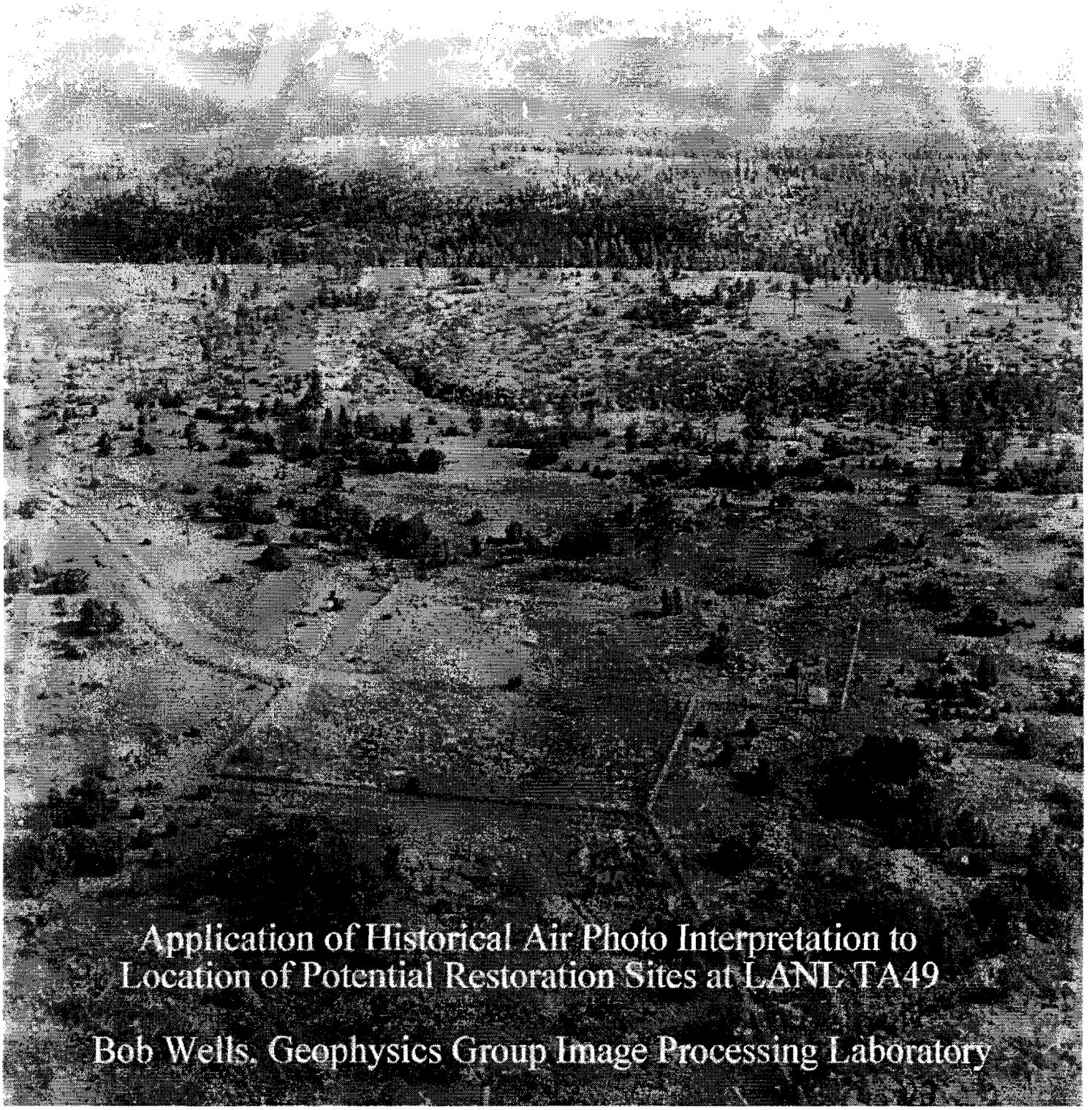
ER ID 44820



Application of Historical Air Photo Interpretation to Location of Potential Restoration Sites at LANL TA49

Bob Wells, Geophysics Group Image Processing Laboratory

30888

Application of Historical Air Photo Interpretation to Location of Potential Restoration Sites at LANL TA-49

Image Processing/GIS Laboratory (EES-3) Tasking:

By a memorandum dated July 6, 1994, the Project Leader for Operating Unit 1144 (OU1144) requested the Geophysics Group's Image Processing/GIS Laboratory to undertake an evaluation of historical air photos to assist the TA-49 Environmental Restoration Team in locating several Solid Waste Management Units (SWMUs) that had not been located by conventional methods (e.g., site maps, as-built drawings, reports, worker recollections, signs, or other markers). The following SWMU tasks were specified:

SWMU No:	Area No:	Description:	Priority:
49-003(2)	11	Small-scale shot area	Secondary
49-003(2)	11	Interim waste storage box area	Secondary
49-003(2)	11	Leach field	Secondary
49-005(a)	10	Small landfill east of Area 10	Primary
49-005(b)	5	Small landfill in Area 5	Secondary
49-006	5	Sump(s)	Primary

Available funding initially limited the scope to locating the two primary SWMUs; however, the image scientist was able to add results for each of the secondary tasks.

The objective of the project was to demonstrate the relative utility of various types of historical aerial imagery to assist the Site Restoration Team in locating poorly documented waste features, such as landfills and liquid waste sumps. Aerial photography was collected, digitally processed and enhanced to facilitate interpretation of historical patterns that might provide the location of these SWMUs. Aerial imagery from 1935 through 1993, including black and white, color, infrared vertical and oblique photography, was used in the project. Interim (40%) interpretation results were presented to the OU1144 Deputy Team Leader in late July and, in late September, 95% interpretation results were presented to a retiree who had played a key role in the construction and operation of TA-49 during 1959-1961. This latter presentation included a field visit by the OU1144 Deputy Team Leader, the image scientist and the retiree. The results of of the study were assembled in a draft report in late October and reviewed by the OU1144 Deputy Team Leader and a member of the 1984 TA-49 Site Restoration Team in November, 1994. This review included a site visit with the image scientist,

which verified the suspected locations of the primary tasks [i.e., SWMU # 49-005(a) and SWMU #49-006]. The project results were used by the Site Restoration Team to guide field surveys. Of the six tasks, four suspect sites were interpreted with high confidence, one with medium-to-high confidence, and one with medium confidence. These results, however, depended heavily on the availability of high resolution (typically 1:10,000 scale or better) photos. When such imagery is available, interpretation should be universally beneficial for environmental monitoring and assessment tasks.

Location of TA-49:

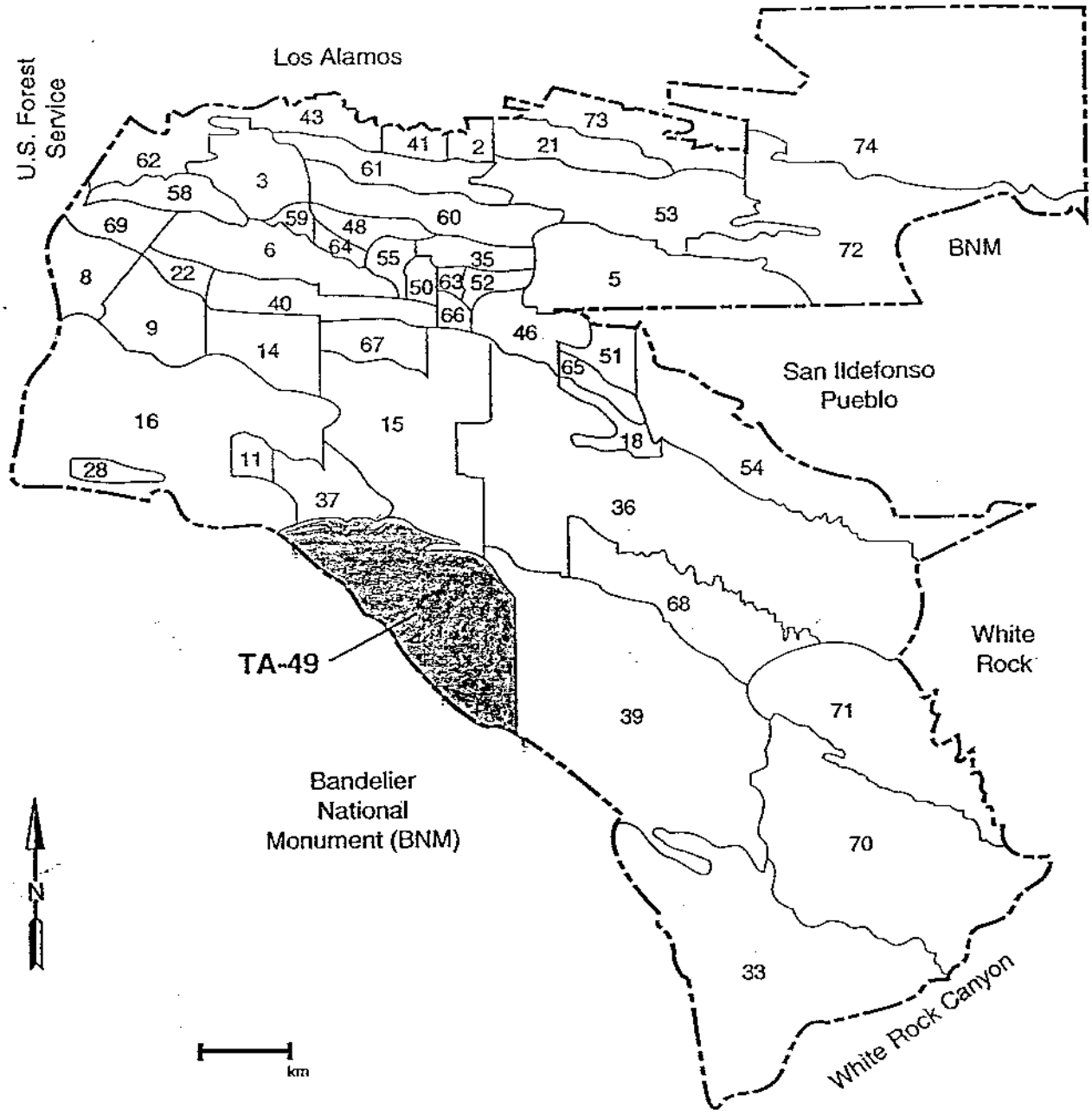
The following charts show (a) the location of TA-49 within the Laboratory and (b) the SWMU sites within TA-49, with Area 5 located in the center, Area 11 being located just north of Area 5, and Area 10 located to the east (i.e., right hand side of the image). Note that SWMU #49-005(a), a 1984 landfill, is actually just north of Area 10 (rather than further east as shown on the Environmental Restoration Team's chart). Also note a suspect area further east (below the bend in the road).

The 1280 acre site, which is also known as the Frijoles Mesa Site, is located north of Bandelier National Monument. State Route 4 forms TA-49's southern boundary. The cover photo is a 1991 low altitude view of Area 5 looking north towards the main areas of Los Alamos National Laboratory, with the Jemez Mountains in the background. Area 11 is just north of Area 5, while Area 10 is outside the photo to the right (east).

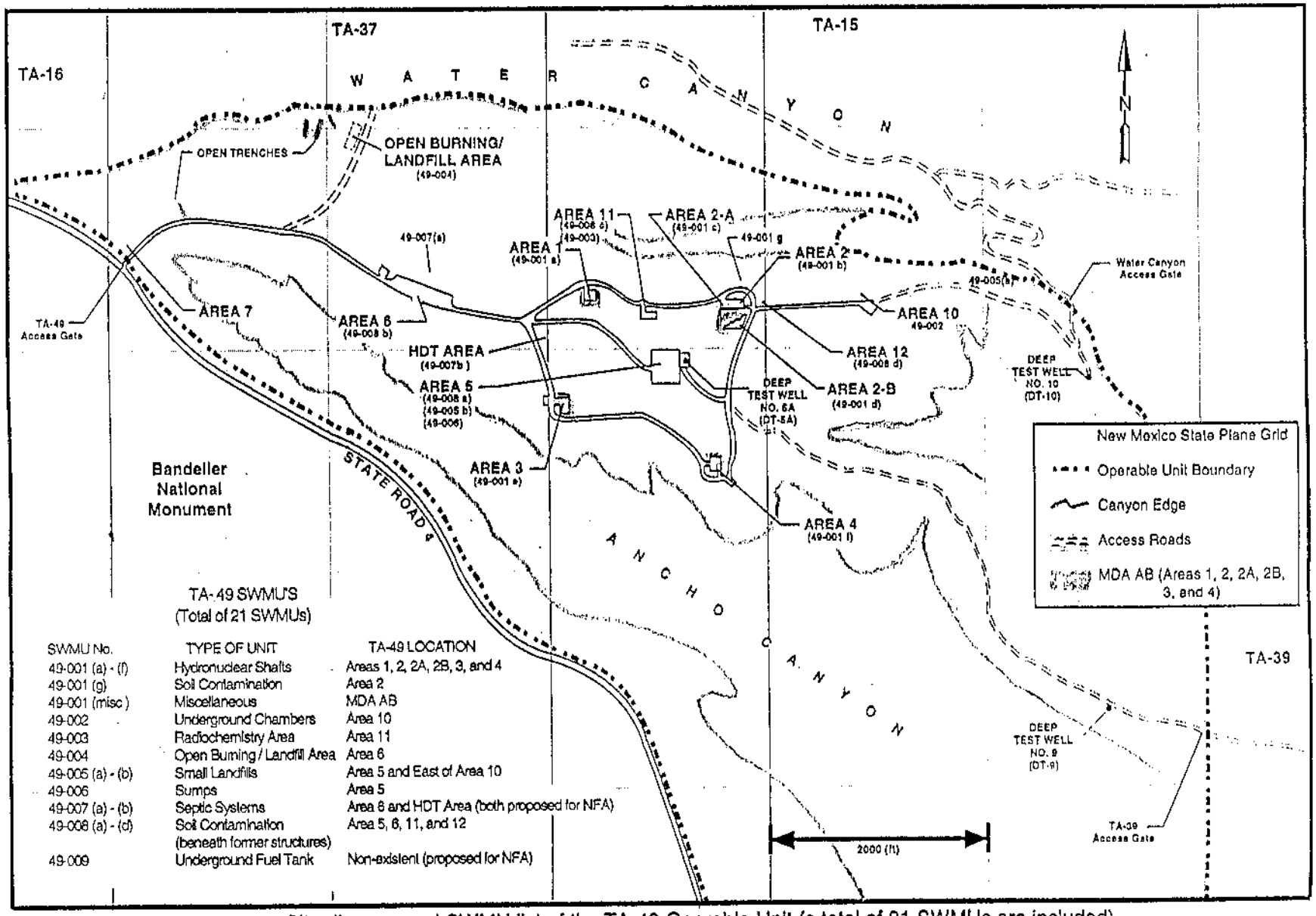
Historical Background:

Frijoles Mesa contains extensive prehistoric Indian ruins and artifacts. The area that now comprises TA-49 was part of the Ramon Vigil land grant. In the late 1800s and early 1900s the area was used for ranching, farming and timber harvesting. The 1935 Soil Conservation Service photo (1:20,000 scale) shows the alignment of current State Route 4 and a homestead era road running generally East-West through what would become TA-49. The sparsely vegetated area in the center of the image would become the main technical areas, such as Area 5. The 1983 Forest Service photo (1:24,000 scale) shows the locations of Areas 4, 10 and 11.

In late 1959 the Laboratory was tasked to undertake a very high priority mission that required expeditious preparation of TA-49 for a series of experiments involving high explosives and radioactive materials. The experiments were conducted underground in large diameter holes (3'-6'), some as deep as 120-feet. Residual materials dispersed by detonation of the high explosives remain at the bottom of the experimental holes. The experimental area is presently identified as a radioactive and hazardous material disposal area (MDA-AB, established in January, 1986).



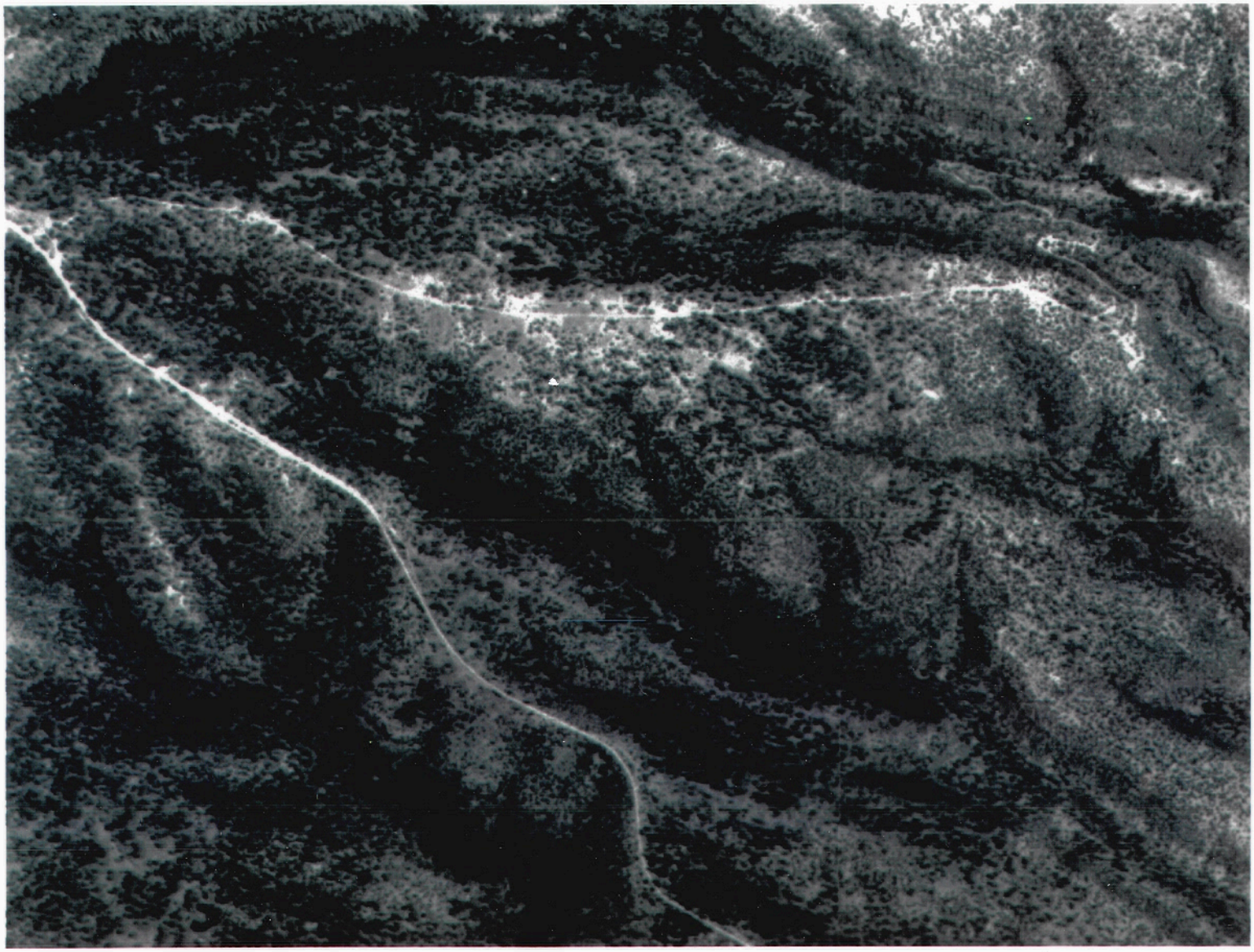
Location of TA-49 in relation to other TAs and landholdings surrounding the Laboratory.



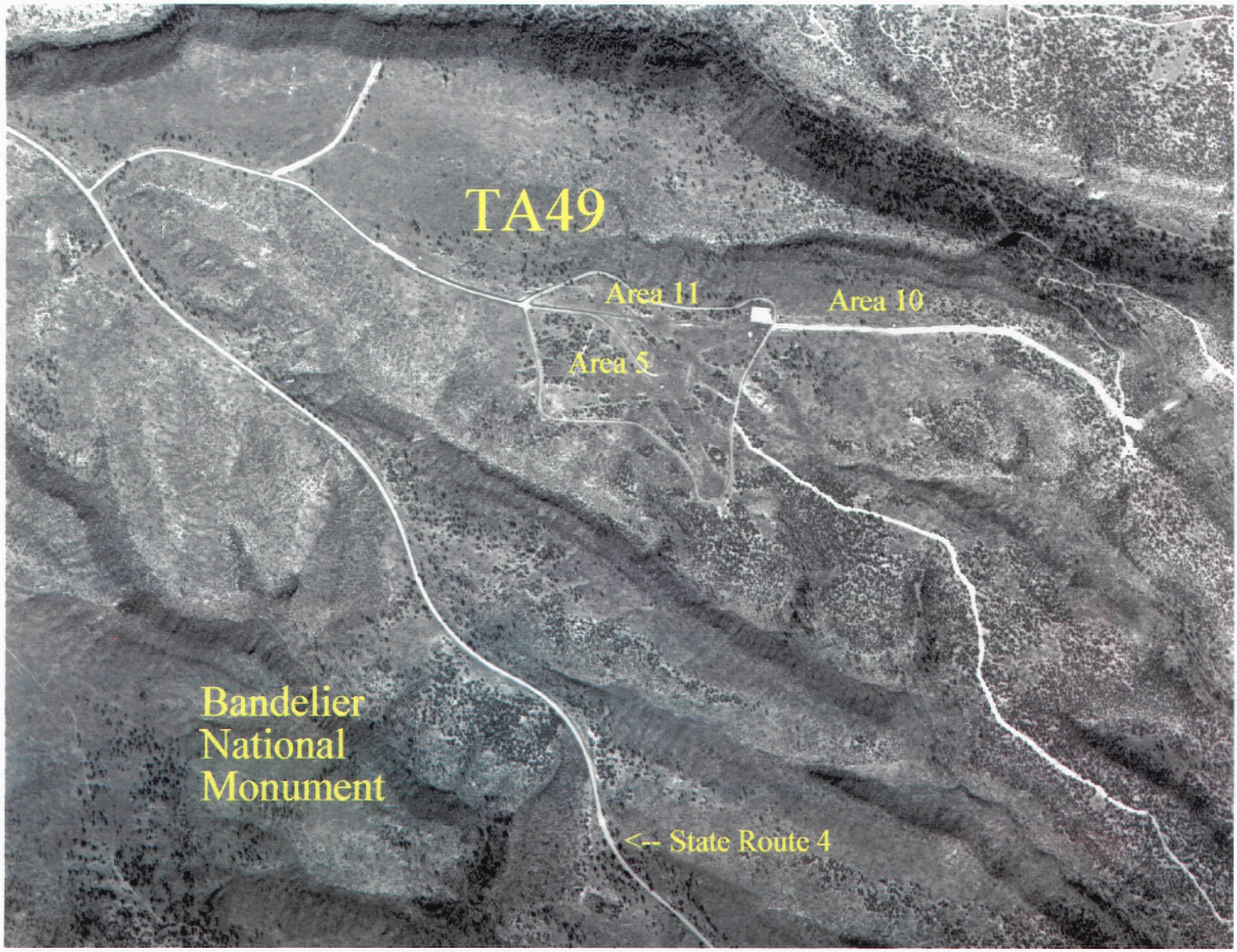
TA-49 SWMU'S
(Total of 21 SWMUs)

SWMU No.	TYPE OF UNIT	TA-49 LOCATION
49-001 (a) - (f)	Hydronuclear Shafts	Areas 1, 2, 2A, 2B, 3, and 4
49-001 (g)	Soil Contamination	Area 2
49-001 (misc.)	Miscellaneous	MDA AB
49-002	Underground Chambers	Area 10
49-003	Radiochemistry Area	Area 11
49-004	Open Burning / Landfill Area	Area 6
49-005 (a) - (b)	Small Landfills	Area 5 and East of Area 10
49-006	Sumps	Area 5
49-007 (a) - (b)	Septic Systems	Area 6 and HDT Area (both proposed for NFA)
49-008 (a) - (d)	Soil Contamination (beneath former structures)	Area 5, 6, 11, and 12
49-009	Underground Fuel Tank	Non-existent (proposed for NFA)

Site diagram and SWMU list of the TA-49 Operable Unit (a total of 21 SWMUs are included).



1935 Soil Conservation Service Photo of TA49



Sep. 12, 1983 Forest Service 1:24,000 scale photo of TA49

There is no information indicating that TA-49 was used for any Laboratory purpose prior to 1959. Historically, including the present and the foreseeable future, TA-49 has served as a shrapnel buffer zone for the explosives testing at TA-15 (to the north) and TA-39 (to the east).

From the time the hydronuclear experiments were completed in the summer of 1961, TA-49 has been used sporadically for Laboratory purposes. During 1962-1963, firing assembly (squib) experiments were performed at Area 10 involving release of pressurized gas to drive pistons against water in cylinders. In 1965, lightning observation experiments were conducted using a photographic tower that remained in the northwest corner of Area 5. In the mid 1960s a cable-stretching facility with a powerful hydraulic ram system was built at Area 12 (its anchors are still in place along the south side of the road opposite Area 10). Pulsed gas laser and shock tube experiments were conducted briefly in 1967-68 at unidentified locations within TA-49. In 1968, explosively driven plasma gun experiments were conducted at Area 1 or Area 2 and lightning flash experiments using large capacitor banks were carried out at Area 12.

In the early 1970s, additional atmospheric observations were carried out from the Area 5 tower and further shock tube work was carried out at an unidentified location. In 1977, a seismic study of TA-49 was performed employing explosives in 37 shot holes drilled to depths of about 6 feet in an area extending from Area 5 to Deep Test Well DT-9. No waste units were impacted by the seismic studies, both because the SWMU areas were avoided and the explosive quantities were very small.

In May, 1977, the La Mesa forest fire burned over much of TA-49, destroying essentially all remaining combustible structures. Little visible physical evidence remains of the 1961 to 1977 (i.e., post-hydronuclear) activities at TA-49. The only surface structures currently existing at TA-49 that were associated with the early site activities are the cable-stretching facility, the "Bottle House" used for containment experiments in Area 12, and a few portable concrete radiation shields scattered around the site.

Currently, there is only small-scale use of TA-49. The High Power Microwave Group occasionally uses the Area 6 "Day Room" building (TA-49-115) and its immediate vicinity for equipment development. The roadway between Areas 10 and 12 has a microwave test range. The Hazardous Devices Team (HDT) uses TA-49-113 as a training facility and an associated high explosives magazine, TA-49-114, for small-scale explosives training exercises. Building TA-49-113 also houses the Laboratory's Alternate Emergency Operations Center, which is sometimes used for routine training. A security operations group periodically conducts electrical grounding measurements in a small area immediately west of the HDT Training Facility.

Prior Site Restoration Activity:

In September, 1971, all the structures at Area 11, which was primarily a radiochemistry and change room complex, were decontaminated and demolished, with contaminated debris removed from the site to TA-54 and uncontaminated debris buried in a landfill in the northwest corner of TA-49, about half a mile from the experimental area. A contaminated subsurface leach field that served the radiochemistry facility was left in place and represents a remaining source of near-surface contamination. The wastes include acids, organic and other laboratory chemicals in addition to plutonium, fission fragments, lead, and possibly very small amounts of beryllium. Alpha contamination has been detected in the pipes that lead to the leach field. In addition, samples taken from the leach field during the DOE Environmental Survey in 1988 were found to contain above background levels of plutonium, americium and alpha activity.

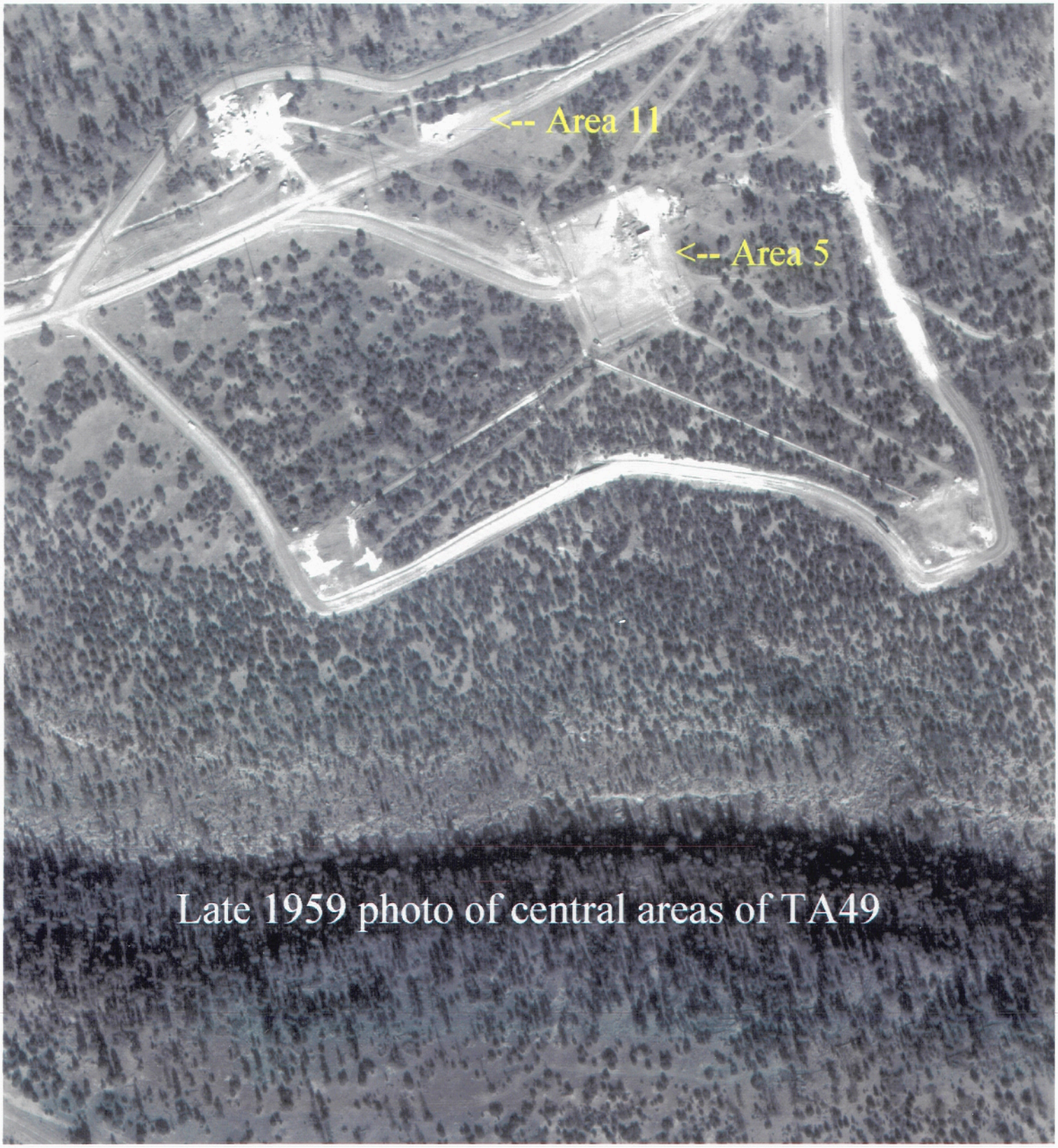
By 1984 all the structures in Area 5 had been removed, with the exception of a guard shack and a well house. During site restoration work in 1984, two small disposal areas were created. One was described as a small trench located in the vicinity of Area 10 [SWMU #49-005(a)]. The other landfill was described as utilizing an existing pit in Area 5 [SWMU #49-005(b)]. The wastes at both sites reportedly consist mainly of non-contaminated debris removed during the 1984 site cleanup operations.

According to the hydronuclear site superintendent, now retired, a large diameter vertical sump was drilled near the photo lab and was used to collect photo lab liquids, including spent photo solutions. The RFI Plan indicates that another sump existed only for emergency collection of water to prevent room flooding (but not for wastes).

Area 5 Historical Aerial Photos Interpretation:

Late 1959 aerial photos show the construction of the central hydronuclear experimental complex, with Area 5 reflected as a large "square" in the upper center of the image. Note that the road that bisects the experimental area along a Southwest-Northeast path in the upper part of the photo is the original homestead era road. Area 11 is located just north of the old homestead road. The linear features emanating from Area 5 are cable trenches to the various deep underground shafts (where the hydronuclear experiments were conducted). The perimeter fence, an entry road from the west, and the main electrical cable trench running N-S inside the eastern edge of the compound can be seen in this image. In the upper right (NE) corner, there appears to be activity associated with construction of a monitoring well (this area would later be annexed within the fenced compound).

The 1966 image, derived from a Koogle and Pouls 1:6,000 scale photo, uses a 1960 "as-built" map overlay to relate image features to structure map locations. Key align-



Late 1959 photo of central areas of TA49

May 1966 view of Area 5
(1:6000 scale)

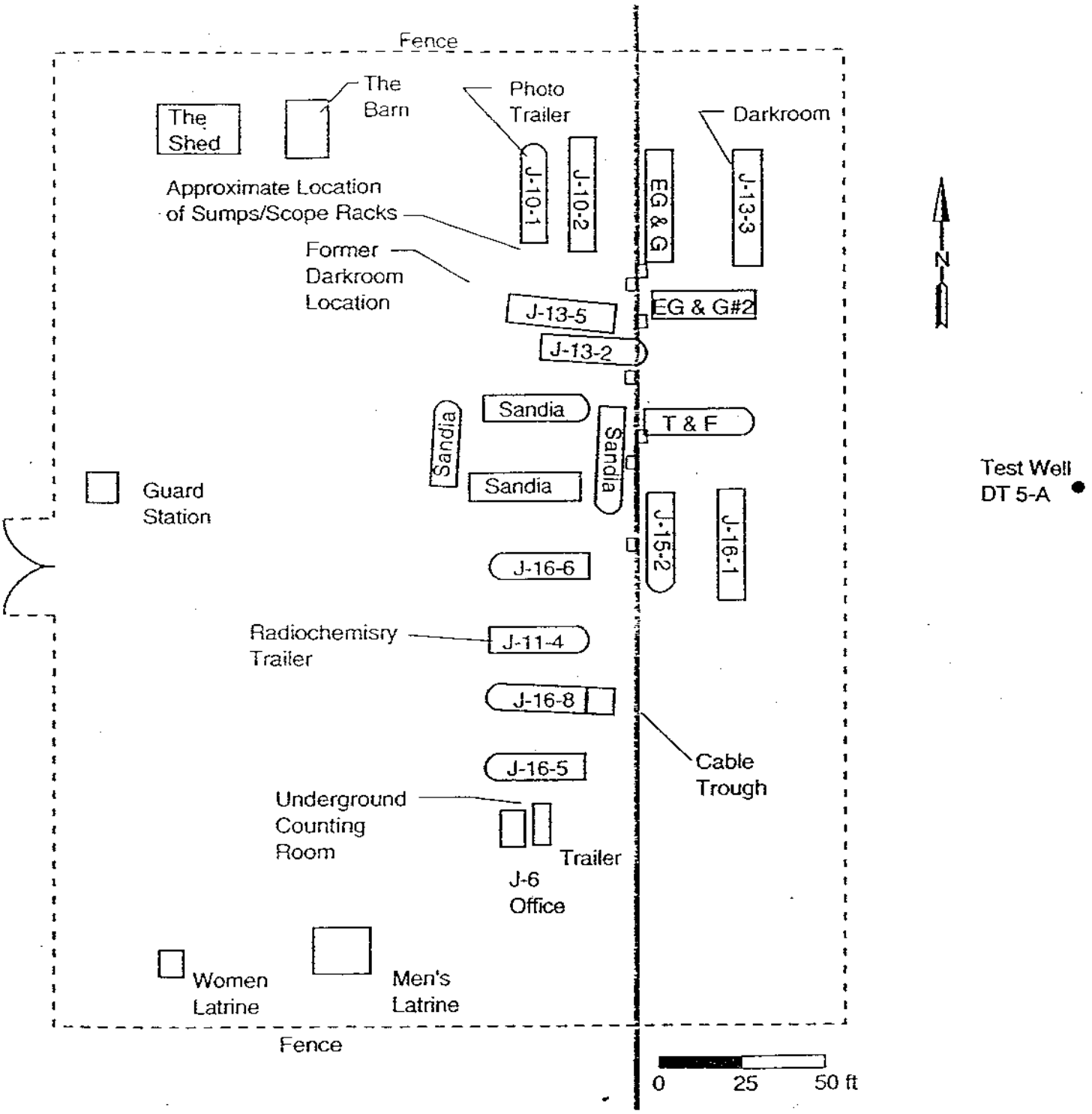
ment features for the overlay are the main electrical cable trench, whose outline is faintly detectable in the photo, and the perimeter fencing. Note that the overlay does not correlate strongly with the photo locations of key facilities. A key issue is the actual location of the photo lab trailer and its associated liquid waste sump. The site construction superintendent, now retired, recalls that the sump, which was located very near the photo trailer, was a vertical "French drain"; i.e, probably a three-foot diameter hole (excavated with the type of bucket drill used for the experimental shot holes), backfilled with gravel and covered at the surface with several inches of tamped soil. The August, 1960, overlay suggests that the photo trailer was located under the western edge of the dark roofed structure in the upper center of the compound.

The next photo shows the overall experimental area in September, 1974, as derived from a Forest Service 1:15,840 scale image. The associated enlargement of Area 5 uses the August, 1960, overly to compare the structure location mappings to image locations. This photo shows that virtually all relocatable structures have been removed and that only permanent or "fixed" structures remain. The white square in the northwest corner of the compound is the photo tower. The "shed" is located just east of the tower, and the concrete pad for the "Barn" is located just east of the Shed. The shed roof that apparently covered the photo lab trailer is the large white feature in the upper center of the compound; it is doubtful that the trailer remains, since no other transportables are evident. Note that the perimeter fence has been extended to the northeast and now encloses the monitor well house (SE corner of the new fencing).

It is not clear what the white square structure (as evidenced by its NW tending shadow) in SW corner of the compound might be, since it is not indicated on any of the structure maps. This structure, however, had been in this location since at least 1965. (A 1963 shows something in the area, but not explicitly the structure evident in 1965 and later photos.) Please also note the exposed "underground counting room" in the lower central area of the photo, just west of the main electrical cable trench (which is evident as a faint dark N-S line). Other structures remaining in the compound are an entry guard shack and a latrine just inside the southern fence.

The July, 1977, photo shows that most remaining buildings were extensively damaged by the La Mesa forest fire in May, 1977. This image was enlarged from a Koogle and Pouls 1:6000 scale photo. Apparently, the shed that once covered the photo lab trailer, the photo tower and the adjacent "shed", were destroyed or extensively damaged. The white roofed structure in the SW corner of the compound, however, appears in tact, suggesting asbestos covered metal roofing. The latrine and the monitoring well house appear in tact. Note that the area where the photo lab trailer once stood appears "scorched", suggesting complete destruction of any vegetation in that area.

In addition to the photo lab sump, the OU1144 Team is trying to locate a pit or small landfill in Area 5 that was used in 1984 for disposal of uncontaminated wastes from



Early layout of structures at Area 5, August 29, 1960 [adapted from ENG C28286 (03-000)

May 1966 view of Area 5
(1:6000 scale)

Sept 25, 1974 view of Area 5
Photo
Lab -->
Counting
<-- Room

July 28, 1977 EG&G photo of Area 5
(after May 1977 forest fire)
Scorched
Area
Counting
<-- Room

the site restoration conducted within the compound that year. Note that this 1977 photo shows a fairly level surface throughout the compound, with the exception of the exposed counting room. Field investigation in 1994 by the image scientist and the OU1144 Deputy Team Leader, however, revealed a pile of rubble covering this area.

As shown in the 1991 photo (1:6000 scale), Area 5 now consists of only its perimeter fence, the well house, the guard shack, and concrete pads for the former "shed", "barn", and men's latrine. Considerable vegetation has grown within the compound. Note that the August, 1960, facilities location map overlay of the 1991 photo indicates an earlier location of the darkroom trailer, which might have had a sump. If so, the large bush in the upper center of the compound (SW of the labeled bush) should also be investigated as a possible waste sump. Generally, aggressive vegetation growth (particularly trees and large shrubs) anywhere within the compound is an indication of moisture collecting in such locations. Consequently, the location of tree and large bush locations may warrant field investigation by the Site Restoration Team.

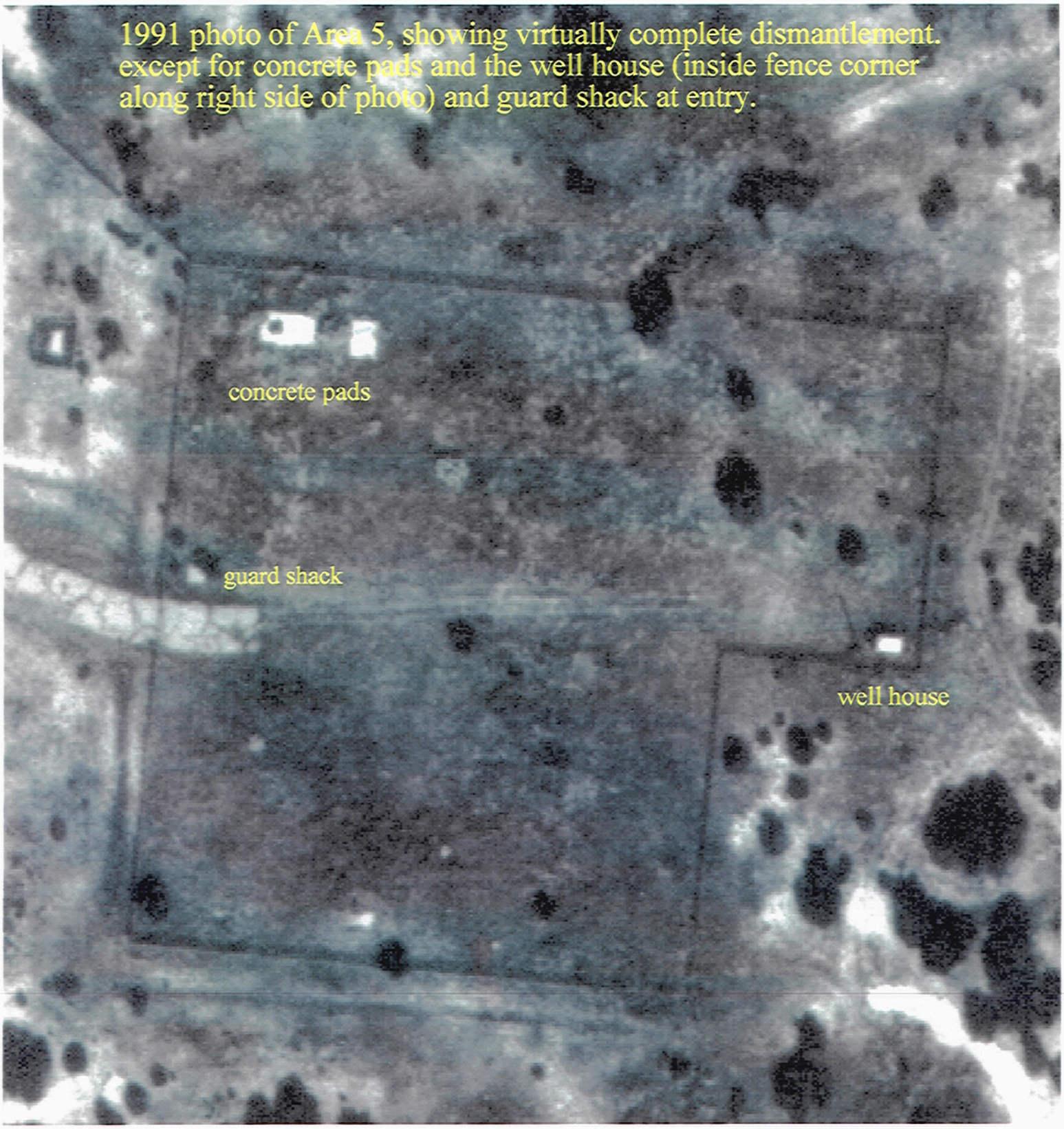
A very high resolution photo survey of the area was flown in May, 1993. The EG&G 1:2000 scale photo is labeled with the suspected photo lab sump location. Specifically, this bush is in the vicinity of the likely location of the photo lab during the 1960-1961 hydronuclear experiments. Additionally, it must have grown after the 1977 fire, since this area was particularly heavily burned. Lastly, the porous material surrounding the "vertical French drain" that constituted the sump would collect considerable moisture, that, in turn, would be conducive to vegetation growth.

The 1993 photo also labels the suspected location of the 1984 burial pit or small landfill as being coincident with the former counting room basement. During a subsequent site visit, a member of the Site Restoration Team responsible for TA-49 in 1984 confirmed that debris had been buried in this location.

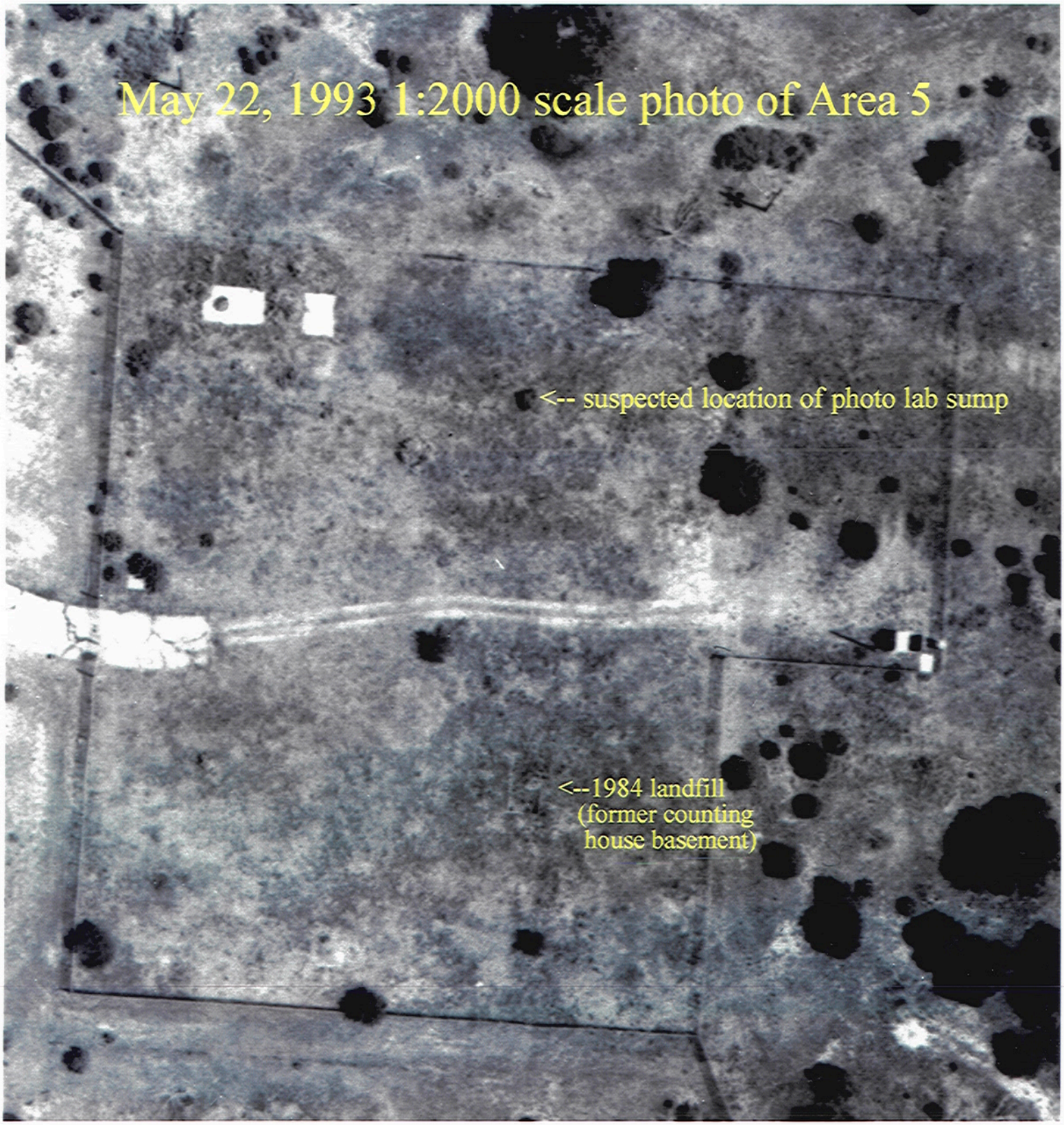
In general, the TA-49 Site Restoration Team should investigate all "shrub" locations within the Area 5 compound. The interior was totally cleared in 1959 and extensively burned in 1977; consequently, significant shrub growth suggests collection of water, which may also indicate collection of waste material in depressions or former sumps.

Area 11 Historical Aerial Photos Interpretation:

The 1959 photo of Area 11 shows extensive ground disturbance in an area to the west of the future Radiochemistry/Change Room Building. Also note that the entrance road comes in further to the west (left) than the eventual Area 11 entry road. The disturbed area may be a staging area for construction of the Radiochemistry facility or it may be associated with the installation of the small-scale shot test area (which eventually would be located in the disturbed area.



1991 photo of Area 5, showing virtually complete dismantlement. except for concrete pads and the well house (inside fence corner along right side of photo) and guard shack at entry.


May 22, 1993 1:2000 scale photo of Area 5
<-- suspected location of photo lab sump
<--1984 landfill
(former counting
house basement)

1959 initial construction of areas 1, 11 and 5
homestead era road
Area 1
Area 11
construction pad (structures may be storage buildings)
Area 5 (NE corner)
There is no evidence of construction of the small-scale shot area, the leach field or the interim waste storage boxes in this photo.

The 1965 "inverted" photo uses a "negative" contrast to emphasize subtle features, such as a dark line that angles south from the main facility, suggesting some type of buried trench. Such a trench may have been a drain line or it could have been used for some type of electrical cable. The locations of the original road (as shown in the 1959 photo) and the subsequent road are indicated.

The 1966 photo is an enlargement of a high resolution (1:6000 scale) image depicting the Radiochemistry/Change Room Building and associated structures. An area to the east shows faint linear features, suggesting buried liquid waste disposal lines (typical of leach fields). A line of dark "cap" like objects runs E-W mid-point at the western (left) edge of the photo, suggesting the location of the small-scale shot test area. There appears to be a "box" like structure just east of the main building that could be the interim waste storage box area.

The 1993 EG&G 1:2000 photo summarizes the conclusions of photo interpretation for Area 11. Identification of the small-scale shot test area and the leach field are highly probable, while the suspected location of the of the interim waste storage box area is a medium probability estimate.

Area 10 Historical Aerial Photos Interpretation:

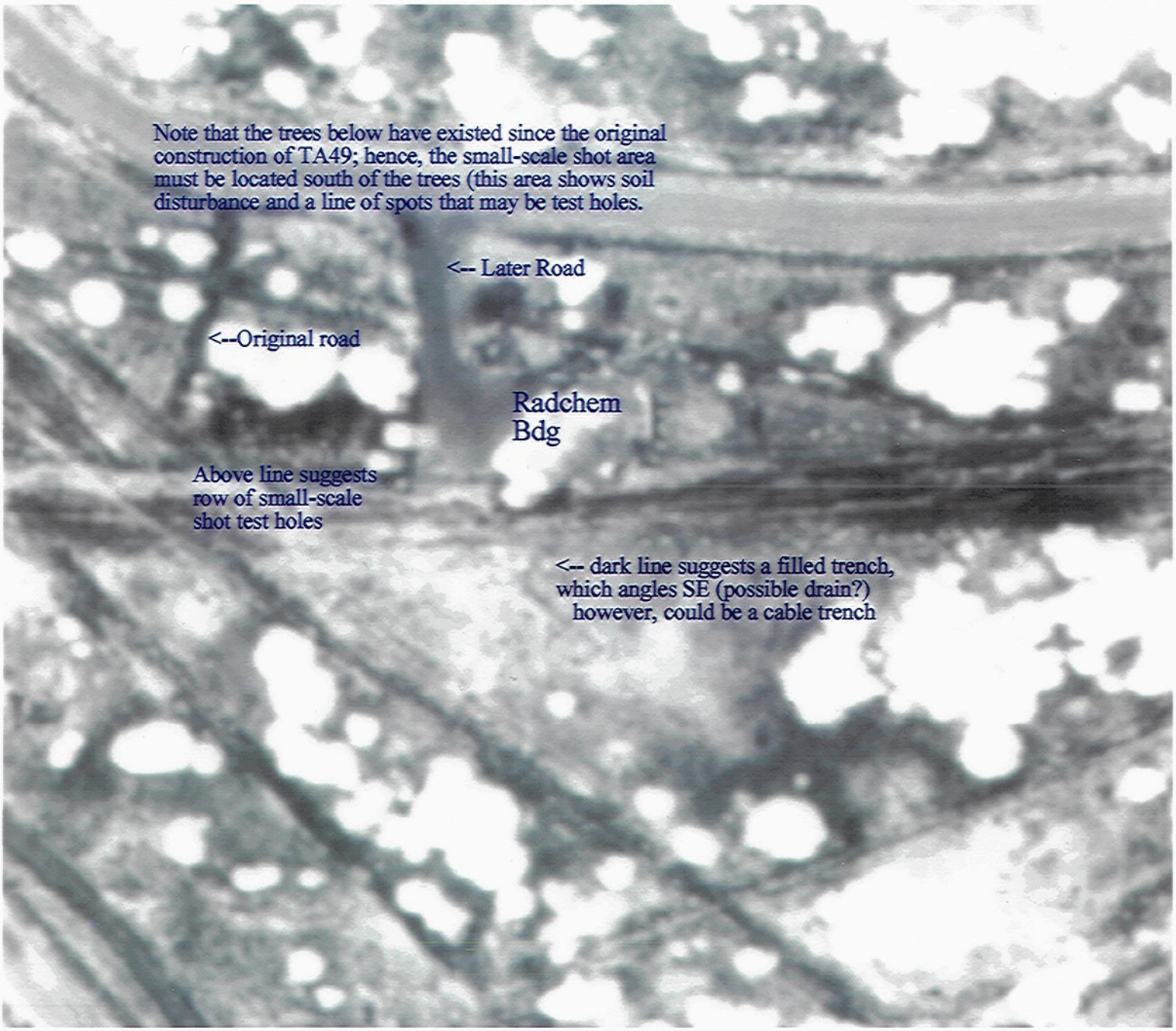
The enlargement of the 1935 Soil Conservation Service photo shows a homestead era road running East-West past what would become TA-49 Area 10. The road alignment is largely unchanged to this day.

The 1959 photos show considerable vegetation within an area east of Area 10, designated "suspect area"; i.e., this area would show a demise of trees in the early 1980s. The roadway has been widened and has rudimentary drainage culverts along each side. A fire break is also evident.

The 1959 enlargements of Area 10 include "crosses" to indicate the suspected location of a landfill established in 1984 to bury non-contaminated site restoration debris. The area is undisturbed in 1959 and has no distinguishing features; i.e., there is no evidence of new construction or earth moving.

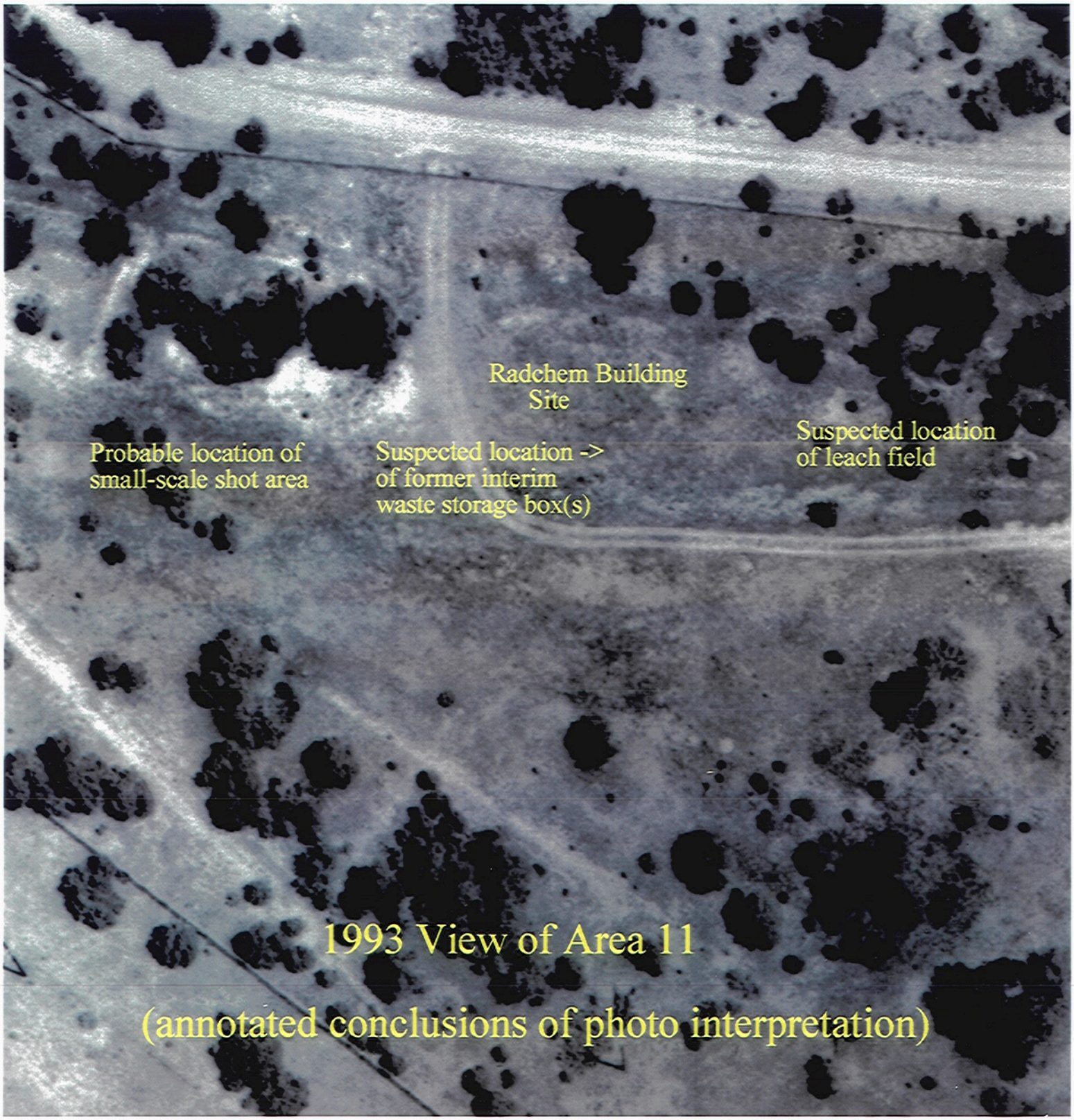
The 1963 Forest Service photos show the existence of Area 10 and the continued relatively dense vegetation in the "suspect area" further east.

The 1965 high resolution enlargement pair (positive and negative images, 1:12,000 scale, flown by Koogle & Pouls Engineering of Albuquerque) for Area 10 indicate a bermed area just north of the technical area that would become the suspected site of a 1984 landfill for burial of non-contaminated site restoration debris.



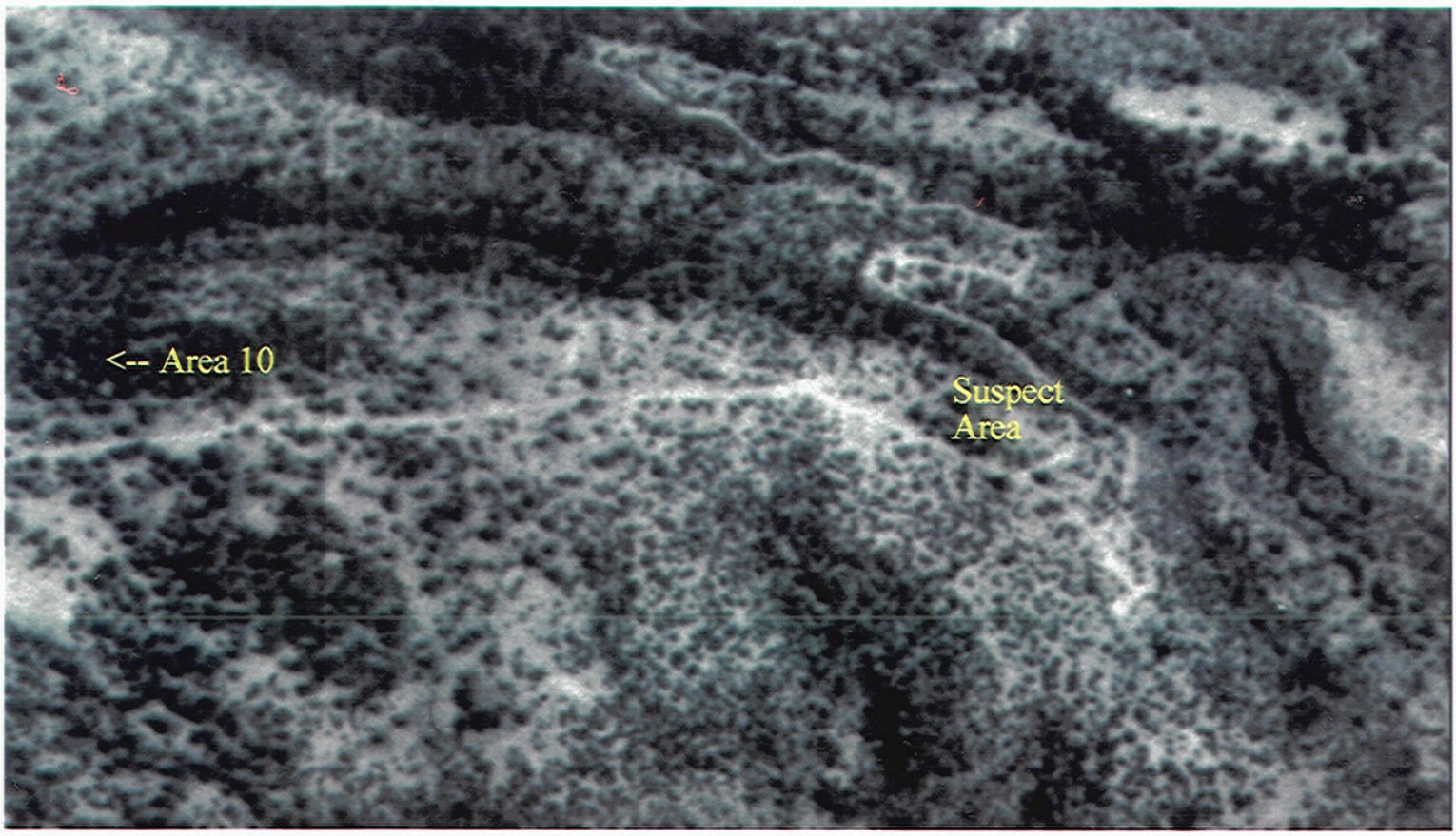
Oct 1965 View of Area 11
(inverted or negative contrast)

May 1966 View of Area 11
suspected disposal field
(note E-W furrows that may
reflect disposal lines) ----->
Probable locationof interim
<-- waste storage box
l location (above) of small-scale shot area
V row of box-like objects in light area)



1993 View of Area 11

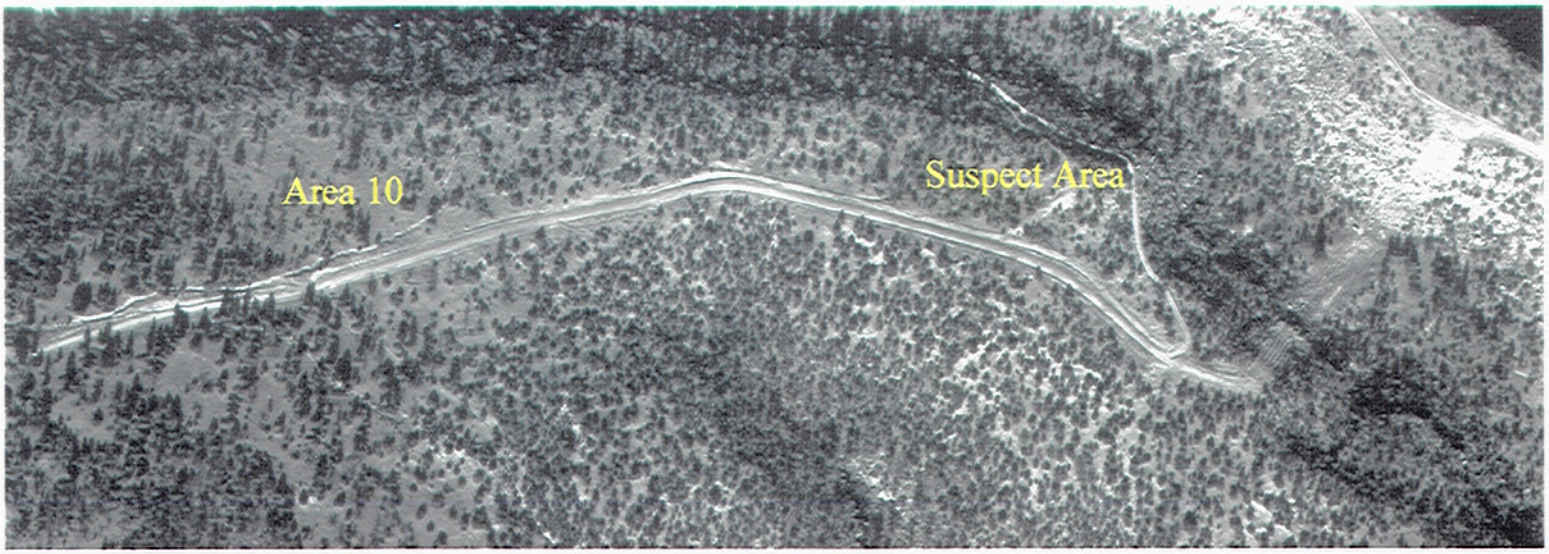
(annotated conclusions of photo interpretation)



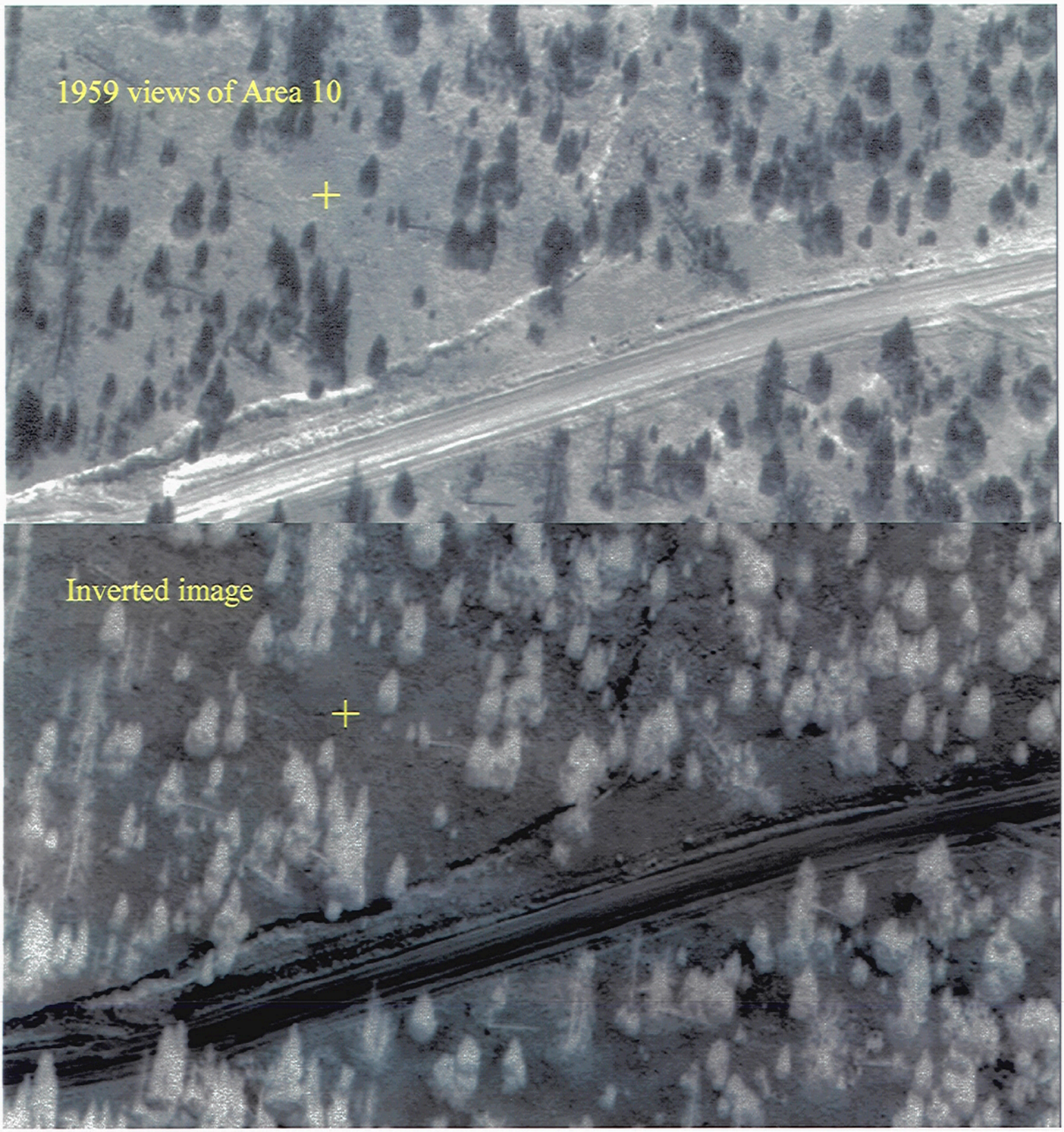
1935 photo enlargement showing a road bend east of TA49 Area 10 where the homestead era road winds into the canyon.

Note that the short section of road running SE from the bend has reasonably dense evergreen tree growth. This area will show a distinct reduction in tree growth in the mid-1980s, suggesting either delayed damage from the 1977 La Mesa Fire (which swept through this area) or possible Laboratory-related activity (i.e., possible undocumented waste site, in addition to the cited mid-1980's disposal area near Area 10).

An apparent excavation can be found in the suspect area. This excavation, which is heavily eroded, has the characteristics of a landfill cut, as opposed to a drainage cut. Recommend that it be investigated by the TA49 Team.

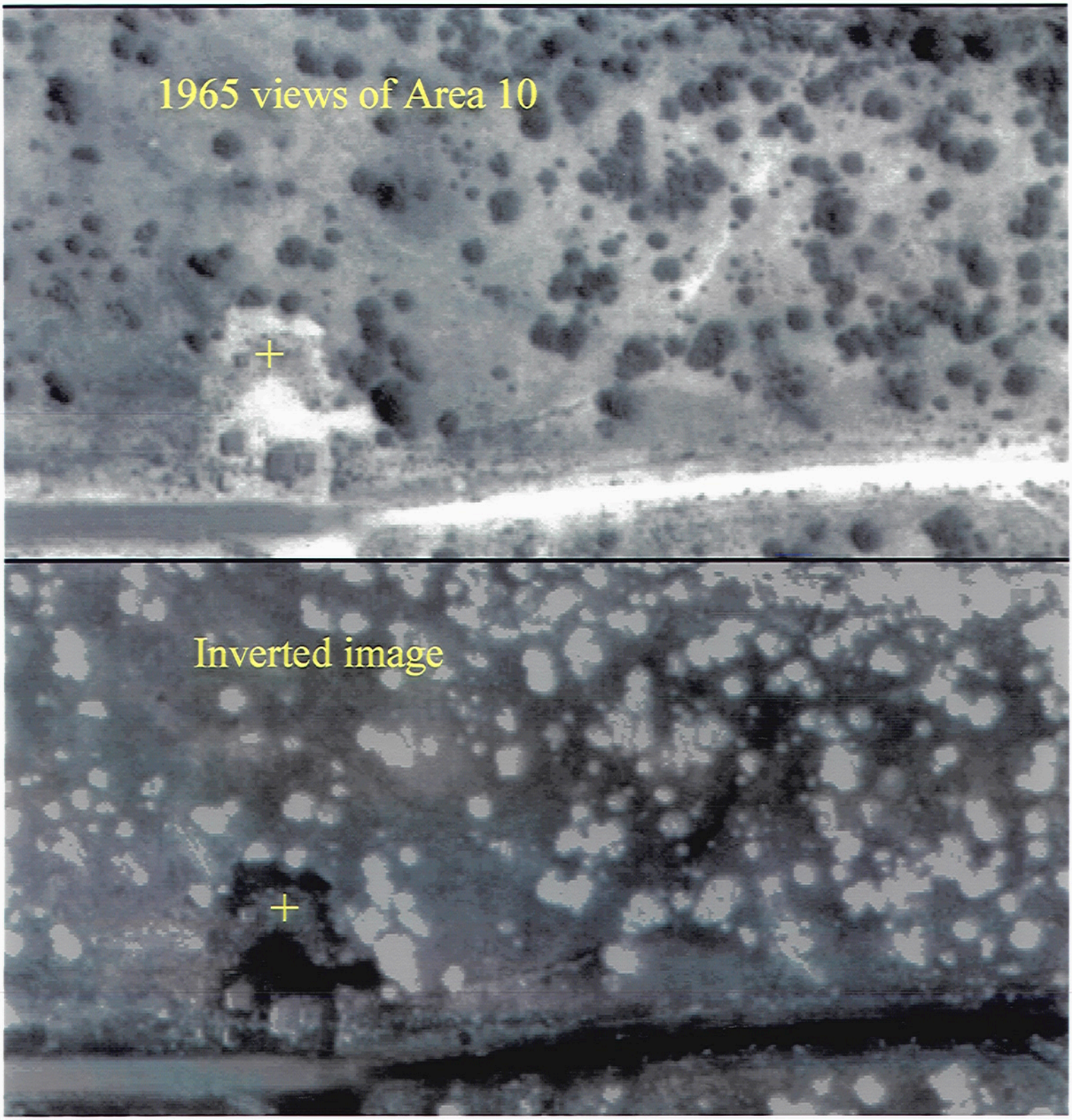


Late 1959 photos of Area 10 and suspect area to the east


1959 views of Area 10
Inverted image

1963 Forest Service photo of road running east of Area 10

1963 enlargement of suspect area


1965 views of Area 10
Inverted image

The 1974 Forest Service 1:15,840 scale images continue to show little change in the "suspect area"; i.e., it continues to be densely vegetated. The November, 1976, photo (flown by Bovey Engineers at 1:13,200 scale) also continues to show little change.

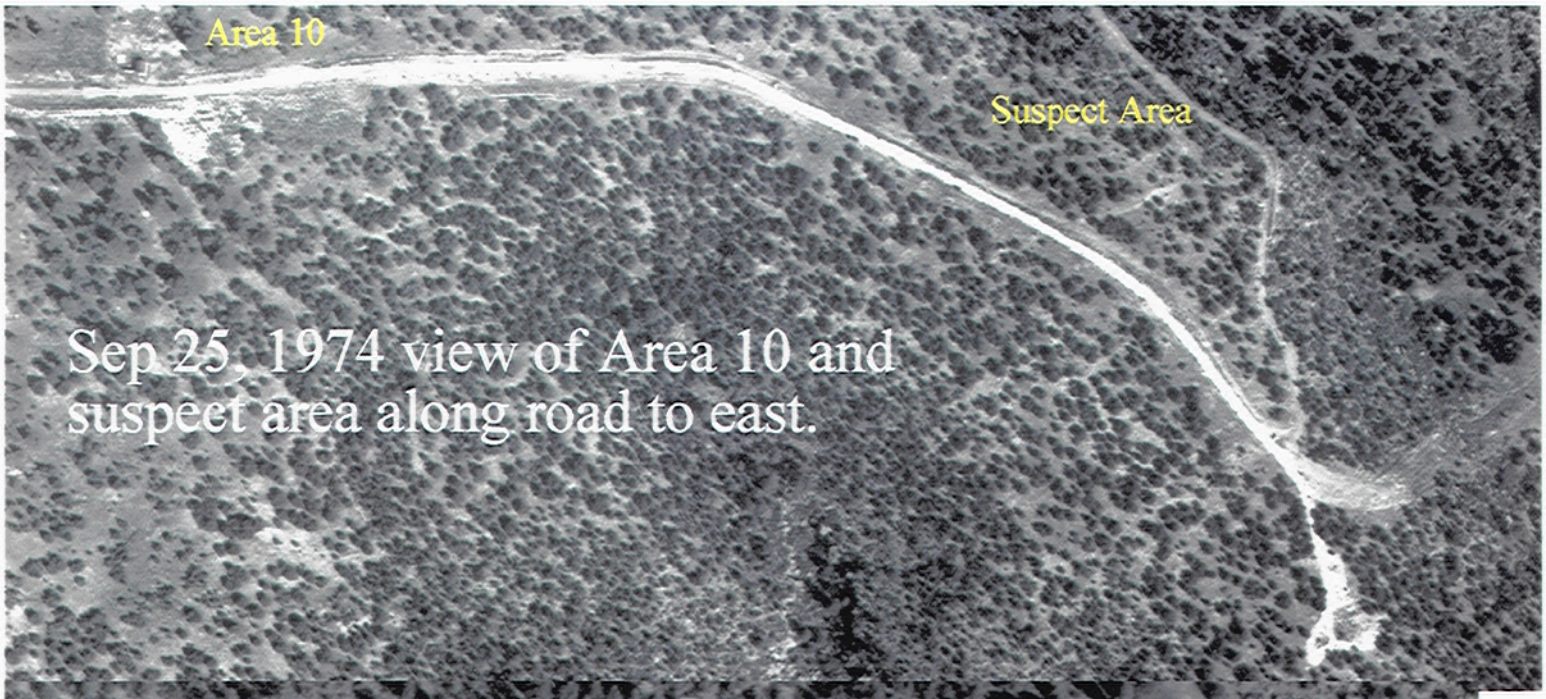
The next images, taken in July, 1977, are the first available aerial photos of the area after the La Mesa forest fire (May, 1977), which burned over much of TA-49. These 1:6000 scale photos, which were flown by EG&G, show some scorching (e.g., in the center of the lower enlargement under the label "suspect area"). Otherwise, there appears to be little change from pre-fire conditions.

The next photos, a low resolution (1:68,400 scale) image flown by EG&G in July, 1982, and a medium resolution (1:24,000 scale) image flown by the Forest Service in September, 1983, show a significant loss of trees and large shrubs in the area of interest. It is not clear whether this change was due to delayed demise of vegetation damaged by the La Mesa fire or whether there was some Laboratory activity in the area. Since there is no record of Laboratory activity in the area during this period, it is presumed that the change resulted from delayed forest fire damage. The "opening up" of this area, however, might have made the area a convenient landfill location.

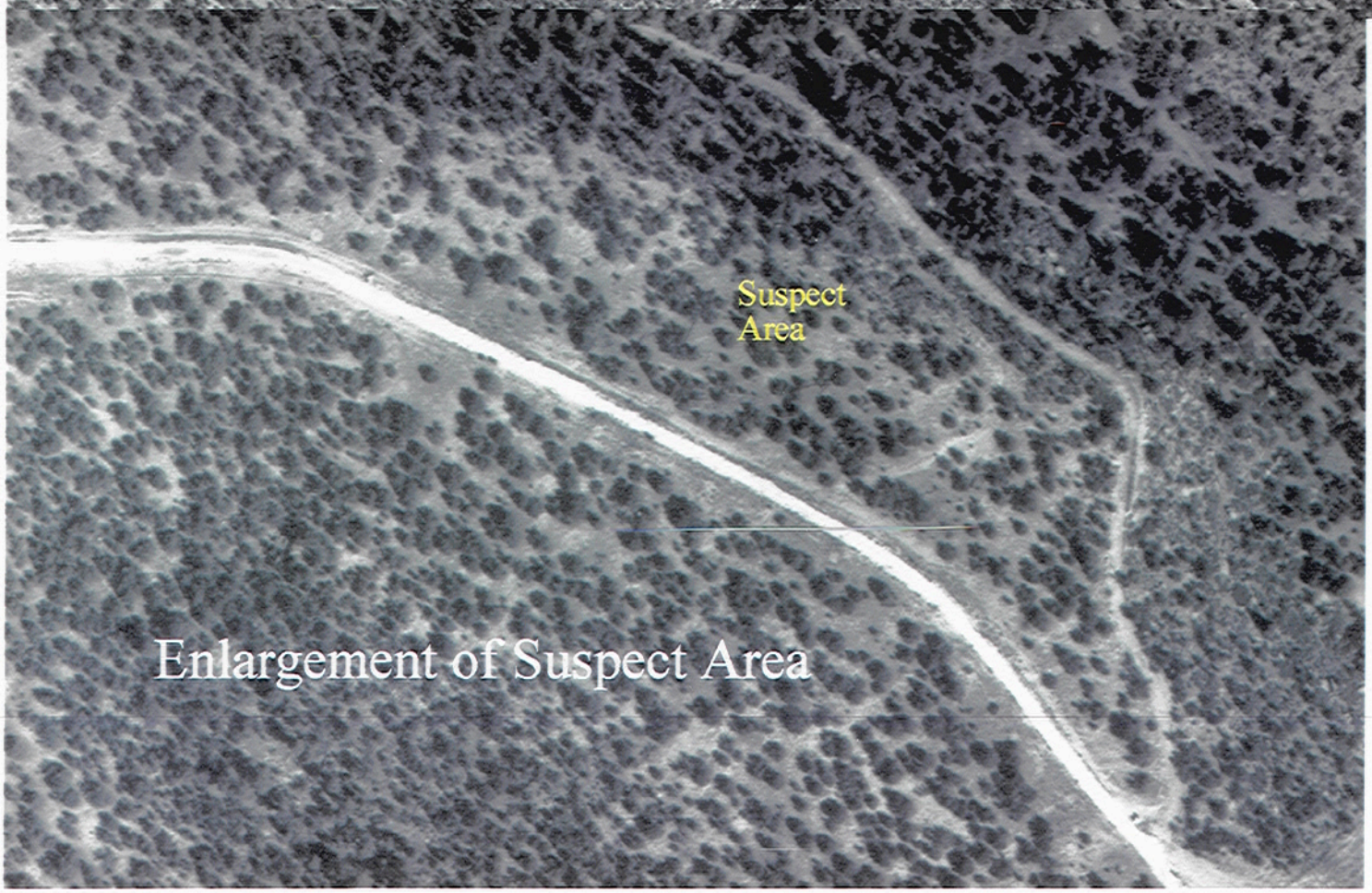
Koogle and Pouls Engineering provided the November, 1986, photo (1:9800 scale), when a light snow fall remained in shaded areas (thus helping neutralize the effect of shadows). This is the first available air photo after the construction of the 1984 landfill. Note that there is no indication of change anywhere in the region (when compared to every photo considered since 1935), except in the "cleared area". Although there is no definitive photographic evidence of a landfill in this image, there is only one place where the land has been visibly changed.

The 1986 enlargement pair (derived from 1:9800 scale photos) for Area 10 mark the the suspected 1984 landfill with "crosses"; however, there is no explicit evidence of a landfill or trench cut in the area.

The 1991 enlargement pairs (positive and negative images, derived from a 1:6000 scale photo) are the highest resolution available for Area 10 and vicinity. A "horse shoe" feature jutting out northeast from the road roughly mid-way along the cleared area (just under the label "suspect area") is faintly evident in the bottom enlargement of the first pair. By 1994, this area had added considerable tree and shrub growth; however, the excavated feature was easily located on the ground by the image scientist and the OU1144 Deputy Team Leader when they made a field investigation using this photo interpretation project as a guide. Specifically, the site, while now considerable reforested, had been excavated by bull dozer, with tailings causing a berm around the downhill side of the excavation (which would not have been characteristic for a drainage cut). The excavation appeared to be either a shallow cut or only partially backfilled. While there is no historical evidence that this area was used for site

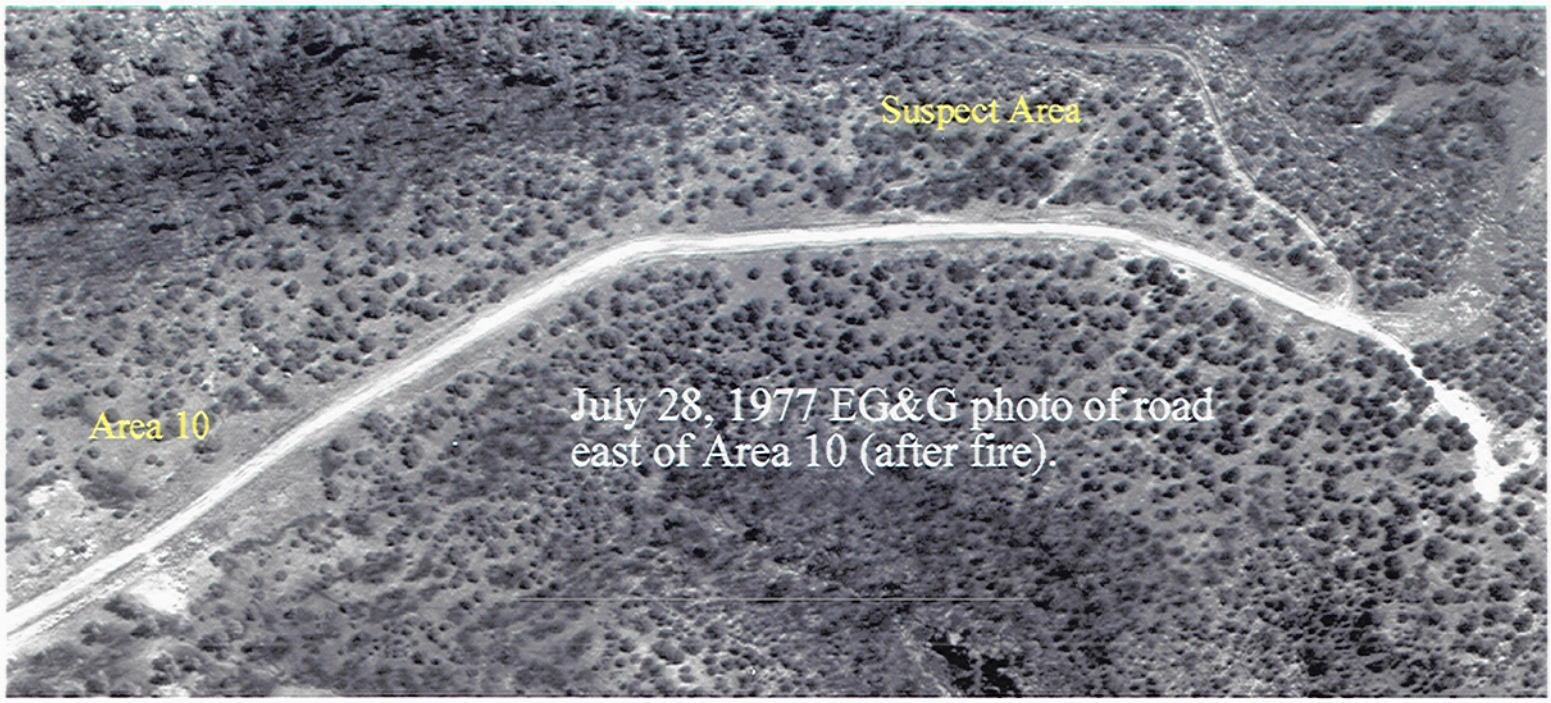


Sep 25, 1974 view of Area 10 and suspect area along road to east.



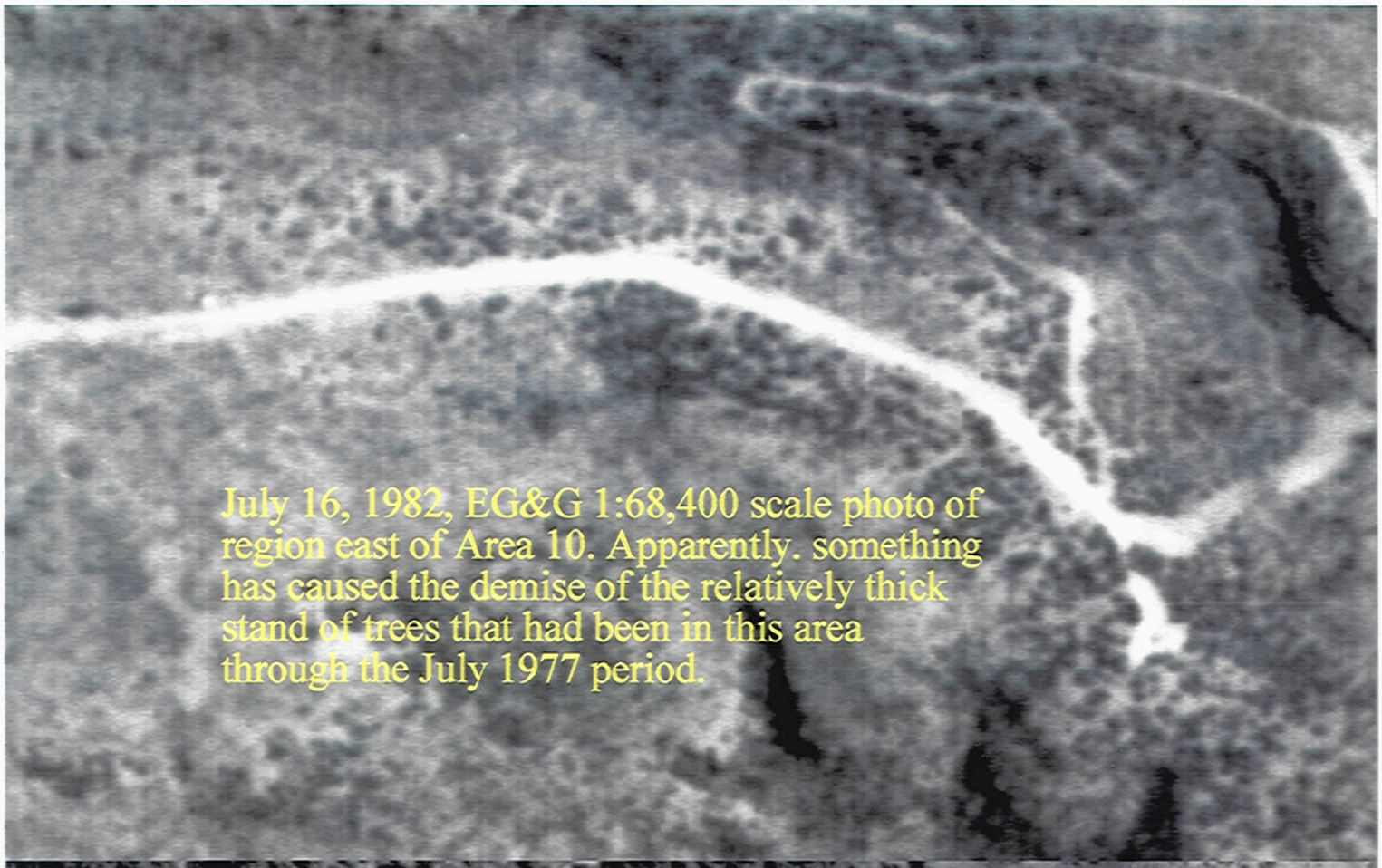
Enlargement of Suspect Area

Nov 11, 1976 View of Region East of Area 10



July 28, 1977 EG&G photo of road east of Area 10 (after fire).

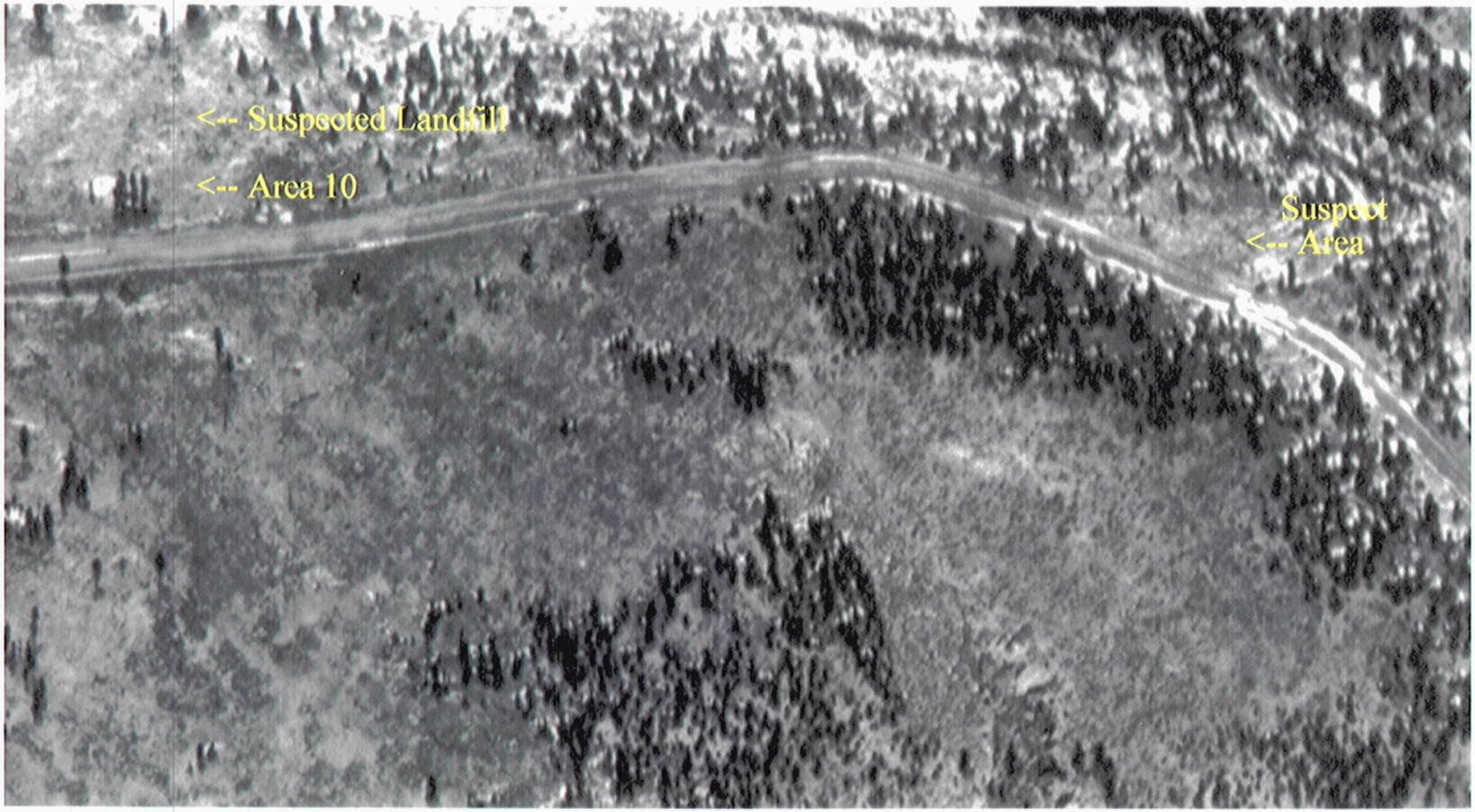
Enlargement of area showing little fire damage



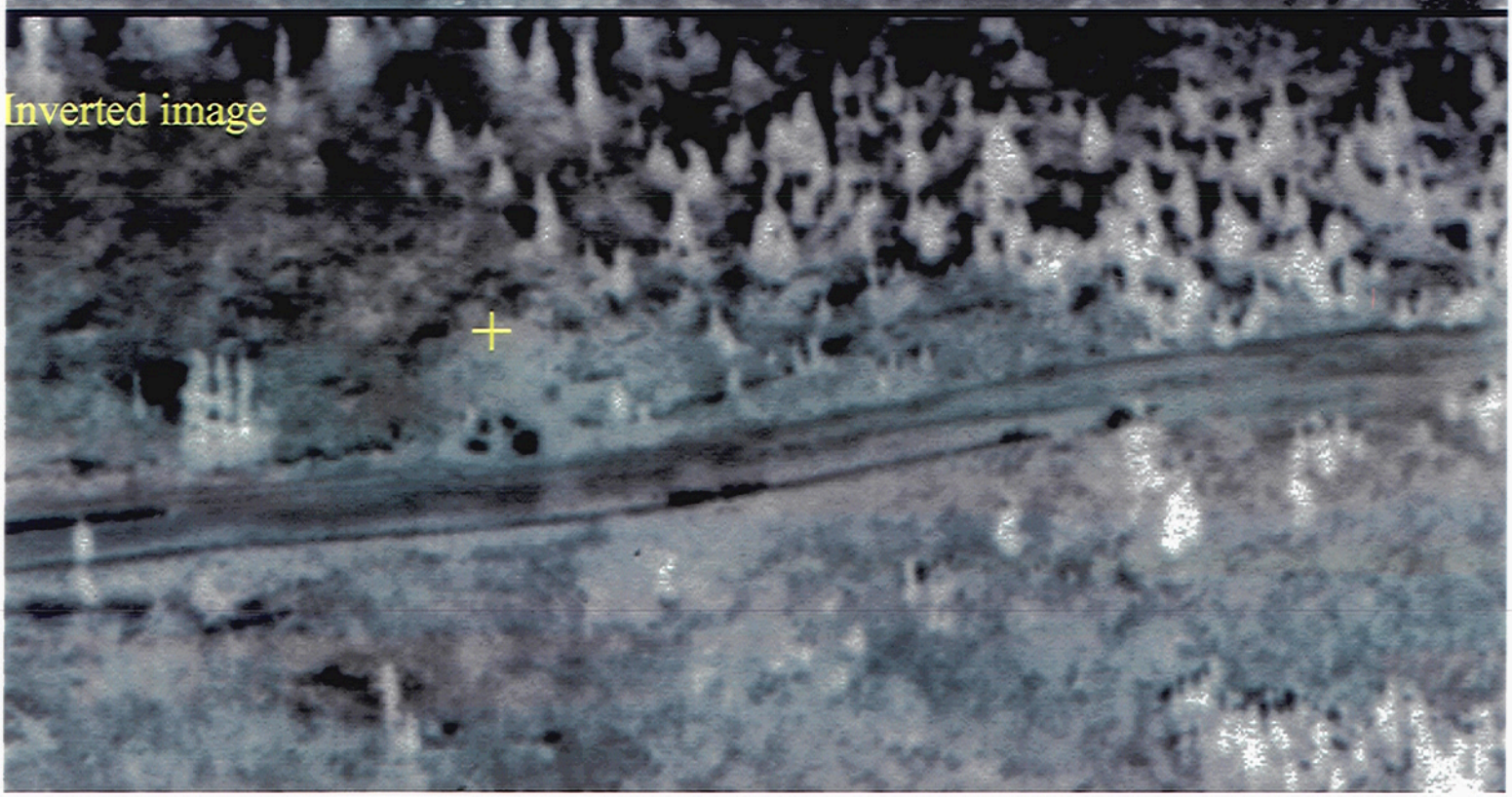
July 16, 1982, EG&G 1:68,400 scale photo of region east of Area 10. Apparently. something has caused the demise of the relatively thick stand of trees that had been in this area through the July 1977 period.

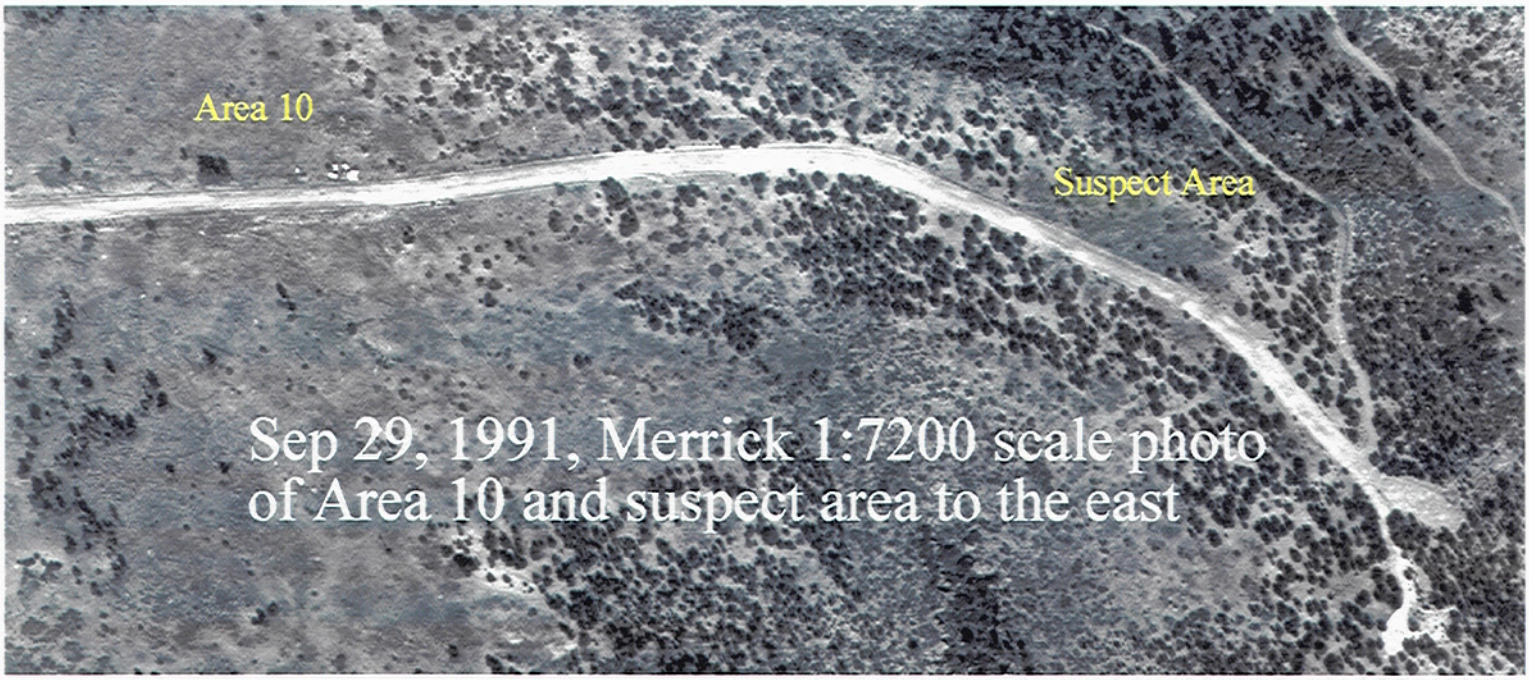
Sep 12, 1983 Forest Service 1:24,000 scale photo of area, more clearly showing the loss of trees in question

Nov 28, 1986 1:9800 scale photo of Area 10 and and suspect area along road running east of Area 10. This is the first photo of Area 10 and vicinity after the site restoration work in 1984. (A light snow cover is apparent along top of photo.)



1986 views of Area 10


Inverted image



Sep 29, 1991, Merrick 1:7200 scale photo of Area 10 and suspect area to the east

Enlargement of suspect area; note reduction in tree cover.

remediation waste disposal, it should be investigated by the Site Restoration Team.

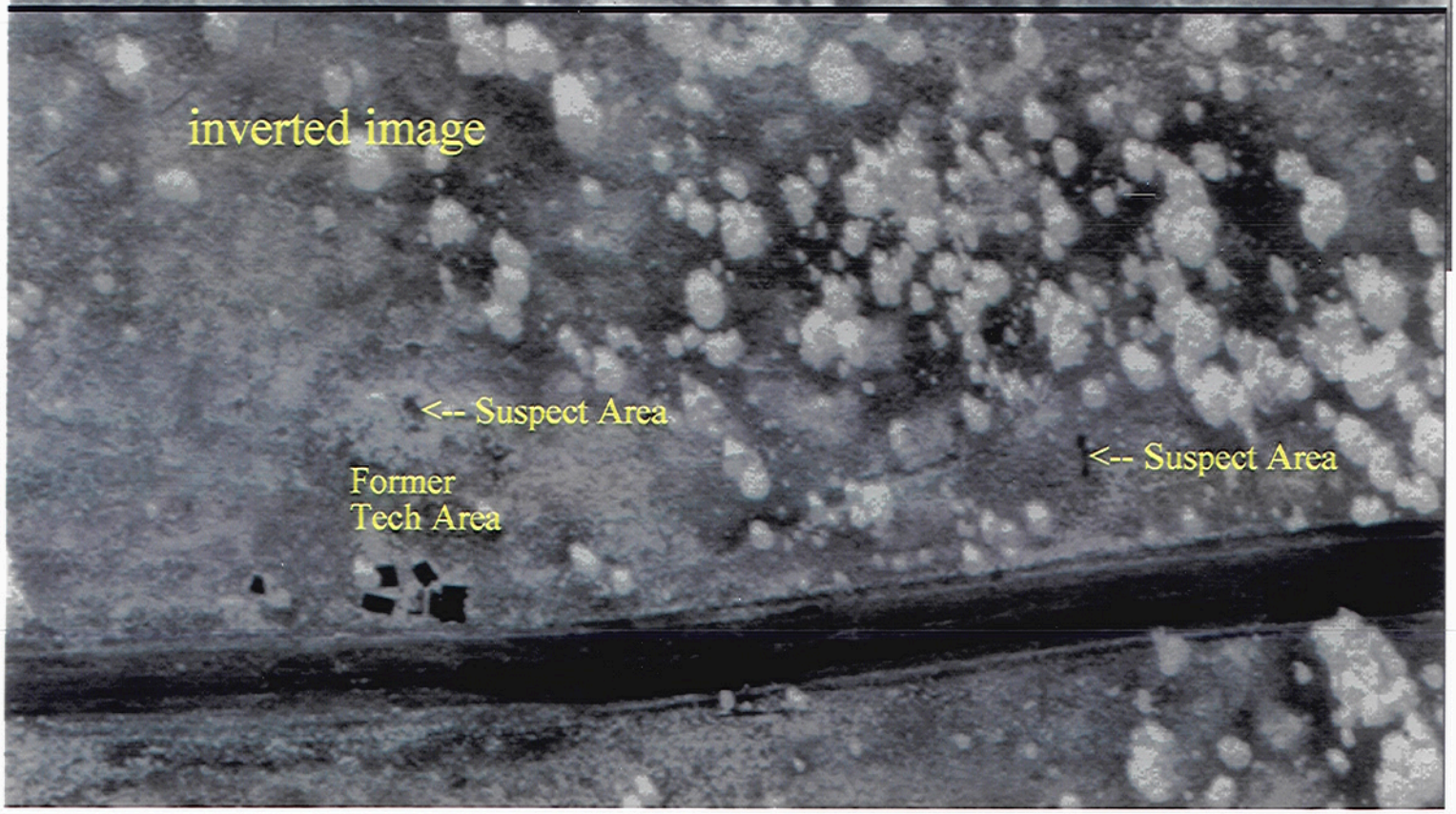
The last enlargement pair (1991 1:6000 scale positive and negative images) focuses on the suspected 1984 non-contaminated waste landfill at Area 10. Both images show two suspect "linear" features, characteristic of small bull-dozed trenches to be used for landfills. A subsequent site visit by the OU1144 Deputy Team Leader, the image scientist, and a member of the 1984 Site Restoration Team confirmed the western most (left) suspect location as being the 1984 landfill site. A field investigation of the site to the east revealed that it was a concrete flow (apparently the result of cleaning out the bowl of a concrete mixer truck). This image pair provided useful correlation of subtle features typical of environmental image interpretation.

Summary of Historical Air Photo Interpretation Results with respect to Taskings:

SWMU:	Area No:	Description:	Location Probability:
49-003(2)	11	Small-scale shot area	High
49-003(2)	11	Interim waste storage box area	Medium
49-003(2)	11	Leach field	High
49-005(a)	10	Small landfill east of Area 10	Medium-to-High
49-005(b)	5	Small landfill or pit in Area 5	High
49-006	5	Photo lab sump	High

General finding: High resolution photos (1:6,000 or better) are desirable for interpretation of subtle environmental features and patterns, such as buried trenches, sumps, landfills, and drainage lines. In this regard, pending release of previously classified high resolution "national asset" imagery should be very beneficial for environmental monitoring and assessment tasks throughout the world.

1991 view of Area 10
<-- Suspect Area
<-- Suspect Area
Former
Tech Area


inverted image
<-- Suspect Area
<-- Suspect Area
Former
Tech Area

References:

Robert N. Thorn and Donald R. Westervelt, Hydronuclear Experiments, LA-10902-MS, February 1987.

William D. Purtyman and Alan K. Stoker, Environmental Status of technical Area 49, Los Alamos, New Mexico, LA-11135-MS, November 1987.

RFI Work Plan for Operable Unit 1144 Environmental Restoration Program, Los Alamos National Laboratory, May 1982.

Bill Francis, Zia Company TA-49 Site Superintendent 1959-1961; personal communications and site visit, September 30, 1994.

Max Maes member of 1984 TA-49 Site Restoration Team; personal communication and site visit, November 1, 1994.

Aerial photography, as cited

Distribution:

Bennie Martinez, DOUPL-OU1144, MS J514 (2 copies)
EES-3 Image Processing/GIS Laboratory (2 copies)
ESS-3 files, MS C335 (1 copy)

Note: Additional copies may be obtained upon request to the project image scientist, Robert F. Wells, EES-3, MS C335