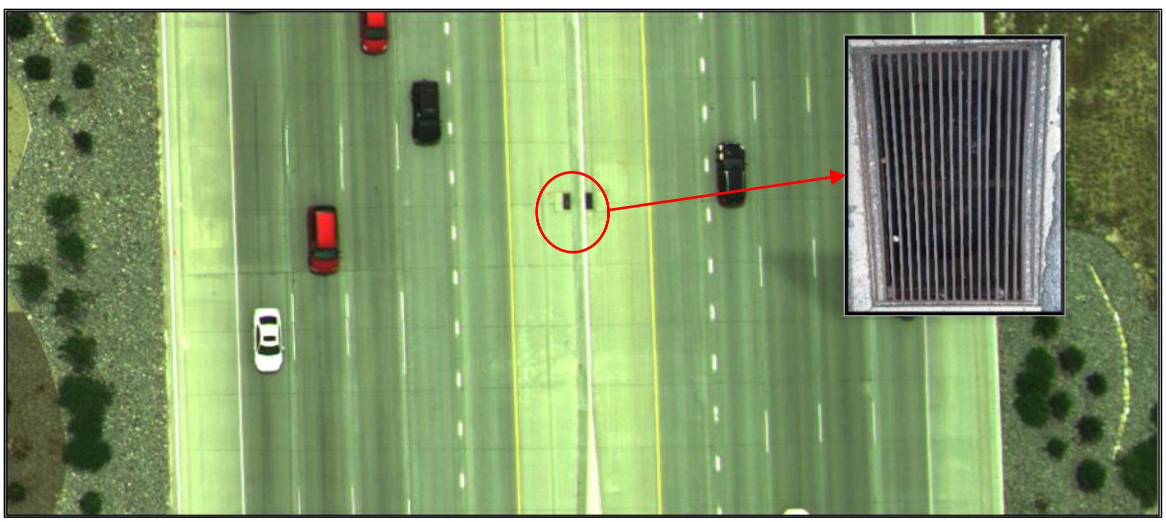


Figure 6.1 Drainage Grates from an Aerial Image

Figure 6.2 shows the flowchart of the algorithm for drainage grate detection.

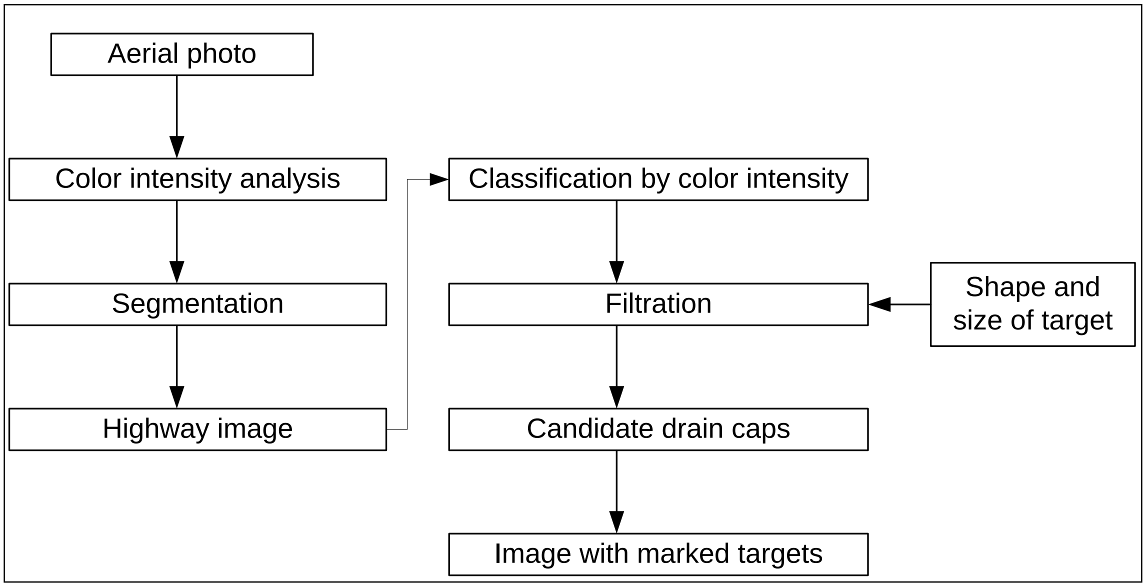


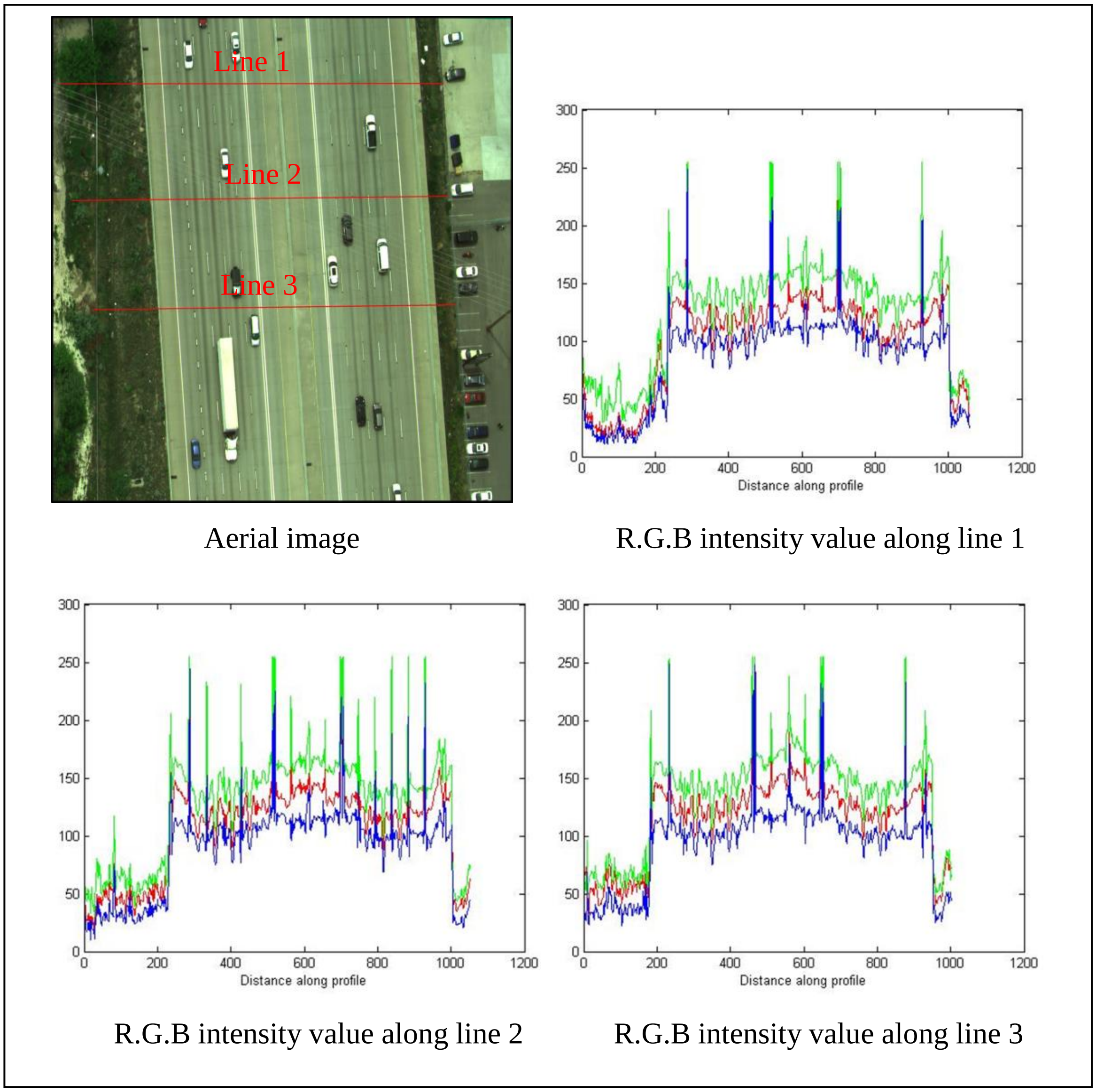
Figure 6.2 Drainage Grate Detection Flowchart

6.1 Road Segmentation

For the drainage grates on the highway, the main features that can distinguish them are their dark color and rectangular shape. However, other objects in the image also have either a similar color or shape. Within the highway surface, the main objects similar to the drainage grates are the windshields of white cars. Outside the highway surface, the shrubs or other objects may have a similar dark color as the drainage grates. In order to eliminate the interference of the bare ground and shrubs, we first extracted the highway surface from the aerial images. As we can see in Figure 6.1, the highway surface has a relatively light color compared to the color of the bare ground or shrubs. Based on this characteristic, we can roughly divide the image into two parts, where the light-colored part should be the highway surface and the dark-colored part will be the bare ground and shrubs.

In order to get an appropriate demarcation, we first analyzed the color distribution within the image. As shown in Figure 6.3, we chose several profiles of the highway and analyzed the color composition of each pixel along the profile. We can observe that, approximately, the intensity values of red, green and blue of pixels representing highway surface are all larger than the values of pixels representing bare ground or shrubs.

Obviously, for each pixel, the intensity values for R, G, and B colors have the same trend. If the intensity level of red for one pixel is high, the intensity level of green and blue for that pixel will also be high, and vice versa. From Figure 6.3, we can observe that the intensity value of pixels that represent ground or shrubs falls into the 0−100 range, while road surface falls into the 80−180 range. In order to make the difference (between highway surface and ground) more significant, we sum up the intensity values of red, green, and blue for each pixel and assign the value to the corresponding pixel, resulting in a new matrix I (Figure 6.4).



Aerial image

R.G.B intensity value along line 1

R.G.B intensity value along line 2

R.G.B intensity value along line 3

Figure 6.3 Road Surface Color Characteristic Analysis

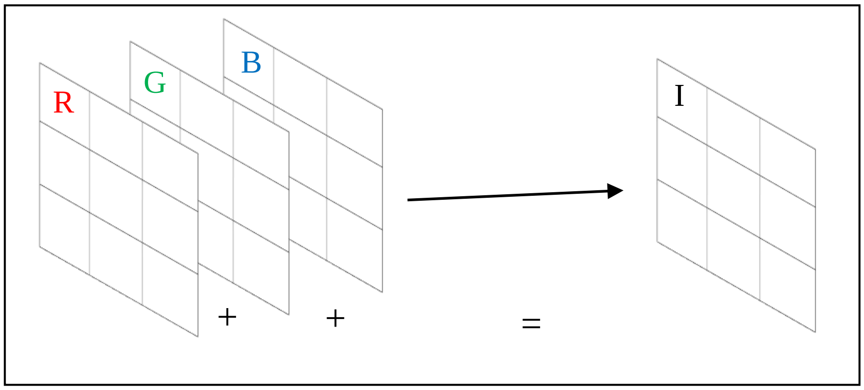


Figure 6.4 Summation of R, G, B Color Band

$$I(i,j) = R(i,j) + G(i,j) + B(i,j) \qquad \forall\, i \in [1, M], j \in [1, N] \tag{9}$$

$$I(i,j) = 1 \qquad \forall I(i,j) \geq T_1 \tag{10}$$

$$I(i,j) = 0 \qquad \forall I(i,j) \leq T_1 \tag{11}$$

where I is the summation value, M is the number of columns in the image, N is the number of rows in the image, and T_1 is the threshold value that determines the boundary of the road and non-road. In this project, we use $T_1 = 300$.

We assigned 0 to pixels whose values are smaller than 300 and 1 to pixels whose values are larger than 300. Figure 6.5 is the original image. After using the thresholding method, the resulting image is shown in Figure 6.6, where white pixels have a value of 1 and black pixels have a value of 0. Note that, within the range of highway surface, pixels representing dark-colored objects were assigned a value of 0 whereas outside the range of the highway surface, some objects, such as parking lots and light-colored roofs, are misclassified as highway. Thus, the morphological opening and closing as well as BoundingBox methodologies were used to eliminate the misclassified data. Figure 6.7 shows the resulting image. Finally, the non-highway part was deleted from the original image.

Figure 6.5 Original Image

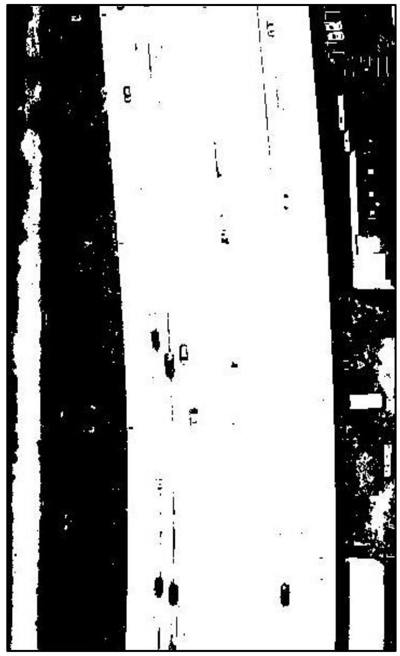


Figure 6.6 Thresholded Image

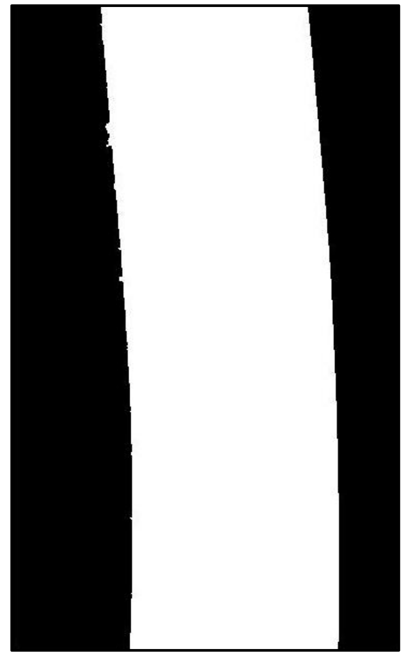


Figure 6.7 Road Surface

6.2 Drainage Grate Detection

Color Thresholding

After segmenting the highway surface from the image, our next step was to extract the drainage grates. As with the road extraction, we also used color characteristics to detect the drainage grates because their color is quite different from the highway surface color. We still used the profile analysis method to evaluate the intensity value of the drainage grates. Figure 6.8 shows the results of three profiles displaying the contradistinction between the intensity values of drainage grates and highway surface. It is fairly clear that the intensity values for all R, G, and B bands for the drainage grates were no greater than 80 in most cases. Similarly, we summed up the intensity values of red, green, and blue colors for each pixel and assigned the value to the corresponding pixel, then used the threshold value of $240 = 3 \times 80$ to classify the image.

$$I(i,j) = 1 \qquad \forall I(i,j) \leq T_2 \qquad (12)$$

$$I(i,j) = 0 \qquad \forall I(i,j) \geq T_2 \qquad (13)$$

where $T_2 = 240$.

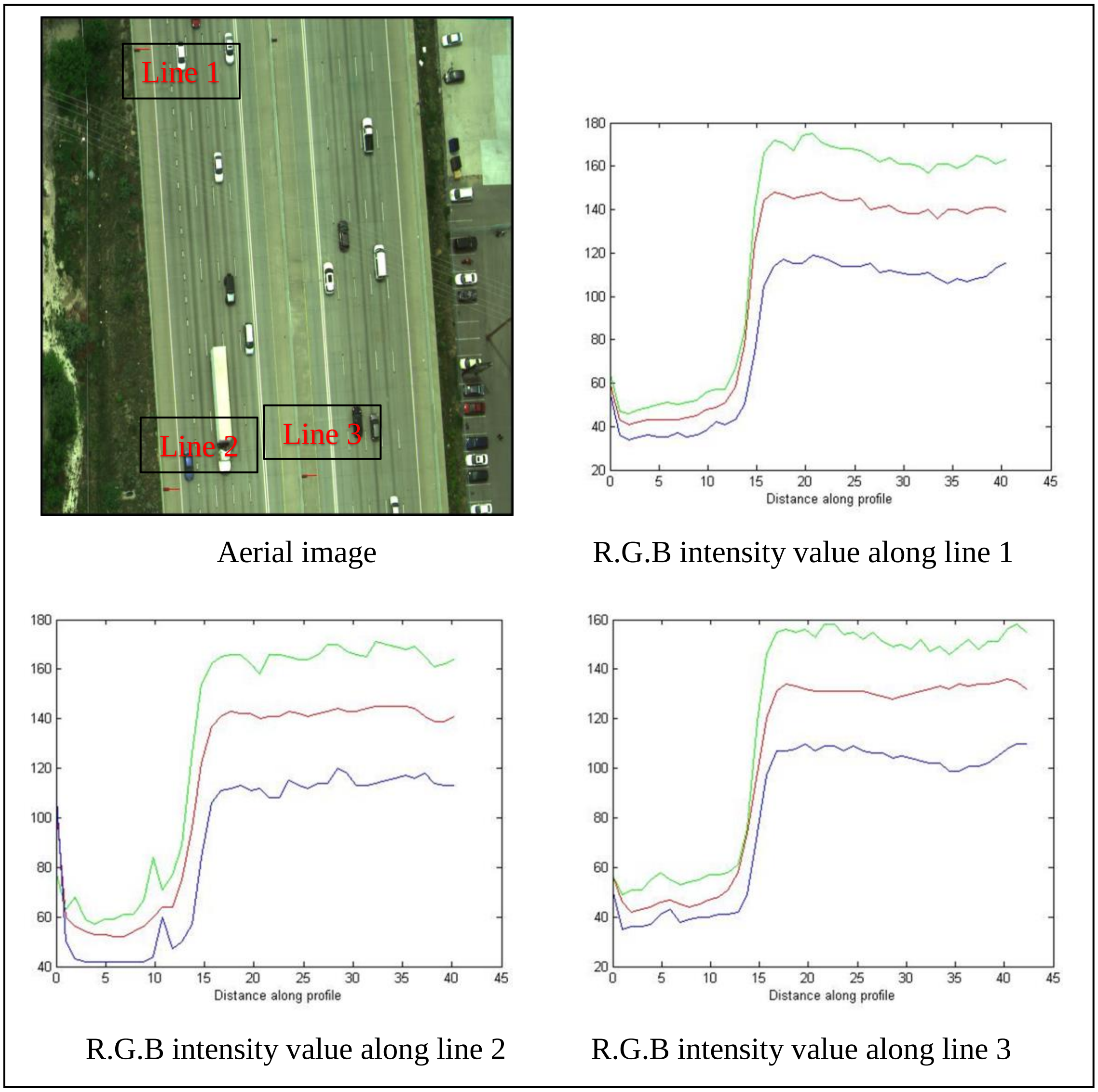


Figure 6.8 Drainage Grate Color Characteristic Analysis

Shape Analysis

We can observe from the original aerial image that black cars or the windshields of white cars have a similar color as the drainage grates. Thus, using only color thresholding is not enough to get the ideal extraction results. We thus used shape characteristics for further analysis. The previously discussed results of color thresholding will be the image with a series of connected components that represent the drainage grates, black cars, windshields, or some other objects. Each connected component has its own shape and area. The shape of the connected components that represent the drainage grates is nearly rectangular, and size is also relatively unified. For the purpose of evaluating the property of the drainage grates, we measured the length, width and area of 31 connected components that we preliminarily determined to be drainage grates. Table 6.1 shows the statistical values of the 31 connected components.

Table 6.1 Statistics of the Chosen Samples

Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Length	14	16	15	13	14	14	14	15	13	14	13	13	14	11	5	14
Width	7	7	8	8	5	6	5	6	5	7	6	7	6	5	13	5
Area	81	84	87	83	58	75	62	81	60	83	71	84	81	52	60	63
Number	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	
Length	14	15	14	15	13	15	15	14	15	7	15	6	7	13	6	
Width	9	8	7	8	8	6	8	8	7	15	7	14	14	6	14	
Area	110	102	84	94	97	79	88	83	91	86	87	75	84	67	77	

Based on the data in Table 6.1, length ranged from 5 to 16, width ranged from 5 to 15, and area ranged from 52 to 110. We set the lower and upper limits of length and width to 5 and 20, respectively, and the threshold values of area were set to 30 and 150 to cover more cases. The connected components that satisfy the following constraints were regarded as candidate drainage grates.

$$T_2 \leq L(k) \leq T_3 \quad (14)$$

$$T_2 \leq W(k) \leq T_3 \quad (15)$$

$$L(k) + W(k) \leq T_4 \quad (16)$$

$$|L(k) - W(k)| \geq T_5 \quad (17)$$

$$T_6 \leq \mathrm{A}(k) \leq T_7 \quad (18)$$

where $L(k)$, $W(k)$, and $\mathrm{A}(k)$ are the length, width, and area of the kth connected component, respectively, and $T_2 = 5, T_3 = 20, T_4 = 30, T_5 = 5, T_6 = 3,$ and $T_7 = 150$. For each connected component, constraints (14) and (15) restricted the range of length and width while constraint (16) limited the area. Constraints (17) and (18) further restricted the shape of the connected components to be approximately rectangular.

Filtration

Shape analysis can help us eliminate the interference of dark-colored cars while the windshield of white cars, whose color and shape are both similar with the drainage grates, cannot be completely removed. Hence, we used the following procedure to further filtrate the drainage grates:

a. Use color thresholding to identify white cars, excluding the windshield.
b. Use morphological operation to get the entire range of cars.
c. Remove all candidate connected components that fall into the range of cars.

Figure 6.9 is the original image. Figure 6.10 shows an example of the detection results; the drainage grates are marked by blue crosses.

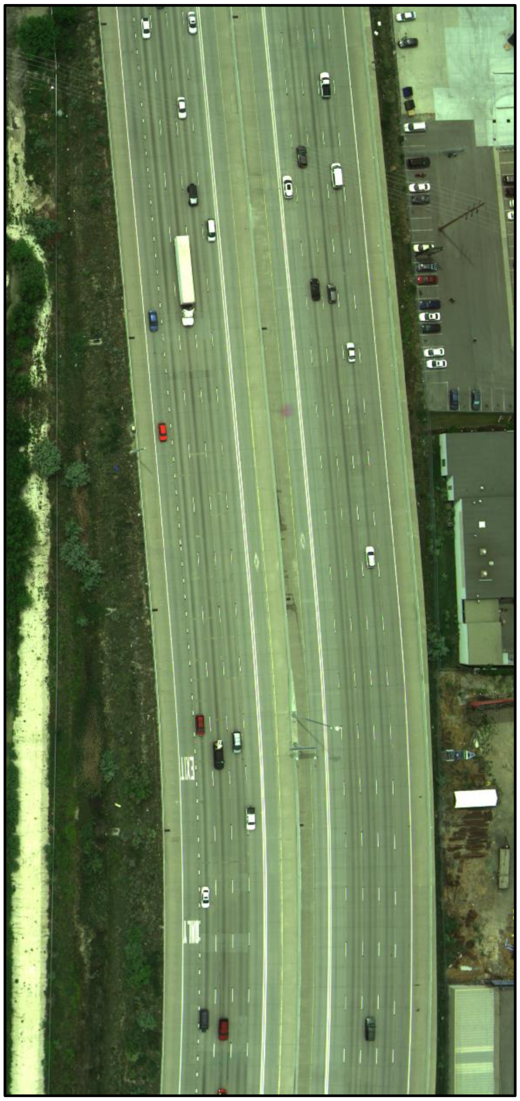


Figure 6.9 Original Image

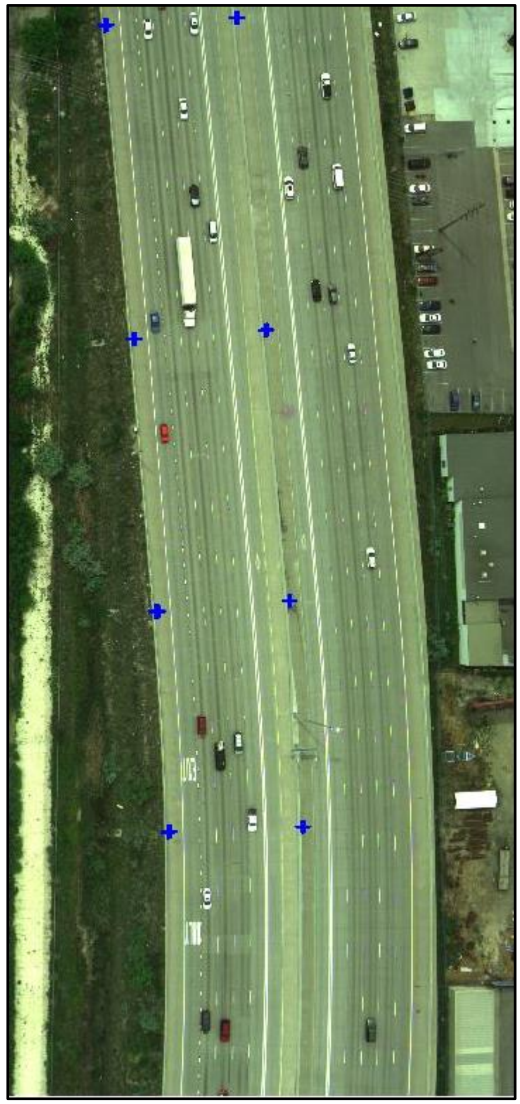


Figure 6.10 Detection Result

6.3 Results and Conclusion

The algorithm was tested on 20 images, and the results are given in Table 6.2. In the evaluation table, True Positive (TP) means that the drainage grate was correctly detected, True Negative (TN) means that the drainage grate was missed, and False Positive (FP) means that the object was not a drainage grate, but was detected as a drainage grate. Actual Number (AN) is the number of drainage grates counted manually, which is the summation of TP and Missed TN. AN is considered as accurate in our study. Completeness is the completion rate, and Correctness is the right detection rate.

$$AN = TP + TN \tag{19}$$

$$Completeness = \frac{TP}{AN} \tag{20}$$

$$Correctness = \frac{TP}{TP + TN + FP} \tag{21}$$

According to the data in Table 6.2, the completeness of the algorithm on the 20 testing images is 89.3% while correctness is 77.9%. For some images, we can see that both completeness and correctness are high; for other images, the algorithm does not work well. The quality of images and road segmentation are the main factors influencing the performance of our algorithm. To further improve the image quality, we should collect data on fair-weather days and fly the plane at lower altitude. In addition, in our algorithm, the parameters used to filtrate drainage grates are adjustable. If we choose those parameters that can eliminate more interference objects similar to drainage grates, some drainage grates that are less legible may also be eliminated; if we try to detect all the drainage grates, even those that are irregular or illegible, more interference objects will be misidentified as drainage grates. In the future, we should focus on the improvement of the road segmentation method and the refinement of our algorithm to make it more robust.

6.4 Summary

In this chapter, we discussed how to detect highway features from aerial images, which are obtained with LiDAR data as byproduct. According to the characteristics of different features on the highway, a MATLAB-based methods were developed to extract and detect drainage grates on highways based on the legible color and regular shape of the objects. The special color and size of the drainage grates make it quite easy for detection.

Although the testing results showed that the proposed methods worked well, they have some limitations because the methods are very strict in terms of image quality. In future work we need to improve the methods to increase their accuracy rate and make them more robust in applications.

Table 6.2 Drainage Grate Detection Results and Accuracy Evaluation

	Detection Results				**Accuracy Evaluations**	
Image Number	True Positive	True Negative	False Positive	Actual Number	Completeness (%)	Correctness (%)
1	17	0	1	17	100	94.4
2	8	0	0	8	100	100
3	10	0	1	10	100	90.9
4	12	1	1	13	92.3	85.7
5	9	2	3	11	81.8	64.3
6	8	0	3	8	100	72.7
7	14	2	5	16	87.5	66.7
8	10	5	1	15	66.7	62.5
9	16	4	2	20	80	72.7
10	4	2	1	6	66.7	57.1
11	11	0	1	11	100	91.7
12	14	2	4	16	87.5	70
13	15	4	2	19	78.9	71.4
14	20	0	1	20	100	95.2
15	17	2	3	19	89.5	77.3
16	18	0	2	18	100	90
17	8	0	1	8	100	88.9
18	18	3	2	21	85.7	78.3
19	10	2	7	12	83.3	52.6
20	19	2	1	21	90.5	86.4
Total	258	31	42	289	89.3	77.9

7.0 CONCLUSION AND FUTURE WORK

Highway inventory data collection is a complicated and repetitive work that requires a lot of manpower and resources. State DOTs and transportation agencies are always looking for better techniques to reduce costs. Currently, the commonly used techniques include field inventory, photo/video log, integrated GPS/GIS mapping systems, aerial/satellite photography, terrestrial LiDAR, mobile LiDAR, and airborne LiDAR. Among them, the air-based methods, namely, aerial/satellite photography and airborne LiDAR, are less popular. The concerns about the low accuracy and high cost of air-based methods are the main reasons that hinder their application in highway feature inventory.

We conducted field data collection along several highway segments in Utah. Four highway sections were mapped: I-15 North, I-15 South, I-84, and US-191, covering approximately 86 miles of highway in total. Based on the collected data, we analyzed and reported the accuracy of the data and compared it with the required accuracy standard from USGS. The results showed that the accuracy of the collected data generally meets the requirements.

To verify the economic efficiency of airborne data collection methods, we compared the cost of our field data collection with a mobile-based data collection reported by Jayaler et al. (2014). We found that, although the fixed cost and the hourly cost of airborne data collection are higher than mobile-based method, the average data collection cost per mile of airborne method is less than mobile-based method due to the much higher mapping speed of aircraft. Thus, for large mapping areas, airborne data collection method is more economical than mobile-based method.

Although we can efficiently map highways using aircraft, the process of extracting highway features from airborne data is time- and manpower-consuming. The advantage of efficient data collection of airborne method would be compromised if the feature extraction process can only be finished manually. Therefore, we proposed an ArcGIS-based algorithm and a MATLAB-based algorithm to efficiently extract highway features from airborne LiDAR data and aerial imagery data, respectively. We processed all the valid LiDAR data and some of the high-quality images using our algorithms. The experimental results demonstrated the feasibility of our proposed algorithms in detecting certain types of highway features (e.g., barriers, traffic signs, bridges, large culverts, and drainage grates). We also compared the efficiency and the cost of the feature extraction in our experiment with that reported by Jayaler et al. (2014). The results showed that, with the proposed algorithm, we could achieve higher feature extraction efficiency than that reported by Jayaler et al. (2014).

In the process of highway feature extraction, we successfully identified large traffic signs, large traffic signals, bridges, large culverts, light poles, billboards and barriers from the airborne LiDAR data and extracted drainage grates from aerial imagery data. However, due to the limited point density and the overhead view of airborne LiDAR data, small traffic signs, small traffic signals, and cable barriers can hardly be identified in the collected airborne LiDAR data. Nevertheless, the drawback of missing small targets from airborne LiDAR data could be alleviated through repeating mapping process, lowering flight altitude, and slowing flight speed. With the development of LiDAR technology, its scanning frequency may also be improved significantly in the near future. Furthermore, this disadvantage could also be compensated by combining air-based data collection methods with other data collection techniques (e.g., mobile-based method or manual inventory). On the other hand, airborne LiDAR has the advantage over ground-based inventory technologies of being able to provide a different perspective. As a result, it can detect objects, such as culverts and ditches, which may have been hidden from the mobile platform. Therefore, airborne LiDAR is a promising technique that can serve as a complement to other techniques for road inventory data collection.

Based on the results of this research, we can conclude that with currently available technologies, airborne data collection could reach required data accuracy. In addition, for large mapping areas, airborne data collection method could be more efficient in terms of both time and money. Hence, when creating or updating a statewide database of highway assets, airborne data collection methods are competitive alternatives.

In summary, we investigated the applicability of airborne data collection methods, including the airborne LiDAR technique and aerial photography method, for collecting highway inventory data. The main contributions of this research include:

- Airborne data collection methods were used to map several highway segments in Utah;
- The accuracy and the cost of airborne data collection methods were analyzed and reported;

- An ArcGIS-based algorithm and a MATLAB-based algorithm were proposed to efficiently extract highway features from airborne LiDAR data and aerial imagery data, respectively;
- We developed a shape file for each mapping section, which can be directly added to UDOT database;
- Based on the application results, we analyzed the advantages and disadvantages of using airborne data collection methods in highway inventory and provided some guidelines for future studies and applications.

A number of research extensions can be considered in future studies. First, the ArcGIS-based algorithm we proposed is semi-automatic; we plan to develop a program to make it fully automatic. Second, we will combine the LiDAR data with imagery data to improve detection accuracy and develop new methods to detect some additional features.

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APPENDIX ADDITIONAL INFORMATION OF THE DETECTED ASSETS

Note: Coordinate system is NAD 1983 UTM zone 12N.

I-84 Data

Table 1. Overhead Sign Assemblies on I-84

NUMBER	MOUNT_OFFSET	SIGN_POSITION	LONGITUDE	LATITUDE	ALTITUDE
1	2.682	RIGHT	4545663.95	451658.288	1589.459
2	3.093	RIGHT	4544596.415	448161.805	1569.641

Table 2. Overhead Sign Faces on I-84

NUMBER	LENGTH	WIDTH	HEIGHT	LONGITUDE	LATITUDE	ALTITUDE
1	1.524	3.894	7.093	4545655.829	451662.098	1595.1
2	1.5	5.638	6.935	4544605.663	448162.259	1575.634

Table 3. Billboard Assemblies on I-84

NUMBER	LONGITUDE	LATITUDE	ALTITUDE	BILLBOARD_TYPE
1	444056.058	4543737.12	1547.236	V-Shaped
2	443879.76	4543844.396	1546.6	Back to Back
3	443752.954	4543932.652	1548.533	-
4	443624.348	4544012.301	1546.42	-
5	443452.831	4544161.409	1546.398	V-Shaped

Table 4. Billboard Faces on I-84

NUMBE R	LONGITUDE	LATITUDE	ALTITUDE	WIDTH	HEIGHT	HEIGHT_ABOVE_ PAVEMENT	DISTANCE_FROM_ PAVEMENT
1	444050.003	4543727.747	1556.446	15.177	5.334	3.568	17.73
2	444046.5261	4543730.267	1556.3627	15.177	5.334	3.568	17.73
3	443877.199	4543839.663	1552.051	14.955	5.335	2.667	18.0628
4	443877.0192	4543840.21	1552.0289	14.955	5.335	2.667	18.0628

5	443751.372	4543921.445	1552.585	15.8177	5.277	4.179	16.97
6	443619.411	4544007.001	1555.272	14.228	5.43	7.993	10.0813
7	443617.0098	4544008.73	1555.2989	14.228	5.43	7.993	10.0813
8	443450.073	4544149.901	1554.498	14.7203	5.274	7.7	11.978
9	443449.772	4544150.153	1554.5153	14.7203	5.274	7.7	11.978

Table 5. Road Lights on I-84

NUMBER	LONGITUDE	LATITUDE	ALTITUDE	HEIGHT_FROM_BASE
1	455204.132	4545243.017	1604.747	13.086
2	455118.517	4545280.711	1604.592	13.353
3	455051.846	4545298.027	1604.351	13.572
4	454676.983	4545364.277	1605.315	13.197
5	454622.135	4545418.263	1604.472	13.221
6	454576.975	4545466.211	1604.687	13.185
7	443693.433	4543945.062	1551.975	13.21
8	443634.344	4543987.844	1554.657	12.065
9	443374.453	4544194.576	1552.513	12.161
10	443298.2498	4544132.974	1547.1162	11.814
11	443255.052	4544113.004	1544.21	13.225
12	443221.852	4544077.404	1552.152	14.523
13	442864.975	4544403.977	1544.316	12.693
14	442812.194	4544435.247	1552.529	12.735
15	436198.748	4551539.324	1514.361	11.263
16	436135.875	4551575.905	1509.991	11.573
17	436078.294	4551624.14	1514.183	11.914
18	435836.975	4551829.711	1506.785	12.216
19	435803.482	4551848.255	1504.375	11.934

Table 6. Bridges and Culverts on I-84

NUMBER	TYPE	START_ACCUM	END_ACCUM	HEIGHT	SPAN	WIDTH	BEGIN_LAT	BEGIN_LONG	BEGIN_ELEV	END_LAT	END_LONG	END_ELEV
1	OVERPASS	112.738051	112.759327	7.458	112.33728	29.728	4543837.857	456013.39	1615.2442	4543807.295	456041.2993	1614.6069
2	OVERPASS	111.3	111.336776	7.1	194.17728	28.15	4545485.881	454596.2662	1604.6043	4545450.803	454635.2307	1605.1649
3	OVERPASS	110.856646	110.9	5.015	228.90912	38.029	4545968.178	454078.4308	1599.1137	4545926.997	454118.1159	1598.1241
4	BRIDGE OVER RIVER	109.491193	109.668725	5.308	937.36896	29.978	4545759.651	451983.2892	1590.252	4545802.8	452266.3427	1592.9538
5	OVERPASS	108.685683	108.755635	10.286	369.34656	10.084	4545482.417	450771.1853	1593.4483	4545444.824	450861.2092	1592.5591
6	OVERPASS	108.685683	108.755635	10.286	369.34656	10.084	4545472.878	450741.5332	1593.8113	4545438.737	450836.9632	1593.295
7	OVERPASS	108.267254	108.290972	7.037	125.23104	11.5747	4545329.604	450205.2027	1585.6771	4545365.496	450213.0106	1586.3882
8	OVERPASS	108.267254	108.290972	7.037	125.23104	11.5747	4545324.168	450229.9558	1585.2272	4545363.107	450238.3209	1585.36
9	BRIDGE OVER RIVER	107.7	107.74505	9.071	237.864	12.316	4544826.54	449685.394	1580.4819	4544813.084	449753.5083	1580.6844
10	BRIDGE OVER RIVER	107.7	107.74505	9.071	237.864	12.316	4544854.896	449670.9516	1580.2419	4544842.82	449736.3242	1580.6335
11	BRIDGE OVER RIVER	107.309904	107.345696	9.376	188.98176	14.494	4544489.214	449198.6665	1577.8332	4544533.399	449229.8578	1578.8718
12	BRIDGE OVER RIVER	107.309904	107.345696	9.376	188.98176	14.494	4544516.374	449184.8802	1576.7185	4544562.579	449216.6009	1577.9456
13	OVERPASS	106.168584	106.189361	5.918	109.70256	12.649	4544603.388	447461.6331	1569.4241	4544602.444	447495.6446	1569.2054
14	OVERPASS	106.168584	106.189361	5.918	109.70256	12.649	4544637.018	447461.8674	1569.3731	4544636.796	447498.3387	1569.282
15	OVERPASS	103.9	103.926688	6.915	140.91264	12.233	4543668.324	444106.0026	1553.2174	4543693.232	444068.859	1553.2549

16	OVERPASS	103.9	103.926688	6.915	140.91264	12.233	4543641.911	444087.1123	1552.4108	4543665.894	444050.337	1552.1324
17	OVERPASS	103.332263	103.360895	6.481	151.17696	12.561	4544187.502	443304.825	1550.2604	4544165.379	443339.9612	1550.9411
18	OVERPASS	103.332263	103.360895	6.481	151.17696	12.561	4544162.842	443282.4602	1549.7599	4544138.687	443319.1618	1549.4611
19	OVERPASS	102.284873	102.306027	5.612	111.69312	12.582	4545077.24	441870.9944	1543.0492	4545062.51	441892.2129	1542.324
20	OVERPASS	102.284873	102.306027	5.612	111.69312	12.582	4545048.664	441853.538	1543.0527	4545035.111	441875.0169	1542.3289
21	UNDERPASS	100.97299	100.980419	8.268	342.778	12.149	4546400.258	440250.923	1534.5541	4546347.206	440163.2639	1535.1178
22	OVERPASS	100.438161	100.453583	5.815	81.42816	12.073	4547076.084	439708.1327	1526.7367	4547056.818	439724.1401	1526.1579
23	OVERPASS	100.438161	100.453583	5.815	81.42816	12.073	4547055.908	439681.5645	1526.1873	4547036.109	439697.3024	1526.1559
24	OVERPASS	98.21824	98.234313	5.549	84.86544	11.998	4550002.029	437690.3311	1508.5463	4549981.582	437700.5639	1507.7904
25	OVERPASS	98.21824	98.234313	5.549	84.86544	11.998	4549987.338	437660.4806	1507.8234	4549965.488	437671.9828	1508.1958
26	OVERPASS	96.51145	96.53981	8.53	149.7408	12.398	4551879.99	435857.0395	1512.4253	4551836.565	435871.9606	1513.1894
27	OVERPASS	96.51145	96.53981	7.608	149.7408	12.398	4551888.475	435889.337	1510.8859	4551850.343	435902.1854	1511.3

US-191 Data

Table 7. Billboard Assemblies on US-191

NUMBER	LONGITUDE	LATITUDE	ALTITUDE	BILLBOARD_TYPE
1	642033.956	4236430.163	1833.155	V-Shaped

Table 8. Billboard Faces on US-191

NUMBER	LONGITUDE	LATITUDE	ALTITUDE	WIDTH	HEIGHT	HEIGHT_ABOVE_PAVEMENT	DISTANCE_FROM_PAVEMENT
1	642033.956	4236430.163	1833.155	3	1.5	1.892	23.47
2	642033.956	4236430.163	1833.155	3	1.5	1.892	23.47

Table 9. Bridges and Culverts on US-191

NUMBER	TYPE	START_ ACCUM	END_ACCUM	HEIGHT	SPAN	WIDTH	BEGIN_ LAT	BEGIN_ LONG	BEGIN_ ELEV	END_ LAT	END_ LONG	END_ ELEV
1	CULVERT	84.954011	84.966797	5.096	67.51008	24.952	4213522.602	645287.6036	1833.8429	4213551.416	645306.5437	1833.1317
2	CULVERT	96.771026	96.77445	9.557	18.07872	41.05	4231958.217	642219.6258	1740.7995	4231958.217	642219.6258	1740.7995
3	CULVERT	103.047735	103.062444	5.872	77.66352	58.895	4240860.575	640044.6917	1800.5685	4240862.933	639984.6631	1800.0111
4	CULVERT	107.217808	107.230437	8.298	66.68112	58.968	4246287.213	636743.4018	1655.964	4246259.056	636794.647	1657.9675
5	CULVERT	109.30843	109.318238	8.171	51.78624	35.879	4248930.346	635063.5059	1548.3988	4248948.897	635094.9854	1549.3441
6	OVERPASS	110.6	110.639866	6.113	210.49248	18.331	4250873.578	635219.7359	1562.8124	4250911.702	635241.6131	1564.1407

I-15 North Data

Table 10. Overhead Sign Assemblies on I-15 North

NUMBER	MOUNT_OFFSET	SIGN_POSIT	BEGIN_LONGITUDE	BEGIN_LATITUDE	BEGIN_ALTITUDE
1	8.34	OVERHEAD	4480948.068	423282.532	1422.027
2	7.58	OVERHEAD	4484602.232	424467.3181	1357.8706
3	1.08	OVERHEAD	4484602.435	424499.2437	1354.8211
4	1.48	SIGN	4485287.359	424532.3173	1357.421025
5	2.13	SIGN	4484846.179	424472.6254	1355.582225
6	2.57	SIGN	4484919.537	424530.7077	1354.135325
7	2.13	SIGN	4485287.359	424532.3173	1357.421025
8	2.33	OVERHEAD	4485395.062	424475.6759	1356.966125
9	1.69	OVERHEAD	4485724.34	424478.6804	1355.926825
10	1.35	OVERHEAD	4485723.85	424509.5146	1355.985825
11	0.864	OVERHEAD	4486055.762	424514.718	1352.461625
12	0.653	OVERHEAD	4486072.561	424545.5509	1355.362225
13	1.058	SIGN	4486464.53	424546.2686	1358.457525
14	1.951	SIGN	4486682.401	424546.5284	1357.939593
15	4.02	SIGN	4486966.312	424451.7952	1351.949325
16	1.911	OVERHEAD	4487128.851	424440.9646	1354.795725
17	0.73	OVERHEAD	4487163.645	424467.271	1352.131593
18	4.15	SIGN	4487003.098	424449.7135	1351.673425
19	3.86	SIGN	4487316.172	424406.9177	1350.941025
20	3.73	SIGN	4487380.891	424464.9889	1353.631725
21	4.15	SIGN	4487551.472	424368.5861	1352.641493
22	0.75	OVERHEAD	4487550.075	424403.1434	1354.829025
23	2.61	SIGN	4487607.017	424426.7619	1352.663225
24	1.28	SIGN	4487757.054	424400.5378	1354.566793
25	2.01	OVERHEAD	4487880.655	424313.4657	1356.212593
26	0.85	SIGN	4487942.503	424336.1789	1355.502193
27	0.95	OVERHEAD	4487978.072	424330.0579	1358.388325
28	1.27	OVERHEAD	4487999.111	424359.9334	1359.465693

29	1.75	SIGN	4488444.531695,	424221.2755	1359.422793
30	3.02	SIGN	4488676.553	424181.1207	1354.787693
31	2.22	OVERHEAD	4489114.747	424171.2353	1345.793093
32	1.63	OVERHEAD	4489141.992	424131.6975	1345.502493
33	2.09	OVERHEAD	4489205.747	424088.144	1348.375793
34	1.15	OVERHEAD	4489405.079	424087.0124	1341.131593
35	1.93	SIGN	4489593.655	424017.9329	1339.861193
36	2.71	OVERHEAD	4489696.363	423999.6637	1339.449393
37	1	OVERHEAD	4489703.075	424035.4431	1340.120593
38	2.41	OVERHEAD	4489708.924	424068.1679	1341.952893
39	2.22	SIGN	4490124.05	423933.5696	1336.402493
40	0.96	SIGN	4490275.836	423909.2029	1337.791393
41	2.86	OVERHEAD	4490741.398	423843.6084	1343.45233
42	0.635	OVERHEAD	4490744.884	423874.5634	1343.299593
43	1.11	OVERHEAD	4490928.403	423854.7193	1341.29383
44	1.27	SIGN	4491140.042	423805.8855	1341.45443
45	0.95	SIGN	4491267.48	423828.9164	1347.401093
46	1.74	OVERHEAD	4491713.827	423779.283	1343.91813
47	0.809	OVERHEAD	4491718.827	423810.9128	1344.02273
48	0.952	OVERHEAD	4491719.583	423841.6527	1343.42673
49	1.46	OVERHEAD	4491984.726	423841.6434	1347.30833
50	1.9	OVERHEAD	4492786.878	423823.6736	1340.26133
51	1.3	OVERHEAD	4492788.472	423854.3726	1342.51753
52	1.85	OVERHEAD	4494010.903	423597.0804	1337.89203
53	0.95	OVERHEAD	4494275.777	423620.5138	1334.29833
54	0.836	OVERHEAD	4494272.314	423589.8425	1332.78633
55	1.61	SIGN	4494320.245	423548.4309	1333.07243
56	2.12	OVERHEAD	4494717.311	423494.2591	1334.67553
57	1.36	SIGN	4494709.084	423530.8939	1334.43653
58	1.34	OVERHEAD	4494965.85	423462.2018	1336.63653
59	1.06	OVERHEAD	4494970.07	423495.4633	1334.13203

60	0.26	OVERHEAD	4495306.167	423449.6286	1335.03953
61	1.61	OVERHEAD	4495310.112	423480.0104	1336.92723
62	1.06	SIGN	4495492.766	423423.8576	1336.95383
63	1.54	OVERHEAD	4495839.652	423377.3014	1338.80763
64	1.61	OVERHEAD	4495871.462	423372.7446	1338.74733
65	0.793	OVERHEAD	4495875.277	423403.3601	1341.85573
66	1.909	OVERHEAD	4496314.595	423355.9633	1337.22545
67	1.058	OVERHEAD	4496311.966	423389.5521	1337.50235
68	1.18	OVERHEAD	4496630.876	423414.3144	1335.87953
69	2.13	OVERHEAD	4496621.505	423446.5992	1335.95283
70	3.19	OVERHEAD	4497358.626	423640.0693	1331.57425
71	3.52	OVERHEAD	4497353.504	423662.7699	1332.77494
72	8.51	OVERHEAD	4497653.673	423708.2108	1335.43784
73	1.74	OVERHEAD	4497652.121	423733.223	1335.93484
74	1.72	OVERHEAD	4497758.441	423608.4194	1335.80805
75	1.2	SIGN	4497880.443	423649.4859	1337.12775
76	3.65	OVERHEAD	4498041.352	423531.0898	1336.71685
77	0.8047	OVERHEAD	4498046.934	423550.0225	1336.503525
78	0.59	SIGN	4498110.402	423559.3966	1337.03974
79	1.36	OVERHEAD	4498114.746	423586.8578	1337.521125
80	1.54	SIGN	4498391.03	423454.0351	1329.969925
81	0.935	OVERHEAD	4498668.1	423443.1595	1326.74254
82	1.1974	SIGN	4498711.22	423506.5259	1322.932225
83	2.43	SIGN	4498900.82	423491.7039	1323.858025
84	1.255	OVERHEAD	4499273.25	423594.6688	1329.170925
85	0.953	OVERHEAD	4499267.523	423628.1905	1331.286125
86	0.545	OVERHEAD	4499436.131	423647.007	1330.670625
87	1.54	OVERHEAD	4499433.463	423677.43	1329.834625
88	0.714	SIGN	4499655.021	423666.0635	1326.425425
89	0.95	OVERHEAD	4499847.115	423652.2805	1321.494225
90	1.01	OVERHEAD	4499844.12	423682.8205	1323.479025

91	1.065	OVERHEAD	4500114.097	423706.1144	1319.228725
92	1.46	OVERHEAD	4500113.984	423740.148	1320.888225
93	1.76	OVERHEAD	4500499.267	423767.4551	1325.554925
94	1.59	SIGN	4500978.375	423809.7826	1322.249186
95	1.329	OVERHEAD	4501499.161	423777.08	1309.631986
96	1.329	OVERHEAD	4501498.942	423808.4601	1308.125825
97	0.664	SIGN	4501750.32	423809.5847	1307.041486
98	1.09	OVERHEAD	4501740.534	423839.0628	1307.735925
99	0.67	OVERHEAD	4501897.908	423809.4334	1307.122086
100	3.87	OVERHEAD	4501897.167	423840.4525	1307.002925
101	0.529	SIGN	4502168.016	423810.6672	1307.157086
102	1.59	OVERHEAD	4502174.705	423779.8022	1308.645186
103	0.953	OVERHEAD	4502174.562	423810.6075	1311.427886
104	1.63	OVERHEAD	4502397.444	423781.0162	1311.245386
105	0.836	OVERHEAD	4502486.87	423812.3366	1307.018586
106	1.928	OVERHEAD	4502487.322	423845.3485	1310.916286
107	1.911	OVERHEAD	4503133.648	423775.6366	1309.718286
108	2.06	OVERHEAD	4503558.649	423734.6108	1303.983286
109	0.245	OVERHEAD	4503561.909	423771.7967	1301.941886
110	0.653	SIGN	4503726.319	423759.0629	1298.141886
111	3.012	SIGN	4503961.707	423705.7532	1299.985386
112	1.28	OVERHEAD	4504170.741	423691.5795	1306.120786
113	1.453	OVERHEAD	4504249.795	423717.0151	1305.342486
114	1.912	OVERHEAD	4504252.224	423748.2628	1304.984186
115	0.502	OVERHEAD	4504432.107	423672.5383	1306.645086
116	1.04	OVERHEAD	4504434.378	423703.2082	1305.281786
117	0.856	OVERHEAD	4504595.608	423721.3576	1305.934786
118	1.04	SIGN	4504782.909	423676.673312,	1306.384686
119	1.15	OVERHEAD	4505117.791	423725.4624	1313.573654
120	2.48	OVERHEAD	4505109.136	423755.1645	1312.608586
121	1.905	OVERHEAD	4505136.359	423698.8916	1311.848986

122	4.19	SIGN	4506013.425	423764.8859	1299.521554
123	1.65	OVERHEAD	4506342.131	423627.6229	1302.680254
124	0.653	OVERHEAD	4506344.843	423661.1015	1300.775654
125	1.74	OVERHEAD	4506523.328	423691.0865	1300.112954
126	0.81	SIGN	4506691.147	423654.0049	1300.682754
127	0.65	SIGN	4506701.163	423653.6724	1297.424554
128	1.27	OVERHEAD	4506861.058	423650.8889	1304.155154
129	1.309	OVERHEAD	4506861.876	423681.246	1303.727454
130	1.77	OVERHEAD	4506930.19	423617.9103	1298.335354
131	0.798	OVERHEAD	4507240.314	423631.8587	1300.150154
132	1.28	OVERHEAD	4507242.477	423665.3218	1300.940854
133	2.249	OVERHEAD	4507540.625	423664.176	1299.929
134	2.447	OVERHEAD	4507569.731	423614.556	1302.756
135	1.984	OVERHEAD	4507571.377	423646.018	1299.882
136	1.29	OVERHEAD	4507789.4	423651.587	1303.164
137	1.06	OVERHEAD	4507790.523	423636.96	1308.604
138	1.011	OVERHEAD	4508121.615	423675.652	1315.631
139	1.751	OVERHEAD	4508118.451	423695.517	1317.66
140	3.531	OVERHEAD	4508254.636	423483.227	1306.653
141	3.563	OVERHEAD	4508256.063	423507.238	1307.8
142	1.275	OVERHEAD	4508400.185	423690.389	1311.024
143	1.748	OVERHEAD	4508401.593	423714.301	1310.913
144	1.825	OVERHEAD	4508625.136	423679.042	1306.334
145	1.19	OVERHEAD	4508625.026	423704.802	1306.893
146	1.292	OVERHEAD	4508623.037	423656.765	1302.922
147	1.693	OVERHEAD	4508622.409	423545.202	1300.846
148	2.366	OVERHEAD	4508617.632	423573.307	1299.1
149	2.328	OVERHEAD	4508713.269	423584.686	1304.442
150	1.27	OVERHEAD	4508713.884	423616.547	1299.614
151	1.998	OVERHEAD	4508833.265	423662.681	1308.797
152	1.191	OVERHEAD	4508835.01	423678.368	1308.848

153	1.852	OVERHEAD	4508979.705	423585.235	1293.127
154	1.595	OVERHEAD	4509221.342	423546.795	1292.996
155	1.906	OVERHEAD	4509220.726	423562.496	1293.284
156	0.667	OVERHEAD	4509291.476	423611.72	1294.373
157	2.675	OVERHEAD	4509348.67	423647.86	1300.861
158	2.05	OVERHEAD	4509349.993	423671.294	1295.736
159	1.905	OVERHEAD	4509455.432	423582.211	1304.444
160	0.635	OVERHEAD	4509455.838	423609.266	1298.059
161	1.706	OVERHEAD	4509483.851	423556.659	1303.473
162	2.971	OVERHEAD	4509483.88	423581.843	1296.15
163	2.116	OVERHEAD	4509804.101	423640.411	1304.66
164	2.116	OVERHEAD	4509800.928	423668.481	1299.307
165	0.906	SIGN	4509980.506	423621.887	1300.376
166	2.548	OVERHEAD	4510137.108	423677.66	1297.527
167	2.325	OVERHEAD	4510134.021	423704.548	1298.293
168	1.996	OVERHEAD	4510283.067	423593.884	1300.585
169	1.496	OVERHEAD	4510281.547	423616.823	1301.738
170	0.846	OVERHEAD	4510316.035	423647.306	1298.059
171	2.162	OVERHEAD	4510316.572	423676.79	1299.937
172	3.254	SIGN	4510582.648	423697.954	1299.248
173	0.648	OVERHEAD	4510590.415	423667.917	1300.234
174	1.951	OVERHEAD	4510588.313	423696.115	1299.357
175	3.048	SIGN	4510745.776	423689.699	1300.732
176	2.477	OVERHEAD	4510891.35	423546.801	1296.952
177	2.295	OVERHEAD	4510898.378	423563.783	1295.965
178	0.325	SIGN	4510984.218	423561.145	1302.415
179	3.268	OVERHEAD	4511165.673	423354.839	1307.085
180	0.952	OVERHEAD	4511190.48	423382.527	1308.73
181	0.355	OVERHEAD	4511259.51	423320.388	1307.866
182	2.918	OVERHEAD	4511283.376	423347.351	1309.815
183	3.195	SIGN	4511435.007	423140.097	1303.142

184	3.716	OVERHEAD	4511559.41	423092.808	1307.156
185	0.506	OVERHEAD	4511567.993	423128.934	1301.258
186	0.456	OVERHEAD	4511702.578	423102.727	1298.196
187	3.033	OVERHEAD	4511708.753	423141.822	1296.253
188	0.323	OVERHEAD	4511864.293	423077.079	1294.963
189	1.322	OVERHEAD	4511870.212	423106.251	1294.109
190	5.118	OVERHEAD	4511867.054	423039.66	1294.531
191	0.452	OVERHEAD	4512075.057	423004.991	1290.49
192	2.74	OVERHEAD	4512093.178	422957.554	1290.606

Table 11. Overhead Sign Faces on I-15 North

NUMBER	LENGTH	WIDTH	HEIGHT	BEGIN_LONGITUDE	BEGIN_LATITUDE	BEGIN_ALTITUDE
1	2.252	4.303	6.757	4484601.329	424492.698	1357.532
2	1.843	3.883	7.33	4484601.699	424506.057	1359.298
3	1.884	4.702	8.518	4484601.857	424478.844	1360.096
4	2.251	2.667	4.101	4484783.492	424530.519	1354.687
5	2.4	2.597	3.191	4484846.179	424472.194	1354.803
6	1.656	2.219	2.377	4484919.537	424530.708	1354.135
7	3.481	4.524	3.286	4485287.268	424535.043	1354.694
8	2.061	5.651	8.385	4485395.28	424488.692	1359.792
9	1.576	7.141	7.058	4485723.983	424501.565	1358.765
10	2.113	4.886	7.02	4486055.453	424521.842	1356.069
11	1.704	3.946	7.94	4486055.218	424506.56	1357.914
12	2.013	5.163	7.877	4486071.665	424535.888	1357.472
13	1.947	4.076	3.127	4486464.53	424546.269	1358.458
14	3.859	4.289	2.583	4486682.195	424545.651	1359.275
15	1.392	1.695	2.76	4486966.312	424451.795	1351.949
16	1.672	1.429	2.221	4487003.098	424449.713	1351.673
17	2.083	4.842	7.764	4487129.696	424451.462	1357.003
18	1.566	3.981	7.481	4487165.323	424475.223	1356.836
19	2.088	4.828	6.524	4487161.382	424460.799	1356.03

20	2.962	4.181	2.506	4487316.382	424407.997	1352.27
21	2.327	5.785	8.126	4487379.66	424451.973	1358.245
22	2.686	3.716	2.581	4487552.002	424369.449	1354.002
23	2.253	5.113	6.074	4487550.076	424405.658	1356.96
24	3.234	4.581	2.208	4487607.536	424430.028	1353.94
25	1.161	2.72	2.345	4487689.252	424345.507	1354.737
26	2.15	4.019	2.723	4487756.536	424399.773	1355.481
27	4.72	4.903	5.726	4487883.73	424325.506	1359.708
28	1.855	1.072	3.205	4487942.447	424336.306	1357.41
29	2.676	5.086	6.034	4487979.02	424337.298	1360.596
30	3.484	3.863	5.705	4487977.263	424322.455	1360.361
31	4.16	5.835	5.533	4487995.911	424346.989	1360.184
32	4.017	5.655	6.829	4489111.758	424160.136	1349.339
33	3.079	4.826	5.873	4489141.428	424124.09	1349.833
34	1.672	3.747	7.72	4489143.419	424139.579	1350.156
35	3.657	4.485	5.824	4489207.81	424099.9	1347.591
36	1.877	5.923	5.732	4489405.368	424089.78	1345.793
37	1.503	2.884	2.554	4489593.63	424017.857	1340.827
38	1.707	4.562	7.949	4489706.473	424056.373	1345.413
39	1.976	1.621	6.288	4489705.232	424041.964	1343.644
40	2.56	6.381	8.219	4489699.016	424014.228	1345.598
41	2.832	3.956	6.034	4490743.231	423866.515	1344.08
42	3.879	10.869	5.727	4490743.251	423858.769	1343.786
43	2.603	4.143	6.616	4490929.478	423862.891	1344.636
44	2.904	4.534	2.342	4491140.008	423806.303	1341.484
45	1.864	5.683	7.437	4491267.503	423831.638	1347.934
46	2.268	7.403	6.079	4491717.933	423829.63	1344.812
47	3.763	5.616	6.706	4491714.565	423788.774	1345.347
48	3.646	6.337	8.805	4491984.235	423831.001	1349.141
49	1.822	7.169	6.141	4492152.103	423809.712	1347.26
50	3.167	4.735	2.363	4492221.603	423847.367	1343.283

51	1.831	4.314	3.663	4492535.187	423786.341	1342.556
52	2.928	5.564	7.307	4492788.231	423843.058	1344.711
53	2.981	4.291	5.83	4492786.719	423830.248	1343.301
54	1.767	3.891	7.466	4492787.037	423816.473	1344.973
55	1.626	2.97	3.566	4493590.557	423816.254	1339.986
56	2.502	7.525	7.667	4494012.959	423611.605	1339.378
57	1.722	2.601	4.446	4494073.544	423653.002	1334.833
58	3.069	4.495	5.974	4494270.523	423584.08	1336.06
59	1.901	4.472	7.767	4494273.245	423602.642	1337.887
60	1.874	2.625	8.011	4494274.895	423610.458	1337.934
61	2.718	4.265	4.344	4494320.51	423550.105	1333.821
62	1.423	4.861	6.857	4494709.195	423533.473	1336.289
63	2.397	6.481	8.331	4494717.709	423509.465	1337.92
64	2.048	6.737	6.206	4494969.927	423484.077	1336.617
65	2.261	7.155	6.218	4495306.98	423467.982	1338.398
66	1.081	5.636	7.039	4495490.45	423426.985	1340.379
67	3.754	3.327	6.115	4495838.467	423369.432	1342.943
68	3.604	8.904	7.852	4495874.17	423393.771	1342.761
69	3.025	12.331	7.401	4495873.316	423385.637	1342.597
70	3.072	5.691	8.038	4496312.378	423387.031	1339.994
71	3.725	5.63	8.104	4496312.695	423381.794	1340.148
72	1.961	4.612	7.777	4496313.69	423371.529	1340.091
73	4.338	5.676	7.074	4496622.452	423442.851	1336.617
74	4.605	11.027	6.14	4496625.026	423433.785	1335.974
75	2.231	2.84	6.891	4497354.83	423654.547	1333.905
76	2.082	5.044	7.189	4497355.697	423650.617	1334.196
77	3.124	5.045	5.728	4497581.876	423593.562	1334.654
78	3.072	5.876	6.249	4497582.532	423586.518	1335.483
79	3.899	12.308	5.49	4497652.163	423728.796	1337.835
80	3.036	4.033	7.243	4497759.463	423616.687	1340.184
81	1.806	4.467	3.66	4497880.443	423649.486	1337.128

82	2.801	6.448	2.234	4497902.137	423718.562	1338.5
83	2.009	5.668	6.732	4498046.515	423546.1	1339.261
84	2.117	4.15	6.949	4498044.171	423538.867	1339.317
85	2.356	5.142	7.225	4498129.173	423692.118	1346.912
86	1.728	4.65	7.643	4498129.903	423685.72	1347.534
87	4.227	3.92	5.523	4498111.8	423578.693	1338.581
88	2.354	5.367	6.373	4498107.892	423563.444	1339.324
89	4.016	4.292	6.572	4498667.429	423451.748	1329.095
90	3.228	4.585	2.16	4498711.118	423505.997	1323.645
91	2.164	4.371	2.596	4498900.857	423492.219	1326.037
92	2.851	3.608	7.956	4499269.158	423617.82	1333.015
93	3.447	12.332	8.088	4499270.556	423609.757	1332.915
94	2.831	6.402	7.474	4499433.598	423669.733	1333.021
95	2.152	3.17	7.927	4499435.094	423652.619	1333.032
96	2.281	6.791	7.912	4499468.067	423622.298	1332.758
97	2.616	5.366	5.655	4499654.955	423668.884	1328.462
98	3.432	9.335	6.703	4499845.952	423666.757	1324.954
99	3.003	3.142	7.132	4499844.932	423673.782	1325.583
100	1.826	4.26	2.1	4499848.406	423713.182	1319.886
101	1.578	1.759	7.557	4500114.46	423698.883	1324.098
102	2.9974	4.717	5.705	4500113.185	423712.55	1322.277
103	2.549	6.317	8.71	4500115.777	423729.433	1325.123
104	2.293	4.591	8.576	4500500.567	423757.419	1331.13
105	2.183	2.743	4.236	4500978.38	423809.519	1324.237
106	3.08	4.904	5.908	4501498.849	423801.741	1308.938
107	3.268	4.961	6.474	4501499.401	423797.213	1309.534
108	1.823	6.291	7.857	4501498.814	423787.937	1310.659
109	3.978	6.302	6.582	4501740.689	423829.243	1307.405
110	1.322	5.462	7.288	4501750.106	423811.944	1308.247
111	2.461	7.204	5.73	4501896.164	423820.641	1308.845
112	1.103	5.85	7.21	4502167.738	423813.479	1313.314

113	2.205	7.465	6.173	4502174.469	423799.538	1313.694
114	1.948	6.524	8.263	4502398.107	423792.143	1313.785
115	2.284	6.369	8.348	4502487.189	423834.855	1312.473
116	3.465	14.319	5.513	4502486.96	423818.326	1310.068
117	2.287	4.815	8.204	4503133.916	423784.877	1312.623
118	2.495	5.404	8.1	4503559.742	423745.369	1306.792
119	3.141	4.973	5.636	4503560.363	423762.107	1304.522
120	1.509	3.529	7.7	4503562.094	423779.99	1306.535
121	2.551	8.442	6.814	4503726.872	423763.361	1304.007
122	2.172	5.807	8.039	4504172.005	423702.456	1307.706
123	2.149	6.966	6.319	4504250.552	423735.624	1306.334
124	2.204	6.937	6.076	4504434.96	423689.983	1307.315
125	2.553	6.41	8.52	4504594.741	423709.976	1310.358
126	1.947	5.078	7.061	4504783.382	423679.306	1310.299
127	2.97	4.772	6.136	4505116.287	423731.812	1312.715
128	2.606	4.232	7.228	4505113.276	423739.312	1313.789
129	3.25	6.265	6.528	4505110.296	423749.661	1313.071
130	2.06	4.729	7.347	4505133.86	423707.586	1314.109
131	2.596	6.415	2.292	4506012.5	423762.309	1301.197
132	3.229	6.315	6.646	4506343.061	423634.131	1302.055
133	4.42	4.278	6.019	4506343.566	423656.51	1300.151
134	2.359	4.38	8.455	4506523.167	423681.962	1303.124
135	2.097	8.333	6.861	4506690.712	423657.997	1302.404
136	1.881	4.864	7.215	4506700.91	423656.255	1302.703
137	4.259	5.858	7.155	4506861.81	423676.297	1302.19
138	3.861	8.311	6.928	4506861.607	423666.135	1302.251
139	2.142	5.148	8.292	4506929.958	423629.227	1303.058
140	2.571	4.281	8.268	4507242.316	423661.901	1301.357
141	2.501	3.899	8.268	4507242.07	423656.721	1301.32
142	2.362	7.361	8.06	4507241.156	423649.455	1301.426
143	2.115	4.295	7.971	4507541.002	423655.493	1302.388

144	2.452	3.428	8.215	4507570.975	423640.565	1304.177
145	3.31	4.911	6.805	4507570.886	423637.114	1304.182
146	1.341	5.022	8.897	4507789.972	423644.434	1308.964
147	1.684	5.606	6.535	4508013.676	423609.567	1307.878
148	1.54	3.104	7.456	4508119.239	423691.78	1315.753
149	1.109	3.752	7.579	4508119.793	423687.64	1315.798
150	3.697	5.612	7.332	4508120.405	423683.413	1315.842
151	1.447	1.897	7.398	4508255.835	423500.524	1313.676
152	1.287	1.964	7.666	4508255.269	423492.123	1313.809
153	2.163	3.695	6.97	4508401.564	423710.829	1309.457
154	1.082	4.883	7.09	4508401.119	423703.072	1309.449
155	3.846	3.658	7.03	4508400.605	423696.586	1309.455
156	1.833	3.687	8.107	4508623.518	423647.706	1306.088
157	2.122	4.316	7.846	4508618.909	423570.695	1306.95
158	1.415	3.405	8.039	4508619.787	423564.29	1307.102
159	2.507	13.21	7.286	4508714.069	423606.043	1304.62
160	1.331	2.093	6.828	4508834.181	423674.271	1308.868
161	4.079	3.299	7.085	4508834.493	423669.086	1310.399
162	1.712	2.747	7.851	4509220.89	423557.922	1298.817
163	2.074	3.425	5.026	4509291.507	423617.682	1296.758
164	1.563	2.476	8.478	4509349.301	423664.664	1300.52
165	1.623	2.129	8.658	4509348.986	423659.655	1300.545
166	2.766	4.943	8.899	4509348.606	423653.812	1300.877
167	4.214	5.52	6.159	4509456.055	423599.357	1301.268
168	4.053	4.812	7.011	4509484.192	423575.209	1304.377
169	3.615	3.521	7.066	4509484.183	423568.871	1301.74
170	2.26	2.119	6.352	4509802.463	423655.827	1302.113
171	2.932	5.765	6.596	4509802.48	423654.967	1302.125
172	4.642	4.01	7.085	4509803.063	423648.805	1303.016
173	2.338	5.833	6.486	4509980.577	423619.645	1300.382
174	2.522	2.749	6.196	4510134.788	423694.407	1298.072

175	1.426	3.195	7.402	4510136.517	423685.315	1299.501
176	3.911	4.764	6.98	4510281.619	423614.408	1300.558
177	4.393	9.549	7.1	4510282.075	423607.742	1300.564
178	2.746	3.98	5.96	4510316.989	423669.013	1299.779
179	3.415	3.911	5.424	4510317.498	423661.705	1299.516
180	3.147	3.393	5.625	4510318.108	423653.815	1299.729
181	1.817	4.894	2.357	4510582.823	423695.07	1300.061
182	2.469	7.293	5.814	4510587.589	423685.453	1303.193
183	3.266	4.19	5.735	4510589.911	423661.08	1303.222
184	4.498	5.511	6.11	4510897.09	423560.773	1301.236
185	1.358	3.352	7.044	4510894.15	423554.397	1301.142
186	2.95	6.106	6.922	4510987.185	423562.32	1305.259
187	4.383	5.339	6.538	4511172.583	423362.243	1306.694
188	2.972	4.088	7.058	4511176.358	423366.789	1307.18
189	2.798	7.31	7.821	4511277.072	423340.163	1307.924
190	3.815	4.332	7.63	4511269.538	423331.793	1307.949
191	3.561	3.868	7.439	4511263.535	423325.026	1307.921
192	2.421	6.466	2.666	4511435.561	423141.641	1303.172
193	5.568	5.971	6.032	4511562.905	423103.238	1304.472
194	2.037	3.307	8.717	4511569.247	423123.8833	1305.8077
195	2.458	7.929	6.977	4511707.498	423134.539	1301.6
196	4.44	4.24	7.057	4511705.802	423124.307	1302.066
197	3.226	6.833	7.559	4511870.545	423051.027	1299.667
198	4.428	5.885	6.553	4511868.756	423101.473	1299.347
199	2.427	7.329	5.908	4512099.823	422970.43	1294.565
200	3.29	5.076	2.431	4510745.27	423687.321	1301.013

Table 12. Billboard Assemblies on I-15 North

NUMBER	BEGIN_LATI	BEGIN_LONG	BEGIN_ALTI	BILLBOARD_TYPE
1	4476601.737	423926.901	1412.673	
2	4476935.208	423854.734	1418.803	

3	4477035.416	423746.741	1417.84	
4	4477145.795	423632.331	1412.886	
5	4477098.195	423484.22	1409.626	
6	4477331.249	423428.476	1419.136	
7	4477241.776	423298.353	1410.255	V-shaped
8	4477610.731	422867.252	1412.837	V-shaped
9	4478929.135	422411.618	1460.021	
10	4479107.285	422384.093	1456.3195	
11	4479280.25	422391.708	1455.1476	
12	4480357.732	422834.778	1432.4419	
13	4480489.569	422904.229	1426.3956	
14	4480625.243	422979.955	1421.6217	
15	4480759.928	423051.237	1418.6687	
16	4480844.187	423323.194	1431.9875	
17	4480927.339	423109.269	1411.7456	
18	4482506.289	424419.968	1380.8191	V-shaped
19	4482826.37	424539.004	1366.504	
20	4482974.45	424545.682	1362.4999	
21	4483241.169	424550.036	1357.5889	
22	4483589.164	424542.745	1352.8801	
23	4484952.933	424437.294	1350.5917	V-shaped
24	4485172.359	424566.858	1350.811	
25	4485327.052	424563.935	1351.0752	
26	4485567.641	424442.906	1349.6727	V-shaped
27	4485608.493	424565.447	1351.1104	
28	4485854.108	424561.797	1350.1799	
29	4486016.596	424568.054	1349.4376	V-shaped
30	4487155.614	424558.183	1348.1436	
31	4487954.418	424388.102	1361.1138	
32	4488261.442	424345.472	1355.9277	
33	4491405.392	423775.167	1334.6181	V-shaped

34	4491555.045	423773.141	1335.0349	V-shaped
35	4491707.674	423763.454	1337.5404	
36	4491719.126	423765.946	1337.4477	
37	4491930.692	423731.846	1344.2056	
38	4492085.704	423738.663	1340.4986	
39	4492282.901	423887.067	1343.7833	V-shaped
40	4494182.608	423540.231	1331.6635	
41	4494572.136	423470.729	1327.6483	
42	4494786.501	423439.021	1328.1993	
43	4495536.543	423345.45	1327.9759	V-shaped
44	4495691.862	423324.259	1328.7772	V-shaped
45	4495779.343	423432.835	1332.2701	
46	4495769.103	423320.486	1329.2672	V-shaped
47	4495842.826	423301.008	1330.9214	V-shaped
48	4495991.787	423408.398	1332.9071	
49	4496050.218	423248.565	1330.8404	
50	4499079.786	423646.622	1319.9697	
51	4499232.163	423676.8	1319.6957	V-shaped
52	4499434.556	423701.016	1319.2494	V-shaped
53	4499830.359	423768.093	1314.6741	V-shaped
54	4500078.249	423791.519	1313.6319	V-shaped
55	4501570.371	423855.114	1308.0353	
56	4501606.292	423758.796	1302.4337	
57	4501727.368	423864.47	1302.5088	V-shaped
58	4501801.933	423724.891	1300.3236	
59	4501950.89	423855.695	1298.3753	V-Shaped
60	4502000.564	423859.225	1298.6478	
61	4502151.693	423861.418	1299.3657	
62	4502320.588	423863.953	1307.2624	
63	4502382.917	423864.367	1307.0951	
64	4502382.611	423758.173	1298.6942	

65	4502476.457	423862.391	1305.6785	
66	4502880.865	423875.806	1297.7074	
67	4503351.921	423837.599	1304.618	
68	4503382.229	423836.907	1301.3356	
69	4503621.763	423723.594	1297.2362	V-shaped
70	4503751.652	423806.126	1295.6301	V-shaped
71	4503772.219	423687.17	1295.6449	
72	4503918.931	423790.14	1298.0538	
73	4503961.494	423691.135	1304.5679	
74	4504057.382	423779.454	1298.58	V-shaped
75	4504057.386	423688.886	1301.1261	
76	4504162.033	423764.718	1301.3717	
77	4504168.582	423680.054	1301.5721	V-shaped
78	4504211.666	423761.359	1300.8324	
79	4504423.928	423751.471	1300.2198	
80	4504417.493	423663.857	1301.3016	
81	4504576.938	423739.619	1299.228	
82	4504592.718	423645.963	1298.9524	
83	4504757.107	423750.072	1299.4454	
84	4504774.649	423631.322	1297.2918	
85	4504835.811	423631.219	1297.3671	
86	4504919.66	423743.887	1299.7767	V-shaped
87	4504940.176	423644.698	1296.8334	V-shaped
88	4505057.782	423771.449	1297.9565	V-shaped
89	4505098.948	423671.291	1296.9682	V-shaped
90	4505198.209	423697.56	1296.2185	V-shaped
91	4505234.462	423818.85	1295.6036	V-shaped
92	4505362.348	423852.907	1295.3425	
93	4505414.161	423870.23	1295.1981	
94	4505977.056	423822.605	1293.091	
95	4506311.603	423581.805	1293.4647	V-shaped

96	4506464.013	423614.419	1293.3597	V-shaped
97	4506553.194	423713.978	1294.5738	V-shaped
98	4506568.469	423559.362	1293.2103	
99	4506708.137	423704.592	1294.4423	V-shaped
100	4506708.231	423699.682	1294.7983	
101	4506724.601	423580.572	1293.1397	
102	4506860.858	423699.985	1293.1323	
103	4506896.717	423603.829	1292.5039	
104	4507018.328	423710.344	1293.2094	
105	4507051.916	423602.17	1291.7142	
106	4507222.82	423697.158	1292.8245	
107	4507226.099	423590.443	1291.9764	
108	4507281.592	423689.439	1292.1033	
109	4507281.234	423580.331	1291.2628	
110	4507489.194	423693.406	1291.5695	
111	4507469.397	423529.659	1291.5552	
112	4509208.63	423689.571	1290.3575	
113	4509381.031	423687.965	1289.4793	
114	4509541.157	423703.286	1288.6962	V-shaped
115	4509800.312	423681.367	1288.8669	
116	4509958.331	423694.171	1289.4408	V-shaped
117	4510733.292	423767.931	1289.6731	
118	4510877.982	423727.966	1289.0579	
119	4511112.126	423683.703	1289.0097	
120	4511106.335	423530.742	1289.0254	
121	4511323.217	423340.572	1288.4986	V-Shaped
122	4511277.616	423225.731	1289.2037	
123	4511446.843	423227.416	1289.8265	
124	4511460.442	423096.563	1288.6593	

Table 13. Billboard Faces on I-15 North

NUMBER	BEGIN_LATI	BEGIN_LONG	BEGIN_ALTI	WIDTH	HEIGHT	HEIGHT_ABOVE_PAVEMENT	DISTANCE_FROM_PAVEMENT
1	4476609.333	423931.105	1417.24	15	5.34	1.647	25.673
2	4476604.96	423933.6123	1417.289	15	5.34	1.647	25.673
3	4476927.956	423851.113	1422.001	14.119	5.268	6.18	49.28
4	4476927.956	423851.1125	1422.0013	14.119	5.268	6.18	49.28
5	4477030.6	423741.683	1420.897	14.318	5.346	5.928	44.585
6	4477033.399	423739.4031	1420.8331	14.318	5.346	5.928	44.585
7	4477138.077	423629.444	1416.314	14.092	5.308	2.245	43.449
8	4477140.552	423627.179	1416.2809	14.092	5.308	2.245	43.449
9	4477108.021	423484.568	1423.461	14.52	5.323	9.243	32.838
10	4477107.641	423484.742	1423.4763	14.52	5.323	9.243	32.838
11	4477322.172	423426.929	1421.701	13.776	5.342	4.259	36.022
12	4477324.455	423424.4053	1421.6317	13.776	5.342	4.259	36.022
13	4477248.222	423303.259	1427.808	14.409	5.254	9.8	56.017
14	4477247.936	423303.5517	1427.8246	14.409	5.254	9.8	56.017
15	4477614.794	422876.02	1439.272	13.012	5.354	3.985	75.893
16	4477614.058	422876.4749	1439.2903	13.012	5.354	3.985	75.893
17	4478930.125	422412.781	1465.651	14.568	5.315	4.341	29.506
18	4478925.568	422412.6414	1465.7575	14.568	5.315	4.341	29.506
19	4479105.803	422395.094	1462.421	14.097	5.22	1.547	41.675
20	4479105.803	422395.0944	1462.4206	14.097	5.22	1.547	41.675
21	4479281.323	422399.438	1463.04	15.603	5.284	3.508	48.603
22	4479277.844	422398.9703	1462.9554	15.603	5.284	3.508	48.603
23	4480351.707	422841.903	1440.531	14.612	5.411	0.429	37.829
24	4480351.096	422841.5877	1440.5052	14.612	5.411	0.429	37.829
25	4480485.119	422913.237	1437.025	14.065	5.17	0.713	42.709
26	4480483.204	422911.9146	1437.0113	14.065	5.17	0.713	42.709
27	4480618.889	422986.583	1433.907	15.135	5.103	1.91	38.158
28	4480618.889	422986.5829	1433.907	15.135	5.103	1.91	38.158
29	4480754.601	423061.07	1429.165	14.584	5.407	1.87	45.561

30	4480753.444	423059.3367	1429.1951	14.584	5.407	1.87	45.561
31	4480929.288	423110.911	1432.042	13.831	5.501	9.342	78.142
32	4480925.86	423108.5626	1431.9971	13.831	5.501	9.342	78.142
33	4480845.595	423320.321	1439.286	14.697	5.209	16.124	91.802
34	4482507.632	424412.752	1390.486	14.575	5.144	12.9	41.607
35	4482510.492	424414.3134	1390.3791	14.575	5.144	12.9	41.607
36	4482827.056	424532.643	1380.163	14.503	5.466	12.92	33.546
37	4482829.387	424533.5033	1380.1732	14.503	5.466	12.92	33.546
38	4482976.075	424538.111	1376.434	14.293	5.384	13.52	28.774
39	4482977.027	424538.2345	1376.517	14.293	5.384	13.52	28.774
40	4483241.585	424542.517	1371.582	14.599	5.424	14.041	30.694
41	4483241.585	424542.5166	1371.5816	14.599	5.424	14.041	30.694
42	4483588.863	424541.414	1359.598	8.856	3.965	5.424	21.498
43	4483588.863	424541.4141	1359.5983	8.856	3.965	5.424	21.498
44	4484951.322	424438.765	1361.067	13.727	5.03	9.458	38.246
45	4484951.322	424438.7649	1361.0666	13.727	5.03	9.458	38.246
46	4485172.367	424559.175	1355.589	14.229	5.255	3.923	28.682
47	4485172.367	424559.1748	1355.5892	14.229	5.255	3.923	28.682
48	4485326.391	424556.188	1355.597	14.6	5.167	7.181	24.542
49	4485326.738	424556.3067	1355.603	14.6	5.167	7.181	24.542
50	4485569.05	424446.587	1359.718	14.518	5.147	8.524	33.789
51	4485565.885	424446.5622	1359.745	14.518	5.147	8.524	33.789
52	4485608.446	424554.982	1362.885	14.328	5.262	11.885	16.62
53	4485609.35	424555.1361	1362.9826	14.328	5.262	11.885	16.62
54	4485855.013	424561.156	1364.573	14.002	5.205	13.979	19.122
55	4485855.013	424561.1563	1364.5729	14.002	5.205	13.979	19.122
56	4486014.443	424565.295	1363.919	14.496	5.495	13.939	20.359
57	4486017.606	424565.3678	1363.843	14.496	5.495	13.939	20.359
58	4487155.954	424553.822	1372.319	18.028	5.848	22.887	49.064
59	4487155.954	424553.8217	1372.3194	18.028	5.848	22.887	49.064
60	4487953.611	424387.412	1370.816	14.739	5.223	16.61	22.066

61	4487955.539	424387.54	1370.8337	14.739	5.223	16.61	22.066
62	4488259.815	424343.549	1369.833	14.431	5.275	13.728	32.988
63	4488263.014	424343.1431	1369.867	14.431	5.275	13.728	32.988
64	4491406.767	423780.1506	1345.8564	14.59	5.245	4.858	11.975
65	4491403.725	423780.5527	1345.8363	14.59	5.245	4.858	11.975
66	4491556.958	423776.2549	1344.9166	14.443	5.201	4.941	10.438
67	4491554.227	423776.1484	1344.9301	14.443	5.201	4.941	10.438
68	4491700.861	423762.1887	1342.7036	13.974	5.178	4.104	11.961
69	4491719.853	423769.7197	1344.422	6.766	2.943	5.904	11.917
70	4491933.159	423744.7159	1353.2465	14.976	5.276	13.19	34.081
71	4491928.649	423744.7254	1353.222	14.976	5.276	13.19	34.081
72	4492087.313	423746.2673	1347.7722	14.201	5.328	6.602	33.742
73	4492083.716	423746.0518	1347.7428	14.201	5.328	6.602	33.742
74	4492280.779	423882.2718	1355.2107	14.36	5.357	14.491	38.631
75	4492284.497	423882.3238	1355.2445	14.36	5.357	14.491	38.631
76	4494184.797	423542.3968	1340.6124	14.501	5.138	9.839	25.179
77	4494180.64	423543.7653	1340.5953	14.501	5.138	9.839	25.179
78	4494574.188	423477.8409	1337.1697	14.542	5.47	8.248	37.483
79	4494570.991	423478.2905	1337.1832	14.542	5.47	8.248	37.483
80	4494788.878	423446.7575	1338.776	14.792	4.847	9.389	40.369
81	4494785.819	423447.107	1338.8976	14.792	4.847	9.389	40.369
82	4495539.995	423351.8103	1342.1937	14.493	5.533	8.339	33.567
83	4495536.561	423352.1852	1341.7914	14.493	5.533	8.339	33.567
84	4495693.935	423330.644	1342.3397	14.286	5.101	8.221	33.157
85	4495690.149	423331.2497	1342.8363	14.286	5.101	8.221	33.157
86	4495770.084	423321.9208	1335.7866	7.354	3.893	0.881	32.179
87	4495768.094	423321.9172	1335.8007	7.354	3.893	0.881	32.179
88	4495777.981	423425.126	1343.314	14.235	5.021	8.694	10.254
89	4495781.176	423424.9681	1343.2275	14.235	5.021	8.694	10.254
90	4495843.683	423306.661	1347.0178	14.513	5.238	10.251	37.511
91	4495841.916	423307.2934	1345.6962	14.513	5.238	10.251	37.511

92	4495989.514	423400.4486	1345.1398	14.27	5.184	10.468	13.144
93	4495992.171	423400.2013	1345.2113	14.27	5.184	10.468	13.144
94	4496053.207	423253.9642	1345.7229	14.697	5.24	10.457	66.711
95	4496050.105	423254.8892	1345.7677	14.697	5.24	10.457	66.711
96	4499080.144	423644.8031	1329.9143	6.679	3.827	4.291	25.527
97	4499080.144	423644.8031	1329.9143	6.679	3.827	4.291	25.527
98	4499228.624	423673.0817	1340.2344	14.635	5.3	14.548	18.547
99	4499232.252	423673.7371	1340.2039	14.635	5.3	14.548	18.547
100	4499435.513	423694.9916	1337.2076	14.747	5.452	11.633	18.598
101	4499439.958	423695.1059	1337.294	14.747	5.452	11.633	18.598
102	4499829.933	423763.7574	1324.4393	13.598	5.3	6.255	52.465
103	4499833.339	423764.0117	1324.4334	13.598	5.3	6.255	52.465
104	4500076.513	423786.1107	1320.0181	13.548	5.443	4.026	52.121
105	4500080.024	423785.9967	1320.0218	13.548	5.443	4.026	52.121
106	4501569.386	423851.9042	1318.0954	14.72	3.835	16.84	11.708
107	4501571.6	423852.384	1318.1776	14.72	3.835	16.84	11.708
108	4501606.797	423765.4454	1314.5749	14.577	5.402	13.712	3.569
109	4501602.96	423764.8456	1314.6005	14.577	5.402	13.712	3.569
110	4501725.66	423856.3144	1323.1903	14.543	5.318	22.452	17.782
111	4501729.296	423856.2939	1323.1773	14.543	5.318	22.452	17.782
112	4501804.205	423731.6838	1320.2559	14.617	5.324	18.846	43.524
113	4501800.402	423731.5844	1320.2357	14.617	5.324	18.846	43.524
114	4501950.105	423850.9698	1308.8757	7.558	4.462	5.252	11.536
115	4501953.049	423851.2685	1308.8992	7.558	4.462	5.252	11.536
116	4501998.94	423852.2682	1314.9703	14.052	5.165	10.519	12.263
117	4502001.94	423852.3346	1314.9887	14.052	5.165	10.519	12.263
118	4502151.521	423851.5455	1307.2421	13.475	5.635	1.446	11.271
119	4502153.32	423851.3418	1308.0618	13.475	5.635	1.446	11.271
120	4502319.774	423857.5982	1313.1747	14.173	5.161	7.099	16.986
121	4502323.081	423857.8345	1313.2351	14.173	5.161	7.099	16.986
122	4502381.992	423858.8408	1313.5318	8.946	3.643	7.945	17.542

123	4502385.554	423858.9005	1313.5498	8.946	3.643	7.945	17.542
124	4502383.625	423765.9835	1314.6526	15.154	4.392	9.135	16.669
125	4502381.15	423766.1135	1314.7004	15.154	4.392	9.135	16.669
126	4502475.021	423859.3203	1312.542	8.962	3.858	8.04	15.528
127	4502477.476	423858.8387	1312.4749	8.962	3.858	8.04	15.528
128	4502878.708	423873.5708	1309.2671	7.007	3.596	4.713	33.934
129	4502882.653	423873.4493	1309.2992	7.007	3.596	4.713	33.934
130	4503350.523	423835.4623	1308.1124	6.88	3.772	6.421	4.847
131	4503352.1	423834.6988	1308.1334	6.88	3.772	6.421	4.847
132	4503380.51	423833.6559	1313.0144	6.601	3.174	11.744	7.588
133	4503383.774	423833.3211	1312.8991	6.601	3.174	11.744	7.588
134	4503623.606	423726.1117	1304.1567	7.092	4.34	6.354	7.422
135	4503621.024	423726.3819	1304.2176	7.092	4.34	6.354	7.422
136	4503749.383	423799.2512	1309.4145	14.328	5.369	12.224	14.388
137	4503753.096	423799.1962	1309.434	14.328	5.369	12.224	14.388
138	4503773.244	423691.2476	1305.3086	14.789	3.86	8.257	31.434
139	4503771.168	423691.4163	1305.2406	14.789	3.86	8.257	31.434
140	4503916.177	423783.5624	1308.2036	14.268	5.329	10.151	9.609
141	4503919.748	423783.2403	1308.1814	14.268	5.329	10.151	9.609
142	4503962.278	423691.2005	1309.395	14.36	5.056	10.967	17.545
143	4503959.581	423691.6087	1309.3669	14.36	5.056	10.967	17.545
144	4504054.669	423775.6397	1312.525	14.367	5.336	13.568	11.973
145	4504057.907	423775.3859	1312.577	14.367	5.336	13.568	11.973
146	4504058.608	423694.6461	1302.5902	9.793	3.994	3.687	7.051
147	4504055.8	423694.6092	1302.3419	9.793	3.994	3.687	7.051
148	4504160.237	423765.7038	1313.1437	11.963	4.124	13.517	9.939
149	4504164.181	423765.4319	1313.3034	11.963	4.124	13.517	9.939
150	4504170.254	423684.1947	1310.9569	14.427	5.241	11.301	9.408
151	4504166.174	423684.0038	1310.9464	14.427	5.241	11.301	9.408
152	4504209.684	423760.0626	1309.2577	14.505	5.14	9.387	10.085
153	4504212.246	423759.9417	1309.2717	14.505	5.14	9.387	10.085

154	4504424.552	423744.1787	1305.7393	14.353	5.241	4.907	11.916
155	4504420.88	423666.91	1304.4656	14.083	4.936	3.86	8.192
156	4504574.439	423733.9919	1308.973	14.29	5.139	7.248	12.485
157	4504577.584	423733.5552	1309.0152	14.29	5.139	7.248	12.485
158	4504593.476	423647.6407	1306.0791	14.76	5.515	4.29	13.253
159	4504590.684	423646.9257	1305.9273	14.76	5.515	4.29	13.253
160	4504754.935	423742.2954	1309.901	14.407	5.274	7.55	34.487
161	4504757.228	423742.0867	1309.9194	14.407	5.274	7.55	34.487
162	4504776.358	423638.3264	1307.2014	14.526	5.561	3.509	8.89
163	4504774.13	423639.3271	1307.2101	14.526	5.561	3.509	8.89
164	4504836.941	423634.4226	1307.7489	7.961	3.827	3.491	12.541
165	4504834.634	423634.6052	1307.7784	7.961	3.827	3.491	12.541
166	4504918.851	423737.3803	1314.5462	14.703	5.315	11.11	26.889
167	4504922.715	423737.7559	1314.4171	14.703	5.315	11.11	26.889
168	4504947.042	423646.5408	1313.3014	15.212	5.298	8.012	9.249
169	4504943.701	423646.0286	1313.4589	15.212	5.298	8.012	9.249
170	4505056.566	423763.4858	1315.6157	14.272	5.437	9.854	24.417
171	4505060.313	423764.197	1315.6355	14.272	5.437	9.854	24.417
172	4505098.096	423672.2868	1312.9412	14.458	5.432	6.509	16.955
173	4505097.449	423672.0664	1312.901	14.458	5.432	6.509	16.955
174	4505199.341	423697.7384	1309.5989	18.097	6.938	2.163	13.513
175	4505195.51	423697.0413	1309.5113	18.097	6.938	2.163	13.513
176	4505231.382	423818.7728	1317.6104	14.837	5.302	9.883	24.829
177	4505235.422	423818.417	1317.6094	14.837	5.302	9.883	24.829
178	4505360.118	423852.827	1317.1124	13.798	5.328	8.728	19.941
179	4505363.963	423853.8307	1317.072	13.798	5.328	8.728	19.941
180	4505414.372	423868.1737	1312.4613	4.451	2.643	4.261	30.234
181	4505414.856	423868.2732	1312.2364	4.451	2.643	4.261	30.234
182	4505976.936	423821.0777	1299.0667	7.384	3.974	2.206	6.749
183	4505976.936	423821.0777	1299.0667	7.384	3.974	2.206	6.749
184	4506247.177	423715.8134	1297.8266	10.767	4.217	2.684	5.855

185	4506249.105	423715.4015	1297.8172	10.767	4.217	2.684	5.855
186	4506322.337	423593.9704	1311.0644	14.649	5.668	15.327	35.873
187	4506317.761	423594.3129	1311.0844	14.649	5.668	15.327	35.873
188	4506466.118	423614.6198	1308.9582	14.557	5.564	14.055	14.817
189	4506461.354	423613.7524	1308.9789	14.557	5.564	14.055	14.817
190	4506551.23	423699.2894	1305.4738	14.338	5.53	10.56	11.712
191	4506555.476	423699.7542	1305.3176	14.338	5.53	10.56	11.712
192	4506570.229	423563.1061	1302.5844	6.986	4.405	7.696	63.913
193	4506566.724	423563.2586	1302.6575	6.986	4.405	7.696	63.913
194	4506706.349	423697.3691	1303.7622	13.902	4.619	8.5	13.828
195	4506709.954	423697.2403	1303.8129	13.902	4.619	8.5	13.828
196	4506706.41	423696.2764	1299.4224	6.97	3.925	4.139	10.914
197	4506709.567	423695.8954	1299.3856	6.97	3.925	4.139	10.914
198	4506724.992	423587.6211	1304.5535	14.613	5.394	9.295	37.361
199	4506722.304	423587.4825	1304.5668	14.613	5.394	9.295	37.361
200	4506858.781	423692.4994	1306.6774	14.678	5.533	11.662	11.925
201	4506861.983	423691.89	1306.7051	14.678	5.533	11.662	11.925
202	4506898.148	423605.1839	1301.0208	14.868	5.237	6.243	15.518
203	4506896.086	423605.4385	1302.4103	14.868	5.237	6.243	15.518
204	4507017.9	423703.5746	1305.87	14.268	5.218	11.671	29.104
205	4507021.34	423703.5769	1305.9416	14.268	5.218	11.671	29.104
206	4507053.361	423601.7673	1301.4709	14.146	5.287	6.184	8.826
207	4507050.86	423601.5418	1300.0672	14.146	5.287	6.184	8.826
208	4507221.56	423689.8295	1301.013	14.474	3.935	7.81	25.416
209	4507225.173	423591.6033	1299.9126	14.631	5.203	6.635	7.545
210	4507282.186	423581.5948	1297.5118	14.842	5.283	4.909	11.818
211	4507280.645	423687.9164	1295.1776	7.054	3.889	2.432	23.619
212	4507470.874	423528.7639	1300.8041	14.382	5.15	4.661	24.485
213	4507467.628	423530.4953	1300.8465	14.382	5.15	4.661	24.485
214	4507488.896	423692.7065	1295.4866	7.4	3.741	1.644	30.006
215	4509208.084	423689.376	1296.7186	14.398	5.166	6.038	16.486

216	4509209.2	423689.3395	1296.7707	14.398	5.166	6.038	16.486
217	4509381.247	423681.4268	1295.6926	14.372	5.001	3.357	13.869
218	4509382.454	423681.4442	1295.8209	14.372	5.001	3.357	13.869
219	4509540.055	423703.6541	1307.7505	14.545	5.187	12.151	45.879
220	4509543.875	423703.521	1307.7379	14.545	5.187	12.151	45.879
221	4509799.336	423680.1976	1300.9502	14.484	5.194	5.441	13.987
222	4509801.58	423680.5259	1301.0166	14.484	5.194	5.441	13.987
223	4509955.503	423690.7044	1302.559	13.87	5.368	8.772	7.852
224	4509959.751	423690.8639	1302.5119	13.87	5.368	8.772	7.852
225	4510730.34	423761.047	1313.4241	14.127	5.566	17.778	17.671
226	4510733.713	423760.2462	1313.5013	14.127	5.566	17.778	17.671
227	4510873.606	423721.7152	1311.3973	14.431	5.563	17.81	20.698
228	4510877.527	423720.4537	1311.3884	14.431	5.563	17.81	20.698
229	4511108.051	423677.6514	1310.9933	14.658	5.306	14.169	39.445
230	4511110.789	423676.3849	1311.0405	14.658	5.306	14.169	39.445
231	4511104.064	423531.0573	1309.2374	14.387	5.415	9.368	19.888
232	4511107.049	423527.5779	1309.1472	14.387	5.415	9.368	19.888
233	4511316.983	423336.4742	1307.1576	13.953	5.332	7.192	17.568
234	4511319.699	423333.8428	1307.2405	13.953	5.332	7.192	17.568
235	4511279.519	423224.4637	1312.9408	14.07	5.291	11.901	24.622
236	4511276.381	423227.2421	1312.9698	14.07	5.291	11.901	24.622
237	4511444.039	423227.002	1304.5169	14.44	5.252	5.852	8.036
238	4511446.794	423225.2492	1304.4695	14.44	5.252	5.852	8.036
239	4511465.965	423102.4775	1307.1656	14.623	5.303	7.07	25.581
240	4511463.158	423103.8193	1307.1556	14.623	5.303	7.07	25.581

Table 14. Road Lights on I-15 North

NUMBER	LATITUDE	LONGITUDE	ALTITUDE	HEIGHT_FROM_BASE
1	4475920.476	424605.3466	1421.433514	12.569
2	4475911.993	424419.9959	1415.650614	13.122
3	4476137.467	424470.5991	1419.750914	12.228

4	4483421.16	424516.8386	1358.220525	11.672
5	4476116.557	424284.9022	1417.694114	13.341
6	4476164.101	424261.5469	1414.366714	13.171
7	4476466.532	424161.9148	1421.401314	12.252
8	4483497.022	424517.678	1362.091125	12.09
9	4486025.426	424544.7104	1353.033225	12.486
10	4486109.233	424547.2862	1355.487625	12.456
11	4486192.639	424554.0925	1354.397525	12.58
12	4486327.432	424469.9692	1356.975325	9.476
13	4486999.141	424452.9276	1356.975325	12.632
14	4487083.13	424446.9049	1360.470693	12.457
15	4487159.015	424436.5844	1358.772225	13.472
16	4487486.567	424414.1451	1351.981525	30.127
17	4487651.078	424385.9464	1353.339993	30.612
18	4487816.313	424357.4534	1354.477393	30.834
19	4487981.583	424329.5358	1355.743893	31.032
20	4488145.487	424301.5787	1357.257693	37.837
21	4488310.839	424273.7267	1357.986193	37.828
22	4488476.386	424245.5941	1358.510293	46.588
23	4488642.667	424216.6121	1355.421493	46.63
24	4488808.767	424188.5084	1349.747593	37.568
25	4488973.698	424160.7868	1345.529093	37.944
26	4489138.476	424132.3231	1343.442993	31.19
27	4489028.86	424108.6465	1343.020393	12.427
28	4489104.52	424101.0912	1342.253493	12.463
29	4489138.589	424132.4012	1356.956593	31.629
30	4489174.287	424093.542	1344.746993	12.503
31	4489302.874	424104.3581	1358.016393	30.301
32	4489468.659	424076.0328	1356.624293	30.389
33	1355.581193	424076.0328	1359.162293	30.567
34	4489633.483	424047.8198	1355.581193	30.455

35	4489794.714	424018.7468	1353.901793	37.149
36	4489969.131	423989.1561	1355.843293	36.296
37	4490132.917	423961.2787	1361.856493	46.474
38	4490238.965	423943.5513	1358.978493	46.05
39	4498120.399	423588.1857	1366.898125	45.854
40	4497917.429	423644.9328	1369.06085	46.105
41	4490402.558	423918.4492	1361.407493	36.689
42	4490575.462	423894.3321	1356.32063	30.459
43	4490749.674	423873.4372	1358.26043	30.714
44	4490924.173	423855.2114	1357.29563	31.067
45	4491097.293	423840.7637	1340.795293	30.577
46	4491272.069	423828.4945	1361.969493	30.806
47	4491445.808	423818.8651	1372.03793	30.484
48	4491621.611	423812.7732	1344.79513	30.755
49	1341.17633	423810.9726	1341.17633	30.49
50	4491971.525	423810.7816	1351.57963	30.867
51	4492146.705	423813.3438	1372.92723	30.866
52	4492320.647	423812.7603	1372.39453	30.654
53	4492495.733	423815.9767	1371.23443	30.837
54	4492670.633	423820.0565	1369.99313	30.753
55	4492845.463	423824.6424	1368.91063	30.673
56	4493021.902	423827.8692	1338.69343	30.821
57	4493195.403	423828.698	1361.94533	36.561
58	4493358.849	423815.4801	1344.13713	45.991
59	4493467.215	423798.2722	1386.70843	45.637
60	4493601.993	423766.7991	1343.42773	36.573
61	4493767.423	423712.3621	1355.56983	30.98
62	4493932.418	423653.8051	1345.59973	30.595
63	4494102.731	423613.6276	1345.65553	31.121
64	4494276.69	423589.3504	1353.17123	30.703
65	4494450.016	423565.8437	1351.20383	30.565

66	4494622.954	423542.4692	1352.66063	30.589
67	4494799.516	423518.4073	1353.83873	30.618
68	4494974.565	423494.6314	1351.67403	30.744
69	4495133.486	423472.9967	1349.33173	30.872
70	4495310.855	423448.8549	1353.35043	31.006
71	4495485.134	423425.2005	1354.80303	31.018
72	4495658.192	423401.6014	1351.69073	30.843
73	4495834.549	423377.7373	1355.26053	30.889
74	4496004.821	423356.5083	1361.02283	37.124
75	4496179.629	423349.8729	1359.69853	36.914
76	4496354.062	423359.8844	1362.44055	36.659
77	4496527.147	423388.6453	1359.37793	36.694
78	4496693.23	423431.8304	1363.01643	46.099
79	4496864.589	423478.6961	1349.91245	45.977
80	4496999.22	423516.3226	1362.71504	46.214
81	4497107.985	423546.7685	1365.76094	46.454
82	4497252.711	423586.9757	1364.58794	46.316
83	4497399.142	423620.2387	1361.61354	46.045
84	4497547.481	423637.7589	1336.79224	46.463
85	4497698.249	423639.2001	1366.88335	46.193
86	4497917.435	423644.935	1362.20475	46.112
87	4498120.352	423588.2522	1357.693125	46.038
88	4498249.09	423547.3145	1348.993525	37.211
89	4498372.777	423484.627	1359.005525	45.993
90	4498564.464	423465.1298	1356.574425	46.026
91	4498712.92	423475.1491	1355.759425	45.665
92	4498816.587	423496.0006	1355.914225	46.187
93	4498946.454	423536.4803	1352.59784	45.646
94	499097.4758	423585.7774	1351.016825	36.504
95	4499262.397	423627.1851	1349.700025	30.822
96	4499430.919	423646.3602	1349.255425	30.839

97	4499600.341	423661.1718	1344.515825	30.588
98	4499769.512	423676.1252	1343.889225	30.842
99	4499938.93	423690.9682	1336.629025	30.604
100	4500107.931	423705.6883	1342.476825	30.816
101	4500277.201	423720.4245	1343.446325	30.855
102	4500446.634	423735.267	1349.093125	36.943
103	4500639.78	423752.2362	1351.025925	37.242
104	4500767.197	423763.5606	1349.732225	36.939
105	4500876.54	423773.2582	1350.562586	36.587
106	4501045.966	423788.008	1349.833425	36.949
107	4501220.299	423802.0581	1337.459525	36.701
108	4501395.034	423807.7376	1328.212925	30.616
109	4501568.086	423808.3851	1324.813025	30.908
110	4501744.697511,	423808.9565	1326.108325	30.853
111	4501919.622	423809.7525	1317.336625	30.902
112	4502094.526	423810.2702	1310.306886	30.527
113	4502264.382	423810.8906	1326.004086	30.667
114	4502439.466	423811.5586	1324.306386	30.588
115	4502614.242	423812.3579	1312.829286	30.49
116	4502789.451	423813.0864	1323.823186	36.796
117	4502954.191	423812.0548	1331.942386	46.1
118	4503063.834	423807.1842	1320.240686	36.749
119	4503208.444	423796.7084	1310.621686	36.786
120	4503383.03	423785.0699	1333.180986	30.449
121	4503557.218	423771.8339	1330.560886	30.84
122	4503732.329	423758.8457	1329.070086	30.938
123	4503906.126	423741.3201	1329.851486	30.569
124	4504080.113	423728.2951	1318.748786	31.011
125	4504254.061	423716.7756	1329.156286	37.065
126	4504429.162	423703.4468	1322.672986	30.868
127	4504603.581	423689.8822	1324.848586	30.764

128	4504776.803	423676.8596	1318.758354	30.751
129	4504952.536	423685.3705	1330.891086	30.192
130	4505122.658	423726.8553	1337.570386	36.817
131	4505317.687	423781.9796	1313.372354	36.954
132	4505462.07	423808.2491	1329.985654	36.496
133	4505636.895	423812.8452	1327.070054	36.359
134	4505777.858	423794.85	1331.655454	36.729
135	4505889.966	423767.422	1313.674254	36.703
136	4506024.656	423730.2751	1330.373254	30.688
137	4506188.506	423685.607	1328.351454	30.6
138	4506355.232	423659.9785	1317.734454	31.08
139	4506526.374	423656.5211	1316.182354	30.71
140	4506696.239	423653.6605	1315.551854	30.717
141	4506866.008	423650.4115	1317.318654	30.875
142	4507043.649	423643.1808	1317.192754	30.495
143	4507205.446	423633.8887	1316.744354	30.645
144	4507374.793	423624.49	1314.096254	36.896
145	4507542.709	423614.8021	1323.566954	45.024
146	4507735.451	423605.7026	1325.527654	46.175
147	4507914.704	423527.3145	1319.236654	46.048
148	4507956.345	423674.3831	1338.820154	46.385
149	4508049.649	423646.6119	1311.994654	45.548
150	4508173.86	423577.8088	1332.452254	45.78
151	4508221.185	423650.5761	1339.801954	45.407
152	4508284.511	423516.9846	1335.334754	46.252
153	4508390.771	423685.5066	1309.702554	43.805
154	4508466.769	423616.3988	1327.987954	46.479
155	4508475.96	423530.8548	1332.234054	45.678
156	4508613.744	423618.3911	1317.815954	46.034
157	4508733.461	423620.45	1308.618054	46.688
158	4508838.084	423493.2461	1331.767054	46.164

159	4508930.913	423617.3361	1332.376454	47.234
160	4509121.372	423614.3177	1317.030354	45.932
161	4509286.236	423611.6795	1315.475654	36.637
162	4509450.889	423609.0082	1322.237554	36.908
163	4509626.223	423606.4013	1308.375954	36.79
164	4509800.659	423609.5554	1311.193954	36.479
165	4509974.923	423621.9291	1331.998254	36.932
166	4510159.034	423635.4713	1330.029154	36.581
167	4510324.643	423647.6524	1339.769154	44.801
168	4510513.481	423661.6686	1344.064154	46.156
169	4510662.216	423668.4673	1334.544298	46.373
170	4510812.684	423642.8092	1332.948298	45.691
171	4510989.774	423556.9053	1332.807254	45.818
172	4511142.875	423425.5824	1338.030898	36.645
173	4511267.535	423312.5651	1330.889798	38.53
174	4511434.599	423183.6906	1322.528498	36.325
175	4511575.033	423126.0916	1335.842098	36.661
176	4511709.836	423101.7402	1320.283298	36.957
177	4511869.527	423075.9212	1329.394298	45.298
178	4512016.741	423029.0739	1312.455598	45.282

Table 15. Bridges and Culverts on I-15 North

NUMBER	TYPE	START_ACCUM	END_ACCUM	HEIGHT	SPAN	WIDTH	BEGIN_LAT	BEGIN_LONG	BEGIN_ELEV	END_LAT	END_LONG	END_ELEV
1	OVERPASS	283.985048	284.047638	8.411	330.4752	21.76	4475994.514	424491.2678	1414.469814	4476066.525	424414.5048	1414.956614
2	OVERPASS	283.985048	284.047638	8.411	330.4752	21.76	4475991.313	424455.5731	1414.351214	4476058.835	424381.6627	1414.017314
3	OVERPASS/ UNDERCONSTRUCTION	288.279788	288.299587	8.744	104.53872	33.389	4481847.266	423795.3578	1406.940646	4481887.54	423827.1306	1405.384546
4	UNDERPASS	289.821814	289.856754	6.851	181.4580111	39.413	4484095.075	424469.2596	1358.525825	4484086.882	424524.568	1358.630325

5	OVERPASS	291.346493	291.408835	8.291	329.16576	53.965	4486521.94	424545.6694	1356.277625	4486683.613	424491.4765	1356.057093
6	OVERPASS	292.567786	292.641382	7.002	388.58688	55.008	4488520.335	424265.4749	1356.736393	4488629.349	424189.9191	1354.301793
7	UNDERPASS	293.648228	293.601781	6.889	213.5259255	56.816	4490222.133	423919.4753	1341.412793	4490152.261	423984.558	1341.961193
8	OVERPASS	294.356199	294.395447	7.075	207.22944	59.313	4491352.124	423852.9313	1340.81673	4491413.158	423791.336	1340.80703
9	OVERPASS	295.613989	295.67094	7.803	300.70128	52.369	4493364.216	423840.663	1339.68183	4493455.024	423774.7865	1338.45553
10	OVERPASS	296.89469	296.929361	6.382	183.06288	61.305	4495383.006	423467.7857	1332.54813	4495431.888	423399.4133	1332.79643
11	OVERPASS	297.237739	297.284129	6.176	244.9392	60.612	4495925.557	423395.0806	1334.91783	4495992.262	423325.9076	1335.56805
12	OVERPASS EXIT	297.897791	297.973226	9.906	398.2968	13.107	4496954.056	423566.6504	1334.23365	4497098.494	423607.5076	1335.15455
13	OVERPASS	297.925369	297.965537	8.53	212.08704	46.176	4497003.833	423543.8618	1331.96895	4497103.557	423522.0777	1331.79405
14	OVERPASS ENTRANCE	297.879747	297.983562	8.263	548.1432	14.954	4496946.509	423451.0736	1329.26015	4497100.749	423462.803	1329.12275
15	OVERPASS	298.48708	298.605353	11.053	624.48144	52.71	4497925.081	423637.2531	1334.70335	4498105.922	423588.2927	1333.25255
16	OVERPASS	298.377909	298.549345	15.73	905.18208	17.313	4497745.409	423585.1119	1333.51914	4498005.425	423543.3078	1333.19245
17	OVERPASS	298.63301	298.680933	14.896	253.03344	51.517	4498147.496	423574.9938	1332.349825	4498221.843	423552.0753	1331.03914
18	OVERPASS	298.608362	298.653849	10.575	240.17136	18.816	4498089.589	423516.6814	1330.43584	4498159.581	423494.1189	1328.12584
19	OVERPASS	298.653174	298.792692	21.262	736.65504	12.674	4498189.344	423705.0954	1339.44314	4498385.134	423739.5899	1331.88074
20	OVERPASS	298.653174	298.95033	21.262	1568.98368	13.047	4498189.344	423705.0954	1339.44314	4498630.262	423629.2976	1322.15784
21	OVERPASS	298.734736	298.776461	13.172	220.308	52.517	4498298.218	423529.3997	1329.383125	4498365.032	423512.595	1327.200125
22	OVERPASS	298.739866	298.769771	13.172	157.8984	21.3379	4498290.259	423452.9423	1326.530025	4498351.523	423459.1881	1324.944425
23	OVERPASS	298.912293	298.961019	7.664	257.27328	54.891	4498583.763	423494.0925	1321.68774	4498655.33	423497.9513	1321.23284
24	OVERPASS	298.9122	298.961019	7.664	257.27328	54.891	4498606.	423432.6	1313.821	44986	42342	1322.8

		93					399	007	225	72.981	7.886	24225
25	OVERPASS	299.000803	299.057037	13.416	296.91552	55.237	4498723.196	423506.7	1321.640225	4498809.98	423524.4719	1321.80374
26	OVERPASS	299.000803	299.057037	13.416	296.91552	13.293	4498723.053	423434.0426	1323.484125	4498820.252	423452.4414	1323.220625
27	OVERPASS	299.490631	299.521492	7.916	162.94608	59.197	4499489.546	423681.1517	1325.292925	4499530.259	423684.6733	1325.058625
28	OVERPASS	300.324017	300.379118	8.864	290.93328	51.649	4500782.636	423790.1435	1322.642125	4500867.696	423798.8097	1321.241225
29	OVERPASS	300.718335	300.733522	10.57	311.48	15.994	4501472.551	423767.96	1309.829986	4501500.374	423851.16	1309.687786
30	OVERPASS	301.172895	301.198286	6.638	134.06448	59.498	4502200.022	423839.5086	1306.050886	4502239.203	423839.9114	1306.097486
31	OVERPASS	301.652014	301.705267	8.082	281.17584	51.72	4502961.598	423786.6957	1304.606886	4503052.855	423781.715	1304.583386
32	CULVERT	302.111184	302.116737	2.92	29.31984	73.59	4503697.765	423721.1358	1295.593686	4503705.137	423720.4159	1295.656786
33	OVERPASS	302.522929	302.522929	8.507	322.48	26.646	4504364.815	423666.7409	1307.657286	4504355.741	423751.9605	1309.478586
34	OVERPASS	303.004238	303.146755	9.837	752.48976	60.466	4505129.887	423759.1858	1306.859286	4505362.957	423750.7805	1305.697854
35	OVERPASS	303.418274	303.48114	8.761	331.93248	51.518	4505784.603	423767.0975	1301.631454	4505892.286	423739.972	1300.399354
36	OVERPASS	304.325921	304.325921	7.478	325.648	13.0001	4507245.303	423583.6787	1299.576754	4507244.538	423679.8387	1299.550254
37	OVERPASS NB	304.7	304.751663	9.281	272.78064	21.661	4507846.533	423610.6721	1300.660654	4507928.055	423632.2668	1301.421554
38	OVERPASS SB	304.720644	304.803459	8.237	437.2632	21.402	4507881.687	423576.3724	1300.933954	4508015.273	423576.4488	1301.264554
39	OVERPASS	304.985493	305.015131	9.168	156.48864	32.724	4508305.768	423650.8668	1299.561554	4508352.754	423652.1919	1299.313454
40	OVERPASS	304.987009	305.015385	6.136	149.82528	22.081	4508307.91	423584.3755	1299.718154	4508354.72	423585.8415	1299.498454
41	OVERPASS	305.189465	305.238792	7.919	260.44656	9.715	4508642.029	423547.3334	1298.4767	4508701.467	423549.0486	1299.1982
42	OVERPASS	305.189465	305.238792	8.288	260.44656	12.237	4508646.316	423559.3682	1299.3138	4508700.069	423564.3386	1297.7636
43	OVERPASS	305.189465	305.238792	7.735	260.44656	29.983	4508643.475	423582.2616	1299.1063	4508700.056	423585.4584	1297.1229

44	OVERPASS	305.189465	305.238792	8.472	260.44656	29.51	4508635.797	423626.4361	1298.9626	4508696.787	423625.8531	1297.2746
45	OVERPASS	305.189465	305.238792	7.735	260.44656	26.464	4508641.227	423679.4653	1299.1455	4508693.816	423680.9984	1298.256
46	OVERPASS	305.748278	305.793892	8.889	240.84192	21.076	4509542.411	423557.5133	1295.5276	4509603.705	423556.8243	1296.3571
47	OVERPASS	305.748278	305.793892	8.239	240.84192	51.741	4509540.436	423581.9555	1296.3535	4509599.482	423580.9541	1297.249
48	OVERPASS	305.748278	305.793892	8.022	240.84192	20.862	4509535.058	423636.5124	1296.8364	4509595.59	423635.647	1297.531
49	OVERPASS	306.312646	306.356798	7.967	233.12256	21.065	4510428.252	423605.8643	1295.6067	4510505.466	423610.6983	1296.467
50	OVERPASS	306.312646	306.356798	8.171	233.12256	52.063	4510430.116	423630.2366	1295.4796	4510502.972	423635.0186	1297.3443
51	OVERPASS	306.312646	306.356798	7.967	233.12256	12.75	4510430.237	423728.2432	1295.3471	4510492.448	423736.3593	1297.164
52	OVERPASS	306.56702	306.619226	9.159	275.64768	58.936	4510796.761	423628.1144	1297.9696	4510926.647	423563.6258	1298.958
53	OVERPASS	306.733871	306.8	10.743	349.16112	68.941	4511022.876	423464.8817	1300.9506	4511156.798	423452.6432	1300.1974
54	OVERPASS	306.909271	307.048972	11.56	737.62128	68.926	4511238.605	423290.4223	1301.01	4511422.293	423151.2115	1301.1856
55	OVERPASS	307.138401	307.189691	8.769	270.8112	69.984	4511577.369	423090.4908	1299.0636	4511650.161	423076.27	1296.387

I-15 South Data

Table 16. Overhead Sign Assemblies on I-15 South

NUMBER	MOUNT_OFFSET	SIGN_POSIT	BEGIN_LONGITUDE	BEGIN_LATITUDE	BEGIN_ALTITUDE
1	3.528	RIGHT	4425672.357	434259.92	1507.663
2	2.927	RIGHT	4426392.838	434600.908	1477.949
3	1.575	RIGHT	4427173.054	434770.269	1454.985
4	6.291	CENTER	4429916.29	434923.845	1418.342
5	4.621	CENTER	4432963.277	436538.029	1412.082
6	4.413	CENTER	4436052.936	438955.226	1381.762
7	6.55	OVERHEAD	4439427.114	441724.605	1391.445
8	0.986	CENTER	4439996.982	442271.977	1401.969
9	0.455	LEFT	4441234.331	443507.078	1395.396
10	1.734	RIGHT	4441382.254	443699.105	1398.711
11	2.155	OVERHEAD	4441581.742	443938.568	1397.71
12	1.192	LEFT	4442005.494	444481.476	1393.057
13	3.75	OVERHEAD	4442591.722	444850.667	1393.16
14	1.721	RIGHT	4442775.919	444845.814	1399.302
15	1.569	LEFT	4442973.212	444892.091	1393.785
16	2.051	OVERHEAD	4442973.539	444861.778	1393.425
17	0.846	LEFT/MEDIAN	4443428.262	444897.408	1388.979
18	0.423	OVERHEAD	4443748.495	444901.19	1381.211
19	1.965	OVERHEAD	4443748.904	444873.767	1380.167
20	1.122	LEFT	4443890.953	444902.805	1380.982
21	0.424	MEDIAN	4444292.715	444907.863	1385.201
22	0.87	OVERHEAD	4444572.429	444911.268	1385.34
23	1.735	OVERHEAD	4444573.305	444878.667	1384.975
24	6.112	RIGHT	4445044.527	444949.151	1378.655
25	8.568	OVERHEAD	4445498.76	444964.121	1382.993
26	0.436	OVERHEAD/LEFT	4445499.592	444922.44	1379.895
27	0.433	LEFT	4445742.711	444925.383	1378.103
28	0.864	LEFT	4445983	444928.904	1380.736

29	0.452	MEDIAN	4446229.879	444931.041	1377.54
30	5.992	RIGHT	4446223.958	444891.684	1375.254
31	5.354	RIGHT	4446746.376	444969.281	1379.425
32	3.18	RIGHT	4447030.283	444909.493	1374.532
33	-	MEDIAN	4447292.958	444944.793	1377.857
34	2.364	RIGHT	4443021.566	444922.7963	1390.4416

Table 17. Overhead Sign Faces on I-15 South

NUMBER	LENGTH	WIDTH	HEIGHT	BEGIN_LONGITUDE	BEGIN_LATITUDE	BEGIN_ALTITUDE
1	2.991	4.499	6.349	4425667.113	434268.125	1512.896
2	2.568	4.577	7.437	4426388.491	434610.149	1485.911
3	1.995	4.777	6.2	4427172.757	434780.297	1459.836
4	2.713	8.681	5.492	4429916.381	434928.047	1424.455
5	2.248	8.868	6.807	4432959.77	436541.188	1418.829
6	2.436	8.805	6.833	4436050.515	438958.44	1389.235
7	2.251	7.596	6.222	4439432.146	441718.044	1396.715
8	2.759	9.055	7.422	4439993.352	442274.946	1406.552
9	3.055	4.773	8.534	4441227.448	443512.055	1401.347
10	3.526	6.983	8.738	4441390.084	443692.388	1404.895
11	3.497	9.336	7.781	4441584.406	443936.253	1402.413
12	3.88	4.367	7.626	4441997.844	444485.658	1396.447
13	2.837	10.306	7.864	4442593.077	444844.964	1400.18
14	2.982	3.166	7.916	4442775.308	444853.676	1401.158
15	3.139	4.642	5.842	4442972.954	444900.028	1398.135
16	3.4	4.474	5.842	4442974.029	444880.323	1398.234
17	4.185	5.562	5.667	4442974.043	444873.779	1397.811
18	4.971	3.199	5.667	4442974.168	444867.855	1398.327
19	1.582	4.173	7.863	4443427.276	444909.058	1394.387
20	2.865	9.777	8.01	4443748.791	444889.99	1387.799
21	2.778	2.895	7.003	4443890.541	444910.774	1386.211
22	1.44	9.156	7.45	4444292.784	444912.683	1385.822

23	3.295	8.482	8.413	4444572.839	444899.593	1386.835
24	2.891	6.032	6.987	4445045.523	444938.107	1384.181
25	3.237	5.571	7.028	4445498.593	444950.257	1382.995
26	3.144	4.623	5.826	4445499.621	444929.89	1381.952
27	2.342	4.308	7.821	4445742.951	444937.09	1384.025
28	2.852	4.648	7.771	4445983.295	444916.872	1383.312
29	3.352	3.787	5.797	4446228.853	444926.957	1380.543
30	2.356	4.619	7.791	4446230.065	444906.63	1382.513
31	2.627	5.505	6.885	4446229.081	444938.732	1381.725
32	2.253	5.266	7.652	4446746.991	444961.334	1380.603
33	1.963	5.56	8.204	4447030.537	444920.813	1380.283
34	1.71	8.829	7.536	4447293.661	444948.319	1379.73
35	2.863	4.255	2.481	4443021.498	444920.711	1394.048

Table 18. Billboard Assemblies on I-15 South

NUMBER	BEGIN_LATI	BEGIN_LONG	BEGIN_ALTI	BILLBOARD_TYPE
1	4421769.87	430793.869	1549.969	V-Shaped
2	4423221.515	431969.42	1553.287	
3	4423343.614	432063.224	1552.778	V-Shaped
4	4423441.754	432165.175	1549.551	V-Shaped
5	4423562.262	432276.365	1554.48	
6	4423661.454	432389.6	1555.276	V-Shaped
7	4424063.921	432870.818	1549.785	V-Shaped
8	4424185.519	432950.67	1546.124	V-Shaped
9	4424404.748	433198.749	1549.206	
10	4424465.936	433097.593	1545.2	
11	4424529.327	433333.589	1542.596	
12	4424648.655	433455.122	1539.817	
13	4426219.717	434611.016	1485.118	V-Shaped
14	4426359.826	434665.931	1477.015	V-Shaped
15	4426513.166	434716.581	1471.294	V-Shaped

16	4432133.249	435790.964	1409.963	
17	4432369.896	435975.759	1408.735	
18	4432588.171	436148.646	1407.76	
19	4432822.661	436324.892	1405.683	
20	4435459.004	438395.61	1381.333	
21	4435974.272	438953.793	1379.9152	
22	4439714.291	442078.562	1392.401	
23	4439853.155	442233.333	1392.284	
24	4439983.457	442365.767	1392.897	
25	4440107.932	442482.335	1392.614	
26	4440220.607	442578.011	1392.16	
27	4442549.908	444939.593	1384.61	
28	4442720.224	444962.002	1383.413	
29	4442948.185	444953.102	1382.336	V-Shaped
30	4442798.798	444961.776	1385.113	
31	4442928.319	444823.661	1382.66	
32	4443080.191	444833.91	1380.531	V-Shaped
33	4443102.851	444954.47	1381.3	V-Shaped
34	4443259.423	444819.849	1379.506	
35	4443336.975	444945.453	1379.202	
36	4443477.331	444850.413	1381.032	
37	4444429.504	444831.979	1376.431	
38	4443497.34	444952.247	1378.561	
39	4443653.087	444941.548	1378.543	
40	4443657.806	444857.617	1378.476	
41	4443795.863	444943.628	1377.424	
42	4443810.704	444848.336	1376.983	
43	4443957.659	444952.23	1377.294	
44	4443971.918	444853.726	1376.949	
45	4444123.845	444843.982	1377.054	
46	4444136.481	444968.715	1378.237	

47	4444279.57	444845.898	1376.404	
48	4444634.913	444852.535	1376.168	
49	4444708.786	444975.958	1376.045	V-Shaped
50	4444924.461	444984.555	1376.08	
51	4446889.481	444879.948	1371.01	
52	4446983.009	444987.354	1370.911	
53	4447220.65	444882.221	1370.304	
54	4447282.499	444987.357	1370.564	
55	4447623.526	444995.625	1371.312	
56	4447616.506	(444889.255,	1371.28	

Table 19. Billboard Faces on I-15 South

NUMBER	BEGIN_LATI	BEGIN_LONG	BEGIN_ALTI	WIDTH	HEIGHT	HEIGHT_ABOVE_PAVEMENT	DISTANCE_FROM_PAVEMENT
1	4421769.032	430801.83	1557.3	14.615	5.101	5.002	59.458
2	4421768.289	430801.656	1557.3104	14.615	5.101	5.002	59.458
3	4423227.226	431962.706	1560.85	15.023	5.3	16.067	50.083
4	4423229.751	431964.4813	1560.9043	15.023	5.3	16.067	50.083
5	4423348.898	432057.675	1561.824	15.358	5.359	14.275	39.024
6	4423349.175	432057.8909	1561.6626	15.358	5.359	14.275	39.024
7	4423447.876	432159.536	1558.64	15.306	5.198	9.297	47.799
8	4423450.139	432161.7635	1558.6167	15.306	5.198	9.297	47.799
9	4423564.469	432269.11	1558.999	14.268	5.557	7.518	39.116
10	4423564.469	432269.1096	1558.9986	14.268	5.557	7.518	39.116
11	4423664.834	432382.114	1560.607	14.994	5.281	7.566	41.397
12	4423666.767	432384.4691	1560.5689	14.994	5.281	7.566	41.397
13	4424067.461	432862.271	1559.892	15.165	5.365	8.473	69.905
14	4424068.121	432864.3956	1559.8948	15.165	5.365	8.473	69.905
15	4424190.871	432956.24	1556.6	14.414	5.365	6.344	41.12
16	4424190.871	432956.2402	1556.5996	14.414	5.365	6.344	41.12
17	4424410.515	433189.771	1553.092	14.875	3.98	6.973	40.035
18	4424414.715	433199.2231	1553.3124	14.875	3.98	6.973	40.035

19	4424460.449	433102.092	1551.484	14.149	5.328	5.176	17.392
20	4424457.914	433099.1994	1551.4554	14.149	5.328	5.176	17.392
21	4424536.626	433330.948	1546.669	14.5	5.416	4.296	40.576
22	4424538.073	433332.9418	1546.6661	14.5	5.416	4.296	40.576
23	4424646.745	433449.532	1543.86	14.041	5.072	5.544	39.166
24	4424648.312	433450.7535	1543.8584	14.041	5.072	5.544	39.166
25	4426228.369	434606.188	1490.453	14.303	5.346	5.504	15.598
26	4426230.631	434606.9379	1490.4121	14.303	5.346	5.504	15.598
27	4426370.548	434660.893	1482.717	14.098	5.286	3.866	18.611
28	4426370.723	434661.2973	1482.6854	14.098	5.286	3.866	18.611
29	4426510.907	434707.496	1478.53	14.4	5.348	4.68	23.79
30	4426513.254	434708.208	1478.5247	14.4	5.348	4.68	23.79
31	4432131.998	435799.315	1415.006	14.213	5.463	2.752	47.125
32	4432131.7	435799.1196	1415.0284	14.213	5.463	2.752	47.125
33	4432367.682	435983.947	1412.097	14.209	4.816	1.528	46.801
34	4432367.682	435983.9472	1412.0972	14.209	4.816	1.528	46.801
35	4432583.763	436154.222	1412.671	14.62	5.243	3.711	46.421
36	4432583.746	436153.7025	1412.6923	14.62	5.243	3.711	46.421
37	4432820.302	436334.426	1415.452	14.546	5.322	3.216	50.209
38	4432817.969	436332.4709	1415.4745	14.546	5.322	3.216	50.209
39	4435460.243	438403.447	1381.767	13.766	5.72	-1.773	45.529
40	4435977.139	438953.6101	1379.6847	11.763	6.053	-0.56	23.93
41	4439709.742	442062.635	1401.879	14.103	5.105	8.283	50.523
42	4439711.399	442064.6333	1401.8896	14.103	5.105	8.283	50.523
43	4439867.67	442235.77	1403.684	15.308	5.31	5.832	73.489
44	4439869.43	442238.3493	1403.7024	15.308	5.31	5.832	73.489
45	4439990.411	442363.247	1400.61	14.469	5.481	0.774	66.624
46	4439990.503	442363.6767	1400.6303	14.469	5.481	0.774	66.624
47	4440109.296	442473.564	1405.305	15.318	5.254	4.14	59.453
48	4440111.472	442475.8799	1405.3086	15.318	5.254	4.14	59.453
49	4440224.796	442571.719	1404.775	14.776	5.143	4.693	47.414

50	4440227.733	442573.8785	1404.7588	14.776	5.143	4.693	47.414
51	4442571.99	444933.576	1399.564	14.937	5.389	6.303	34.527
52	4442572.413	444933.7635	1399.5697	14.937	5.389	6.303	34.527
53	4442722.067	444953.763	1396.941	14.518	5.472	2.383	38.507
54	4442722.067	444953.7631	1396.9412	14.518	5.472	2.383	38.507
55	4442794.733	444954.9486	1396.2186	14.304	5.195	2.563	37.01
56	4442798.526	444953.9186	1396.1799	14.304	5.195	2.563	37.01
57	4442926.714	444828.8662	1392.3806	14.362	5.216	0.084	27.035
58	4442929.948	444828.9159	1392.4297	14.362	5.216	0.084	27.035
59	4442952.859	444944.468	1399.695	14.757	5.327	7.605	26.932
60	4442953.223	444944.4407	1399.6881	14.757	5.327	7.605	26.932
61	4443082.151	444841.217	1391.392	14.541	5.312	0.286	25.344
62	4443079.258	444840.8812	1391.4469	14.541	5.312	0.286	25.344
63	4443106.776	444946.598	1398.482	14.636	5.275	7.617	27.45
64	4443108.885	444946.8084	1398.4768	14.636	5.275	7.617	27.45
65	4443256.304	444827.618	1388.684	14.488	5.317	-0.95	41.598
66	4443259.477	444826.2672	1388.6931	14.488	5.317	-0.95	41.598
67	4443343.991	444944.989	1388.722	14.278	4.942	0.297	23.647
68	4443344.793	444945.0262	1388.6899	14.278	4.942	0.297	23.647
69	4443480.944	444850.528	1386.186	14.402	4.406	1.397	21.354
70	4443481.813	444850.516	1386.1828	14.402	4.406	1.397	21.354
71	4443497.184	444945.233	1387.659	14.282	5.295	3.356	22.083
72	4443497.566	444945.2382	1387.6796	14.282	5.295	3.356	22.083
73	4443647.091	444941.585	1388.393	14.651	5.298	7.909	17.473
74	4443650.56	444941.7272	1388.3317	14.651	5.298	7.909	17.473
75	4443665.04	444857.647	1382.187	14.576	5.287	1.984	17.193
76	4443661.961	444856.46	1382.1158	14.576	5.287	1.984	17.193
77	4443801.06	444943.626	1386.681	14.44	5.293	7.364	15.737
78	4443801.804	444943.6941	1386.6584	14.44	5.293	7.364	15.737
79	4443812.807	444857.197	1381.932	14.152	5.291	2.661	19.605
80	4443812.488	444856.348	1381.822	14.152	5.291	2.661	19.605

81	4443957.423	444945.268	1388.18	14.278	5.309	9.392	17.263
82	4443957.904	444945.3244	1388.1684	14.278	5.309	9.392	17.263
83	4443969.07	444858.094	1381.251	14.674	5.356	2.57	19.453
84	4443968.681	444858.0495	1381.3027	14.674	5.356	2.57	19.453
85	4444129.462	444850.323	1381.233	14.374	4.91	3.148	29.21
86	4444129.462	444850.3228	1381.2335	14.374	4.91	3.148	29.21
87	4444139.362	444961.812	1383.495	14.86	5.141	5.396	30.2
88	4444139.362	444961.8122	1383.4954	14.86	5.141	5.396	30.2
89	4444278.772	444851.529	1382.244	14.543	4.871	3.961	30.93
90	4444278.309	444851.5356	1382.2019	14.543	4.871	3.961	30.93
91	4444431.96	444838.2503	1386.1992	14.519	5.325	7.862	46.255
92	4444427.671	444838.0354	1386.1728	14.519	5.325	7.862	46.255
93	4444633.248	444854.829	1383.758	14.182	4.72	5.93	29.719
94	4444631.458	444854.7388	1383.7078	14.182	4.72	5.93	29.719
95	4444704.501	444968.347	1386.168	14.634	5.321	8.494	28.913
96	4444707.252	444969.7508	1386.1433	14.634	5.321	8.494	28.913
97	4444927.415	444976.468	1380.257	13.958	5.271	3.261	34.789
98	4444928.3	444976.4987	1380.3178	13.958	5.271	3.261	34.789
99	4446894.672	444886.421	1376.378	14.288	5.046	3.994	24.313
100	4446892.946	444886.1069	1376.3518	14.288	5.046	3.994	24.313
101	4446981.383	444978.965	1375.413	14.702	5.305	3.236	11.049
102	4446983.655	444979.0095	1375.4636	14.702	5.305	3.236	11.049
103	4447218.783	444889.465	1374.582	14.411	5.34	2.761	24.771
104	4447218.783	444889.4654	1374.582	14.411	5.34	2.761	24.771
105	4447278.738	444983.599	1376.441	14.54	5.143	4.413	13.665
106	4447281.261	444983.621	1376.4642	14.54	5.143	4.413	13.665
107	4447626.961	444987.15	1375.994	14.455	4.844	3.92	13.672
108	4447624.309	444988.3214	1375.9631	14.455	4.844	3.92	13.672
109	4447616.89	444894.516	1374.769	14.34	4.911	2.775	24.633
110	4447616.513	444894.4902	1374.7659	14.34	4.911	2.775	24.633

Table 20. Road Lights on I-15 South

NUMBER	LATITUDE	LONGITUDE	ALTITUDE	HEIGHT_FROM_BASE
1	4422214.28	431226.415	1549.876	12.434
2	4422275.768	431271.385	1547.611	12.101
3	4422638.249	431386.424	1530.041	12.164
4	4422574.87	431479.213	1539.228	11.72
5	4422535.761	431486.355	1532.147	11.796
6	4422621.88	431344.008	1532.225	12.344
7	4422892.241	431597.871	1545.272	12.079
8	4422954.326	431642.051	1536.337	12.381
9	4423015.698	431686.84	1537.569	12.245
10	4425321.005	434127.862	1526.045	12.851
11	4425302.192	433944.254	1519.47	12.879
12	4425587.947	434194.422	1520.604	12.758
13	4425645.889	434239.316	1518.601	12.748
14	4425712.401	434283.935	1505.549	12.84
15	4431021.735	435100.388	1417.275	12.886
16	4431085.423	435135.218	1419.306	13.245
17	4431147.167	435174.545	1415.959	13.294
18	4431886.129	435651.292	1415.249	13.231
19	4431994.562	435746.772	1416.736	13.191
20	4433811.447	437256.116	1415.284	12.852
21	4433865.02	437305.856	1415.08	12.625
22	4433915.673	437358.448	1414.473	12.721
23	4434037.26	437533.071	1402.436	13.101
24	4434256.191	437526.204	1404.115	13.174
25	4434251.544	437553.677	1407.735	12.01
26	4434288.628	437556.513	1407.57	12.235
27	4434325.255	437560.797	1396.844	12.29
28	4434101.97	437564.085	1410.307	12.143
29	4434498.642	437727.409	1396.135	13.29

30	4434557.079	437774.934	1396.432	12.992
31	4434620.075	437819.239	1396.282	12.7
32	4435764.512	438686.521	1386.403	8.812
33	4436793.27	439606.796	1396.07	12.755
34	4436982.966	439750.699	1398.09	12.678
35	4437036.153	439806.127	1397.758	13.16
36	4437087.419	439862.484	1397.339	13.134
37	4437445.781	440048.133	1386.226	13.15
38	4437476.995	440038.95	1391.3	13.085
39	4437505.892	440234.731	1386.023	13.196
40	4437457.808	440228.932	1386.959	12.047
41	4437923.772	440425.231	1390.071	12.329
42	4437983.361	440471.241	1397.449	12.193
43	4438045.786	440514.117	1387.033	13.353
44	4441327.942	443607.514	1395.822	30.656
45	4441446.448	443734.687	1399.714	30.612
46	4441577.398	443875.176	1400.141	30.684
47	4441695.731	444014.187	1398.349	30.846
48	4441799.753	444164.106	1399.414	30.843
49	4441798.369	444051.647	1404.382	12.134
50	4441847.905	444101.477	1394	12.178
51	4441893.236	444156.86	1391.983	12.179
52	4441750.297	444190.984	1390.942	12.242
53	4441897.785	444234.662	1389.351	12.354
54	4441962.148	444267.354	1391.248	12.25
55	4441899.697	444318.003	1396.612	30.886
56	4441989.579	444324.383	1392.84	12.278
57	4442017.71	444385.731	1391.412	12.186
58	4441998.694	444470.708	1392.648	30.765
59	4442019.201	444579.202	1390.264	12.271
60	4442054.689	444664.445	1394.619	12.298

61	4442115.839	444621.865	1391.061	31.012
62	4442229.178	444633.78	1395.763	10.462
63	4442278.983	444638.091	1394.404	12.286
64	4442336.816	444645.766	1394.425	12.179
65	4441960.608	444819.952	1391.93	12.378
66	4441980.711	444855.635	1391.978	12.113
67	4441902.449	444866.784	1396.916	12.101
68	4441927.879	444899.393	1391.547	12.444
69	4441847.234	444919.533	1392.511	12.071
70	4441872.696	444951.089	1390.133	12.46
71	4441794.598	444974.133	1390.232	12.315
72	4442171.354	444785.834	1393.125	12.498
73	4442273.71	444709.252	1400.438	12.629
74	4442249.538	444687.763	1396.692	12.788
75	4442327.393	444682.07	1392.973	12.526
76	4442378.573	444702.002	1391.767	12.265
77	4442262.193	444744.017	1389.905	24.939
78	4442318.526	444822.256	1393.817	12.445
79	4442450.768	444733.796	1389.512	12.015
80	4442409.84	444822.318	1391.156	21.994
81	4442487.072	444880.148	1397.786	12.365
82	4442501.274	444831.903	1395.167	12.039
83	4442514.325	444797.961	1390.709	11.97
84	4442585.099	444874.482	1395.091	15.699
85	4442671.947	444914.751	1396.371	11.314
86	4442679.531	444838.798	1394.619	11.974
87	4442767.521	444889.249	1397.3	12.348
88	4442856.265	444918.267	1394.107	12.285
89	4442880.433	444855.116	1404.546	12.354
90	4442949.238	444892.013	1394.873	30.694
91	4443132.843	444894.32	1392.856	30.997

92	4445451.944	444887.904	1386.664	12.613
93	4445473.788	444954.794	1379.644	12.365
94	4445532.724	444889.251	1387.236	12.631
95	4445613.233	444886.664	1386.71	12.634
96	4445634.893	444967.937	1378.435	12.178
97	4446092.38	444888.403	1386.825	12.717
98	4446133.407	444966.825	1385.802	12.331
99	4446172.779	444897.224	1386.488	12.038
100	4446215.776	444968.003	1375.583	12.173
101	4446253.488	444900.59	1386.03	12.072
102	4446298.091	444967.781	1377.2	12.195
103	4446962.028	444909.34	1381.293	10.489

Table 21. Bridges and Culverts on I-15 South

NUMBER	TYPE	START_ACCUM	END_ACCUM	HEIGHT	SPAN	WIDTH	BEGIN_LAT	BEGIN_LONG	BEGIN_ELEV	END_LAT	END_LONG	END_ELEV
1	OVERPASS	241.380794	241.4	19.84908136	101.40768	42.28674541	4421049.694	430615.7514	1548.2249	4421083.99	430620.9416	1549.1383
2	OVERPASS	241.380794	241.4	24.18307087	101.40768	64.34383202	4421043.437	430649.3956	1550.2852	4421078.387	430653.768	1551.3116
3	OVERPASS	242.448388	242.471996	24.88845144	124.65024	45.50853018	4422581.248	431407.0728	1534.6481	4422616.836	431429.915	1534.457
4	OVERPASS	242.448388	242.471996	24.88845144	124.65024	42.48687664	4422565.945	431431.4999	1535.6062	4422598.847	431452.8274	1535.3111
5	OVERPASS	243.849331	243.876986	21.48950131	146.0184	44.83267717	4424280.542	432931.4017	1549.3001	4424313.044	432965.929	1549.4126
6	OVERPASS	243.849331	243.876986	21.48950131	146.0184	51.56167979	4424249.288	432939.7824	1549.9338	4424280.147	432973.6652	1549.1956
7	OVERPASS	244.8	244.8249	23.27099738	131.472	43.6187664	4425311.499	434003.9679	1519.4377	4425359.263	434041.5274	1518.3824
8	OVERPASS	244.8	244.8249	23.27099738	131.472	46.12860892	4425307.894	434037.4318	1519.8365	4425354.137	434074.554	1518.2997
9	CULVERT	245.723068	245.729206	17.14566929	32.40864	138.8418635	4426624.207	434665.862	1465.9763	4426635.81	434667.8951	1465.7435
10	UNDERPASS	246.9281	246.93417	21.09908	31.870	207.788	4428549.	434875.2	1439.741	44285	43493	1439.0

		34		136	08	7139	724	642	3	50.734	8.0307	074
11	UNDERPASS	247.430205	247.435934	22.14895013	30.24912	206.230315	4429361.012	434895.5775	1428.568	4429360.847	434958.8903	1428.8152
12	UNDERPASS	248.823408	248.836596	22.52624672	69.63264	266.4927822	4431512.143	435355.9897	1418.1249	4431510.733	435437.4389	1418.432
13	OVERPASS	249.873449	249.909503	23.20209974	190.36512	61.43372703	4432846.068	436419.7722	1412.8008	4432890.031	436454.3888	1412.7033
14	OVERPASS	249.873449	249.909503	23.20209974	190.36512	61.42060367	4432847.976	436448.9327	1413.2842	4432888.404	436480.9002	1413.2951
15	OVERPASS	250.304093	250.340458	21.87007874	192.0072	61.94553806	4433392.677	436849.142	1411.852	4433439.977	436885.7588	1412.7529
16	OVERPASS	250.304093	250.340458	21.87007874	192.0072	72.4015748	4433394.799	436879.7471	1412.236	4433435.456	436911.0298	1413.2826
17	OVERPASS	250.938569	250.977537	21.13845144	205.75104	64.33070866	4434183.965	437525.144	1402.9565	4434236.635	437565.5534	1402.5018
18	OVERPASS	250.938569	250.977537	21.13845144	205.75104	59.51115486	4434143.492	437522.7418	1403.4883	4434197.015	437563.5847	1403.8917
19	CULVERT	251.359913	251.367487	14.35695538	39.99072	147.746063	4434746.004	437897.9224	1391.7902	4434752.398	437903.5633	1392.1334
20	CULVERT	252.453708	252.457304	10.34448819	18.98688	155.6102362	4436102.017	438956.0738	1379.6048	4436105.376	438957.3952	1378.8234
21	CULVERT	253.0306	253.035797	11.2664042	27.44016	141.4599738	4436842.244	439560.2001	1383.8586	4436847.272	439564.8015	1383.9827
22	OVERPASS	253.546482	253.572623	23.87139108	138.02448	70.15419948	4437446.673	440092.649	1391.0752	4437489.102	440126.9602	1391.1164
23	OVERPASS	253.546482	253.572623	23.87139108	138.02448	67.38188976	4437443.771	440119.2975	1391.4746	4437485.723	440153.3473	1391.3237
24	UNDERPASS	254.592294	254.6	28.74015748	40.68768	422.7919948	4438907.47	441241.9219	1399.3	4438907.811	441112.595	1398.2232
25	BRIDGE	255.073957	255.092708	12.68372703	99.00528	208.1692913	4439483.884	441700.1302	1389.6868	4439496.177	441710.4412	1389.1076
26	OVERPASS	255.517486	255.55422	24.34383202	193.95552	134.6948819	4439953.033	442191.8538	1398.361	4439988.371	442232.025	1399.0442
27	OVERPASS	255.7	255.746685	32.61154856	246.4968	134.2388451	4440147.646	442403.128	1400.5743	4440201.491	442456.2035	1400.7296
28	UNDERPASS	256.260989	256.270086	28.24146982	48.03216	443.8451444	4440779.056	442942.4402	1399.1632	4440775.67	443078.605	1398.785
29	OVERPASS	256.9	256.927123	25.94816273	143.20944	171.0465879	4441483.093	443734.2755	1396.4201	4441523.693	443778.3582	1396.9749

30	OVERPASS	257.258616	257.3	24.54068241	218.50752	29.89829396	4441854.624	444187.6853	1395.1485	4441894.35	444248.9426	1394.001
31	OVERPASS	257.258616	257.3	24.54068241	218.50752	124.2486877	4441839.31	444190.5334	1395.6475	4441871.491	444240.414	1394.5806
32	UNDERPASS	257.674723	257.693694	27.57874016	100.16688	283.4580052	4442166.85	444722.8371	1394.5463	4442246.318	444690.5594	1394.5845
33	OVERPASS	257.986346	258.023933	32.97244094	198.45936	55.5511811	4442632.19	444836.2734	1392.6949	4442681.199	444839.2323	1392.8951
34	OVERPASS	257.986346	258.023933	32.97244094	198.45936	155.246063	4442659.82	444864.3513	1392.9564	4442710.945	444869.2599	1393.2767
35	OVERPASS	258.363586	258.384547	35.98097113	110.67408	175.574147	4443229.289	444867.784	1389.6851	4443298.006	444868.5315	1388.9997
36	UNDERPASS	258.817546	258.832098	23.26115486	76.83456	232.2998688	4443991.927	444939.2681	1385.355	4443992.561	444867.2737	1385.0535
37	UNDERPASS	259.966013	259.994365	24.57349081	149.69856	268.0544619	4445820.552	444967.0451	1381.5696	4445829.587	444885.919	1381.6152