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Waste Site Characterization Through Digital Analysis of Historical Aerial Photographs at Los Alamos National Laboratory and Eglin Air Force Base

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ABSTRACT

Historical aerial photographs are used to provide a physical history and preliminary mapping information for characterizing hazardous waste sites at Los Alamos National Laboratory and Eglin Air Force Base. The examples cited show how imagery was used to accurately locate and identify previous activities at a site, monitor changes that occurred over time, and document the observable of such activities today. The methodology demonstrates how historical imagery (along with any other pertinent data) can be used in the characterization of past environmental damage.

INTRODUCTION

The US Department of Energy (DOE) and Department of Defense (DOD) face the formidable task of cleaning up their facilities and bases after many years of nuclear and other types of weapons development, testing, production, and stockpiling. Problems at these sites include waste stream outfalls, landfill contaminants, depleted uranium scattering and other similar problems. This paper focuses on how historical imagery and image processing was used for three specific examples: characterizing burial trenches for cleanup purposes, looking for the sources of scattered depleted uranium, and locating where former sumps were located so that soil sampling plans could be executed. The activities that created these environmental signatures occurred some years ago, so archival sources had to be searched in order to reconstruct events. These archives included written records, aerial photographs, ground surveys, satellite imagery, and whatever other resources could be brought to the problem.

MAPPING TRENCHES AT THE MATERIALS DISPOSAL AREA F (MDA-F) SITE AT LOS ALAMOS

This waste site area is located on the northern edge of Two Mile Mesa on the Pajarito Plateau (Fig. 1). The plateau is composed primarily of the Bandelier Tuff, a series of ash-flow deposits that were formed 1.1 to 1.5 million years ago. The tuff is soft and easily workable with power equipment. Soil cover on the mesa tops, as at MDA-F, is typically 3 to 4 feet deep. The disposal trenches were probably excavated through the soil and into the tuff.

Fig. 1. MDA-F waste site area as it exists today.

Before the Los Alamos National Laboratory was established as part of the Manhattan Project in 1943, the mesas of this region were farmed by homesteaders. During World War II, the site was used for explosives testing and later for the burial of classified, obsolete materials (through 1952). These materials were buried in trenches which were then refilled. High explosive lenses were disposed of near this area by detonation. A structure called the "timbered pit," which was used for explosives tests during World War II, is known to exist in this area. Specialized electrical components (spark gaps) containing cesium-137 were also disposed of in the area. It is possible that high explosives may also have been buried there. The exact location of the trench boundaries and whether additional materials were disposed of are not known. Therefore, it is important to identify and delineate the boundaries of trenches in the area so that samples can be taken close to the disposals without intercepting the waste itself.

Various local and national archives were searched for aerial photographs of MDA-F whose dates of acquisition bracketed and spanned the waste site's period of use. Many types of aerial photographs were found, including vertical aerial survey frames with overlap in coverage (stereoscopic) and high and low obliques. The photographs were examined for the quality of characterization information they might yield by a digital analysis. Those which held the best potential for analysis by this technique were selected for digitization by scanning. Selection criteria included high contrast, amount of ground detail, physical condition of the photograph, and position of MDA-F relative to the center of the photograph. This last criterion was employed to reduce the amount of distortion which would have to be corrected. Aerial survey photographs typically have large amounts of overlap along a flight line and side lap between flight lines. Thus, several frames may contain the region of interest. Choosing the photograph that contains the target

closest to the center, or principal point, reduces the inherent distortion effects due to view angle and terrain relief.

The most useful historical aerial photographs were from 1935, 1946, 1949, 1958, and 1972. These photos were chosen for analysis by digital techniques. Orthophoto coverage of the area was available from a more recent (1991) aerial survey of the Los Alamos area. Two orthophotos covered the MDA-F area. These orthophotos provided a base image for mapping of the waste site. The 1946 and 1949 oblique photos were the only ones available which were of good quality and contained sufficient detail of MDA-F during the period when the area was being used for disposal purposes. These acquisitions lacked overlapping pairs of photos. Preliminary comparisons with the vertical photos from the remaining dates pointed to a necessity for transforming the oblique photos so they could be more easily compared.

The digitized and transformed historical aerial photographs are shown in Figs. 2a through 2f. The transformations resampled the digitized photographs so that they matched in scale, orientation, and extent. These images were studied on an individual basis and animated or "flickered" on-screen to view changes in the site through time. A physical history for MDA-F was derived from these coregistered images.

Large changes in the site can be seen by comparing the 1935 and 1946 images (Figs. 2f and 2e). The 1935 image captures the mesa when it was being farmed extensively. Structures and furrows can be seen in this image. Magnified stereoscopic viewing of overlapping photos from the 1935 survey was used as an aid to interpret this digital image (Fig. 2f) because of the coarse spatial resolution incurred by the small scale of the original photo and the 600 dpi digitization limit of the scanner. The structures appear to be cabins, corals, pens, and small garden plots of a homestead. Three shrub oak thickets are also visible. These thickets are present in every image studied and serve as good reference features. The 1946 image shows areas of disturbed soil, a large mound, two open pits, and unimproved roads. The aerial photograph from which this image was derived was taken November 1, 1946, just after disposal activity was documented to have started on May 15, 1946. Thus, this image provides excellent indications of early disposal activity.

Minor changes in the site can be seen by comparing the 1946 and 1949 images (Figs. 2d and 2e). The timbered pit has been filled in, probably after being filled with waste material. The areas of disturbed soil, the large mound, and unimproved roads can still be seen. The main road has been partially paved from the west. Five circular anomalies just west of the large mound were found in

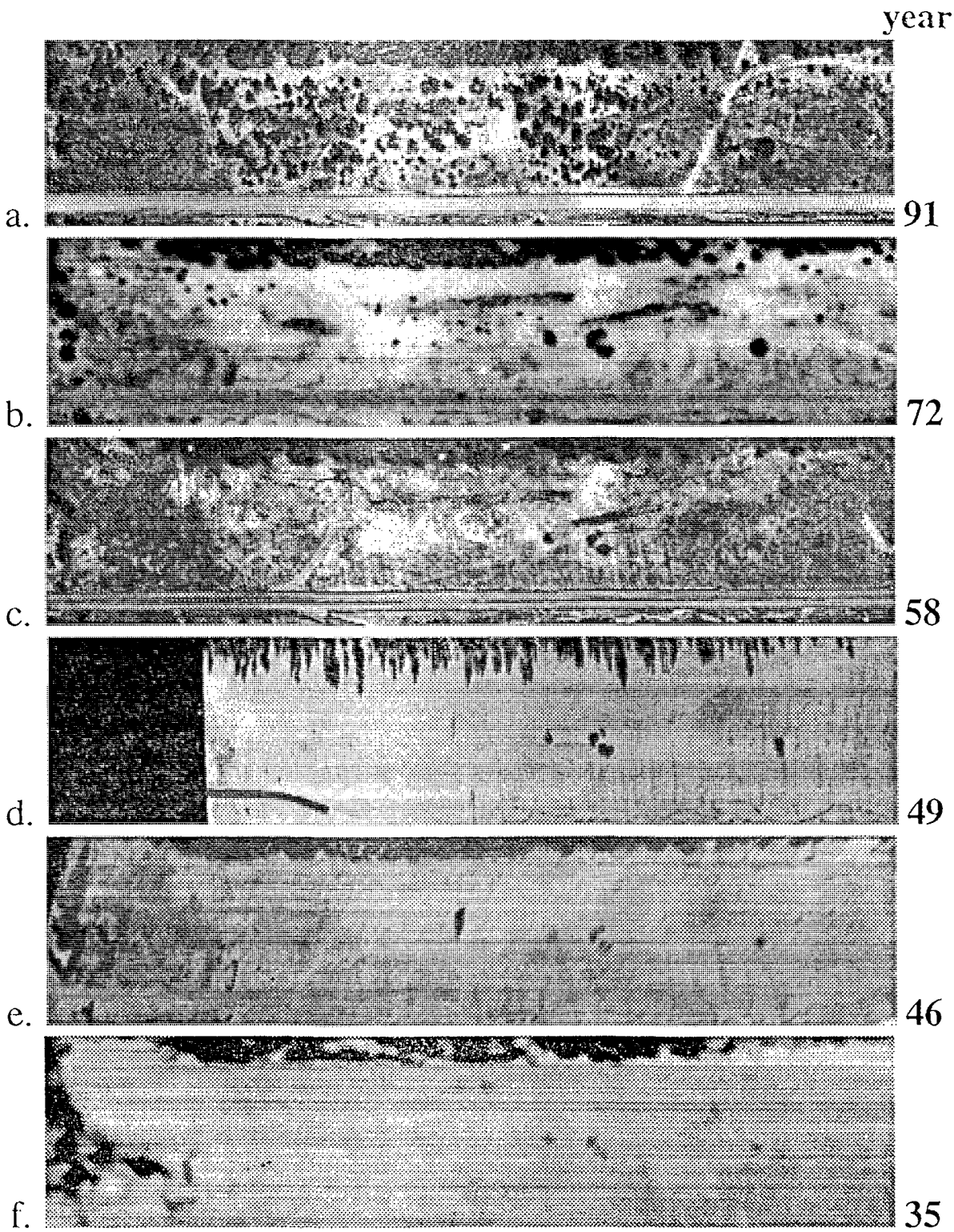

Fig. 2. Digitized and transformed historical aerial photos of the MDA-F site (year shown at the right of each figure).

the 1949 image. Comparison with the 1946 image reveals that these features are also present in this image, although the contrast is not as good due to the poor quality of the original photograph.

The 1958 image (Fig. 2c) was taken more than six years after the date of the last documented disposal at MDA-F. The large mound can still be seen, as well as areas of disturbed soil common to both the 1949 and 1946 images. Access roads into the area are clearly visible as well-defined tire ruts. The most interesting features are several dark rectangles. The dark appearance of these rectangles is probably due to vegetation growing on the refill over the disposal trenches. It is interesting to note that the appearance of this vegetation indicates growth and not stress over these waste sites. Vegetation stress, not growth, is mentioned most often in the literature as an indication of the presence of hazardous waste sites. Growth of vegetation as an indicator of hazardous waste is often associated with organic liquid waste such as raw sewage. In this case, the indication of a waste site is more like the anomalous vegetation signatures used to identify archeological sites. The causes for this growth is likely associated with increased moisture content within the loose refill material. The highly geometrical shape of these features is strong evidence that they were man-made.

Two of these dark rectangles are clearly visible on the 1958 image. However, the 1972 image (Fig. 2b) has better contrast and shows these features as well as two more on the western side. One of these dark rectangles corresponds to the timbered pit. The other three are suspected trench boundaries. The suspected trench north of the timbered pit could also be identified in the 1958 image by on-screen animation of the 1958 and 1972 images. Small, young ponderosa pine can be seen over the central portion of the 1972 image.

The 1991 image (Fig. 2f) shows the greatest change of the site over time. Ponderosa pines cover much of the area, making it difficult or impossible to see the suspected trenches and other features which were easily identified on the imagery derived from the historical aerial photographs. The ponderosa pines seem to cover only the portion of the site that was most disturbed. There is minimal ponderosa pine cover on the western and eastern sides of Fig. 2a. The soil disturbance may have removed herbaceous vegetation that would compete with establishment of the ponderosa pine. The growth of the pine may also have been aided by the lack of severe drought during the past 15 to 20 years. This image serves as an excellent reference for field checking of the features observed in the other imagery, as well as providing location information for roads, fences, and utility poles in the area.

Feature boundaries digitized from the coregistered, geographically coded images are summarized in Fig. 3, where boundaries are combined by using the GIS to overlay them on the 1991 base image. This shows the spatial relationship of these historical features within the context of how the site appears today.

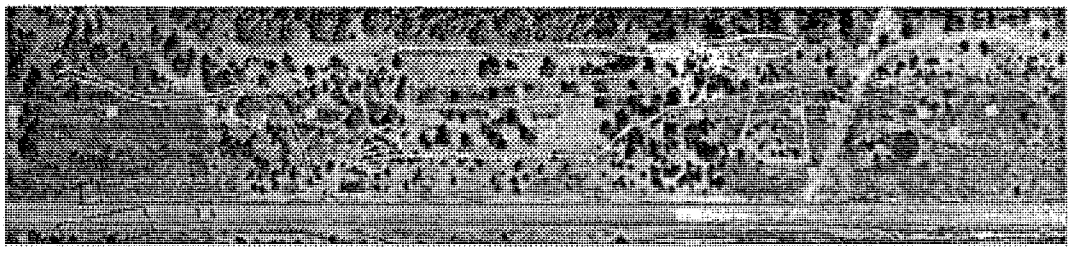

Fig. 3. Various features noted from the historical analysis overlaid on 1991 orthophoto of the area.

A long, rectangular suspected trench boundary lies within a large area of disturbed soil in the center of Fig. 3. The dimensions of this suspected trench are 122 meters long by 11 meters wide. A large mound lies within this area and is close to this suspected trench. Access roads branch into the large area of disturbed soil and pass through or close to other areas of disturbed soil. All of the suspected trenches lie close to these routes or near disturbed soil. The suspected trench boundaries derived from the 1972 and 1958 images are very similar. The only discrepancy is in the length of the eastern-most trench, which appears slightly longer in the 1972 image.

The large circular anomalies lie close to the access roads and the timbered pit. The average radius of these anomalies is 2.7 meters. They are spaced regularly with an average separation of 34 meters vertically and 29 meters horizontally. The boundaries of the timbered pit extracted from the 1946 and 1972 images match the suspected location. This pit was originally used for explosives experiments, but might have been used for materials disposal before being filled in. The systematic arrangement of the circular anomalies and their proximity to the timbered pit suggests that these features may also have been created when the area was used for experimental work.

The presence of the suspected trenches, pits, disturbed soil, large mound, and access roads are strong indications of disposal activity. The imagery suggests that disposal activity was confined to the central portion of the area defined by the 1991 base image. Evidence for disposal activity in this area has been provided by the coregistered and geographically coded imagery of MDA-F.

It is interesting to note that a magnetic survey was performed over the area of interest (the grayed rectangle of Fig. 4). This survey was laid out prior to the results of the historical photographic

study, and did not extend far enough to the right because incomplete information was used. The survey is being extended at this point in time. Those results so far collaborate the imagery results, but will be the subject of another paper.

Fig. 4. Magnetic survey boundaries overlain on the 1958 digital image.

This particular aspect of our work demonstrates the usefulness of digital analysis of historical aerial photographs for characterizing a DOE waste burial site. Historical aerial photographs with varying scales, orientations, and views of the waste site were transformed so that they matched a base image of the region of interest. The 2-D projective transformation allowed the oblique photographs to be resampled so that overhead-like views of the site were created. The images of the waste site provided characterization information for the period of greatest activity, when no vertical aerial photographs of value existed. Coregistered images were easily compared by on-screen animation. Digitized orthophotos provided geographical coding information for an area that contains few sharply defined man-made features. Feature boundaries were digitized from the coregistered and geographically coded imagery. The geographic coding and digitization work was performed by using a GIS. The GIS enabled these features to be combined with each other and the orthophoto mosaic of the area so that their locations could be displayed within the site as it appears currently. Lengths were easily measured on the geographically coded imagery by using tools available in the GIS.

EGLIN AFB TEST AREA C-64C STUDY

Eglin AFB is a key air-delivered armaments testing complex and was very active during the Vietnam War era. The main base area is located on Choctawhatchee Bay, just northeast of Fort Walton Beach. The focus of this particular example is Area C-64C, as observed in a 1985 low altitude oblique view in Fig. 5. In the early 1990s, subsequent to the construction of an experimentation complex at this site, a radiological survey was conducted which resulted in findings of higher-than-background radiation levels. It is believed that this radiation resulted from residual depleted uranium used in ordnance tests during the 1970s and the early 1980s.

The first aerial photo of Eglin we had access to was an enlarged view of the C-64 test complex as it existed on February, 1969 (Fig. 6). The light-colored rectangular complex left of center in the image is Test Area C-64, while the irregular polygon-shaped area in the lower right corner is Test Area C-64A. The upper part of the latter area (i.e., the darker gray area) is now known as Test Area C-64C. Note that, while C-64 shows target range features in place, there are no obvious signs of military use (e.g., no construction nor any ground targets) in the C64A/C area, which shows evidence of agricultural use, as suggested by the furrowed linear features in the center of the area. Titi Creek runs along the upper part of the photo.

An aerial photo from 1974 (Fig. 7) includes several aircraft in an area farther to the east (right side) that may also have been used as a staging area for targets. Specifically, there are no runways or parking aprons in Test Area C-64A/C; further, Eglin is not a surplus aircraft storage facility (like Davis-Monthan AFB in Tucson, Arizona). Therefore, it is probable that these were surplus aircraft to be used for some sort of ordnance testing, most likely as targets for canon experimentation. Thus, as with the area containing cylinder objects further to the west, it likely that this was a staging area where aircraft were stored pending relocation to firing ranges such as Test Area C-64. Using measurements derived directly from the georeferenced aerial images, and the aircraft in the lower center of the image appears to be a North American F100 Super Sabre.

By 1978 the aircraft had been removed; however, the primary area of interest continued to show the type of staging activity evident in 1974. Specifically, as reflected in Fig. 8 (of the same area of the 1974 Fig. 3 photo, but enlarged for the area of interest), the pipe-like objects are in essentially the same area; however, there are three more "pipes" in the area (i.e., eleven, as opposed to eight in 1974).

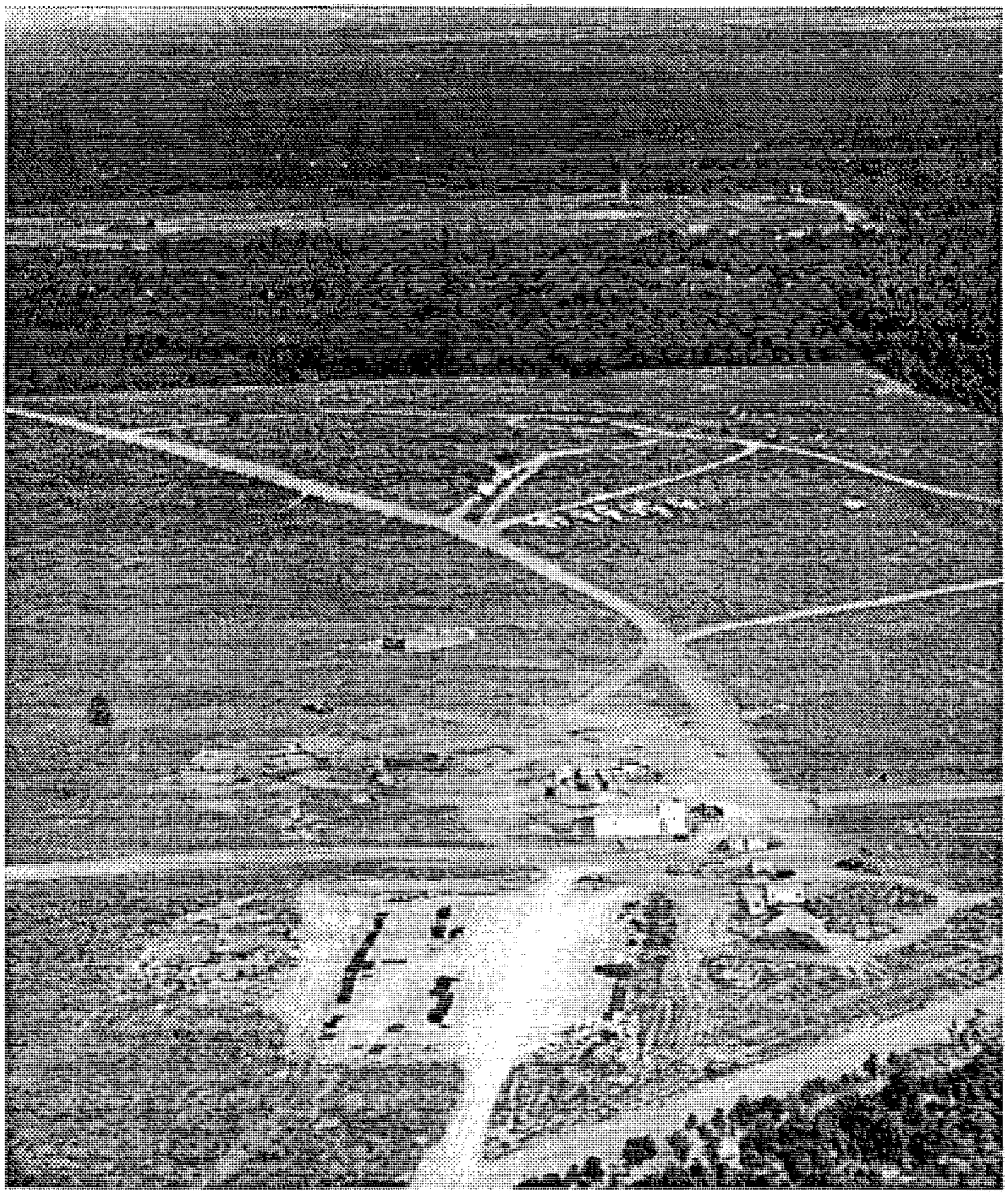

Fig. 5.

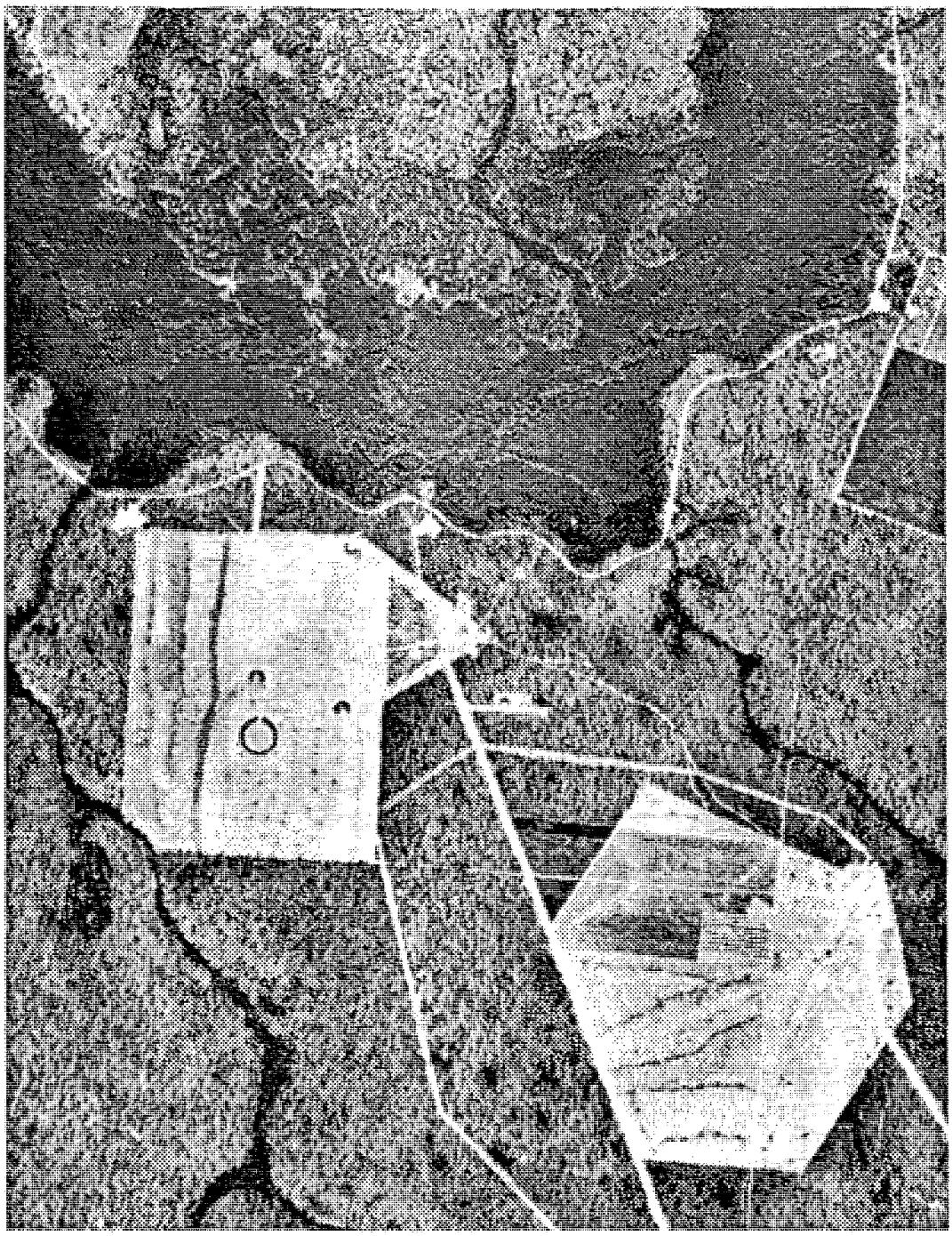

Fig. 6.

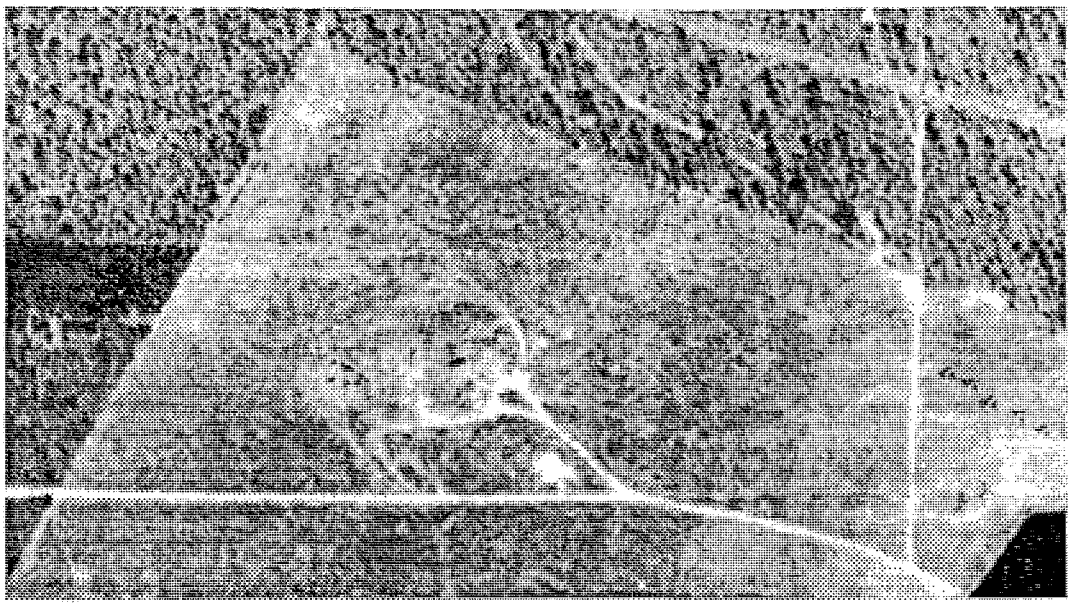

Fig. 7.

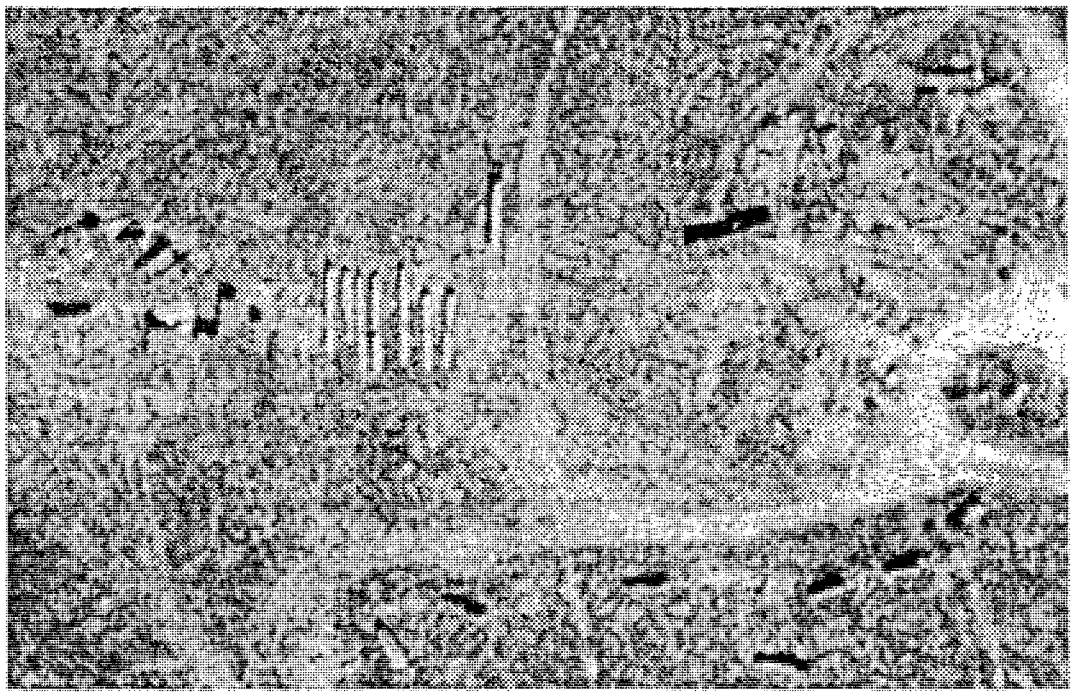

Fig. 8.

Figure 9 shows a georeferenced overlay of the 1974 target area objects on the 1990 laboratory complex. The pipe-like objects would have been located to the west (left) of the new construction. However, the 1974, 1978 and 1985 images suggest that staging area objects were probably located throughout this area at one time or another during the 1970s and early 1980s.

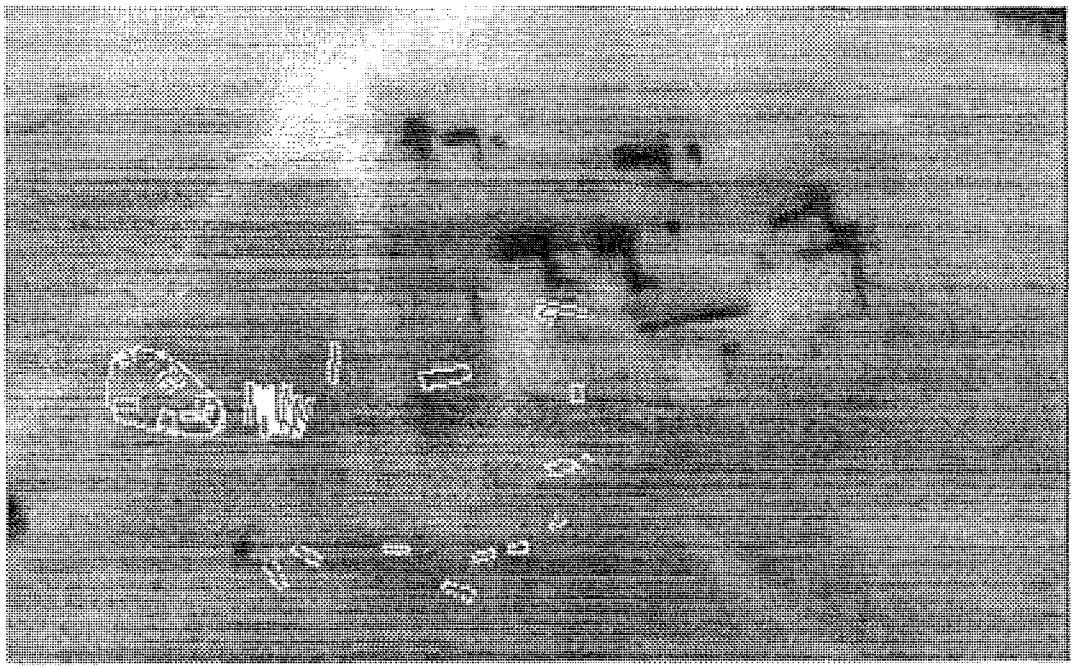

Fig. 9.

The goal of this specific effort was to demonstrate the utility of historical image analysis in characterizing what had taken place at Eglin AFB over time and to provide information to environmental restoration personnel to guide detailed field investigations. The aerial imagery provides relatively precise location and character of objects that existed during the 1970s and early 1980s. However, if the assumption that these objects were ground targets for aerial gunnery using, in some cases, depleted uranium ordnance, the nature of "strafing" suggests that the residual depleted uranium is scattered over a larger area than that occupied by the target objects. The tentative conclusions of this analysis, however, do not support the area being used as an air-delivered ordnance range. Rather, it was apparently a staging area for nearby range facilities. Consequently, any depleted uranium contamination resulted from secondary sources, such as rain wash down of targets brought back to the staging area. There is an additional possibility of residual contamination from ground based experiments, such as from flatbed mounted gattling guns.

This is but the initial analysis of some of the data that exists at Eglin Air Force Base. We are adding additional information on the depleted uranium concentrations and other historical photographs we hope to obtain to further refine this study.

MAPPING SUMP POSITIONS AT THE GMX-2 AREA AT LOS ALAMOS

In the early days of the cold war, Los Alamos had a number of processing facilities for weapons grade materials. One such facility is shown as it existed in 1950 in Fig. 10, and is located at what is known as the GMX-2 facility. This facility was later decommissioned by burning the buildings and removing the sumps as shown in a 1965 aerial view (Fig. 11a). This figure shows the area after the buildings were burned but before the sumps were removed. The sumps are clearly visible as a row of six white rectangles in the scanned 1965 photo of the area. Much later (1991), a drastically different scene is observed (Fig. 11b). The building debris, pipes, utility poles, as well as the sumps have all been removed and the area has grown over with grass to the extent that even some of the roads are no longer visible. Work at the area now consists solely of environmental assessment and remediation.

The purpose of our effort here was to locate the sumps on a current image of the site so that a soil testing plan could be implemented. This particular suite of sumps was a test case for accuracy of location using this methodology, since the depressions from exhumation of the sumps are visible on the 1991 orthophoto, and our location algorithms could be easily checked. If the accuracy of location was within about a meter, then other sump locations (ones which do not show on current orthophotos) could be determined.

First of all, the 1965 image of the GMX-2 area was resampled by a coregistration process to match the 1991 image. There were significant scale distortions due to terrain relief, viewing angle, and enlargement from the original negative, and it was very difficult to estimate the positional accuracy between placement of the sumps in the two images due to the fact that the sumps have been removed subsequent to the 1991 aerial survey and the lack of common features. In fact, the best registration references we had were an old hydrant, two rocks, and a tree.

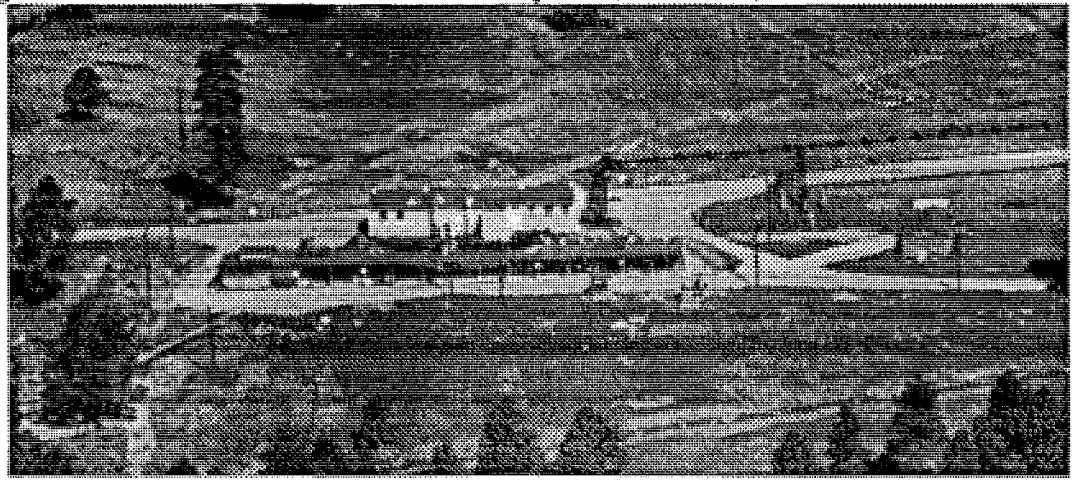

Fig. 10. 1950 oblique view of weapons grade material processing facility.

Fig. 11. Aerial photos taken in 1965 and 1991 of the GMX-2 site. The sumps are clearly visible in the 1965 photo (6 rectangular objects in the lower part of the image). These particular photos have similar scales and are of the same area, but are not registered pixel by pixel as were the photos in Fig. 2.

After performing the coregistration and field surveying the results, the average deviation of the six sump centers relative to where the depressions were in the 1991 image was found to be 2.7 feet, with a maximum of 4.7 feet. An example location is shown in Fig. 12.

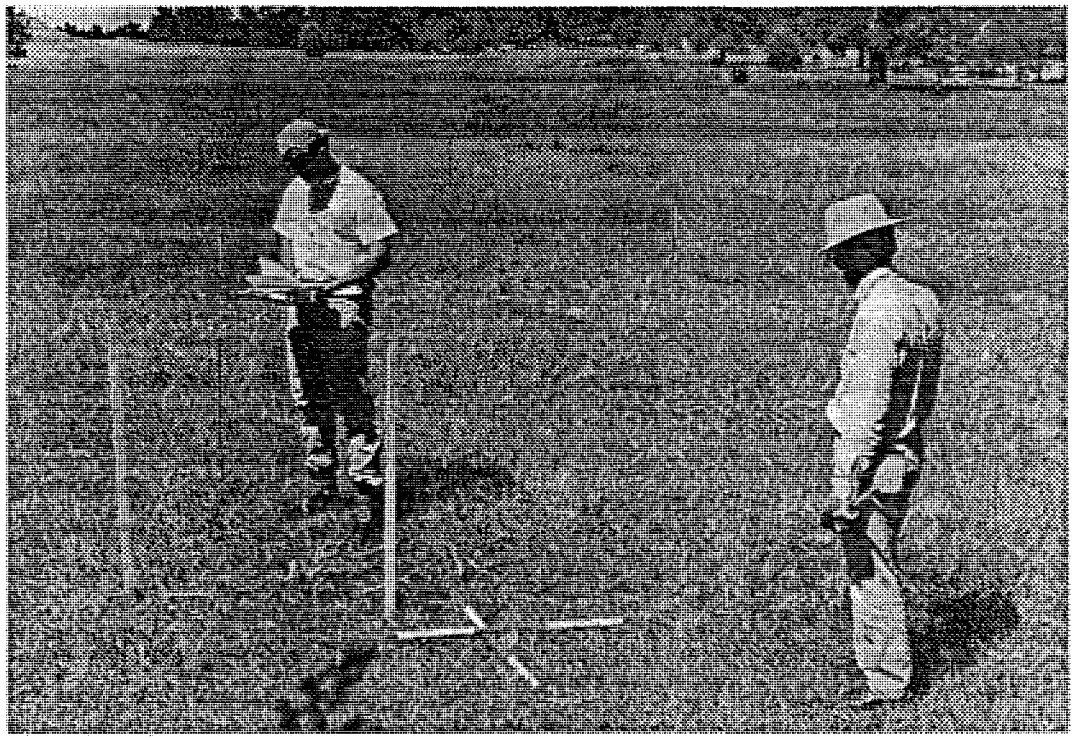

Fig. 12. Example sump location errors (the depression left from the sump is marked with a cross).

This example clearly showed the environmental restoration personnel at Los Alamos that performing the historical archival search and registration process could make the field location simpler, and they are proceeding on that premise.

CONCLUSIONS

Digital analysis of aerial photos at another Los Alamos site allowed disparate views of the waste site to be transformed so that they matched in scale, orientation, and extent. The coregistered images were imported to a Geographic Information System and geographically coded to a common coordinate system. The Geographic Information System was used to extract the boundaries of features such as suspected trenches and disturbed ground. This preliminary analysis is providing the basis for planning and comparing the results from remote sensing and geophysical surveys to further characterize the waste site.

Analyses of historical Eglin AFB photos have indicated possible sources for existing depleted uranium contamination. These analyses have overlain past testing environments on top of today's structures and have detailed areas of environmental concern.

Image analysis of historical photos at Los Alamos National Laboratory located contaminated sites (sumps in this case) that were operational during the early 1960's. Such sites oftentimes are only generally geographically located prior to analysis--this methodology located these sumps to within less than a meter, which is thought good enough to then perform a more detailed soil sampling survey.

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