

# Accident Scene Diagramming Using New Photogrammetric Technique

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## ABSTRACT

One of the challenges for accident reconstructionists is creating accurate accident scene diagrams from photographs. The biggest challenge is when only one photograph is available, and information about the camera that took the photograph is not available. The authors will present a unique technique that enables the user to create an accurate accident scene diagram from only one unknown photograph of the accident scene, by using a combination of processes called Inverse Camera Projection and Photographic Rectification. Inverse Camera Projection allows the user to determine the unknown camera characteristics, which then through Photographic Rectification, the photograph can be rectified and traced to create accurate scene diagrams.

## INTRODUCTION

**BACKGROUND** - In accident reconstruction, it is often necessary to create an accident scene diagram to scale which includes the location of skid marks, vehicle positions, and impact location. By the time an accident reconstructionist investigates the scene, the skid marks have faded and the debris has washed away. This information is usually available only in photographs taken by the police on the day of the accident. Typically, there is little or nothing known about the camera that was used to take these photographs, which makes it difficult to gather information from the photograph. Utilizing photogrammetry, a new technique has been developed by the authors to create scaleable diagrams that incorporates one "old" photograph of the accident scene with "new" photographs taken by the reconstructionist during the site investigation. The new photographs need not contain the same information

such as skid marks and vehicles, but must have discrete points in common with the old photograph such as lane lines, street corners or light posts. A discrete point is a single point that can easily be identified in both the old and new photographs.

**THEORY** - In order to utilize an old photograph, the camera characteristics need to be determined through a process called Inverse Camera Projection. There are seven unknown camera characteristics that must be defined. These characteristics are as follows:

- The position of the camera ( $x,y,z$ )
- The camera rotation about the x-axis, OMEGA ( $\omega$ )
- The camera rotation about the y-axis, PHI ( $\phi$ )
- The camera rotation about the z-axis, KAPPA ( $\kappa$ )
- The camera focal length

In order to determine the unknown camera characteristics, four control points must be identified in the old photograph. Control points are reference points common in both the old and new photographs. The real world coordinates ( $x,y,z$ ) of these four control points must be known. The relationship between the real world coordinates and the photograph coordinates establishes eight equations, four in the x direction and four in the y direction. The seven unknown characteristics can be determined using the eight equations through a process called Inverse Camera Projection.

Photographic Rectification involves determining the relationship between the surface of the object in three-dimensional space and the image in the photograph. Once this three-dimensional relationship is determined, an orthographic projection of the surface can be generated. An orthographic projection is a re-mapping of the image on a flat surface with no perspective distortions.

## DISCUSSION

**METHOD** - In order to create an accident scene diagram to scale requires the user to have access to the accident scene, where new photographs of the scene can be incorporated with the old photograph. A commercially available software program called PhotoModeler<sup>1</sup> allows the user to determine the camera characteristics through Inverse Camera Projection, and perform the photographic rectification.

**Inverse Camera Projection** - In order to determine the camera characteristics of the old photograph, the three dimensional coordinates of four control points within the old photograph need to be determined. This can either be accomplished by surveying the points with either traditional surveying methods, or through photogrammetric methods. This paper discusses the photogrammetric methods.

PhotoModeler allows the user to determine the control point coordinates utilizing photogrammetry, and allows the user to identify these control points in the old photograph to determine the camera characteristics.

**Photographic Rectification** - Once the camera characteristics (position, orientation, and focal length) have been accurately determined, areas within the photograph can be rectified. To rectify a portion of the old photograph the three-dimensional coordinates that outline the area must be known, thus it is best to use these as control points in the Inverse Camera Projection process. PhotoModeler allows the user to choose any plane for rectification. When an area is rectified on a plane parallel to the ground, the rectified image can be traced to create a plan view drawing. This is most useful in determining the length of skid marks within an accident scene. If an area is not planar, multiple planes can be identified for rectification. For example, if a curved surface (i.e. crowned roadway or hilly roadway) is rectified, it should be broken down into as many pieces as reasonable to best represent the curved surface. Since a rectification plane can not be curved, multiple planes must be created that best approximate the curvature of the roadway. Each piece can then be rectified separately and combined after rectification.

**PROCEDURES** - In order to create an accurate scene diagram from a photograph with unknown camera characteristics, the following four steps must be taken.

**1) Determine the Real World Control Point Coordinates** - The following steps allow the user to determine the real world coordinates of the control points through photogrammetry.

a) Identify the area of the old photograph that a scaleable diagram is needed. This area will be rectified. To do this, the camera characteristics must be determined. *Case Study: In this case study, a scene diagram containing the skid marks in lanes two and three in Figure 1 is needed. Therefore the portion of the photograph that contains these two lanes must be rectified.*

b) Investigate the scene, and identify control points that border the area that will be rectified. Control points are identifiable points in the old photograph that

can be easily identified at the scene. These control points will be used to determine the camera characteristics and to rectify the image. At least four control points are needed. *Case Study: From the field investigation, it is determined that the original lane lines are still in place. The original lane lines will be used as control points and will border the area that will be rectified. The control points are identified on the old photograph in Figure Two. In this case, more than four control points were identified, which will increase the accuracy of the project. PhotoModeler utilizes an iterative algorithm to determine the camera characteristics. The algorithm adjusts the positions and angles of the camera station and the positions of the marked control points on each iteration. A greater number of control points, increases the amount of adjustment the algorithm can make, therefore increasing the accuracy of the process.*

c) Photograph the scene ensuring that the control points in the old photograph can be identified in at least two new photographs taken at the scene. It is important that the control points can be clearly seen in the new photography. The closer the photographs are taken to the objects, the easier it will be to identify the control points, and the greater the project accuracy. However, one should realize that there is a balance between accuracy and efficiency. Photographs taken close to the object can be cumbersome to manage and difficult to tie together later. *Case Study: This project was broken down into smaller sections when it was photographed during the field investigation so that the lane lines could be easily identified.*

d) Have the negatives processed to Photo-CD where they can then be utilized by PhotoModeler. Scanning to Photo-CD is the most efficient and economical way to import the images into PhotoModeler. PhotoModeler supports all types of camera formats ranging from film cameras to digital cameras to video cameras. Film cameras deliver acceptable accuracy at a low cost. High resolution digital cameras are expensive and are typically used when a quick turn-around is needed. Video cameras are used when accuracy is not a priority.

e) Import the new photographs into PhotoModeler. Identify the control points in at least two new photographs, and process the project. PhotoModeler will determine the coordinates of the control points. *Case Study: The accident scene consisted of skid marks, gauge marks, and damaged vehicles. In order to clearly see the lane lines over the entire length, the lanes were photographed in sections. For this case study, photographs closest to the beginning of the skid marks are used to explain the process of determining control point coordinates. PhotoModeler will allow the user to relate similar points between different photographs. Figure 3 consists of three photographs that contain similar control points. Once all the control points have been identified in at least two new photographs, PhotoModeler can process the information and determine the three dimensional coordinates of the control points. The coordinates are stored in an AutoCAD DXF file. This information will be*

used to determine the old photograph's camera characteristics.

**2) Determine the Camera Characteristics -**

Once the real world coordinates of the control points are determined, they must be referenced in the old photograph. Once referenced, the unknown camera characteristics can be determined through Inverse Camera Projection.

a) Have the old photograph digitally scanned into the project. Identify the control points in the old photograph and reference them to the same control points in the new photograph. *Case Study: To assign the control point coordinates to the old photograph, import the DXF file previously created. Assign the control points to the old photograph with the control point identification tool (see Figure 4).*

b) After all the control points in the old photograph are referenced in the new photographs, the unknown camera characteristics can be determined through Inverse Camera Projection. *Case Study: PhotoModeler can determine the camera characteristics through Inverse Camera Projection. The results of the process are graphically depicted on the screen with the control points laid over the old photograph. If the control points do not overlay properly, there probably is an error in the referencing of points.*

c) The accuracy of the processing can be checked by comparing a known distance measured in the field to a processed distance in the photograph. PhotoModeler developers claim that the relative accuracy of the software is around one part in two thousand (1:2,000). A relative accuracy of 1:2,000 means that for an object with a 20ft largest dimension, PhotoModeler can produce 3D coordinates with 0.01ft (approximately 1/8 inch) accuracy. Not all 3D coordinates will be of the same quality. PhotoModeler depends heavily on the user marking precise locations on the images. If a point appears in two photographs and the user guessed or approximated the location of the point in one or both of the photographs, then the resulting 3D coordinate will probably be inaccurate. *Case Study: Field measurements were taken to determine the accuracy of the project. A comparison between the field measurements and those determined by PhotoModeler were within one percent. Therefore, the length of the longest skid mark, which was measured to be 281 feet, is within three feet.*

**Comparison Between  
Field Measurements and  
PhotoModeler Processed Measurements.**

<b>Item</b>	<b>Field Dist.</b>	<b>Processed Dist.</b>	<b>Percent</b>
Lane Line Length	10.0'	9.91'	0.9%
Gap between Lane Line	17.0'	17.13'	0.8%
Lane width	12.0'	12.07'	0.6%
Barrier Wall Length	10.0'	9.96'	0.4%

**3) Rectify the Photograph -** Now that the camera characteristics are known, the area of interest on the old photograph can be identified and rectified.

Identify surfaces on the photograph for rectification by choosing control points. A surface is identified by connecting three control points. An entire group of surfaces can be identified to rectify, but only one rectification plane can be chosen. *Case Study: PhotoModeler allows the user to identify a surface using the "surface tool". Connect all the control points with the surface tool and then rectify the image (see Figure 5). The image resolution can be defined in the rectification window.*

**4) Trace the Rectified Image -** Now that the photographs is rectified, it can be traced to create a scaleable accident scene diagram.

Import the rectified image into any drawing package like CorelDraw or AutoCAD, and trace over the image. Use the control point data to determine the drawing scale. *Case Study: Import the rectified image into CorelDraw and trace over the image to create an accident scene diagram (see Figure 6 and 7).*

**BENEFITS AND LIMITATIONS -** The biggest advantage of this process is that the objects, such as vehicles and skid marks, do not need to be in the scene during the field investigation, they only need to be visible in old photography. This is a typical situation for accident reconstructionists. Reconstructionists rarely find that skid marks and gouge marks are still identifiable at the accident site. This method allows the reconstructionist to incorporate old photographs taken of the accident scene, with new photographs of the accident site, to create an accident scene diagram to scale. Utilizing the principles of photogrammetry, there is no need to survey the scene with traditional survey instruments. Therefore, there is no need to get into traffic, which can be dangerous and time consuming. This method can be used for all types of roadway surfaces from flat to curved. The software can use cropped photographs, which is typically the case when only prints are available.

The major limitation of this process is that the results are only as good as the quality of the photographs and the camera used. Cameras with poor lenses, such as point-and-shoot cameras, will not generate good results. However, standard 35mm cameras produce good results. The process cannot be used when the scene has changed significantly. Common points in the old photography must be identifiable in the new photography.

**CONCLUSION**

Utilizing desktop photogrammetry software, a common problem of creating accurate accident scene diagrams from a single photograph can be solved. This process requires that the accident scene be available, and that new photographs of the scene have a minimum of four points in common with the old photograph. The advantage of this process is that the entire process can be accomplished on a desktop computer, utilizing scanned images and Photo-CD images. Updated

technologies in computing hardware and software now allow photographs to be rectified on desktop computers. This new technology has been incorporated into PhotoModeler software. The software is flexible enough to handle cropped photographs, uneven roadway surfaces, and multiple images.

#### **ABOUT THE AUTHORS**

The authors have been utilizing PhotoModeler software since it was first introduced in 1993, and are listed by PhotoModeler as Authorized Service Providers. The authors can be reached at the following address:

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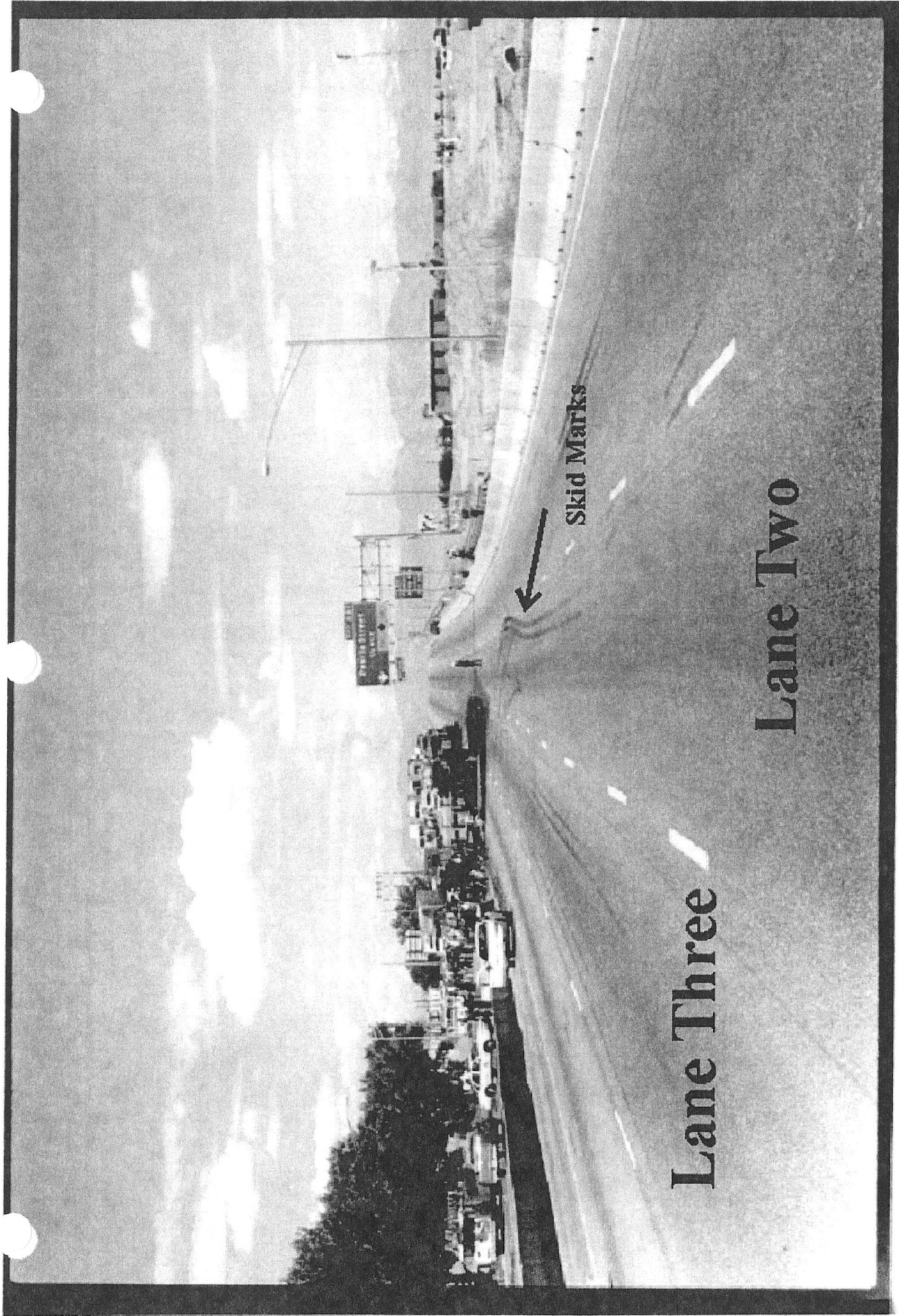


Figure 1 (Old Photograph Depicting Lanes to be Rectified)

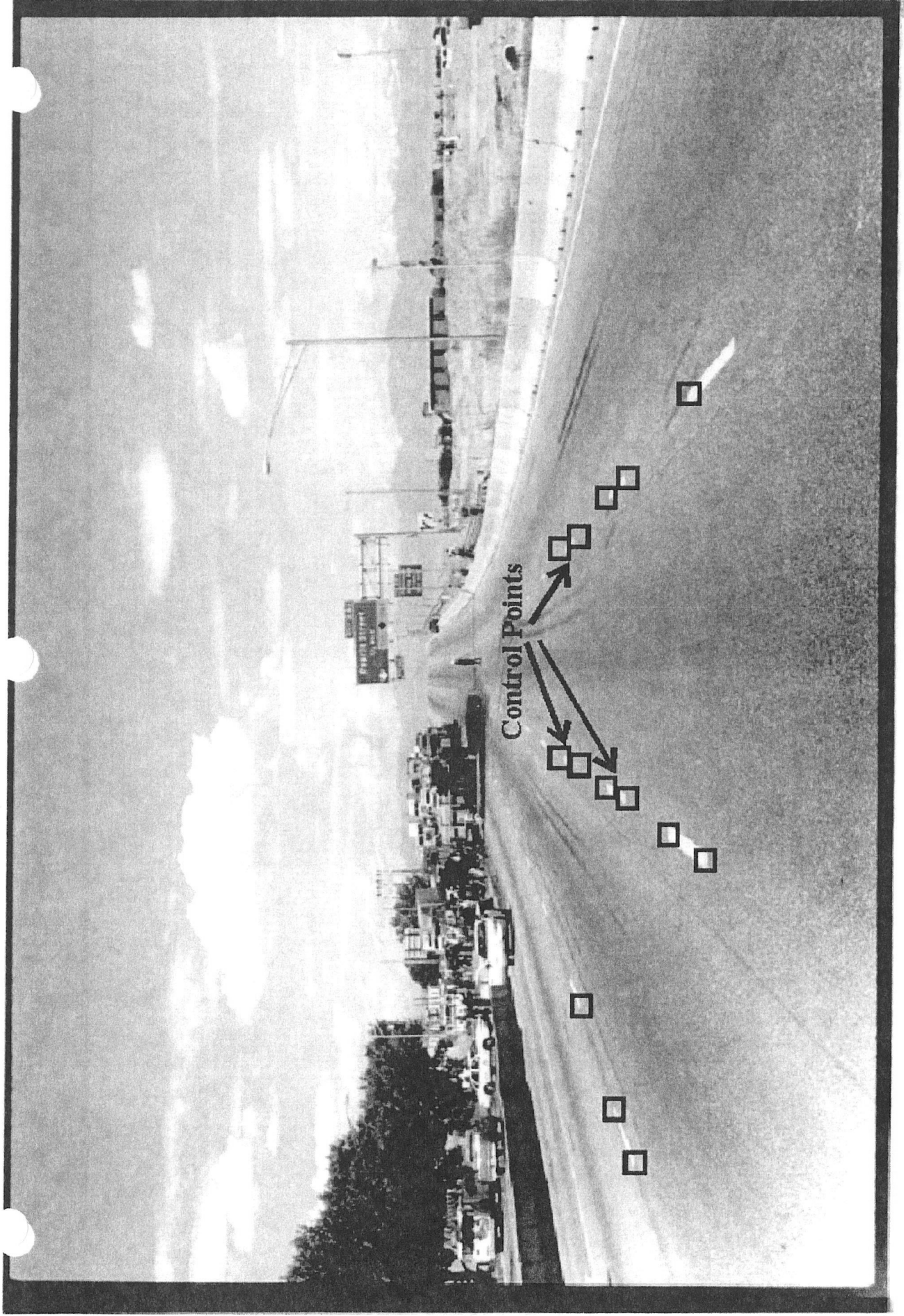


Figure 2 (Old Photograph Depicting Control Points for Rectification)

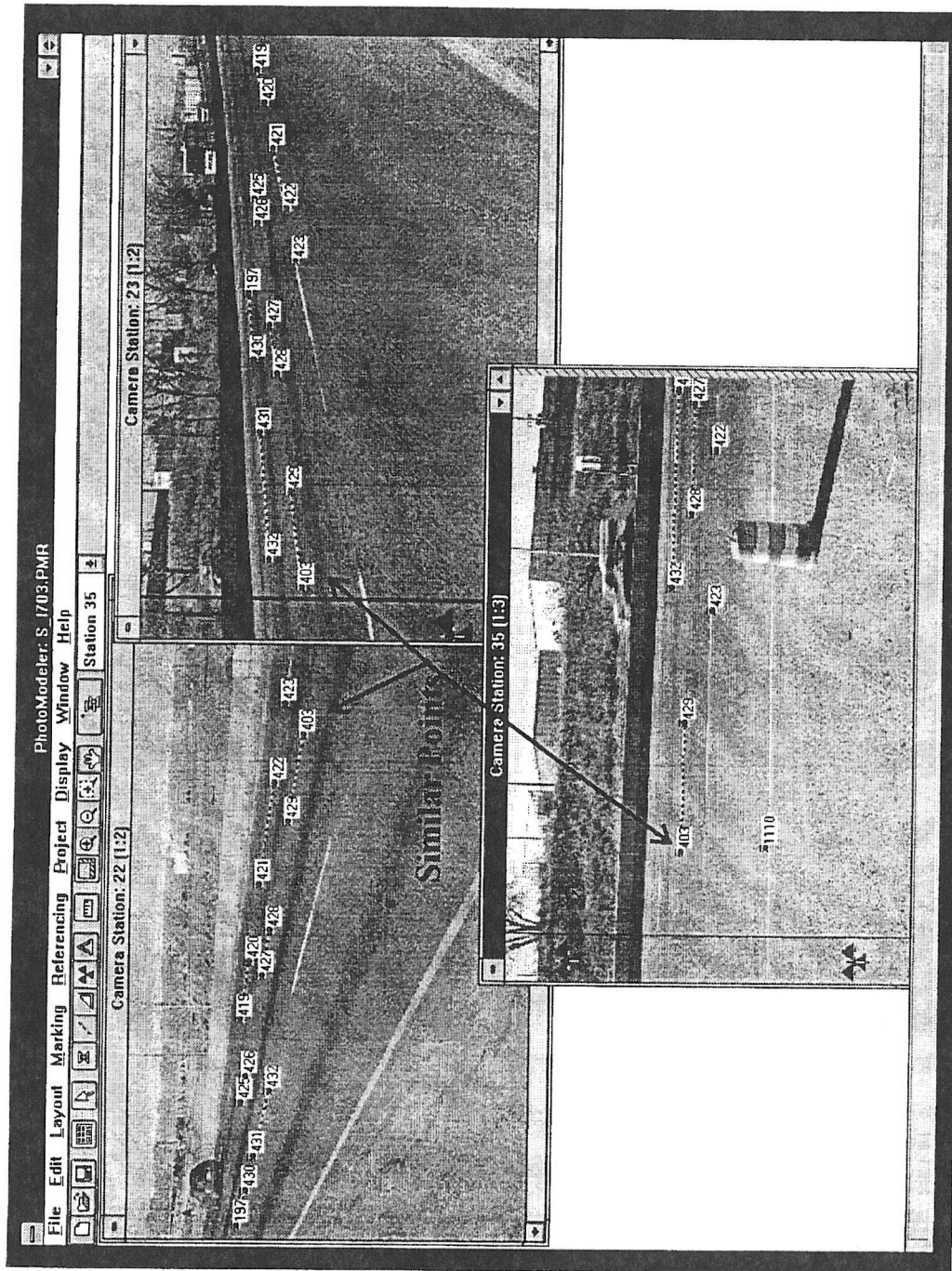
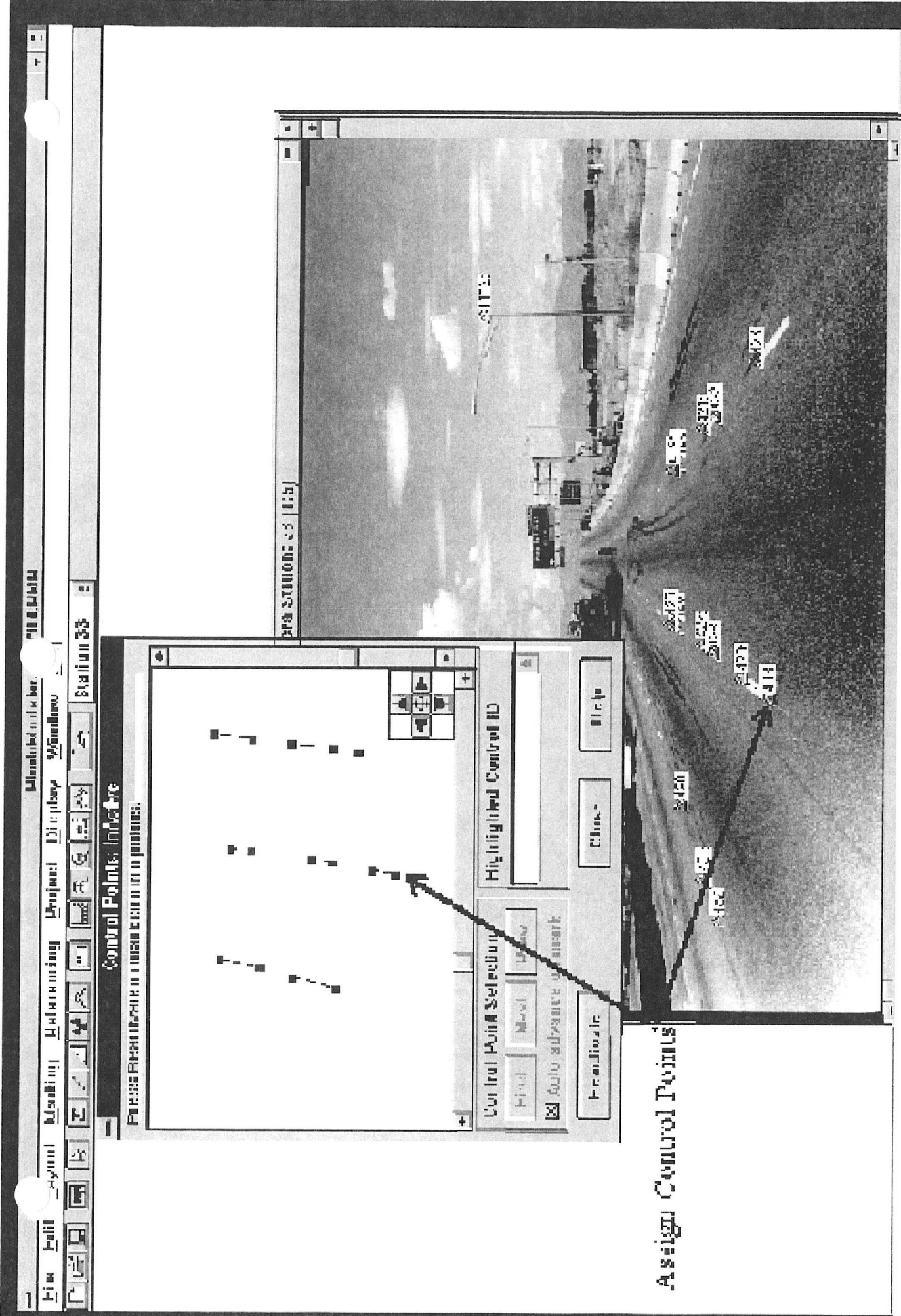


Figure 3 (PhotoModeler Project relating Control Points between Three New Photos)



Assign Control Points

Figure 4 (PhotoModeler Project Assigning Control Points to Old Photo)



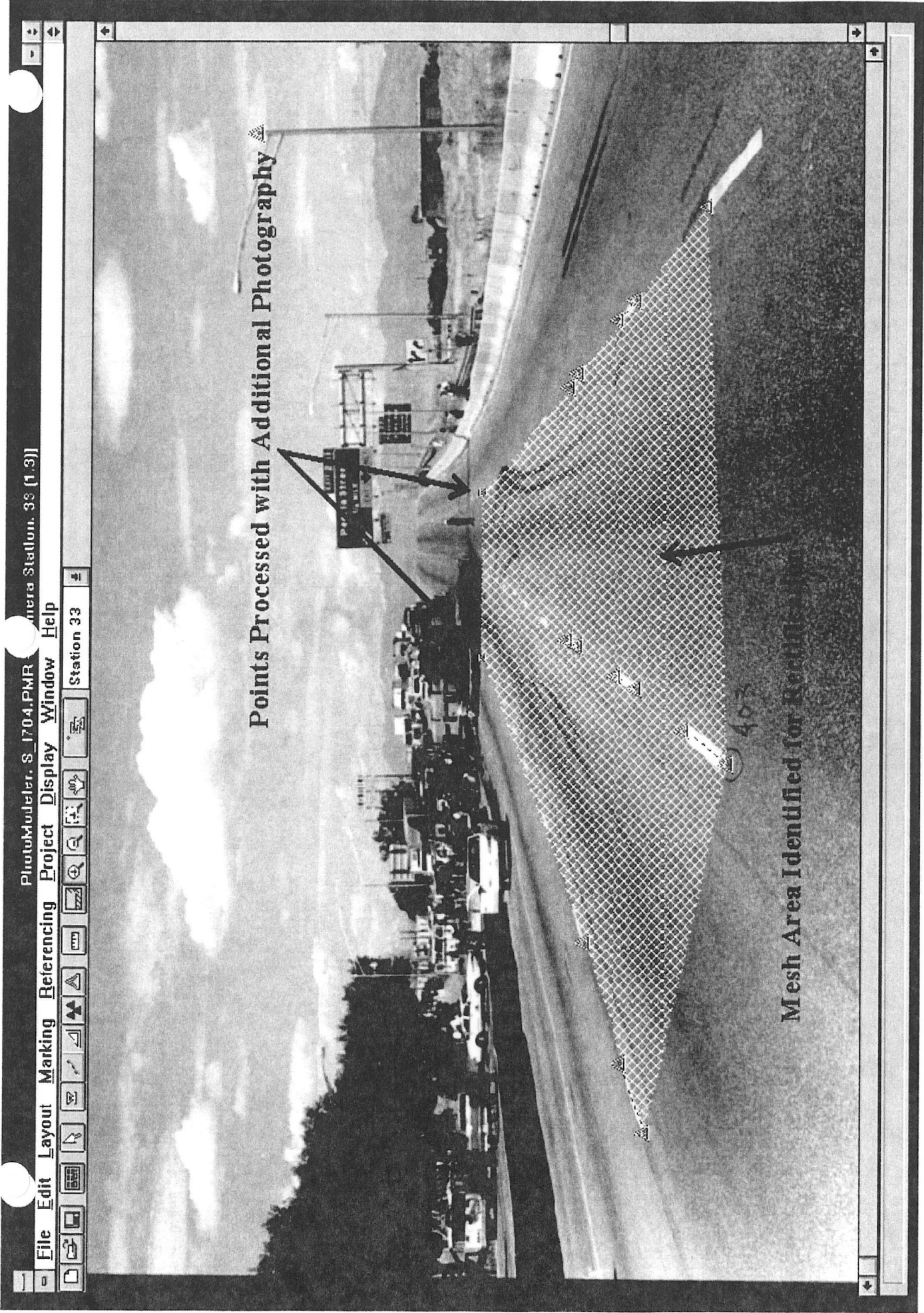
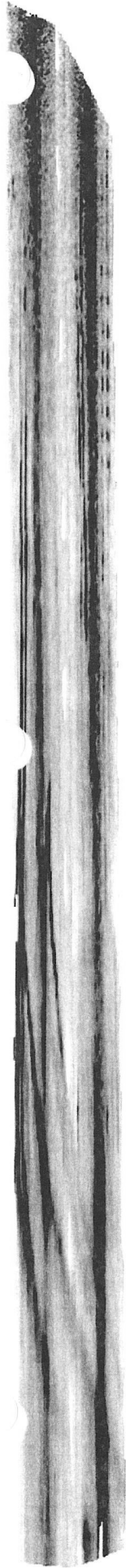
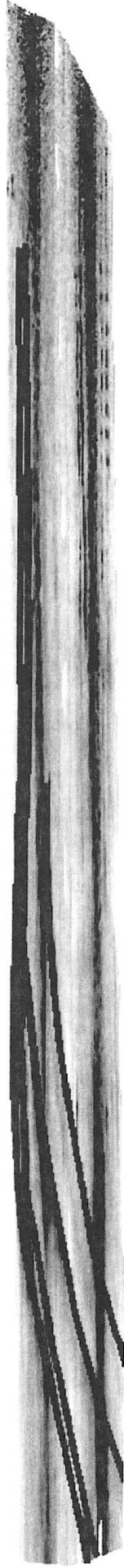


Figure 5 (Identifying Area to be Rectified)



Rectified Photograph



Rectified Photograph & Tracing



Tracing

Figure 6 (Rectified Photograph and Tracing)

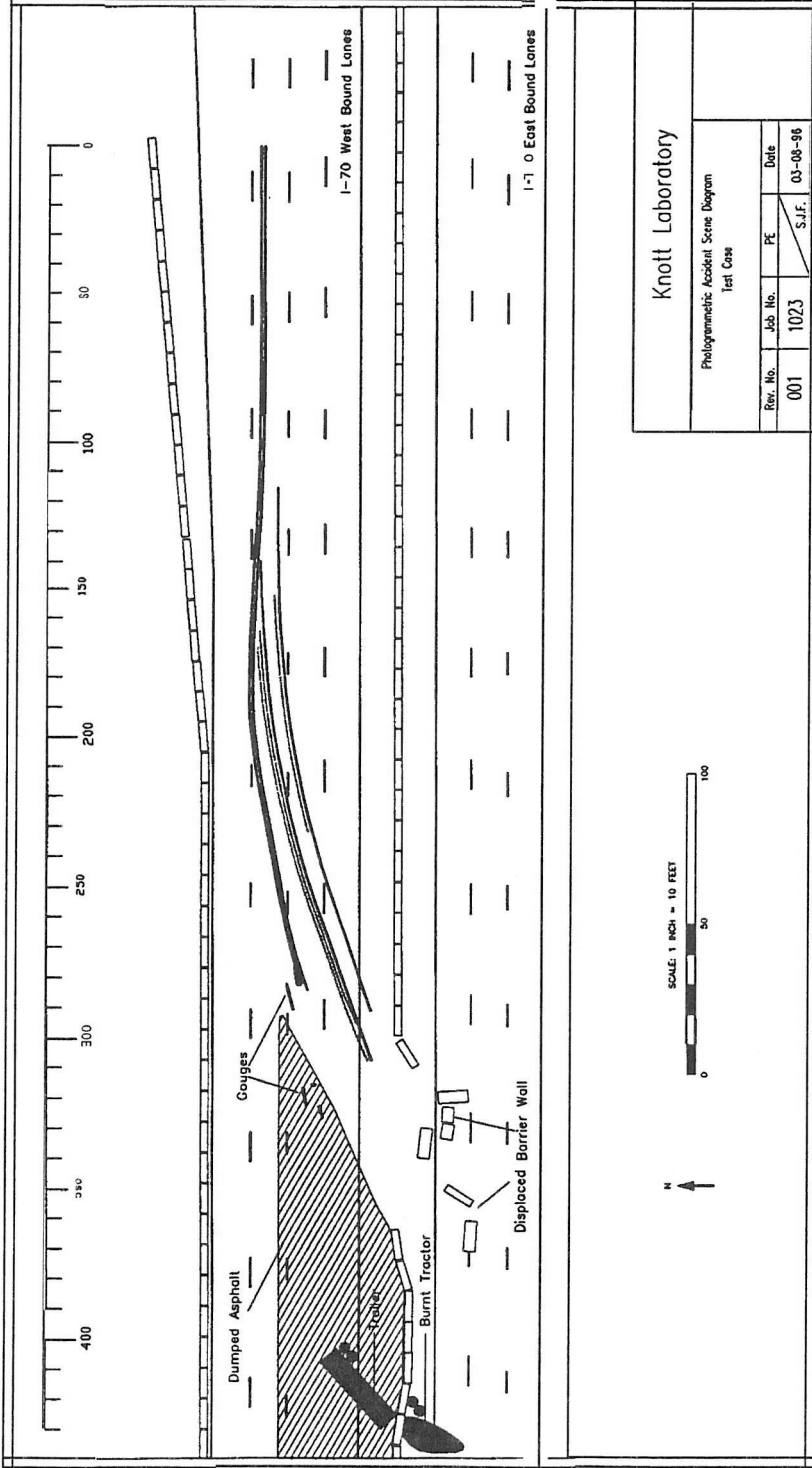


Figure 7 (Completed Accident Scene Diagram)