



SUMMARY OF ANALYSIS

Prepared for:

Tempe Police Department
Attn: Sergeant Steven A. Carbajal

By: James S. Sobek, P.E.
On: August 28, 2019

Your Reference: State of Arizona v Rafaela Vasquez; GO# TE 2018-32694
Wolf Project No.: 19-0117-4827



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Tempe Police Department
Tempe, AZ 85281

Attn: Sergeant Steven A. Carbajal

RE: State of Arizona v Rafaela Vasquez
Claim or File No.: GO# TE 2018-32694
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BACKGROUND

Wolf Technical Services, Inc. (Wolf) was contacted on May 1, 2019 with regard to a motor vehicle collision that occurred in the City of Tempe, Arizona in the evening of March 18, 2018. At about 9:58 p.m. a prototype autonomous Volvo XC90, owned and operated by Advanced Technologies Group, a subsidiary of the ride-sharing company Uber Technologies, Inc., was traveling north on North Mill Avenue approaching the Curry Road intersection. The car's autonomy mode was engaged. Ms. Rafaela Vasquez, a safety backup driver, was seated in the driver position. Ms. Vasquez's mandate was to monitor the car's performance and override the braking and/or steering systems in any case where the car's autonomous systems were not functioning safely. The Volvo was equipped with a number of electronics systems that implemented the self-driving technology. In addition to those systems, two cameras were mounted just below the interior rearview mirror, one facing forward to show the view through the windshield¹ and the other facing rearward to show the safety monitor in her seated position.² To overcome the dark conditions inside the car during night operations, the rearward camera had an infrared illuminator. The infrared energy, while invisible to the driver, could be detected by the camera.

As the car headed north on North Mill Avenue, Ms. Elaine Herzberg was walking her bicycle across the street to the east. As the Volvo was traveling across the bridge which spans the Red Mountain Freeway, the rear-facing camera showed that Ms. Vasquez was not paying attention to the situation ahead, but was streaming *The Voice*, a singing competition television show. Only during the last second prior to impact is Ms. Vasquez seen reacting to the

¹ This camera was labeled "FRONT" on the PC Manager playback

² This camera was labeled "IN CABIN" on the PC Manager playback



impending collision. Data from the data systems showed steering beginning about one second prior to impact and braking beginning one second after impact.

Video from the forward-looking camera was provided to Wolf with a request to determine, if possible, whether that video was a fair and accurate representation of the illumination levels that existed at the scene at the time of the collision.

Mr. James S. Sobek, P.E., a Wolf staff member has performed an analysis of the forward-looking video and the lighting levels at the collision site and has determined that the brightness of the video is far less than what is actually present at the scene.

CONCLUSIONS

It is our opinion that the illumination levels at the collision site along the track walked by Ms. Herzberg from the west edge of Mill Avenue to the point of impact were two to three times higher than those necessary to support color and fine detail vision for a human driver with normal vision.

It is our opinion that at the car location from which Ms. Herzberg was first in Ms. Vasquez's line of sight, street lamp illumination exceeded the Volvo's headlamp illumination by over 50 times.

It is our opinion that Ms. Herzberg could have easily been seen by Ms. Vasquez even if the Volvo's headlamps had been turned off.

It is our opinion that the video from the forward-facing camera is greatly underexposed and consequently is not a fair and accurate representation of what was available to Ms. Vasquez had she been paying attention to the situation ahead.

It is our opinion that with the minimum visual acuity necessary to obtain a driver's license (20/40) and under the lighting conditions at the scene, Ms. Vasquez could have seen and recognized that a person was walking across the road from a distance of 1700 feet away with or without the Volvo's headlights. (We recognize, of course, that the sight distance limit was less than this.)

It is our opinion that with the sight distances available at this scene, had she been paying attention, Ms. Vasquez could have seen Ms. Herzberg starting across the road when the car was a little over 800 feet from the point of impact and visually could have followed her all the way across the road.



EVIDENCE

Information available for our analysis has included the following:

- Tempe Police Department General Offense Report 2018-32694 with supplements
- Tempe Police Department scene photographs
- Topographical map of the collision site from DeLorme's Topo North America 10.0[®]
- Google Earth[®] Aerial and Street View imagery of the collision site
- Vehicle examination conducted on July 9, 2019 at the Tempe Police Department
- Exemplar Volvo XC90 examination conducted on the same date at the Tempe Police Department
- Site inspection conducted on July 9, 2019
- Illuminance measurements made during that site inspection
- .kds movie file UTC20180319_045552 from the subject Volvo XC90
- *PC Manager* video player software to play that file

Our analyses are based on the materials available to us and are provided within a reasonable degree of scientific and technical certainty. Our conclusions are based on the laws of physics, on mathematical computations, on published data, and on Mr. Sobek's education, background and experience in physics, mathematics, lighting, human vision, and visibility. Our analytical methods are generally employed in the field of accident reconstruction, and are set forth in numerous texts and treatises.

DISCUSSION

Site Description

This incident occurred on the northwest side of the city of Tempe. The collision occurred on North Mill Avenue about 440 feet south of the Curry Road intersection. South of the collision site, two bridges carry North Mill Avenue over Tempe Town Lake. The two bridges are separated by as much as 300 feet at the widest separation. The northbound bridge is composed of a long radius left hand curve. The south point of curvature is at the Rio Salado Parkway intersection and the north point of curvature is at about the collision point.

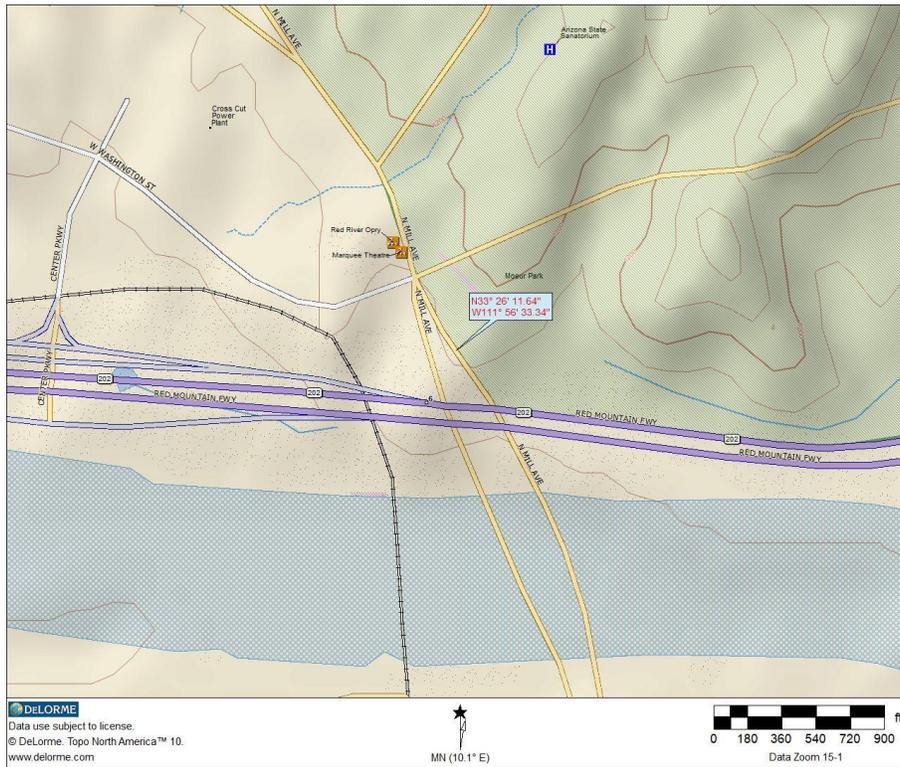


Figure 1 A topographic map showing collision site. The point of impact is indicated by the blue coordinate flag.

As motorists travel over the bridge toward the collision site, they pass under the bridge which carries Arizona State Road 202³ over North Mill Avenue. The bridge support columns and some trees just north of the bridge combine to limit the sight line to the collision site for northbound drivers on North Mill Avenue until those drivers are a little over 800 feet from the collision point.

At night, both sides of both bridges are illuminated by strings of white lights. In addition to the strings of lights, there are streetlamps along both sides of both bridges. The strings of lights end at the south side of the SR 202 bridge, but the line of streetlamps continues north of that bridge. The string of lights and the streetlamps on the North Mill Avenue bridge are LED technology. The streetlamps north of the SR 202 bridge are high pressure sodium arc lamps. In addition, three high mast luminaires along SR 202 spill light onto North Mill Avenue supplementing the light from the closest streetlamps.

On the night of the collision one streetlamp north of the point of impact and on the west side of North Mill Avenue was inoperative. During our site visit, the Tempe Police Department had arranged to have that light again inactive. All other lamps in the area were operating as they were on the night of the collision.

³ Also known as Red Mountain Freeway.

Vehicle and Site Inspection

On July 9, 2019, we conducted an inspection of the Volvo XC90 which had been involved with the collision. We made measurements and took photographs of the inside and outside of the vehicle. We also inspected and photographed the bicycle that Ms. Herzberg had been pushing across the road. During the late afternoon and evening we conducted an inspection of the collision site. We shot video imagery during both sessions.

The afternoon video was taken to capture the scene during daylight hours and show what was within the field of view of motorists approaching the collision site recognizing that during hours of darkness not all those features might show up.

Daytime Video Images



Figure 2 Looking north from the northbound bridge across the Tempe Town Lake. This image is about 811 feet from the point of impact. The red arrow points to where Ms. Herzberg would have initially become visible to Ms. Vasquez.



Figure 3 The view from underneath the SR 202 bridge. The car in the right-hand lane is at about the incident point of impact

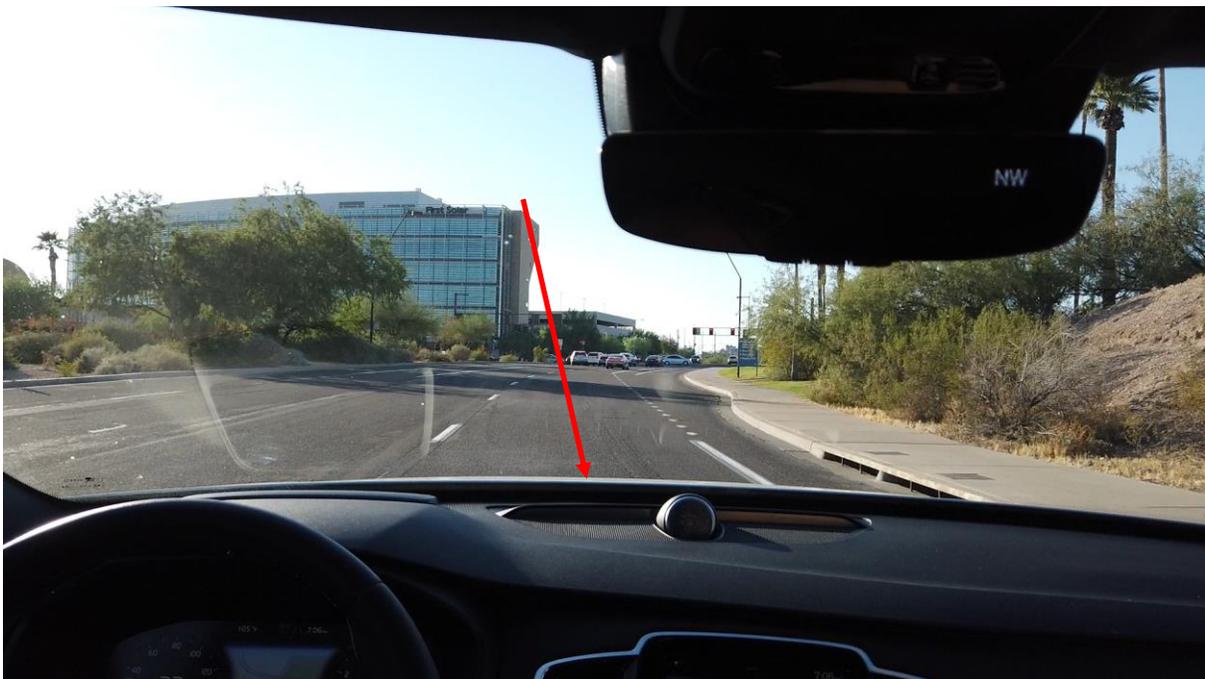


Figure 4 A daytime video image from about 50 feet away from the point of impact. The red arrow marks the bicyclist's feet location on the pavement at the time of impact.

Night Video Images Shot with Osmo Pocket Camera



Figure 5 A night video image from the exemplar Volvo XC90 operating on low beam from a distance of 500 feet from the point of impact.

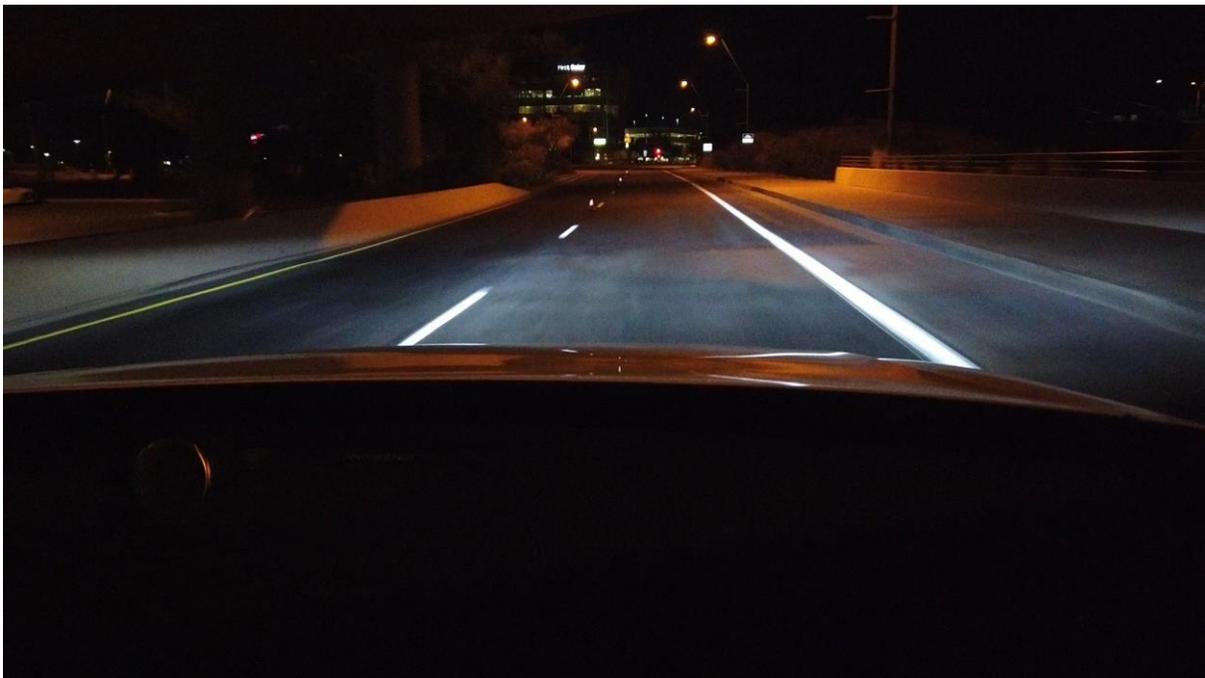


Figure 6 The view from 400 feet from the point of impact.



Figure 7 The view from a distance of 300 feet. The yellow line is the approximate track that Ms. Herzberg walked across the road.



Figure 8 The view from 200 feet. Again, the yellow line marks the track walked by Ms. Herzberg.



Figure 9 The view from the exemplar Volvo on low beam at 100 feet from the point of impact.

Comparison Images

Here we present the pairs of images one above the other so that comparisons can be easily made.



Figure 10 Accident video 500 feet from point of impact.



Figure 11 Osmo Pocket 500 feet from point of impact.



Figure 12 Accident video 400 feet from point of impact.

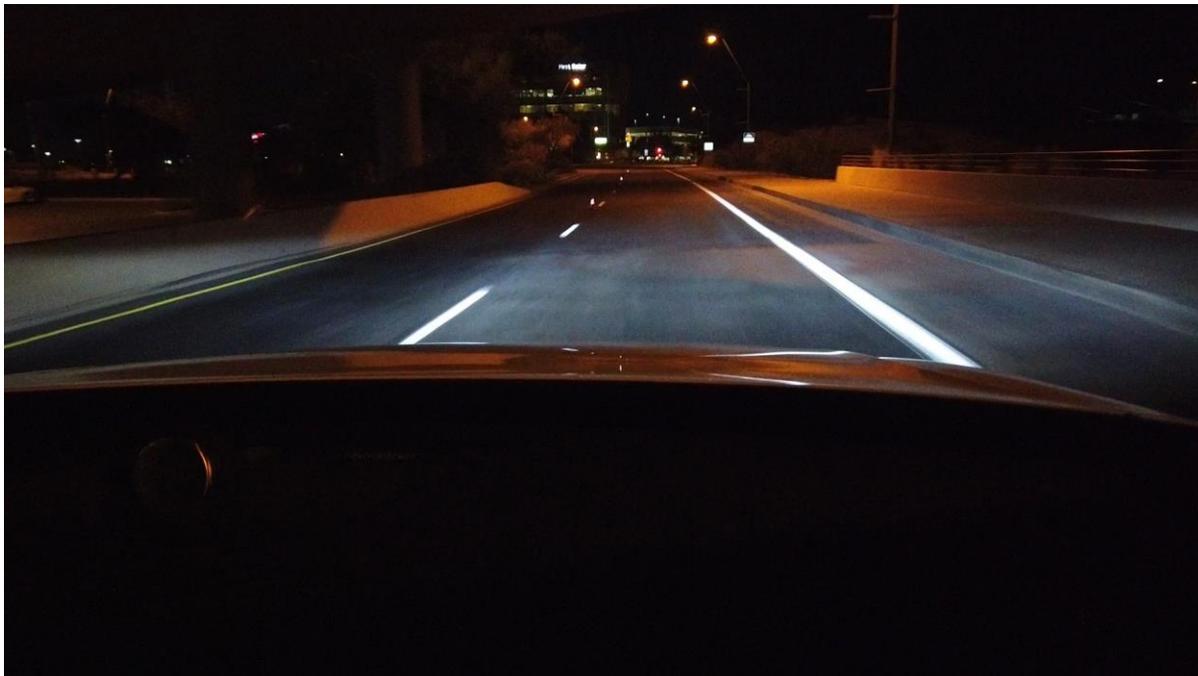


Figure 13 Osmo Pocket 400 feet from point of impact.



Figure 14 Accident video 300 feet from point of impact.



Figure 15 Osmo Pocket video 300 feet from point of impact.



Figure 16 Accident video 200 feet from point of impact.



Figure 17 Osmo Pocket video 200 feet from point of impact.

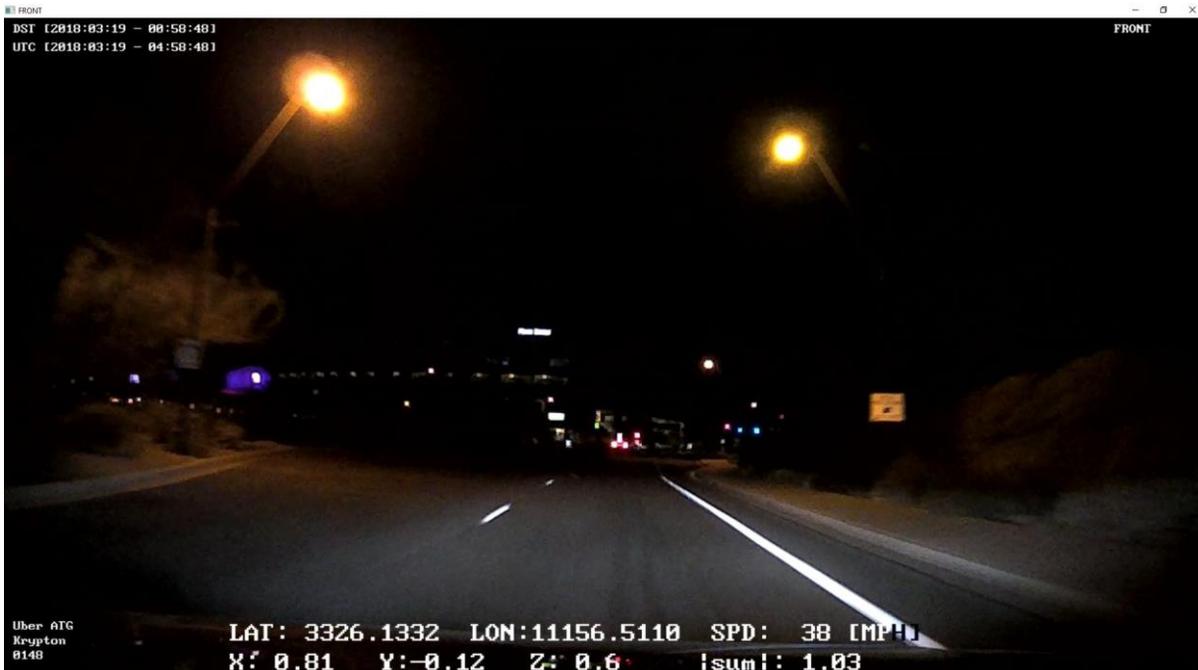


Figure 18 Accident video 100 feet from point of impact.



Figure 19 Osmo Pocket video 100 feet from point of impact.

Illuminance Measurements

During the evening session, we made illuminance measurements along the track that Ms. Herzberg walked as she crossed North Mill Avenue. We made those measurements with the exemplar automobile on low beam at distances of 500 feet, 400 feet, 300 feet, 200 feet, 100 feet and at the point of impact from where Ms. Herzberg was struck. Measurements were made at each of four locations as shown in Figure 20.



Figure 20 The locations where illuminance measurements were taken.

For each location and car position, we measured the illuminance with a Photo Research PR-520 illuminance meter pointed at the exemplar automobile and held at waist level, at knee level and at foot (ground) level. Thus, we were measuring that amount of light reaching the south facing surfaces of Ms. Herzberg and her bicycle. It is important to point out that when illuminance onto an object exceeds about 0.3 foot-candles, the human viewer will be able to perceive color and fine detail about that object. Notice that at all positions leading up to the point of impact, the illuminance values are two and three times that level.



The tables below show the illuminance values (in foot-candles) for each distance, position and elevation.

500 feet			
Position	Waist	Knee	Foot
1	0.6998	0.7623	0.7411
2	0.7681	0.8146	0.7633
3	0.9414	0.8896	0.8735
4	0.8733	0.8100	0.7853

400 feet			
Position	Waist	Knee	Foot
1	0.7379	0.7454	0.6456
2	0.7857	0.7755	0.7566
3	0.9297	0.8644	0.8332
4	0.8864	0.7910	0.8386

300 feet			
Position	Waist	Knee	Foot
1	0.8178	0.6830	0.6873
2	0.9543	0.7738	0.7871
3	0.9339	0.8217	0.9262
4	1.053	0.9398	0.9456

200 feet			
Position	Waist	Knee	Foot
1	0.7531	0.6593	0.7949
2	0.8657	0.7490	0.8266
3	0.8879	0.7877	0.8266
4	0.9169	0.8915	1.120

100 feet			
Position	Waist	Knee	Foot
1	0.7924	0.7378	0.7597
2	0.8530	0.9559	0.8816
3	0.9489	0.9629	1.196
4	0.9570	1.137	3.383

0 feet⁴			
Position	Waist	Knee	Foot
1	0.7710	0.7816	0.6564
2	0.8596	0.7563	0.7278
3	1.089	0.9801	1.045
4	1.078	0.1046	0.0268

Observations made from the interior of the exemplar Volvo XC90 revealed that the road and objects on it were clearly visible from 500 feet away. In fact, once the sight line developed from the car to the place where Ms. Herzberg was crossing, she would have been easily seen as a person walking a bicycle across the road from west to east. Her white tennis shoes and grocery bags would have been the most visible, but once she had been noticed, it would have been completely obvious that she was moving across the road and if nothing was done, a collision was going to ensue.

The video coverage from the front interior camera, however, does not reveal Ms. Herzberg until the more intense portion of the low beam pattern finally reaches Ms. Herzberg's shoes. Even with brightness and contrast enhancement, that video does not reveal any evidence of the pedestrian or the lighted surfaces nearby including the background surfaces against which she was presented. Streetlamp patterns with illuminance values well above 3 foot-candles directly under the lamp heads were not visible in the accident video although they did show in the background of some of the police scene photographs even though those photographs were flash-assisted.

We made video runs through the scene under the same lighting conditions that existed on the night of the collision. We compared what we were seeing on the video monitor with what we were seeing with our own eyes through the windshield. Our site video and the real scene were comparable whereas in comparison, the accident video was severely underexposed. We have attempted to determine why video from the camera in the actual collision was so underexposed. But, no explanation is apparent.

We can say, however, that the accident video is not representative of the scene that was available to Ms. Vasquez. The lighting at the location where Ms. Herzberg was crossing was completely adequate for any driver who was paying a reasonable amount of attention to the task at hand to have seen, understood and reacted to Ms. Herzberg. But, Ms. Vasquez was not paying proper attention to the situation ahead and did not see what was happening until the car was so close to the pedestrian that nothing could be done. Had Ms. Vasquez been paying attention to the task at hand, this collision would not have happened.

⁴ At the 0 feet position, the front of the car was shading the illumination from the street lamp that is located south and east of the point of impact.



ADDITIONAL WORK

The information contained in this report and the conclusions reached are based on information available at the time this report was prepared. We reserve the right to amend and/or modify this report if any new and/or significant data that could impact this investigation becomes available. We recommend that if any additional statements, depositions, photographs, evidence or other information documenting this incident become available, that they be supplied to Wolf for our review so that we may render any further opinions in any future report, deposition, or testimony.

Respectfully submitted,

A handwritten signature in black ink that reads 'James S. Sobek'. The signature is written in a cursive style with a vertical line to the right of the text.

James S. Sobek, P.E.

Reviewed by,

A handwritten signature in black ink that reads 'Jessica L. Ellis'. The signature is written in a cursive style.

Jessica L. Ellis, P.E.



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