The Forensic Mapping Challenge

During the 1880's, Sir Francis Galton, a British anthropologist and a cousin of Charles Darwin, began his observations of fingerprints as a means of identification. In 1892, he published his book, "Fingerprints", establishing the individuality and permanence of fingerprints. The book included the first classification system for fingerprints. Galton identified the characteristics by which fingerprints can be identified. These same characteristics are still in use today, and are often referred to as Galton's Details. In 1903 the New York State Prison system began the first systematic use of fingerprints in the U.S. for criminals. This introduction was followed by the use of fingerprints at the US Penitentiary in Leavenworth, Kansas during 1904. For nearly 100 years the science of fingerprint identification remains solid, but subject to challenge by its application in our judicial system. This ability to challenge data or an opinion is a corner stone of our judicial system and a building block of freedom.

The science of Forensic Mapping, based upon geometry has a much longer history traceable back to the 1600's, but is likewise subject to the same challenges by its application. Forensic Mapping is a term coined in the early 90's to the art and science of electronically documenting a point or coordinate where some physical evidence is located, then using an automated system of graphic generation creating a map. Over the past ten years the advancements in computer software has made this process more an art than science. A benefit that often holds the devils hand. The Forensic Maps intended use often dictates how much science and how art may be ultimately used. Most maps of this nature are intended to document some post event situation. Most of the events are of a critical nature and ultimately end in some form of litigation.

As with any litigation, a plaintiff or defendant may challenge the opponents evidence and its basis before a judge serving as the gatekeeper of the truth. This process is more often referred to as a Fry or Daubert Challenge. Users of Forensic Mapping technology must be weary of some software products that generate graphics without geometry to support them. For each point in a map two things should exist, geometry and a graphic attribute. The geometry is usually generated by a theodolite measuring a horizontal and vertical angle combined with a slope distance from an electronic distance-measuring instrument. This format of measurement is commonly referred to as a polar coordinate, (angle & radius). Attached to this numbered point, the technician assigns a graphic attribute code. The graphic attribute serves as an instruction to the software of how to display the measured point. The code may be something simple such as a line or as complex as a 3D symbol.

The coding is akin to the art within the system while the geometry is the science. During the legal battle the art is difficult to challenge because of its subjectivity to the technicians' observations. The usual technique is a simple photographic comparison to the map. Is the map a fair and accurate representation of the scene? The easiest challenge to present is testing the user or technicians ability to explain the geometry. Officer, can you tell the court how your system measures polar coordinates, then calculates Cartesian (X, Y, Z) coordinates?

The answer can be simple or may need to be exact. In either case the technician must be prepared to independently validate the map to ensure the software has performed its' job correctly. The why, should be obvious. A computer cannot occupy the witness stand and explain what was done. This responsibility rests solely with the technician. Some software packages have the ability to generate graphics as instructed by the technician without any supporting geometry. The danger obviously is meeting the challenge. What is the supporting basis for these graphics and opinions from them? As an example, a 3D view is generated by an automated software feature for a sight distance analysis. You opine from this software feature that sight visibility is restricted. The next step that should also be automated is asking yourself, Can I prove this? Do I have a point of geometry that proves visibility was restricted? Software packages that protect measured data and maintain a history of data changes provide invaluable support to validation.

Automated graphics generation is an invaluable tool to this art and science we call Forensic Mapping. The technician however must be vigilant to protect the integrity of a map. Understanding the basic math that provides support for the geometry (Part II) and sculpting the graphic attributes (Part III) is the responsibility of the technician. While a software product may be capable of generating an animation quality image, the technician must be able to support it. The map remaining a fair and accurate representation of the scene is vital to protecting the next 90 years of success.

Part II

As the Forensic Mapping team measures each point of geometry, the point is individually numbered. Each numbered point is assigned a graphic attribute by entering a code in the map database. The team, usually a station operator and rod person assess the site-specific area to be mapped two ways. First is an evidence assessment to facilitate the technical analysis of the crash or crime scene. Second is a visualization of the evidence in relationship to the surrounding landscape. A crash for example can be mapped and technically analyzed to determine speed without curbs, sidewalks and stop signs being measured. When complete however, and the analysis turns to witness assessment, or during a time distance analysis, the surrounding landscape becomes much more important. The goal should always be measuring the physical evidence in order of its' life expectancy, return traffic to a normal flow as soon as possible then document the surrounding terrain and it's features all the while protecting the validity of each point measured and never assume traffic will yield to your presence.

Protecting the integrity of data points and their assigned graphic attributes is facilitated with an electronic field book. Available from many sources a user can pick the right recorder for their intended environment and budget. More important than the recorder is the software that performs the capture and creates the map. One of the most popular and user friendly is MicroSurvey's Evidence Recorder Pro. EvR Pro operates on the Windows CE platform and in color if supported by the individual recorder. Today's user can enjoy real time mapping that provides a data and graphic confirmation of a measured point. Another benefit of the EvR system that is often overlooked is the reduced mental workload of the team. Now, the team can spend more of their time on personal safety than constantly visualizing the completed map. See Figure 1.

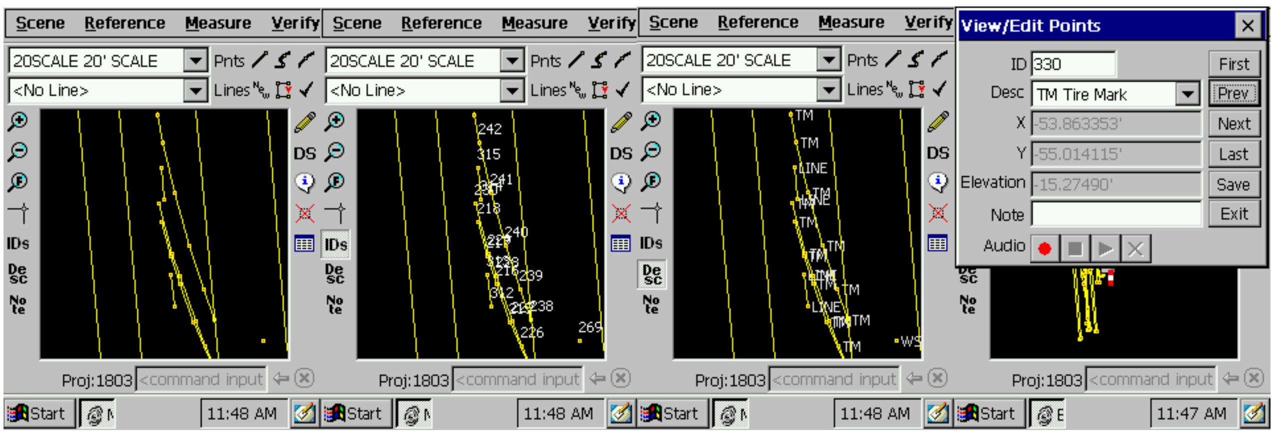

Figure 1 a, Map View b, Map & Id's c, Map & Description d, Verify Point Data

Each point to be measured is assessed by the rod person, who functions as the architect of the site[1] or scene[2]. The two-phase assessment is identification and classification. A skid mark[3] for example may be classified by deceleration, yaw, or critical speed mark, each having different evidentiary and technical value. Additionally, each must be measured in a format that will ultimately meet the Collision Analysis or Reconstructionist's needs.

1

SITE The location of a traffic accident after vehicles and people involved have gone.

2

SCENE The location of a traffic accident while people and vehicles involved are still there.

3

SKID MARK A skid mark is a mark left on the road surface, or on any surface, by a wheel in a skid The term "skit mark" includes all evidence of skidding such as scuffing of a concrete coat surface, even if no rubber is left behind

Virtually every analysis whether at the technical or reconstruction level is based on some form of distance. The electronic total station is well suited to measuring the distances needed in the forensic mapping system.

The adaptation to total station technology in forensic mapping met the need for reducing time during the at-scene investigation[4] and improved accuracy. The precision of measurements needed in collision reconstruction or crime scene analysis is much lower than provided by today's EDM, (electronic distance measuring instrument) or theodolite. In the forensic mapping system, the weakest link is the architect of the map. The rod person / architect not only identifies and classifies each point but ensures the point is accurately mapped by positioning of the optical prism. Utilizing modern EvR software provides a double check in the field for coding and general position.

As a point is captured, three measurements are simultaneous recorded. The EDM measures the slope distance, telling us how far the point is away while the theodolite measures the vertical and horizontal angles. This polar coordinate geometry is usually formatted in feet for distance and degrees, minutes and seconds for angle. Software first performs an interpretation of the polar coordinates and calculates a horizontal distance to the point. The horizontal distance is utilized to calculate the X,Y position followed by yet another calculation for determining the Z or elevation position. While compressing a summarization of the process into one paragraph looks ominous, it's not. The map technician should be prepared to explain what the software did when the polar coordinates were used to calculate the position data used in his choice of CAD program.

The slope distance as measured by the EDM, while accuracy is ensured by the Set operator and rod person. The calculations are taking into account the components of the system. See Figure 2.

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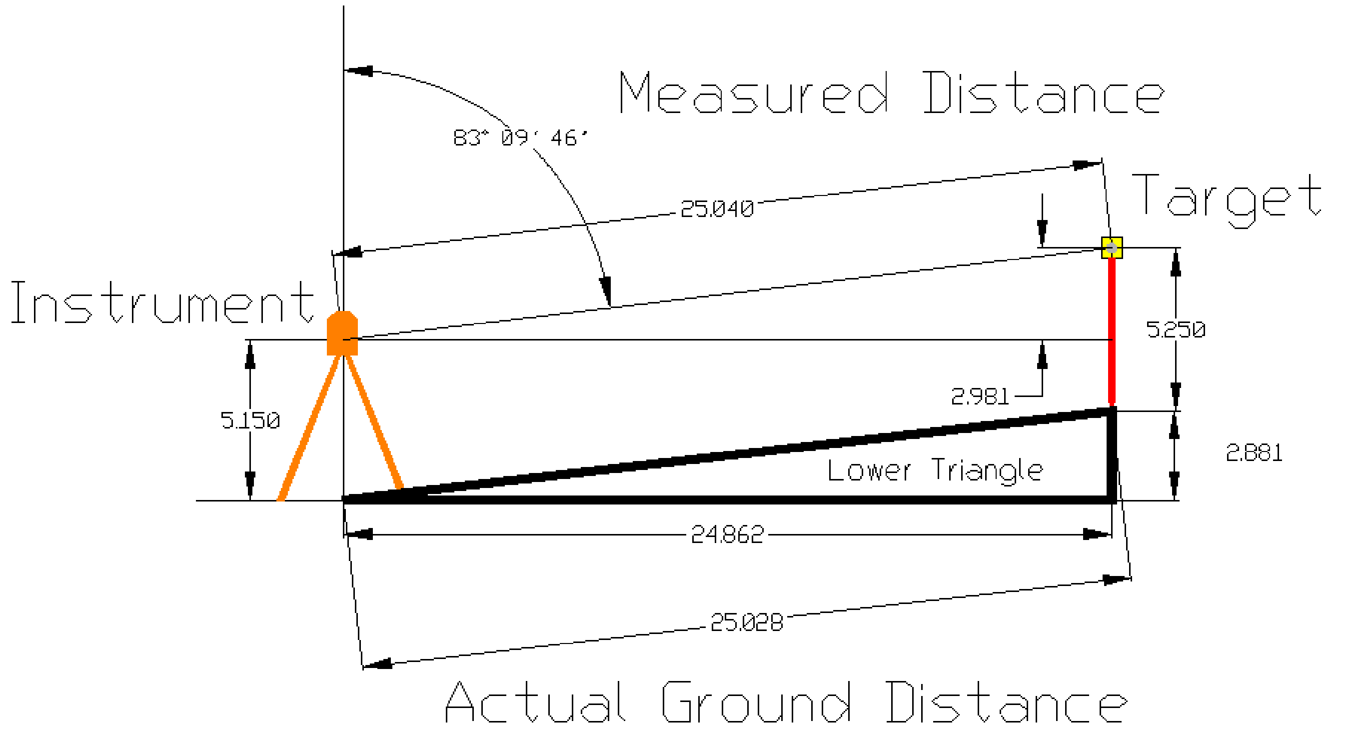
[4] **AT-SCENE INVESTIGATION** Examine and recording results of the accident and obtaining additional information at the scene of a traffic accident which may not be available later and which supplements data obtained for the accident report. The information is factual as far as possible. Level 2 of Accident Investigation.



Measured Distance
83° 09' 46"
25.040
Target
Instrument
5.250
2.981
5.150
2.881
Lower Triangle
24.862
25.028
Actual Ground Distance

Figure 2

In this real world example below, the map is assigned an elevation, (I datum) of 100 as a datum. The I datum is nothing more than an imaginary plane from which the system will calculate the height of the point being measured. The height of the instrument is measured at 5.55, (HI) and the optical prism, (HR) is 6.0 above the point measured. See Figure 3

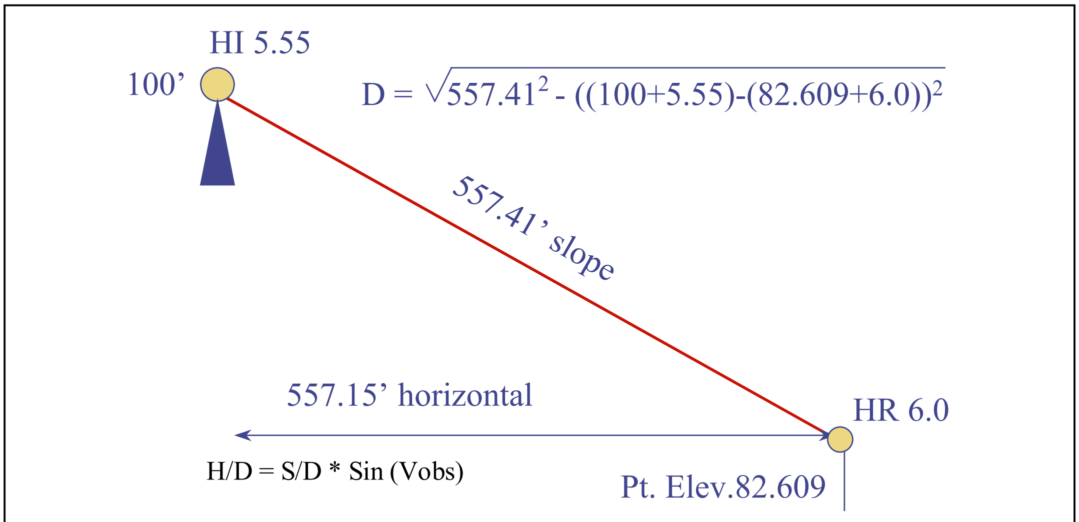


Figure 3 Horizontal Distance

The EDM provides the slope distance to the prism, in usually less than two seconds. The newest technology in electronic total stations utilizes a Class I Laser that does not require the reflector under about 100 meters. The station operator must be vigilant recording the target height. When the Laser is utilized, the target height should be set to zero. Figure 2 displays an example of the calculation applied to determine the horizontal distance from the set or station.

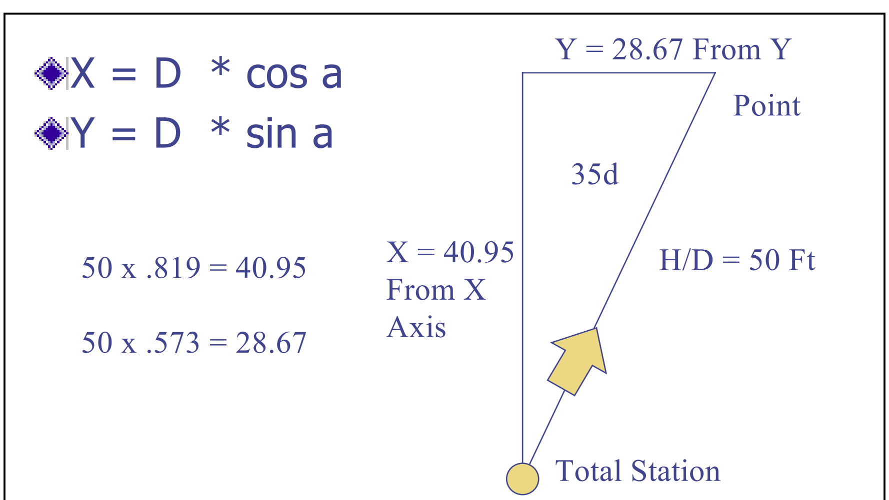


Figure 4

Using another point, we see in Figure 4 how the Cartesian coordinate is calculated. The set was aimed at a point 35° from the horizontal datum, usually magnetic north and the calculated horizontal distance was 50 feet. The X,Y coordinate can easily be calculated by determining the sin and cos of the angle multiplied by the horizontal distance. Remember, we are always referencing the horizontal datum when calculating the X,Y coordinate.

If you are limited to 2D computer drafting extra care should be utilized as the horizontal distances will be displayed. This can be critically important when analyzing a fall or vault.

Once the X,Y position is determined we must evaluate the elevation of the point measured. This step will use the cos of the vertical angle or observation (91°44’30”). You’ll notice the calculation also takes into account the I Datum HR and HI, in the event the set and reflector are different heights.

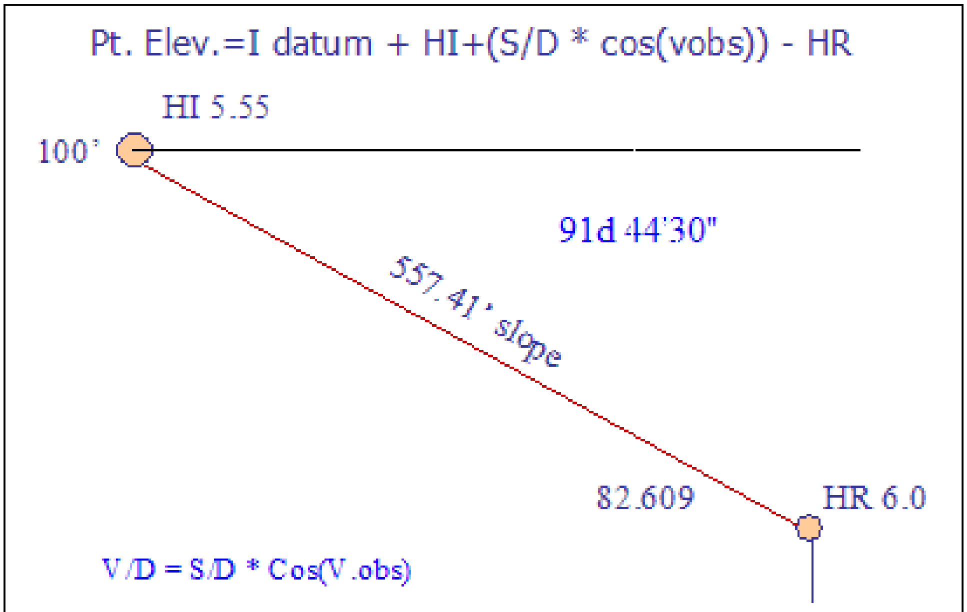


Figure 5

Very few maps are validated point by point. Usually 10% is sufficient to determine if the software performed it’s function correctly. Some programs are more adept to assisting the mapping technician in this process. The latest version of MapScenes PRO uses Active Drawing Technology, See Figure 6. From the EvR screen in Figure 1d we can compare the data to ensure accuracy. You’ll also notice a history feature in Figure Six, MapScenes tracks any changes to the point and codes.

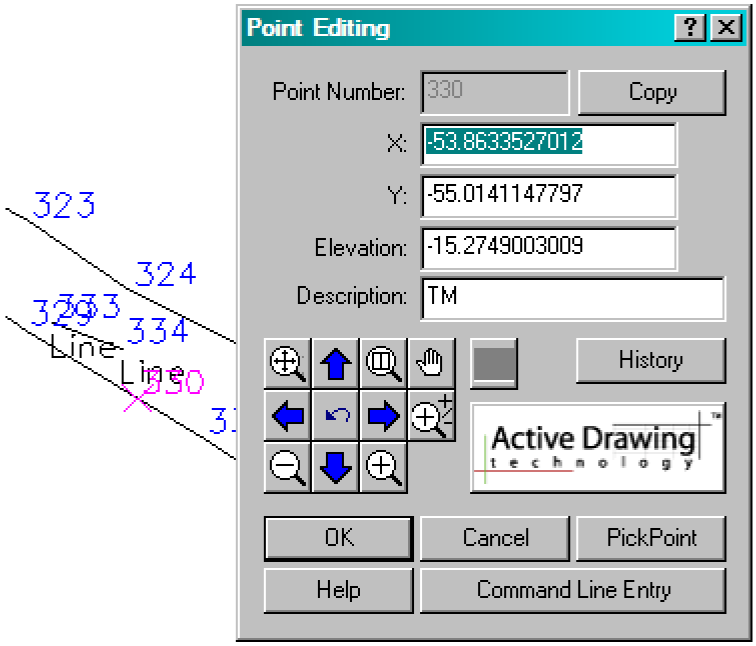


Figure 6 Point Editing May Be Accessed By Simply Clicking On A Point Number

In Figure 7 you see the rounded values from the Active Drawing Technology option.

330	-53.863	-55.014	-15.275	TM	
331	-50.407	-57.055	-14.503	TM	
332	-48.229	-58.508	-14.030	TM	
333	-58.269	-51.053	-16.092	LINE	
334	-54.676	-52.382	-15.373	LINE OIL	
335	-125.978	-293.788	-14.276	ARROW	
336	-112.259	-317.465	-15.773	D	
337	-117.160	-268.731	-16.057	D	
338	-121.449	-221.830	-15.755	D	
339	-3.942	-49.656	-2.954	RP 1230 TIME	

Figure 7 Active Drawing Technology

Finally, the time comes to validate the programs work. It certainly is not a guessing game. This is truly a validation of the software. From the Scene Measurement Menu, the work performed by the MapScenes program is provided for all to see. Figure 8.

Shot Pt	Trgt Ht	Hz Ang	Vt Ang	Slp Dist	Desc	North	East	Elev
330	5.60	224°23'40"	101°05'59"	78.46	TM	-55.014	-53.863	-15.275
331	5.60	221°27'37"	100°39'44"	77.47	TM	-57.055	-50.407	-14.503
332	5.60	219°29'58"	100°21'33"	77.08	TM	-58.508	-48.229	-14.030
333	5.60	228°46'34"	101°36'51"	79.09	LINE	-51.053	-58.269	-16.092

Figure 8 MapScenes, Scene Measurements Option

You will find all mapping software programs calculate the data virtually the same way. MapScenes is one of the very few programs that make the task easier. We can easily slip into a false sense of security due to the flawless manner in which software programs perform these calculations. You must be ever vigilant however and remember the computer cannot take the witness stand and explain what it did. That responsibility will forever rest with the mapping technician.

Part III True 3D Mapping Reveals the Inaccuracy of 'Symbol' Mapping

In Part 1 and 2 we discussed the identification, documentation and validation of an individual point measurement. The measured points are used to create a database of measurement information from which to create the map. The database is manageable and protected. Remember, to each position the rod person has assigned a code. The code sometimes looks akin to a foreign language. It is really nothing more than an abbreviation for a graphic attribute. The coding can be an assignment for a straight line, curved line, (concave or convex) arc or a symbol. Most software suppliers provide a default coding library to launch your endeavors and accompanying editor. Enough emphasis cannot be placed on the responsibility of the rod person. Part of which is the assignment of the forensic code to the measured point. The rod person must be able to visually detect the differences between a straight vs. curved line, crowns, grades, and vertical curves in the area to be documented as well as classification and characterization of physical evidence.

In order to map a straight line for example, two points must be measured. Each Point is assigned a forensic code and an instruction to draw a straight or curved line. Traditionally, you use a command code with the graphic instruction to start and stop the line. A code for example ZEP1, is an instruction to begin a straight line using the graphic instructions found in the library under *Edge of Pavement*. In this example EP1 is a black line 1 pixel wide.

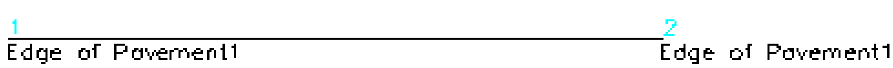


Figure 9

Point 1 starts at position 0,0,0 (0 north, 0 east, 0 elevation) and ends at position 5,0,0, XYZ if you prefer. It is important to understand the measured position may not always reflect the

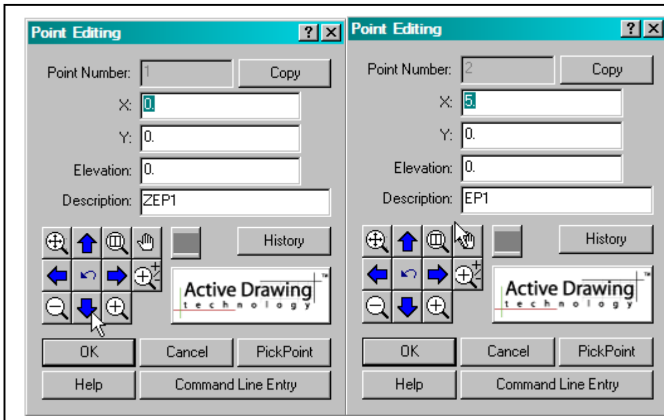


Figure 10 Fig 9 Line Data

line position. If for example point 2 is given a Z position of positive 5 or five units above it's origin, the horizontal distance is different than the slope distance. In a topographic or plane view no change can be detected. However if we examine the line and data from an ISO view we see the line is actually much different.

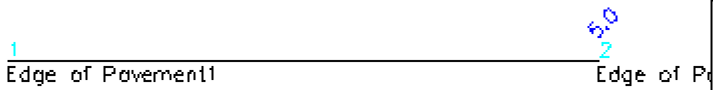


Figure 11 Point 2 w/Elevation

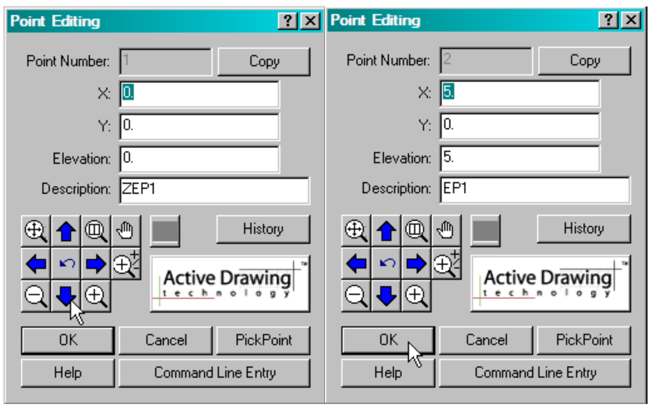


Figure 12 Fig 11 Point Data

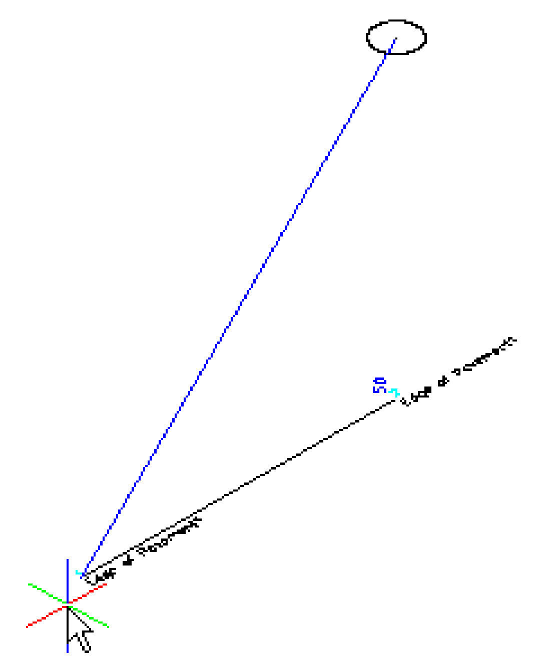


Figure 13 ISO View of Fig 11

In this demonstration the importance of true 3D mapping and hard supporting data is realized.

A complex curve may have multiple measured points to accurately identify the curvature. Each group of multiple points will have the scene graphic code, however a different command maybe found in order to facilitate the line curvature between convex and concave.

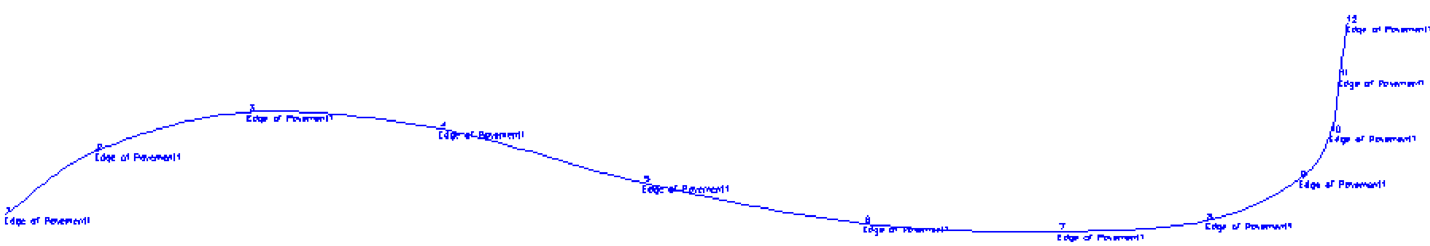


Figure 14 Topographic of Complex Curve

In this 2D topographic view, (Figure 13) the line curves fix the model. When we look at the same line from a profile view the importance of elevation data is appreciated.

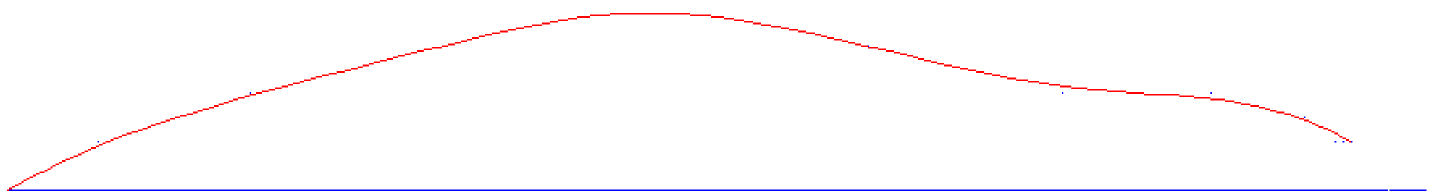


Figure 15 Blue 2D; Red 3D

Yet another example is to create a curve or arc from three measured points, see Figure 16. The difficulty in mapping such an arc is finding a constructed true radius.

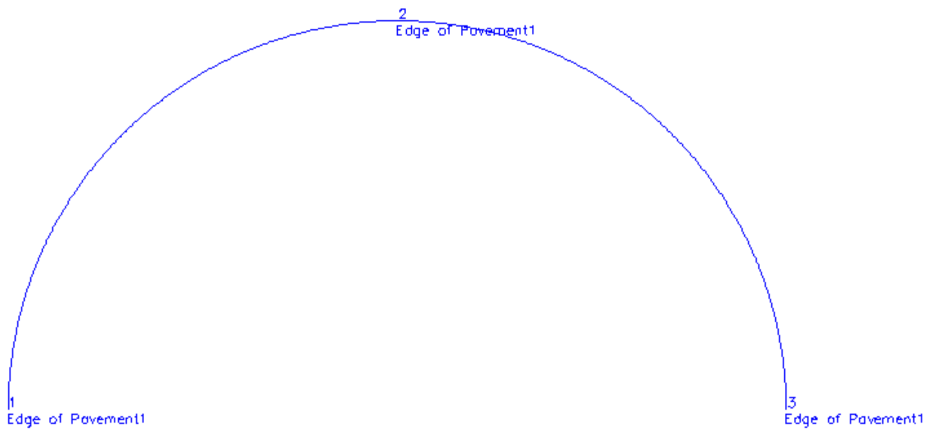


Figure 16 Three Point Arc

Far too much importance is placed on the width of lines. In nearly all cases a line is nothing more than a boundary. A line depicting the edge of pavement adjacent to a gravel shoulder is not a perfect edge. We use a perfect edge in a drawing to depict the boundary not the edge. A fog line near the pavement edge is usually 4 or 6 inches wide. The tighter the budget the narrower the line but that's another story. In our case we are depicting the boundary by mapping the center of the line. The line width can be accommodated when preparing your map as a demonstrative exhibit. Otherwise, save your time & energy for accuracy and foundation. A map is not going to be excluded as evidence while technically correct.

Our imaginary map is now recorded point by point. We have meticulously assigned codes to each point thereby controlling our graphics. When the map data is processed the geometry is controlled by measured data and the lines, arcs, and curves between those points are controlled by the graphic code assigned to each point. This map is technically correct.

Not all landmarks found at a site to be measured are conducive to identifying with a line. While it could be done, it is far too time consuming. Remember, speed is what you promised the boss. Lets take the examples of a fire hydrant and a street light. Both items are regularly found at crash scenes, just as a shell casing can routinely be found at a violent crime scene. The entity ***may*** be placed in the map for visual reference. If we are dealing with a two vehicle intersection collision and the fire hydrant present was not struck and the crash occurred at noon, do they need to be in the map? For the technical analysis or reconstruction of the crash, the answer is no. For the benefit of the prosecutor, defense attorney and mostly the jury, yes it should be included. These entities provide a visual reference for the lay observer. When identifying the position of a street lamp for example you must be familiar with the base point of the symbol to be inserted. Therein lays the importance of being proficient at mapping. The rod person and station operator should be equally knowledgeable with the mapping process and map software to be utilized. During training this aspect of forensic mapping is stressed to students. I still shudder when I hear a student express, "I'll just hold the pole" Well my friend, you have just volunteered for the most hazardous stressful and important job at the incident. I would rather erect a 5000 piece 3D jigsaw puzzle than volunteer with the notion of simplicity in my head. I would jump at the chance however, prepared with proper training, a plan in mind and established communication with the set operator.

A symbol is a group of entities locked together to form a single entity. This new entity is saved in the forensic library to be recalled over and over again. Every time you reuse a symbol, you saved its creation time. The map code library has no idea that the code FH is representative of a fire hydrant. The software only knows the FH code holds an instruction to draw 187 entities locked together. This object however, visually represents what the human observer will recognize as a fire hydrant. A hydrant is usually measured to its center, performed by a distance then offset angle measurement. The measurement is taken to the center because it is a common position between all hydrants and the base point for the symbol is the center. A street lamp could have a base point at the center of the entity. At the physical location of the lamp pole being measured it is not physically possible within acceptable time constraints to identify the physical center of the real world lamp pole.

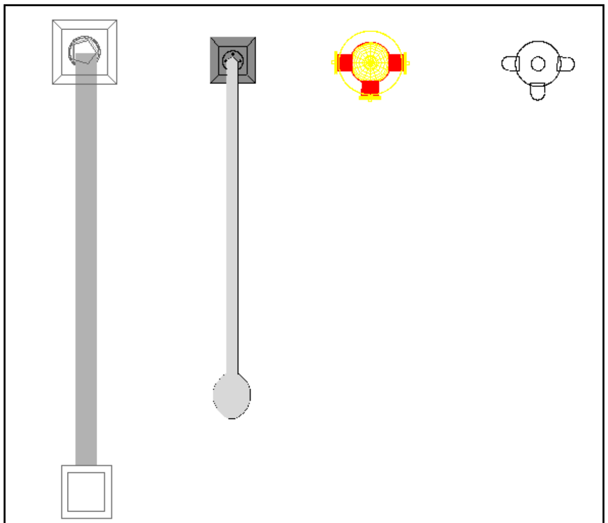


Figure 17 Topographic View

In Figure 17 we examine two pair of similar symbols. The topographic view of a lamp pole and fire hydrant. Simple objects to visualize and consider where on this object should a real world measurement be recorded to accurately and automatically insert a symbol. Center of the vertical pole is a good bet. If the draftsman who created the lamp pole selected the center of the object when it was saved, then without editing, the center of the object must be measured.

Figure 18 3D view

Figure 18 displays the same four objects in a 3D view. Measuring to the center of the hydrant is not a complicated task. The lamp pole however is more complicated if the base point is the center of the object and not the center of the vertical pole. Even more so if we are dealing with a 3D pole with a base point centered on the horizontal arm.

The obvious question is how much extraneous mapping is enough. With experience a properly trained mapping technician will be competent to make that decision as a part of the mapping team. Remember it is a team effort. In the initial learning curve a map or two will be experienced with not enough and you'll likely have a map or two, maybe more with too much. Too much, is not a bad event.

Sokkia R series Callidus scanner Faroarm

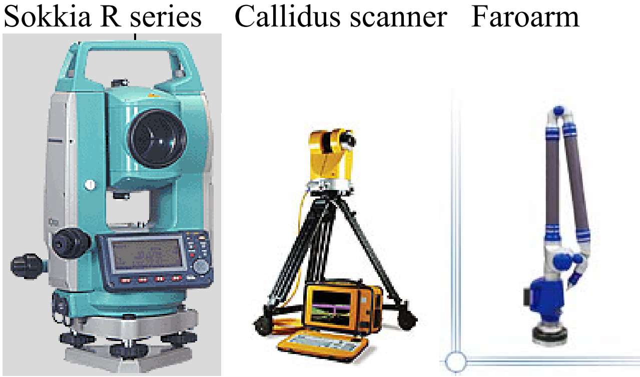


Figure 19

A map technician should utilize restraint in the use of symbols. A symbol is a graphic representation of a real world object. A model is a scaled version of a real work object. In my review of map projects from North and South American, Western Europe and the South Pacific the use of symbols as models is prolific. So much so that it borders on jeopardizing the technical accuracy of the project. The method used to create the symbol is usually not known by the end user. The symbol could be a simple drawing; it may be measured with a Total Station, Laser Scanner, or Faroarm, Figure 19. Each having a different accuracy.

The use of symbols is not discouraged as long as the difference is clearly articulated in an accompanying report or diagram legend. A mapping technician usually struggles with the "how much" question at an incident scene. At a crash scene, determine an estimate for the approach speeds of the vehicles, convert to feet per second and multiple by 10. This simple rule will provide you with about 10 seconds of approach roadway. Keep in mind a vehicle pulling out from a stop will need much less approach than does a vehicle traveling at 90 feet per second. This rule usually provides sufficient roadway for a time distance analysis. At a crime scene a good rule is to include all physical evidence and positions of witnesses. Where was the witness when he heard three pops, turned around and saw victim get shot? Every incident in the investigators mind should be a crime scene until the investigation is complete or nearly so. At least until the analysis is far enough along to make the call, crime or accident.

In a final drawing such as Figure 20, keep the map simple. The more objects you place in the map, the more an observer must visually scan for the object of your testimony. If you are intent on making your map an exact duplicate of the site, take a picture. You will save yourself from headaches, upset stomach and a seat at the bosses desk explaining why it has taken 3 days to finish a technical drawing. Figure 20 was mapped using a Sokkia Set 530R. The prism mode was utilized for all roadway measurements and offsets to poles. The street lamp heads were measured using the reflectorless option. Extra caution while aiming and measuring in the reflectorless mode is necessary to ensure accurate measuring. Real time mapping makes any reflectorless measuring a breeze. The site work was completed in fifty-four minutes totaling 124 measurements.

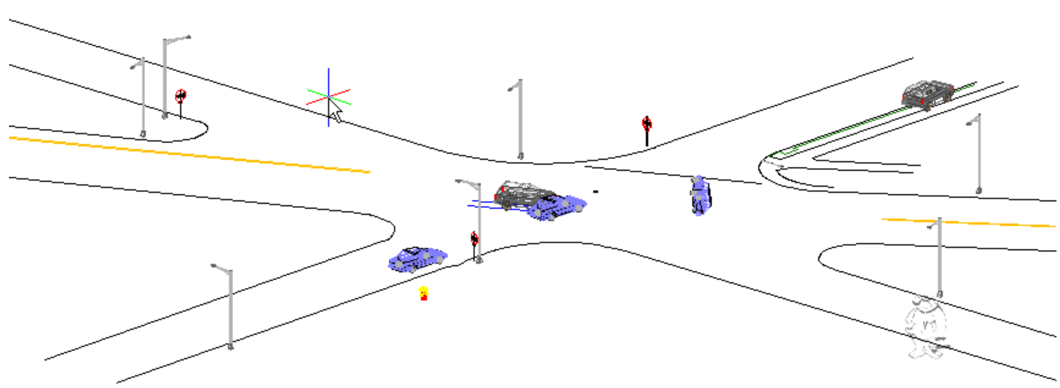


Figure 20

The map was downloaded from a Pananonic with Evidence Recorder via Active Sync to Map Scenes PRO. The transfer using the download wizard takes all of 2 minutes with a slow computer. With the 2.55 gig hz at my desk, I don't have time to fill my coffee cup.

Forensic Mapping certainly has challenges associated to it. The process is truly an art and science. This practice should never be confused with Surveying, a license required position. Once your initial training is complete it is recommended that you participate in a Field Demonstrated Proficiency Program. Once a week for eight weeks, you will perform a test map. These locations should be selected based upon your highest crash locations. The practice exercises can be printed and used for less serious crashes by adding scene evidence. It is important to share with coworkers what you would like them to use as a reference point. At the end of eight weeks, your confidence level will be increased, your set up time will be a few minutes, your mapping skills will be sharp and you will be prepared to meet the challenges of mapping during peak stress periods. The benefits of applying this technology to crash & crime scenes will mount as you and your agency gain experience. Your equipment, skills and application will survive a judicial challenge and keep the scales of justice balanced.

About the Author.

Steve McKinzie is retired from the Kansas Highway Patrol. From 1993 until his retirement Steve created and commanded the Critical Highway Accident Response teams for the Patrol. An instructor for TEEX at Texas A&M, and Sokkia, Steve is now President of McKinzie & Associates L.L.C.   The McKinzie team provides Accident Reconstruction consulting specializing in Heavy Vehicles. Training is offered in Commercial Vehicle Investigation and Reconstruction and Forensic Mapping featuring MapScenes Pro and Evidence Recorder. Working closely with Sokkia, MicroSuyvey and other mapping equipment manufacturers, allows McKinzie & Associates LLC the ability to offer the best combination of equipment and software for Forensic Mapping challenges.