Ohio State Highway Patrol

Reconstruction Report

2015-304-00

1910 West Blvd. Cleveland, OH. (Cudell Recreation Center)
City of Cleveland / Cuyahoga County

RECONSTRUCTION INFORMATION

Case Number: 15-304-00

Reconstructing Officer: Sgt. J. Thorne/ OSP Cleveland Operations

Start Date: June 12, 2015

Reconstruction Aids:

- Cuyahoga County Sheriff's Office Report of Investigation (File #15-00004)
- Automated Vehicle Location Recording – Cleveland Police Vehicle 115A
- Digital Video Recordings from Cudell Recreation Center 11/22/2014 (1100 – 1600 hrs.)
- Cleveland Police Deadly Force Investigation #14-20 (2014-368418) – *Redacted*
- Cleveland Police crime scene photographs of incident #14-20 (2014-368418)
- Trimble S3 Electronic Total Station (2x – 1 passive, 1 active)
- Crash Zone ver. 9.4 – Computer aided drafting software

Reconstructive Efforts Requested:

1) Determine approach speed of Cleveland Police vehicle #115A

SYNOPSIS OF INCIDENT

The present incident took place on November 22, 2014 at approximately 1530 hours. Cleveland Police received notification of a subject at Cudell Recreation Park (1910 West Blvd., Cleveland, OH.) allegedly brandishing a weapon at passersby in the park area outside of the recreation center. Cleveland Police Officers Frank Garmback and Timothy Loehmann responded to the scene where Officer Loehmann shot the suspect, Tamir E. Rice, in the torso. Mr. Rice sustained a fatal wound and died a short time later.

DESCRIPTION OF AREA

Cudell Park and Recreation Center is situated on the west side of the City of Cleveland on the southeast corner of the intersection of West Blvd. and Detroit Rd. The recreation area sits east of West Blvd. and south of Detroit Rd., with an entrance to the main parking area off of West Blvd. The area consists of an enclosed recreation center on the northwest portion of the grounds and a park to the east. The park possesses a large, open field to the north, and a wooded walking area to the south, heading towards W. 99th St. and Marion Seltzer Elementary School. Within the wooded area, there is a gazebo, picnic area, swing set, and play structure situated around various concrete walking paths. There is a large parking area to the immediate south of the recreation center, which is enveloped by the walking area to the east, and a baseball field to the south.

NOTIFICATION AND PRE-INVESTIGATIVE TIMELINE

June 5, 2015 – Assistant Cuyahoga County Prosecutor Matthew Meyer contacted me requesting assistance on the Cudell Recreation Park use of force incident. Specifically, Prosecutor Meyer inquired as to whether or not it was possible to determine a vehicle's speed from a surveillance camera. If this was possible, Prosecutor Meyer requested I attempt to determine the speed of the police vehicle as it approached Mr. Rice immediately prior to his shooting.

June 12, 2015 – I met with Prosecutor Meyer and Assistant Cuyahoga County Prosecutor James Gutierrez at the Cuyahoga County Prosecutor's Office. Prosecutors Meyer and Gutierrez briefed me on the status of their investigation and reiterated their request for a speed determination from surveillance video. I was given a copy of the complete case file from the Cuyahoga County Sheriff's Office, including the Cudell Recreation Center surveillance videos, and a redacted copy of the Cleveland Police Department's use of deadly force investigation.

June 15, 2015 – I met with Brian Kitay, administrator of the Ohio State Patrol's Photographic Services division. I gave Mr. Kitay copies of two relevant videos from Cudell Recreation Center and requested assistance in enhancing the quality of the files. Mr. Kitay used FFMpeg software to open the proprietary DVR file and stated he could possibly extract a higher quality video as well as provide me with a frame by frame breakdown of relevant portions of both videos.

June 16, 2015 – I made my first visit to Cudell Recreation Park. I walked through the park and grounds. I located various items of interest, including camera locations and possible view obstructions. I began formulating a plan to map the area using a total station.

June 19, 2015 – I made my second visit to Cudell Recreation Park. I took photographs of the park and recreation center to be used in subsequent forensic mapping. These photographs were uploaded to the Ohio State Highway Patrol's Photographic Services digital server as pouch #DHQ0401-20501. I also solidified my operational plan to measure the area using a total station.

FORENSIC MAPPING

On June 26, 2015, with the assistance of Lt. C. Kinn (Ohio State Highway Patrol Crash Reconstruction Commander), I measured Cudell Park using two Trimble S3 electronic total stations. One total station was set approximately 54 ft. north of the gazebo on the southern edge of a large open field, while second was set at the northeastern dead end of W. 99th St. The park was measured from these two vantage points, with each mapping diagram incorporating three identical mapped points placed in a small grassy island on the eastern edge of the area.

Once measured, the mapping files were imported into Crash Zone (ver. 9.4.92) computer aided drafting software and used to create a detailed scale diagram. Using the three common points, and other common mapped areas (i.e sidewalks, etc.) the two separate diagrams were merged into a singular map encompassing a large portion of both Cudell Park and W. 99th St.

While creating a useable scale diagram, I discovered two omissions from the scene mapping. The first was a park bench situated almost due south of the southernmost gazebo post along the northern edge of a rubberized play area. The second was a tree, located south of the play area and east of a mapped sewer grate. Using overlapping sight lines in the surveillance video, I was able to plot the location of the park bench on the scale diagram. To plot the location of the tree, I returned to Cudell Park on June 29th, 2015 and measured its location by hand from a mapped utility pole to the south. I also verified the reconstructed position of the park bench using hand measurements.

Unless otherwise indicated, all measurements subsequently referred to in this report were taken from the resultant scale diagram. A copy of the completed diagram accompanies this report.

SURVEILLANCE VIDEO

Vantage Points

Cudell Park is surveilled by ten separate cameras, each of which captures a different area of either the interior recreation center or exterior grounds. Investigating officers obtained copies of the ten digital video recordings for November 22, 2014 beginning at 1100 hours and extending through 1600 hours. I was given copies of all ten digital video files by the Cuyahoga County Prosecutor. While most of the videos capture at least some aspect of the overall investigation into the incident, only two were relevant in determining the speed of Cleveland Police vehicle #115A. These two videos were captured from Cameras #1 and #4.

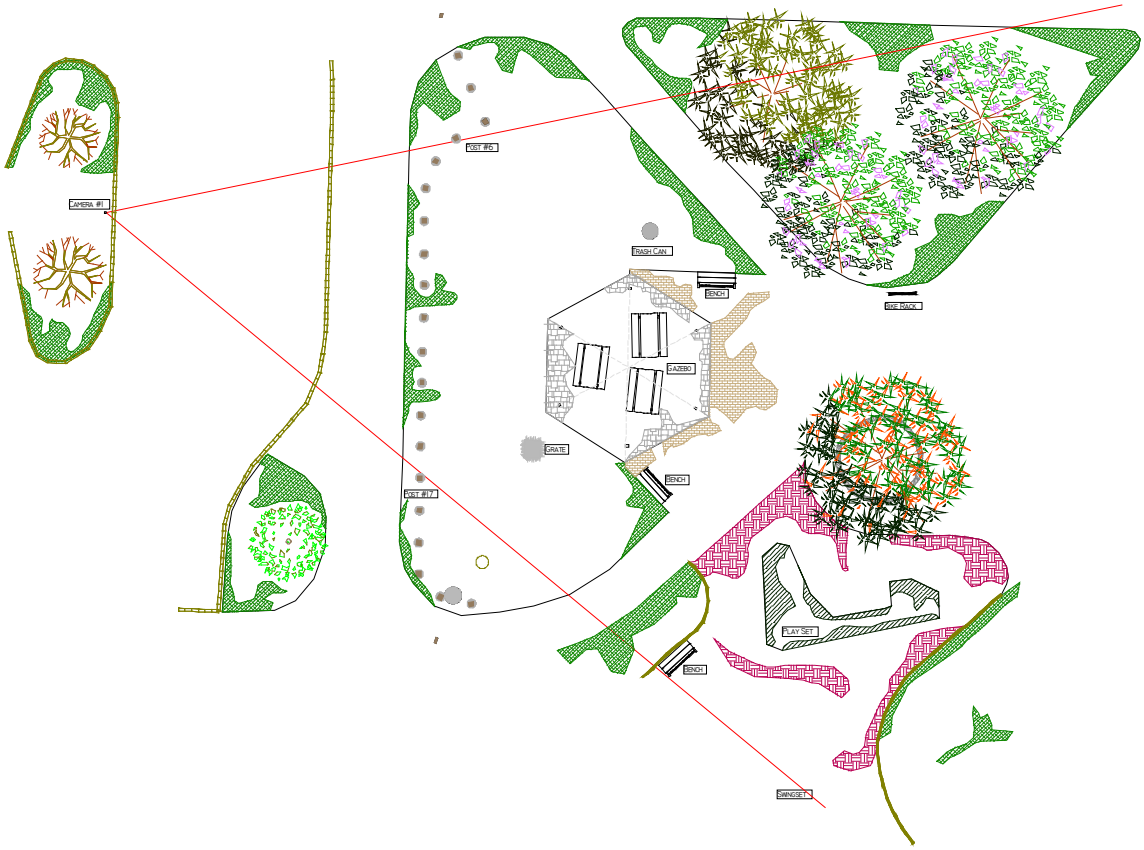
Camera #1 was mounted on a utility pole on the eastern edge of a grassy island in the middle of the Cudell Park visitor's parking area. The camera faces due east and is more or less centered on the western side of a gazebo. The general viewing area of Camera #1 is depicted below.

Camera #4 was mounted on the southeastern side of the Cudell Recreation Center building façade. The camera faces south and focuses primarily on the visitors parking area, but the gazebo and portions of the park are also visible in the background. Additionally, the grassy island where Camera #1 is mounted is viewable slightly right of center frame.

As part of my forensic mapping, I measured the exact locations of the two video cameras. I used these locations, and other mapped points, to determine the approximate limits of each respective camera's viewpoint.

There were twenty nine (29) wooden posts erected on the western edge of the park area. These posts extended from the walking path north of the gazebo to a grassy area south of an additional entrance to the walking path and play area. Camera #1's northern view limit is cut on the south edge of post #6 (from the north). The southern view limit shows thawed ground near the base of post #17, but post #17 is not explicitly visible itself. From the camera's vantage point, post #16 and the left side of a bench are in-line with one another. The right side of this bench denotes the southern limit of the camera's view.

These areas were plotted on the scale diagram to give a high angle depiction of the camera's actual view area. The diagram reproduced on the next page is a portion of the full scale diagram demonstrating an approximate line of sight for Camera #1. The red lines mark the limits of the camera's view.



The sight limits of Camera #4 were determined in a similar fashion. The eastern limit of view cuts through the extreme northeast edge of the gazebo's grassy area. The western edge passes through the southwest corner of a pavement marking box delineating handicapped parking spaces in the visitor's parking area.

Again, these intersecting sight lines were plotted on the scale diagram and used to create an overhead view of the camera's perspective. The limits of this perspective are denoted by blue lines in the following diagram reproduction.

The background (south viewpoint) of Camera #4 is obscured by several trees and landscape. The video from November 22, 2014 was taken during a time when the majority of foliage from the surrounding trees was missing, allowing for a less obstructed view. At the time of forensic mapping, the trees were full of leaves and growth, making absolute comparison to the video impossible with regards to limits of visibility to the south. Although it is not depicted in the diagram above, headlights of vehicles traveling north on W. 99th St. are visible through the trees when viewing the video from November 22, 2014.

Cameras #1 and #4 captured a large majority of the shooting incident within their respective fields of vision. Since it is not within the scope of this report to investigate the shooting itself, my analysis of the surveillance video from each respective camera will be limited to that which is necessary to compute the approach speed of Cleveland Police vehicle #115A.

Cameras #1 and #4 were initially viewed using the proprietary files captured from the Cudell Recreation Center DVR. I viewed relevant portions of the video files again after receiving them as .AVI files in their original respective aspect ratios from the Ohio State Highway Patrol Photographic Services department. Additionally, the photographic services department was able to capture individual frames of the respective videos to assist in my investigation. These individual frame captures were used in the subsequent analysis sections below.

Camera #1 – Capture

Camera #1 begins capturing Cleveland Police vehicle #115A (occupied by Officers Garmback and Loehmann) at time stamp 15:30:18. Car #115A enters the camera viewpoint from the right side of the screen (south) and passes between the gazebo and a series of wooden posts separating the sidewalk from the gazebo. The vehicle comes to a stop in front of the gazebo, roughly in the center of the video's field of vision. The vehicle ceases forward movement at time stamp 15:30:22, where it appears to rock slightly backwards.

While the frame rate of the video varies at different points throughout the recording, for this specific time frame, the video plays at 2 frames per second. After watching the video and examining it frame by frame, I determined the camera captured the vehicle stopping over 7 frames of video. These seven frames are shown below, along with the frame immediately preceding car #115A's entrance and the frame immediately after it has come to a stop.

1. The frame immediately prior to car #115A entering from the south (right side) of the camera's field of vision. Time stamp on video is 15:30:17.

2. The frame appears to be the second frame captured on time stamp 15:30:18. Car #115A is partially visible on the extreme right side of the video frame.

3. Car #115A is nearly fully in view of the camera frame.

4. Car #115A fully in view of the camera frame. Its front bumper appears to be breaking the plane of the western side of the gazebo.

5. The vehicle approaches the midpoint of the gazebo. Tire tracks are visible in the grass behind the vehicle.

6. Car #115A is completely in front of the gazebo, approaching final rest.

7. The vehicle continues north (heading left in frame), but at a slower rate.

8. Car #115A reaches its northernmost location and stops

9. This frame shows Car #115A rocking backwards slightly, likely due to weight shift from braking. The vehicle does not travel any further to the north.

Car #115A came to a stop over 7 frames of video captured at 2 frames/second. From camera #1's vantage point, Car #115A came to a stop over a time period of approximately 3.5 seconds.

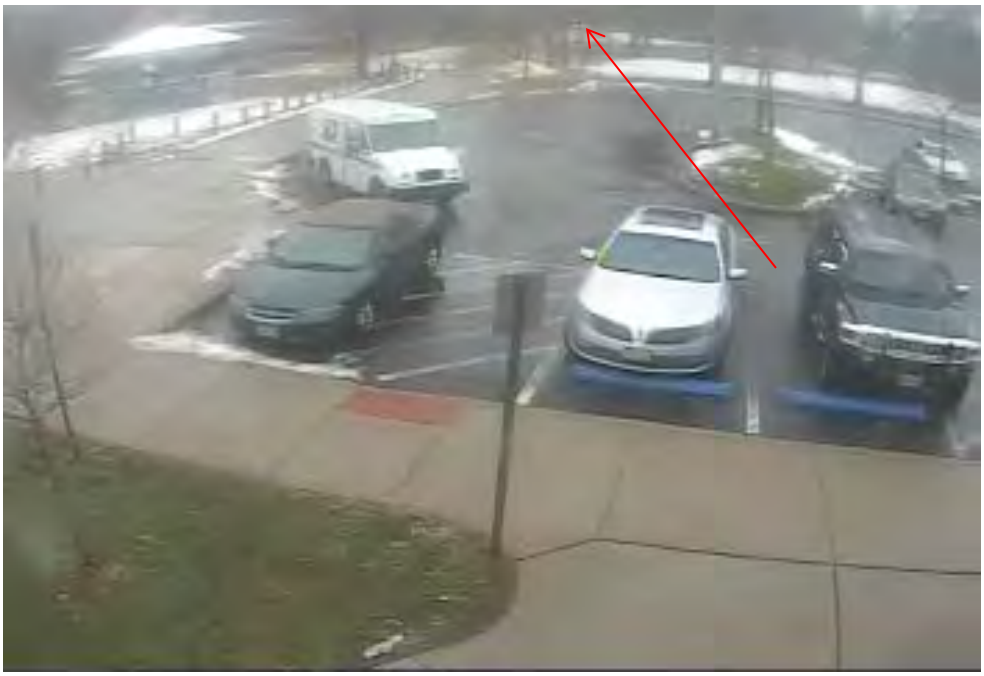
Camera #4 – Capture

While Camera #4 is focused primarily on the western side of the Cudell Recreation Center parking lot. Its position and orientation allowed it to capture Car #115A as it approached the gazebo/shooting area from the south. Unlike Camera #1, however, Camera #4 does not record at a constant 2 frames/second during the entire period of analysis. A portion of Car #115A's approach is captured at a higher frame rate before dropping again to 2 frames/second when it begins to coincide with Camera #1. Camera #4 begins capturing images of Car # 115A at time stamp #15:30:01.

1. The frame immediately prior to the headlights of car #115A becoming visible.

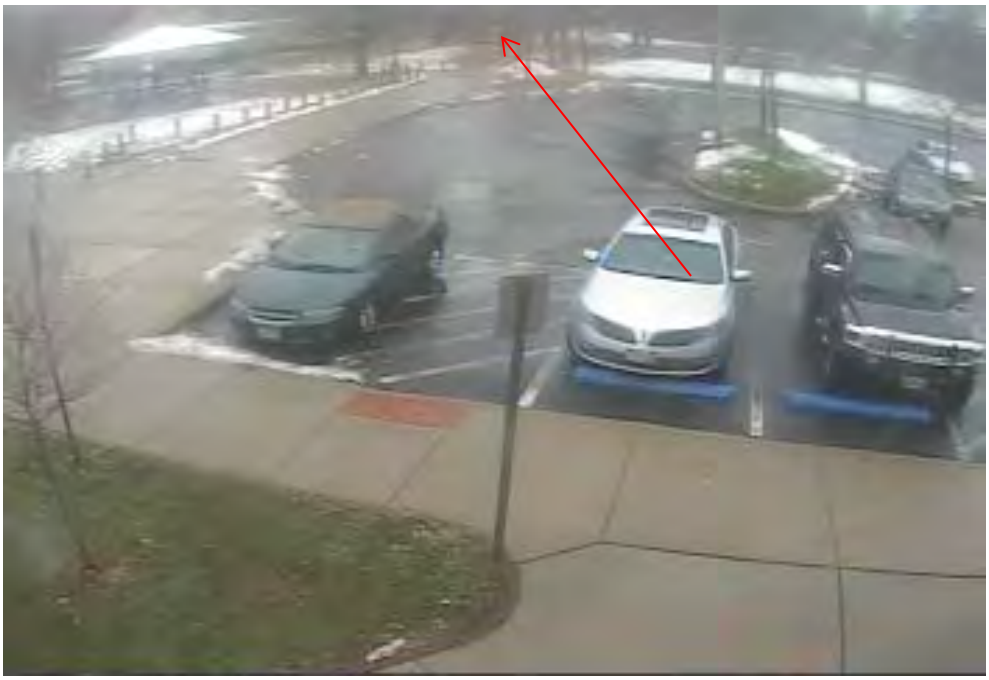
2. The headlights of Car #115A become visible in the top center portion of the camera image.

3. Three frames later, two headlights are clearly visible in the same area, moving towards the camera from a distance.

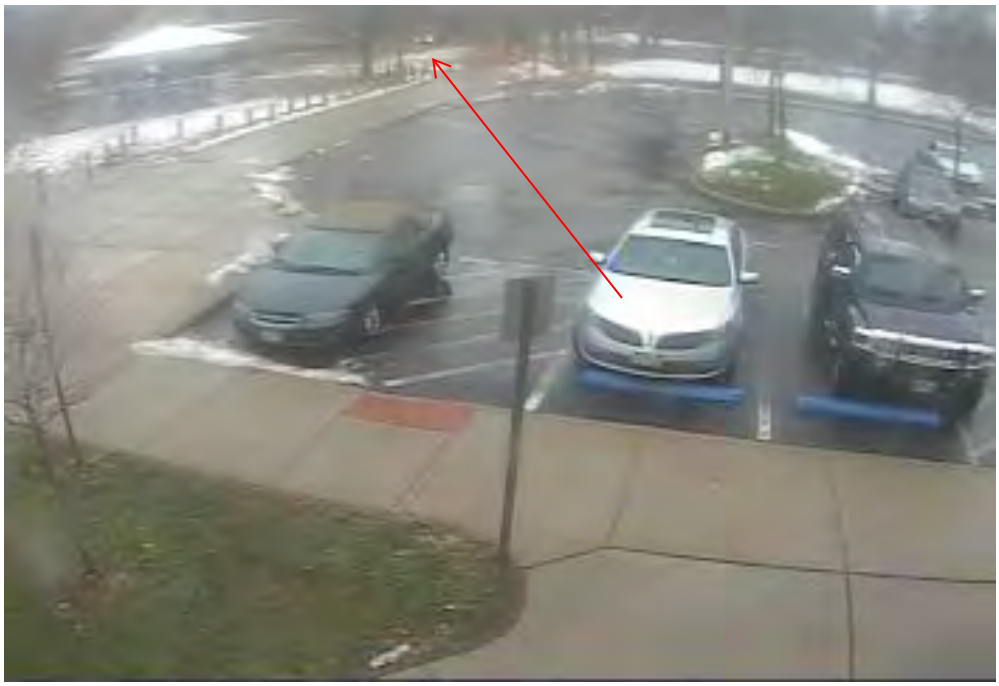


4. The lights remain visible for nine frames, before disappearing from camera view.

5. No lights are visible for 19 frames, then they reemerge on the left (east) side of a view obstruction on the 20th frame.



6. Lights continue to be intermittently visible for 30 frames, before clearly emerging closer to the camera.



7. Lights continue to visible for nine frames before disappearing behind a view obstruction.

8. Eight frames later, both headlights appear just to the left (east) of a large tree in the foreground near the gazebo. Although it is clear the vehicle is not close to this tree in proximity, the tree is serving as a clear view obstruction for the camera.

9. The headlights of the vehicles flash brightly on subsequent frames twelve and thirteen. The vehicle appears to have suddenly changed elevation or traversed a bump as its lights dip downwards and then abruptly rebound.

10. Six frames later, the left front headlight of the vehicle becomes obscured by the foreground tree.

11. Five frames later, the left front headlight is visible. The vehicle is now split by the foreground tree in the camera's perspective.

12. Six frames later, the left front headlight disappears again from the camera's field of vision. The vehicle appears to be steering towards its right (east).

13. Two frames later, the right front headlight flashes brightly, and it appears as if the vehicle has traversed another bump or elevation change. The left front headlight remains obscured.

14. The next frame shows both headlights visible again, but the right headlight still maintains somewhat of a flash. This is the last frame captured at a higher framerate.

15. Over the next eight frames, car #115A comes to a stop. The video resumes playing at 2 frames/second.

Camera #4 shows Car #115A coming to a stop at time stamp 15:30:22. After viewing both videos and comparing them frame by frame, they appear to be synced with one another with regards to time. From the perspective of Camera #4, Car #115A required nine frames of video to come to a stop after traversing a bump. This translates to approximately 4.5 seconds.

SCENE EVIDENCE – CLEVELAND POLICE

While Cameras #1 and #4 provide vital information with regard to speed determination, neither captured the deceleration of Car #115A in its entirety. Camera #1 captured Car #115A during its final period of deceleration, but did not appear to show the beginning of evasive braking. Camera #4 captured the entire approach and deceleration, but its vantage point was of such distance from the event, it was not possible to accurately determine the actual start of evasive action from the video itself. Consequently, the initial scene documentation conducted by Cleveland Police needed to be examined for assistance in determining an area where evasive action likely began.

The following section will examine the scene photographs, field sketch, and initial evidence documentation conducted by Cleveland Police on November 22, 2014. Throughout this section, I will use actual scene photographs to assist in illustrating evidence where available and applicable. I will also refer to specific portions of the field sketch and investigation log.

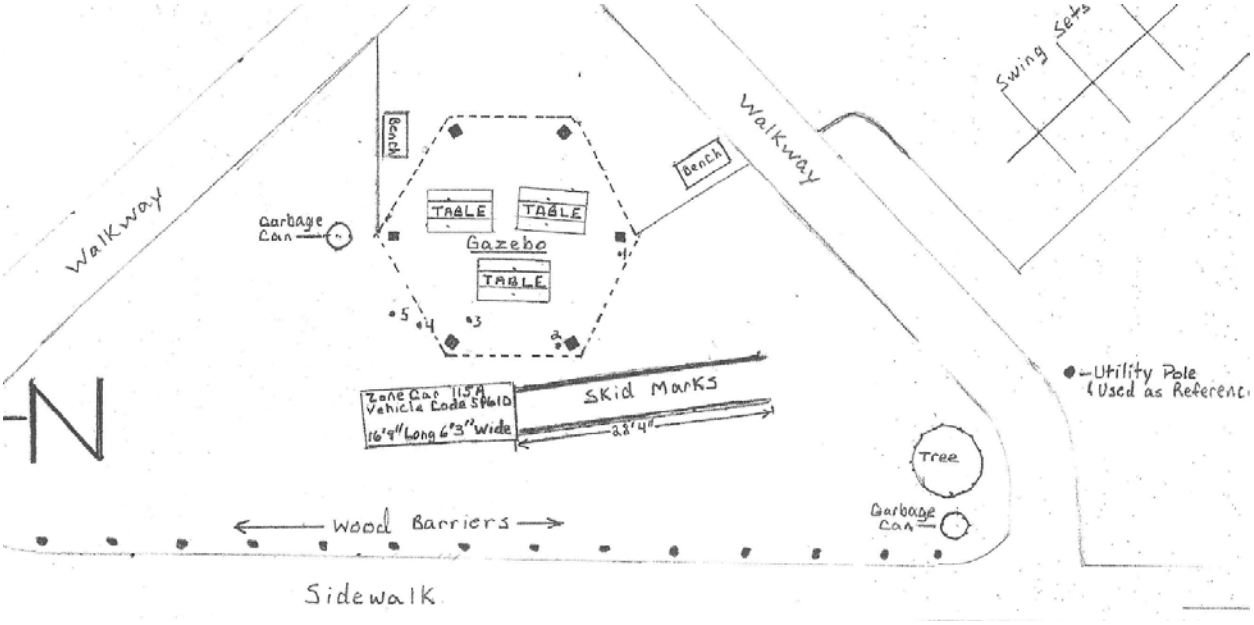
Field Sketch/Measurements

The primary investigating officers at the scene, with regards to evidence documentation and scene diagramming, were Cleveland Police Detectives Diaz and Sandoval. As part of the investigative file, I received a partially redacted investigative narrative from Detective Sandoval detailing his efforts documenting scene evidence. I also received two hand drawn field sketches drawn by Detective Sandoval illustrating both Cudell Park as a whole, and the specific area of the incident. With regards to determining the speed of car #115A, the following excerpt from Detective Sandoval's narrative is instructive:

> Cleveland Police black marked zone car 115A, a 2014 Dodge Charger, vehicle code 5P610, was parked in a northbound, slightly to the west, direction with the engine running, and the exterior lights activated. Zone car 115A is 16'9" long, which includes the push bar attached to the front end, and is 7'1" wide. The rear corner of zone car 115A was 3'11' west of the western edge of the gazebo cement pad.
>
> The front edge of the front driver's side wheel well was 25'4" and the driver's side rear corner was 26'6" east of the east curb of the parking lot. The driver's side corner of the rear bumper was 52'8" north of the reference point utility pole. 28'4" long parallel skid marks in the grass led up to the rear bumper of zone car 115A. When zone car 115A was moved the skid marks were found to continue under where the zone car was positioned for a total length of 40'10".

Of specific interest in this narrative are the measurements indicating the final resting position of Car #115A and the length of the described "parallel skid marks." Minimum speed determination requires a distance of deceleration along with a surface friction component to calculate a resultant speed. In this case, Detective Sandoval indicated Car #115A left 40'10" (40.83 ft.) of "skid marks", 28'4" (28.33 ft.) of which extended south of the vehicle's final rest.

I consulted Detective Sandoval's field sketch for a visual representation of his evidence collection. The portion of his field sketch depicting pre-stop deceleration is reproduced below. **Note – Detective Sandoval's sketch is not drawn to scale.



The field sketch shows the final resting position of Car #115A with two tire marks extending to the rear (south). While the sketch is clearly not drawn to scale, the tire marks do not extend to the illustrated sidewalk or beyond in the officer's representation of the evidence.

Scene Photographs

The following photograph depicts the final resting position of Car #115A from the northwest facing southeast. Faint tire marks are visible on the extreme right side of the frame.

This alternative viewpoint depicts Car #115A from the southwest, facing northeast. Indentations which appear to be parallel tire marks are visible in the grass near center frame. An irregular snowy area in center frame is a sewer grate located in the grass yard.

This photograph focuses on evidence located near the western edge of the gazebo and is taken from a position slightly east of the patrol vehicle, facing south. In the background near two officers standing on a sidewalk, there is a clearly visible tire mark extending south to the sidewalk.

The focus of the following photograph is a bullet casing marked with evidence tent #2. It is taken from a position slightly south of the last image, as is evident by the position of a picnic table in the foreground. The snowy sewer grate is also visible in center frame. The tire mark visible in the previous photograph now comes into plain view, clearly extending to the concrete sidewalk. A second track is visible passing through the snowy, leaf covered sewer grate where it extends south until being obscured by a gazebo post. In the extreme north (top) portion of the camera frame, additional tire marks become visible.

The following photograph depicts Car #115A from a southern viewpoint facing north. The snowy sewer grate remains visible near center frame. Additionally, three tire marks are visible in the lower left foreground. Two of these tire marks appear roughly parallel and head in a direction consistent with the final resting location of Car #115A. The third tire mark cuts diagonally across the right parallel mark, on a more northeasterly trajectory. A concrete curb delineating a play area is visible in the extreme lower right portion of the image.

An image taken slightly south of the previous clearly shows the presence of four tire marks. Two appear straight and head towards final rest of Car #115A. The remaining two marks curve towards the right side of the frame (northeast).

This image is further south of the previous and again depicts four tire marks in a grassy field west of a play area and swing set. The outer set of marks is much more defined and clearly arcs to the northeast. The lighter set remains more or less parallel, with the right mark visible further to the south than the left. The right mark also appears to pass over the extreme northwest corner of the play area.

The following image is taken from a position further south facing north. It again clearly depicts two sets of tire tracks in the leaf covered field west of the play area.

Lastly, this image faces south and is taken from a position roughly 180 degrees from the last image. It depicts W.99th St. in the background and a faint tire track in the grass to the left side of the frame heading north from the concrete sidewalk.

SCENE INVESTIGATION - OTHER

BCI Laser Scan

On April 25, 2015, the Ohio Bureau of Criminal Investigation (BCI) assisted the Cuyahoga County Sheriff's Office in measuring the scene of this incident using a Faro laser scanner. In this laser scan, BCI agents placed an exemplar Dodge Charger at the scene using Detective Sandoval's measurements and took various three dimensional scans of the environment to create a composite electronic diagram.

In this resultant diagram, BCI agents identify suspected tire marks in the grassy field west of the play area. These marks are consistent with the darker, arcing marks identified in Cleveland Police scene photographs. When examining the overhead scan images of the Dodge Charger, parallel tire tracks are visible to the south of the exemplar vehicle, but their total distance is obscured by a tree.

Due to the elapsed time between the incident and laser imaging, it is unknown if the tire marks in the scan were marks left by vehicle #115A on November 22, 2014. It is possible that any impressions visible to the immediate south of the exemplar vehicle in the BCI laser scan time were created by BCI agents themselves as they attempted to place the vehicle. Consequently, I did not use the images or measurements from BCI's three dimensional laser scan in my analysis.

Automated Vehicle Locator

Car #115A was equipped with an Automated Vehicle Locator (AVL) device capable of recording the vehicle's location and speed. The Cuyahoga County Sheriff's Office summarized Car #115A's path of travel in their narrative, as well as briefly addressing the recorded speed.

As part of the investigative file, I was given a copy of a recorded animation from Car #115A's AVL file. The video began at 15:01:58 on November 22, 2014. I observed the video and found it refreshed speed and location approximately every 9-10 seconds. Sometimes, the AVL would skip a refresh and create a 20 second interval between data. Additionally, the speed appeared to lag behind the vehicle's movement and did not necessarily reflect the speed of the vehicle at its reported time stamp. Beginning at time stamp 15:29:19, I created the following summary of the AVL file delineated by time.

Time	Location	Speed
15:29:19	Left turn, Madison to W.99th	13 MPH
15:29:29	W.99th at Cudell Park grass	17 MPH
15:29:40	Within Cudell Park	14 MPH
15:29:59	Stopped in Cudell Park	5 MPH
15:30:09	Stopped in Cudell park	0 MPH

Due to the obvious limitations of the AVL, it was considered, but did not govern my overall analysis.

EVIDENCE CONCLUSIONS

With both the surveillance video and scene investigations examined, it is necessary to arrive at conclusions regarding the placement of Car #115A at various points in time during its approach to the shooting area. Once the location of the vehicle is determined on the scale diagram, the speed of the vehicle can be estimated from a combination of surveillance video and scene evidence.

Approach Path – Car #115A

It is clear from both the AVL and associated surveillance videos that Car #115A approached the shooting scene from the south. The vehicle entered Cudell Park from the dead end of W. 99th St. and drove through the park area to arrive at the gazebo where the incident culminated. This approach is partially captured on Camera #4, but the quality of the video is too low to determine at what exact point on W. 99th St. the vehicle becomes visible to the camera. Moreover, at the time of my investigation the trees in Cudell Park were in full foliage which is not consistent with their state at the time of the incident.

Two important objects were not captured in any scene photography done by Cleveland Police that are illustrative to the approach of Car #115A when compared to the scene evidence and surveillance video. Both are depicted in the photograph below, which was taken as part of my second scene visit to Cudell Park. The first is a small tree in the center of the frame, and the second is a sewer grate positioned at the bottom of a small knoll.

The tree to the left side of the frame in the previous photograph is the same tree depicted in this photograph.

The presence of the northern tree illustrates the fact that Car #115A would have had to drive between two trees in order to approach the gazebo area, thus creating an obvious path of travel supported by the presence of tire marks shown in scene photography. The location of this tree also places the vehicle in-line with the previously mentioned sewer grate. The sudden change in elevation as Car #115A traversed the sewer grate is what caused the first momentary flash of the vehicle's headlights as captured by Camera #4.

Approach Path – Extraneous Tire Marks

The presence of four tire marks moving in essentially the same direction at a crash scene suggests a vehicle in the advanced stages of critical speed yaw. If in critical speed yaw, the vehicle has lost lateral stability and is completely out of control.

The video of this incident suggests otherwise. Camera #1 shows Car #115A moving straight to final rest from the south, with no indication of critical speed yaw. Likewise, Camera #4 shows the vehicle able to make steering inputs at least until the final few frames of its approach. There is no indication in Camera #4 of any lateral instability or non-driver initiated rotation. Additionally, the trajectories of the marks do not appear consistent; with one set traveling almost due north, and the others arcing towards the northeast.

The Cuyahoga County Sheriff's investigation lists additional Cleveland Police officers arriving on scene at 1534 hours, 1536 hours, 1537 hours, 1539 hours, and 1543 hours. Consulting Camera #4 during these times reveals a second Cleveland Police cruiser duplicating the approach path of Car #115A at 15:38:29. The vehicle takes a similar path to Car #115A, but turns wider to the northeast and parks on the concrete walkway south of the gazebo.

The surveillance video clearly demonstrated the darker, northeasterly tire scuffs were created by an additional responding Cleveland Police vehicle and not Car #115A. Consequently, the path of Car #115A was reflected in the lighter, northbound tire marks depicted in the scene photography.

Approach Path – Second Impact

In the analysis of Camera #4, it was evident that Car #115A experienced two abrupt elevation changes causing brief flashes in its approaching headlights from the camera's perspective. The first of these flashes was already identified as being caused by an elevation change from a sewer grate and associated knoll in a grassy area west of the park play area. The second flash appeared to emanate only from the right front headlight and was later in the video analysis, meaning it was closer to final rest of the vehicle.

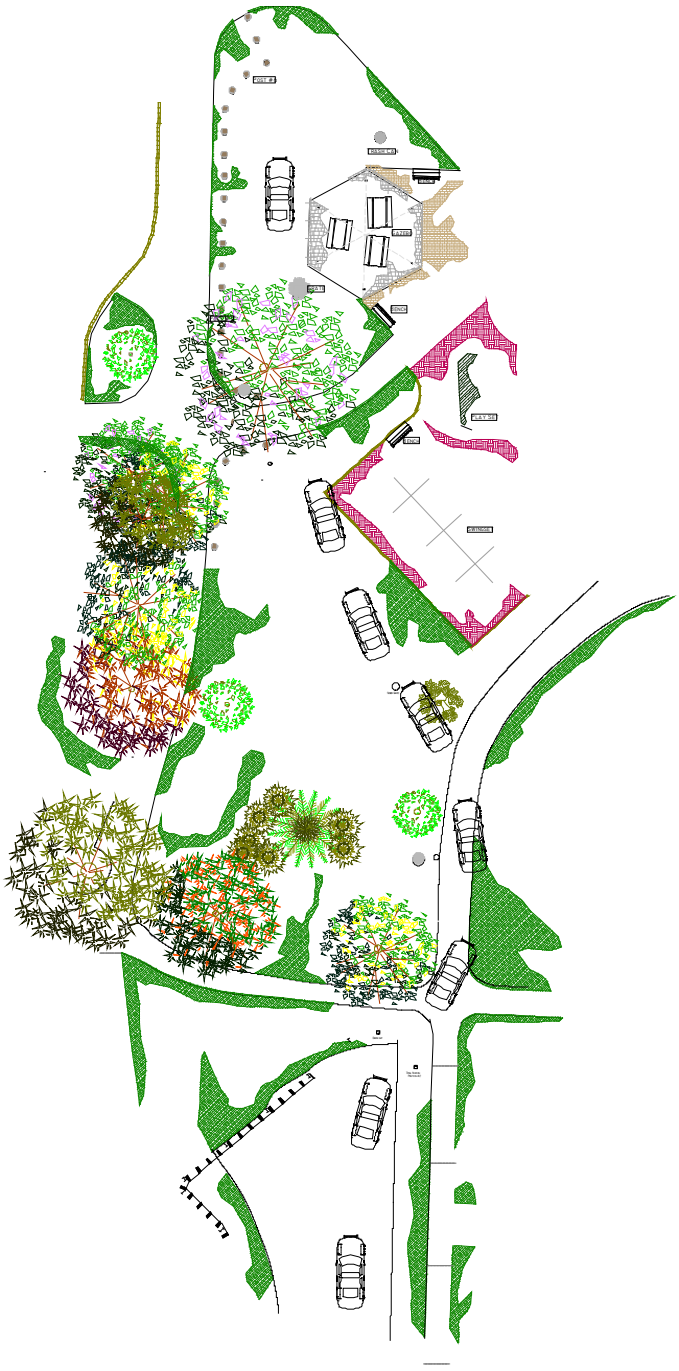
Knowing that extraneous tire marks existed during the scene photography and that they arced to the northeast, the remaining tire marks can be examined via photographs to determine what would have caused the additional elevation change on the right front area of the vehicle.

The following two images are repeated from the crime scene photograph section to illustrate the source of the second impact.

The second headlight flash captured by Camera #4 resulted from the right front wheel of Car #115A traversing the corner of the depressed play area south of the gazebo.

Approach Path – Diagram

Based upon the analysis conducted in the previous section, the approximate approach path of Car #115A to the shooting area can be depicted using the scale diagram.



SPEED DETERMINATION

Methodology

With the evidence discussed and approach path plotted, along with various milestones in the surveillance video, it is possible to begin calculating the approach speed of Car #115A. Determining the speed of Car #115A can be conducted using two methods; constant speed and slide to stop.

A. Constant Speed – The speed of a vehicle can be determined via constant speed equations (distance/time) when it is reasonable to assume a vehicle traversed a distance between two known objects without appreciable acceleration or deceleration over a known period of time. Put succinctly, if a vehicle traveled 50 miles in two hours with no appreciable changes in speed, the vehicle would have been traveling 25 miles per hour.

   In this instant case, knowing the locations of fixed objects (i.e. trees, posts, etc.) and the amount of time it took Car #115A to traverse a perceived distance between them based upon camera angle, it would be possible to calculate the speed of Car #115A, assuming no appreciable acceleration or deceleration.

   There are difficulties with using a constant speed approach in this case. First, the best video of the incident is captured while the vehicle is clearly decelerating to a stop. Additional video of the approach exists, but its quality is not sufficient to determine when or if the vehicle is accelerating or decelerating in the immediate moments prior to the shooting.

   Second, the videos clearly show Car #115A turning and adjusting its heading/bearing throughout its approach. While it is possible to estimate the actual distance traveled by the vehicle by plotting a curved path, the lack of physical evidence present for me to accurately estimate this path would make any distance measurement extremely subjective.

   Lastly, Camera #4 would be the best candidate for completing a constant speed analysis. Camera #4 also possesses the least reliable frame rate leading up to the final approach of Car #115A. Aside from the frames capturing the vehicle after it struck the play area, which clearly play at 2 frames/second, the video plays at an unknown speed and would not provide an accurate time measurement for the subsequent calculation.

B. Slide to Stop – The speed of a vehicle can be determined through “slide to stop” equations if the distance of deceleration is known and the frictional value of the surface the object is decelerating across is also known. The deceleration distance is commonly determined by measuring tire marks at a scene. The frictional value of the surface can be tested independently, or gleaned from published data sources. The frictional value

for the surface can also be calculated if other variables, such as total deceleration time, are known.

Since it is clear Car #115A was decelerating through the clearest portions of the associated surveillance video, and there was sufficient evidence to determine a range of deceleration distances, the slide to stop method is the more accurate methodology for calculating vehicle speed in this instance.

Slide to Stop – Distance Determination

Using the scale diagram, I was able to locate the reference point and line used by Detective Sandoval in his scene narrative and field sketch. From his measurements, I was able to plot the final resting position of Car #115A on the scale diagram. The vehicle location appeared to match the scene photography, at least with regards to its absolute north/south distance. There was a minor discrepancy with the width of the vehicle as measured by detective Sandoval, as it was listed in the narrative at 7'1" and on the field sketch as 6'3". Placing his measurements on the scale diagram produced a resultant vehicle 5.7 ft. (approximately 5'8") in width. I measured the width of an exemplar 2014 Dodge Charger as approximately 6'1", not including rear view mirrors. This discrepancy is a likely result of Detective Sandoval using a curved line (parking lot curb) as a reference line for his measurements, instead of a straight edge.

After plotting the vehicle, I added two parallel lines 28'4" south of the vehicle's rear bumper. I added in the vehicle's measured length and obtained a distance of 40.8 ft. (40'9.6") which was consistent with detective Sandoval's measurements. In his narrative, Detective Sandoval indicated this was his observed length of the skid marks leading to final rest of Car #115A.

The scene photography, while limited, appeared to show different. Several images clearly show at least the left tire mark extending south to the concrete sidewalk, adding approximately 11.3 ft. in additional length to the tire marks. Moreover, the tire marks are visible on the opposite side of the sidewalk near the area of impact with the play area, approximately 32.4 ft. south of the measured skid marks. While the tire marks are visible beyond this area, the video shows evidence of steering input prior to impact with the playground curb. Visible steering input makes the possibility of evasive braking prior to impact with the curb unlikely, even with anti-lock brakes activated.

Based upon the observations of Detective Sandoval, evidence obtained from the surveillance video and scene photography, Car #115A decelerated to a stop over a distance between 40.8 ft. and 73.3 ft.

Slide to Stop – Time

The range in possible deceleration distances requires several calculations to arrive at a speed estimation. For purposes of this report, a maximum, minimum, and hybrid scenario will be examined. For each of these scenarios, a deceleration time and distance must be determined.

A. Minimum – The minimum speed uses the shortest distance, or the distance measured by Detective Sandoval at 40.8 ft. The minimum speed likely underestimates the true speed because it does not account for the possible additional deceleration distance visible in the scene photographs.

   When plotted on the scale diagram, detective Sandoval's measurements begin at the southern boundary of Camera #1's view perspective. This indicates camera #1 would have captured the entire deceleration event if the total deceleration distance were 40.8 ft. During prior analysis, I determine Car #115A slid to a stop over 7 frames of video playing at 2 frames/second. This indicates that under the minimum scenario, Car #115A slid to a stop over 40.8 ft. in 3.5 seconds.

B. Maximum – The maximum speed assumes evasive braking takes place immediately after Car #115A strikes the playground curb and uses the total distance from this impact area to final rest as its deceleration distance. Because it is highly unlikely this impact and evasive braking coincided at an exact moment in time, the maximum likely overestimates pre-deceleration speed of the vehicle.

   Camera #1 did not capture the impact between Car #115A and the curb, but it was captured by Camera #4. This curb impact was the last frame played back at a higher frame rate prior to the video returning to 2 frames/second. Afterwards, Car #115A decelerated to a stop over 9 frames of video playing at 2 frames/second. Under the maximum scenario, Car #115A slid to a stop over 73.3 ft. in 4.5 seconds.

C. Hybrid – The hybrid speed assumes a middle point between the minimum and maximum based upon surveillance video evidence. It uses a longer distance than the minimum, but not quite as long as the maximum. It is intended to be a middle estimate of the speed and also to serve as a check for various other variables.

   The distance between Camera #1's southern sight line and the playground curb was 31.8 ft. If Camera #1 captured 7 frames of deceleration, and Camera #4 showed 9 frames of deceleration from curb impact to final rest, 2 frames of video separated the vantage point of Cameras #1 and #4. This means the vehicle would have traveled 32.4 ft. in one second, or approximately 16.2 ft. per frame of video on average. Splitting the difference between the minimum and maximum distance estimation would indicate Car #115A slid to a stop over 56.9 ft. in 4 seconds.

Slide to Stop – Friction

With the three scenarios identified, it is possible to calculate the frictional value associated with each permutation. This calculated value can be compared to published data sources for accuracy, and subsequently used to calculate vehicle speed.

The equation used to calculate friction when deceleration distance and deceleration time are known is as follows:

$$f = \frac{D}{16.1t^2}$$

Min	Max	Hybrid
$f = \frac{40.8}{16.1(3.5)^2}$	$f = \frac{73.3}{16.1(4.5)^2}$	$f = \frac{56.9}{16.1(4)^2}$
$f = \frac{40.8}{16.1(12.25)}$	$f = \frac{73.3}{16.1(20.25)}$	$f = \frac{56.9}{16.1(16)}$
$f = \frac{40.8}{197.225}$	$f = \frac{73.3}{326.025}$	$f = \frac{56.9}{257.6}$
$\boldsymbol{f = .206}$	$\boldsymbol{f = .224}$	$\boldsymbol{f = .220}$

The friction calculations indicate a value between .206 and .224 for the surface being traversed by Car #115A. According to the video, the grassy surface possessed intermittent snow that had been melting throughout the day. There was some snow on the grass at the time of the video, especially towards the final rest area, but the pre-approach was primarily wet grass with a layer of fallen tree leaves.

The calculated values are consistent with testing done by the Ohio State Patrol for wet grass (.25 to .35), and they are also consistent with published data values from the Institute of Police Technology and Management for loose snow (.10 to .25). I am aware of no specific study measuring the frictional value of wet grass with layers of wet leaves. Regardless, the calculated values appear to accurately reflect the surface friction value during deceleration.

**Note – The calculated values represent the "drag factor" of the surface in the direction Car #115A traversed. Typically, a level coefficient of friction for the surface would be determined and adjusted for the scene evidence. Since actual scene evidence was used to calculate the friction value, the coefficient of friction was not determined in this instant scenario and there was no need for adjustment.

Slide to Stop – Speed Calculation

With the distance and frictional value of the surface known, it is possible to calculate the slide to stop speed of Car #115A.

The equation to determine speed when deceleration distance and surface friction are known is as follows:

$$S = \sqrt{30df}$$

Min	Max	Hybrid
$S = \sqrt{30(40.8)(.206)}$	$S = \sqrt{30(73.3)(.224)}$	$S = \sqrt{30(56.9)(.220)}$
$S = \sqrt{252.144}$	$S = \sqrt{492.576}$	$S = \sqrt{375.54}$
$\boldsymbol{S = 15.879}$	$\boldsymbol{S = 22.194}$	$\boldsymbol{S = 19.378}$

Based upon the available evidence, Car #115A was traveling between **15 and 22 miles per hour** when it began its final deceleration. When limitations of both the high and low range estimate are addressed, the speed estimation narrows to approximately **19 miles per hour** at the beginning of deceleration evidence.

CONCLUSIONS

Based upon the totality of evidence I examined regarding this incident, I can come to the following conclusions:

1. Cleveland Police vehicle #115A approached Cudell Park from the south. After traveling through the dead end of W. 99th St., the vehicle drove north through Cudell Park and came to a stop in front of a gazebo. Portions of this approach were captured on two different surveillance cameras.

2. Views from both surveillance videos allowed for estimations of Car #115A's approach path and travel time to the shooting area. Each surveillance video provided different information regarding the vehicle's approach, along with limitations. Camera #1 captured the final moments of Car #115A's movement with good clarity, but its total approach to the shooting area was outside of the viewable area. Camera #4 captured a great deal of Car #115A's approach, but was further away and recorded the vehicle's approach with an inconsistent frame rate.

3. Using the best available information from scene measurements and photography, approximate deceleration distances could be determined. These distances were ranged in subsequent calculations to allow for a speed estimation within a reasonable confidence interval. Preliminary calculations resulted in frictional values consistent with those published for the surface Car #115A traversed.

4. Using minimum/maximum slide distances and time intervals, Car #115A was traveling between 15 and 22 miles per hour at the time it began its final deceleration. Since both the minimum and maximum distances possessed inherent limitations, a hybrid distance was used as a realistic middle estimation resulting in a speed estimation of 19 miles per hour at the start of the final deceleration.

   These calculations represent an estimation of speed at the time evasive braking began, which places this speed estimation between 40 and 75 ft. south of the shooting incident area. I was not able to calculate an approach speed further south of this location because I could not determine when, or if, acceleration or deceleration was taking place. Additionally, the quality of video and uneven frame rate made determination of an accurate location and time interval all but impossible.

5. The range of speed estimation is at least partially corroborated by the Automated Vehicle Locater (AVL) recording from Car #115A. During its approach to the shooting scene, the AVL file recorded speeds from 13 to 17 miles per hour at 9-10 second intervals. However, the AVL suffered from an obvious lag in its reporting of speeds and an inconsistent refresh rate.