GROUND CONTROL REQUIREMENTS FOR PRECISION PROCESSING OF ERTS IMAGES

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by

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INTRODUCTION

When the first Earth Resources Technology Satellite (ERTS-A) flies in 1972, NASA expects to receive and bulk-process 9,000 images a week. From this deluge of images, a few will be selected for precision processing; that is, about 5 percent will be further treated to improve the geometry of the scene, both in the relative and absolute sense. Control points are required for this processing. This paper describes the control requirements for relating ERTS images to a reference surface of the earth. Enough background on the ERTS-A satellite is included to make the requirements meaningful to the user.

The ERTS-A satellite will circle the earth in near-polar orbit at an altitude of about 900 km (492 n. mi.). It is to be sun synchronous; that is, local time at any given part of the orbit remains the same. As the earth turns beneath the satellite, a different north-south strip of the earth will appear on each orbit until, on the 18th day, the original scene will reappear.

For the mapping community, the prime sensors aboard will be three return-beam vidicon (RBV) cameras configured to focus on the same scene covering an area of 185 X 185 km (100 X 100 n. mi.), in three spectral bands--green, red, and near infrared. The imagery may be scanned and transmitted to earth immediately after exposure, or, if the satellite is out of range for effective transmission, the imagery and other data may be stored on video tape and dumped on command.

Once received on the ground, the information will be recreated on 70-mm film with suitable annotations and marginal information. These will be the so-called bulk-process images. They will reach the user enlarged to 1:1,000,000 scale and on a format of 23 X 23 cm (9 X 9 in.). Ground resolution of 150 to 200 m and positional errors of about 1,000 m are expected. No ground control is used in bulk processing.

Selected portions of the bulk-processed imagery will be precision processed, depending on user requests and availability of good cloud-free imagery. Precision processing will improve the geometry of the imagery but <u>not</u> the resolution. The precision processor will memorize the control-point scenes and their associated coordinates, find the scenes in the ERTS imagery, and scale the imagery to the control coordinates.

POINT SELECTION

Precision-processed imagery should have an estimated standard error of position of less than 100 m. About one-third of this error is budgeted to errors in the ground referencing system. This makes apparent the requirement that the control fed into the system must be obtained from the best available source. Control selected for ERTS will suffice for future space imagery of greater resolution and geometric fidelity if, and only if, sufficient care is taken in selecting points and determining coordinates for them.

Even the experienced photogrammetrist or cartographer should preface any point selection with a study of existing space photographs. A careful inspection of the familiar Apollo scenes of the Salton Sea-Imperial Valley, Dallas-Ft. Worth, and Mississippi River Valley provides considerable background on point suitability in disparate areas (figs. 1, 2, and 3).

Obviously, a selected point must be visible on the photograph and preferably be definitive in both x and y. Nine well-spaced images are required for optimum control of an ERTS image. If points are being selected before ERTS imagery is available, a spacing of about 30 km should provide the required redundancy. The coordinates of these points must be available in a recognized reference system and sufficiently accurate to make precision processing worthwhile. A less obvious requirement is the ability to identify the point. The hundreds of apparently identical field corners in the Imperial Valley south of the Salton Sea illustrate the problem of identification, which in this case might be termed an embarrassment of riches.

The three Apollo photographs in this report show that in the United States our relatively new Interstate Highway provides clean, linear features for control points. This is typified in figures 2 and 3. By inference, any major highway construction will probably image well. Precise coordinates for the structures are sometimes not readily available from standard large-scale maps because the maps predate the highways. The Department of Transportation has lists of coordinates for all Interstate Highway structures in the United States, but considerable time is required to extract the information. There is no easy solution to this problem. The outstanding quality of the points, however, makes their use almost mandatory.

Probably the second most obvious group of points is associated with open water. Points of land or the converse, points of water, should be selected with some information on the stability of the water level. If this information is not available, a contour map of the area should be studied to insure that the slope at the land-water interface is steep enough to minimize horizontal shift due to change in water level. Other water features selected can be oxbows, stream confluences, canals, or various linear features crossing rivers. All three photos have examples of these points. The large "lake" on figure 3 that has no selected points is in reality a temporarily flooded area that illustrates the previous warning on stability of water level.

A third source of points consists of crossings of Federal and State highways, railroads, clearings for power lines and pipe lines, and other linear features. Although not obvious at first glance, these features, if recognizable, are probably the best defined and most precise photogrammetric points available in quantity. All three figures show examples of this type of point.

Paved airport runway crossings often provide excellent targets of good quality with coordinates readily available in most cases. Major cities generally have at least one airport with a definable runway pattern.

In desert and mountain areas where good-quality points are sparse, certain natural phenomena such as volcanic cones, sharp ridge lines, drain intersections, or lava flows must be used. The determination of suitable ground coordinates is generally the limiting factor here. Also, a point may be definitive in one direction only, so a second point must be found in the area to define the coordinate in the other direction.

The problem in the Imperial Valley, alluded to previously, can be alleviated by careful selection. Note that the points circled (fig. 1) are near the border of the irrigated area or are distinctive in other ways. For instance, the point in the center is a water feature, not another irrigated field corner. Proximity to a definable area is of great help in visual referencing. Circling the point on a map is helpful, as is a brief description. Portions of topographic maps with examples of acceptable space-photo control points are shown in figures 4 to 9.

COORDINATE DETERMINATION

The coordinates for most space-photo points in the United States are being scaled from 7 1/2- or 15-minute maps on the Universal Transverse Mercator (UTM) grid. This procedure is economical and provides the required accuracy for any space imaging system thus far defined. Points scaled from standard topographic maps also are automatically on an acceptable reference system (the map projections are mathematically related to the spheroid) and have a readily obtainable elevation above sea level.

Measuring map grid coordinates by coordinatograph with automatic readout is the preferred method of control point acquisition because it provides precision and reduces blunders. If this equipment is not available, hand scaling methods provide acceptable results but require rigorous checking for blunders. If gridded maps are available, manual scaling can be expedited by using a map coordinate reader. A limited number of metric readers for use in earth-resources projects are available from the Cartography Coordinator, EROS Program, U.S. Geological Survey, Washington, D.C. 20242.

If large-scale maps of a particular area are unavailable, a smaller scale series may be used. Although the standard error of points obtained from maps at scales smaller than 1:100,000 will probably exceed the error budget assigned to ground control, positions taken from accurate maps at scales of 1:250,000 or even 1:500,000 may be useful in areas where no other identifiable control exists.

Other lists of coordinates may be available from various Government agencies, but rarely are they directly usable. For instance, Geological Survey Water-Supply Paper 1838 lists the coordinates of every major dam in the United States--but only to the nearest minute (1 n. mi.). The Department of Transportation has the coordinates of nearly every Interstate Highway structure in the United States--to the nearest 1/10 minute. These examples are given with the hope that in the future, photoidentifiable points may be defined with adequate precision. Vast quantities of ground-survey control in the United States are available, but the points are not tied to any photographic image and therefore are not directly usable.

CONCLUSION

Within the context of the previous pages, these things are needed for full precision processing of ERTS imagery:

1. Nine well-spaced photo points per frame that are definitive in x and y and suitably described by word, aerial photo, or map image.

2. Coordinates for these points in the UTM or geographic system, with relative errors within 10 m desirable and within 30 m to be usable. The reference ellipsoid should be identified and any datum inconsistencies either defined or removed.

3. Elevations above sea level within 50 m desirable and within 150 m to be usable.

If available, standard large-scale topographic maps are an ideal source for coordinates and elevations of control points. If large-scale map coverage is nonexistent but a few referenced ground control points are available, these few points are better than none at all for partial processing. Quite simply, the precision-processed imagery can be no better geometrically than the control.

For space photos of totally uncontrolled areas, users should determine by cost-benefit studies whether or not the expense of extending field control is justified. Doppler measurements on U.S. Navy navigation satellites should be investigated for isolated position determinations in undeveloped areas. First- or second-order astronomic positioning, requiring less capital investment, is a further possibility. This method, however, requires highly trained personnel, and the resulting astronomic positions must be properly reduced to geodetic positions.

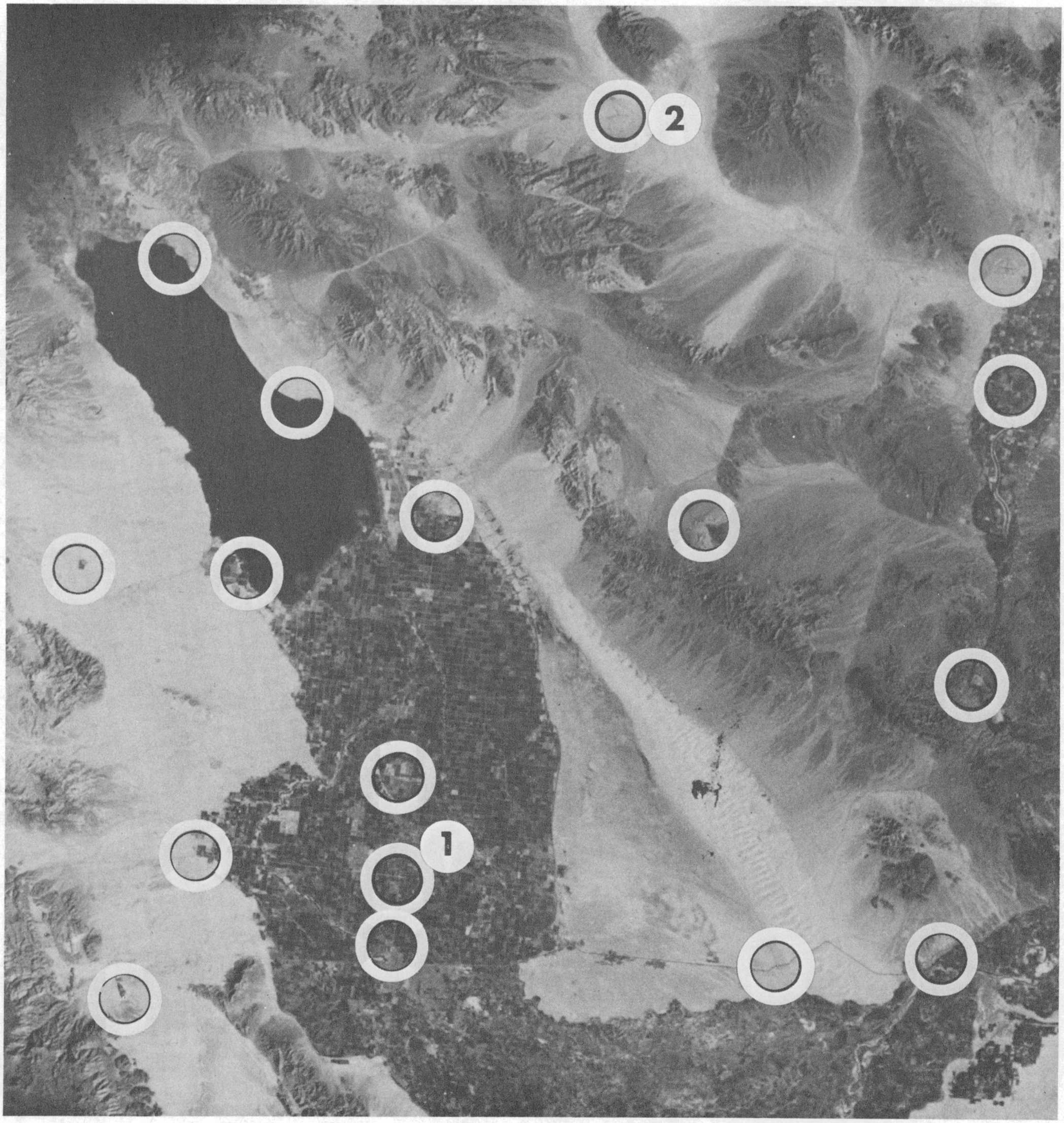


Figure 1.--Apollo photograph of the Salton Sea area with sample control points. Numbered points 1 and 2 are shown on map chips in figures 4 and 5.

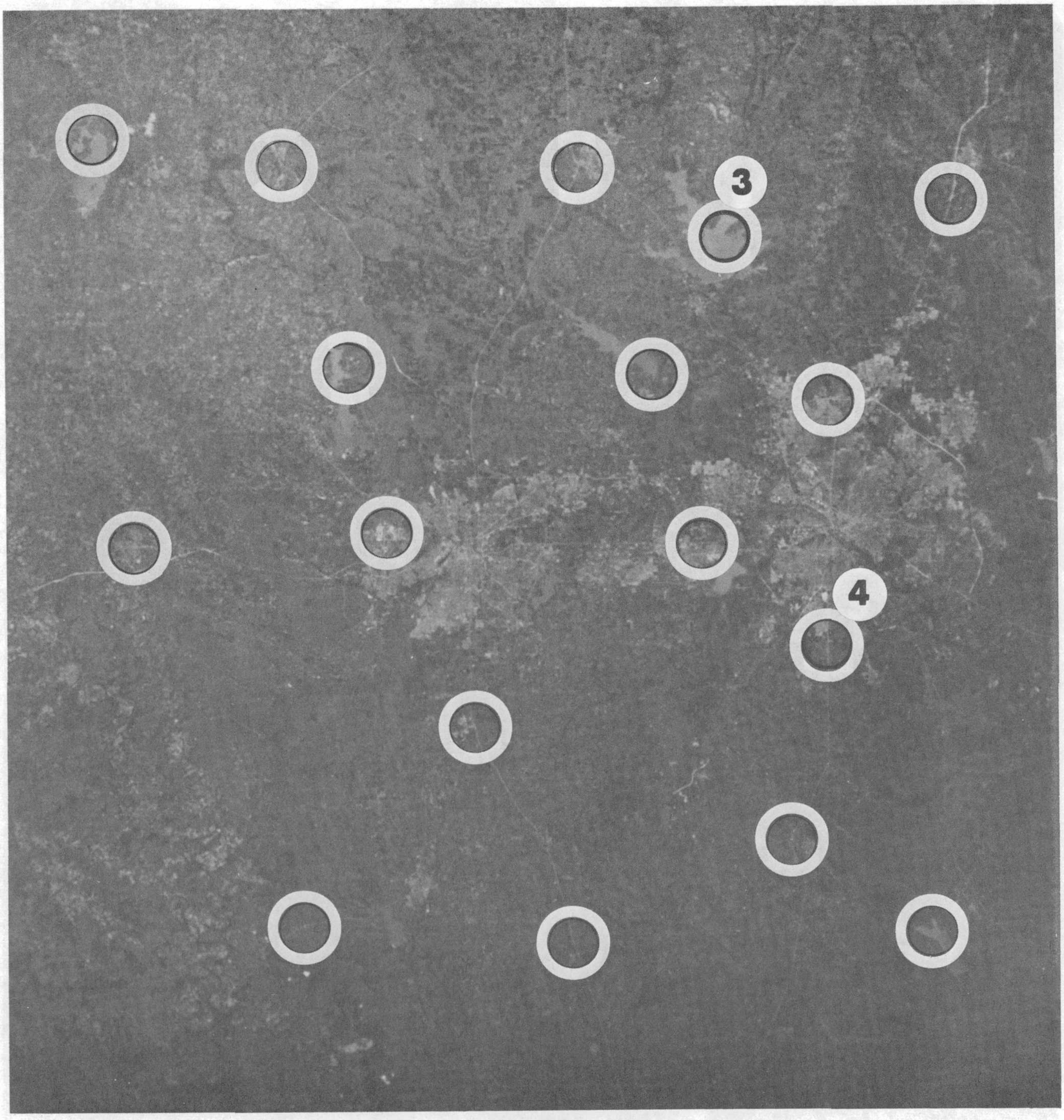


Figure 2.--Apollo photograph of the Dallas-Ft. Worth area with sample control points. Numbered points 3 and 4 are shown on map chips in figures 6 and 7.

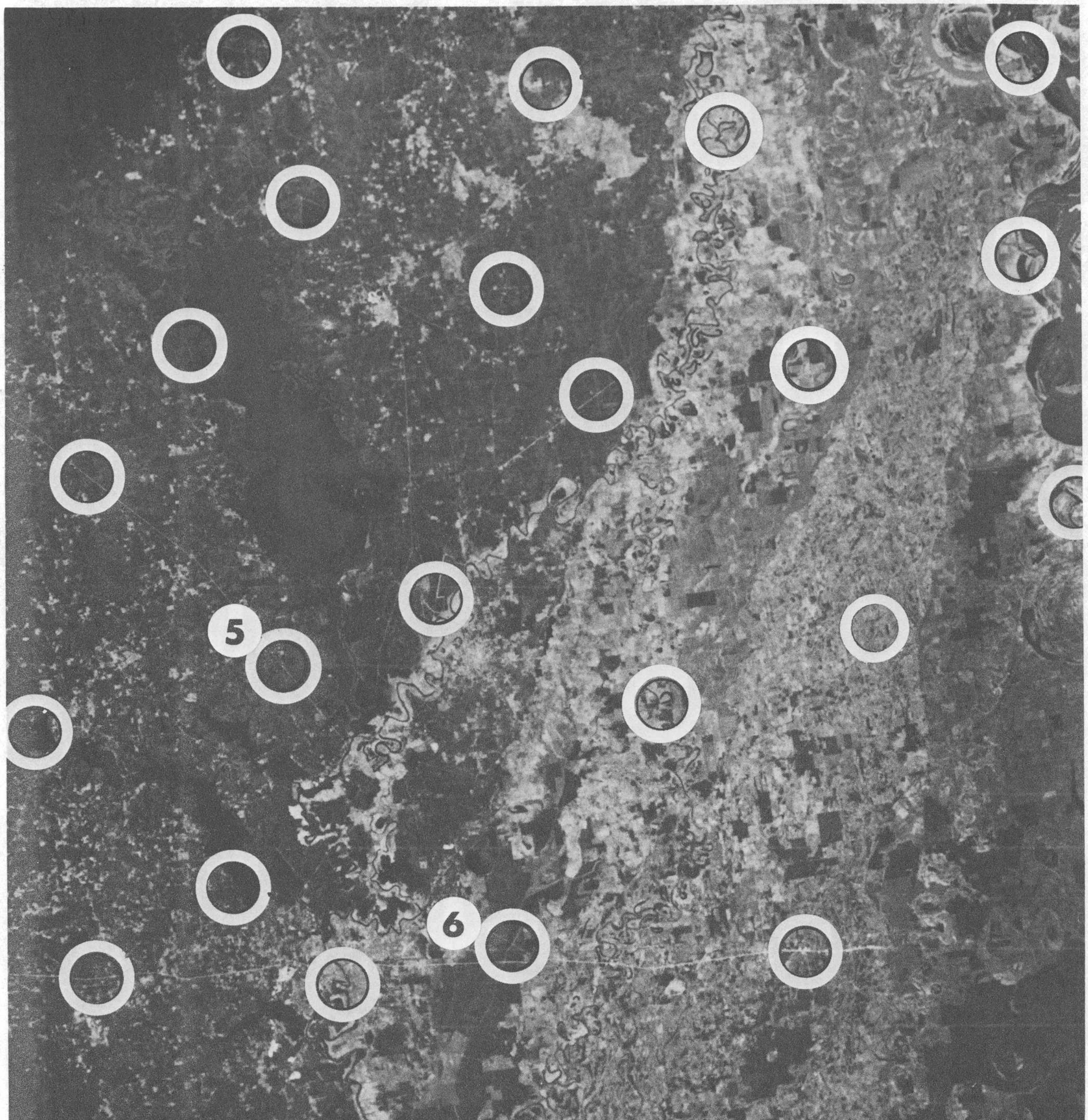
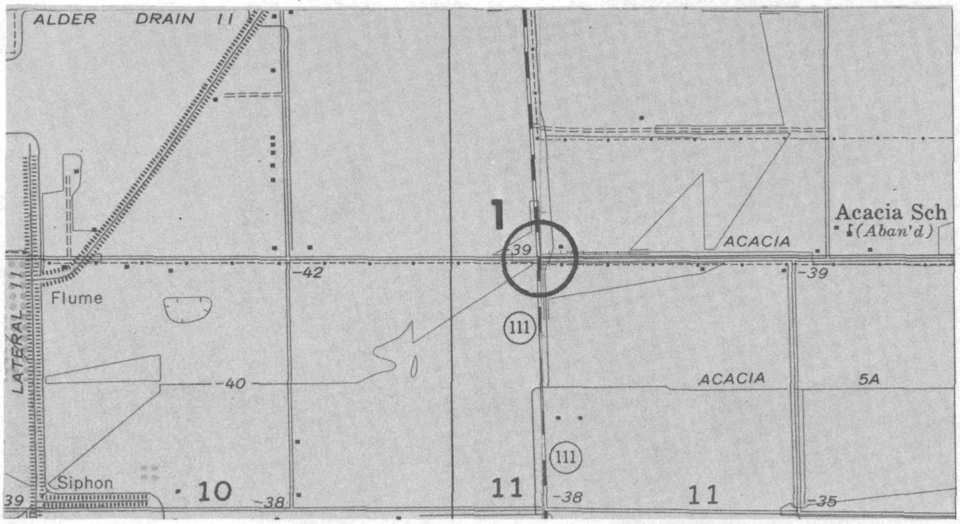


Figure 3.--Apollo photograph of a portion of the Mississippi River Valley. Numbered points 5 and 6 are shown on map chips in figures 8 and 9.



Point # 1 Description + Rd, Center

Area California, USA

F

N ________ E ________ Z ____ Elev ________ M

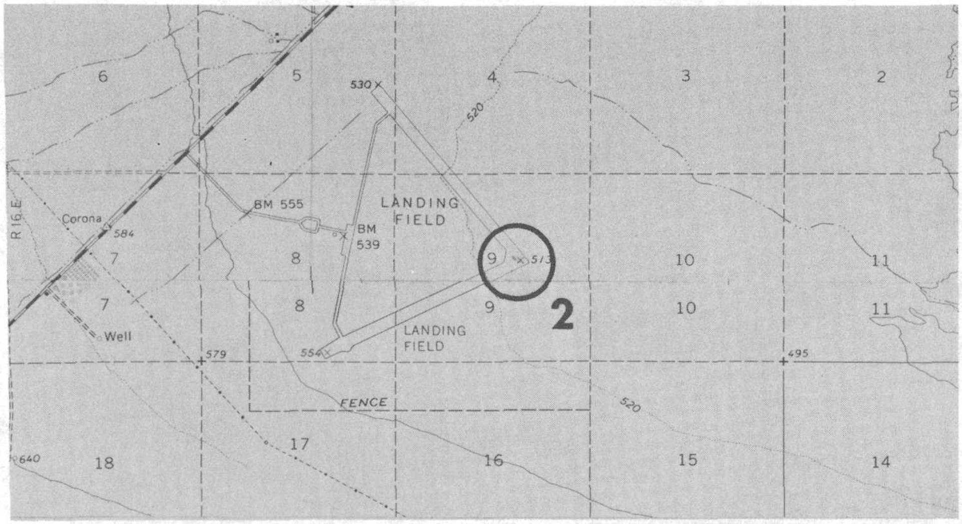
-39 F

Latitude N 32°46'52.5" Long W 115°30'00.0" Elev ________ M

Map Name El Centro 7½ Photo # ________

Spheroid Clark 66

Figure 4.--Map data on control point 1, shown in figure 1.



Point # 2 Description Runway Inter.

Area California, USA

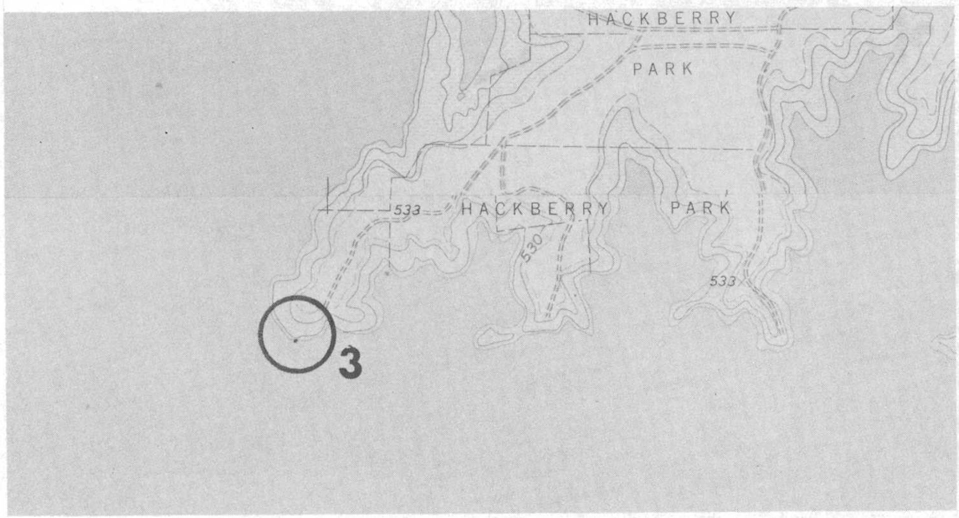
N 3 735 700 E 656 125 Z 11 Elev ____ F / 156 M

Latitude ____ Long ____ Elev ____ F / ____ M

Map Name Coxcomb Mtns. 15 Photo # ____

Spheroid Clark 66

Figure 5.--Map data on control point 2, shown in figure 1.



Point# 3 Description S. Tip Land

Area Texas, USA

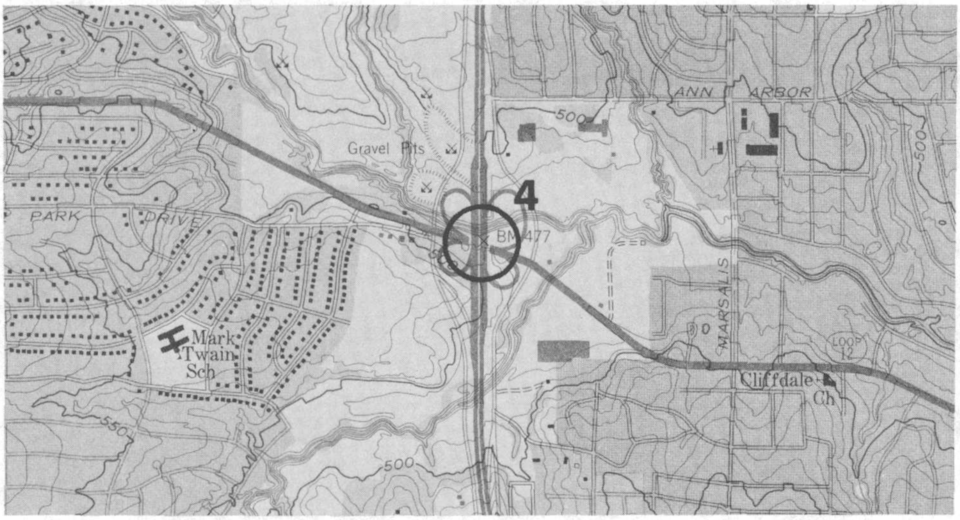
N ______ E ______ Z ______ Elev ______ F / M

Latitude N33°07'14.5" Long W96°57'34.0" Elev 515 F / ______ M

Map Name Lewisville East 7½ Photo # ______

Spheroid Clark 66

Figure 6.--Map data on control point 3, shown in figure 2.



Point # 4 Description Overpass, Center

Area Texas, USA

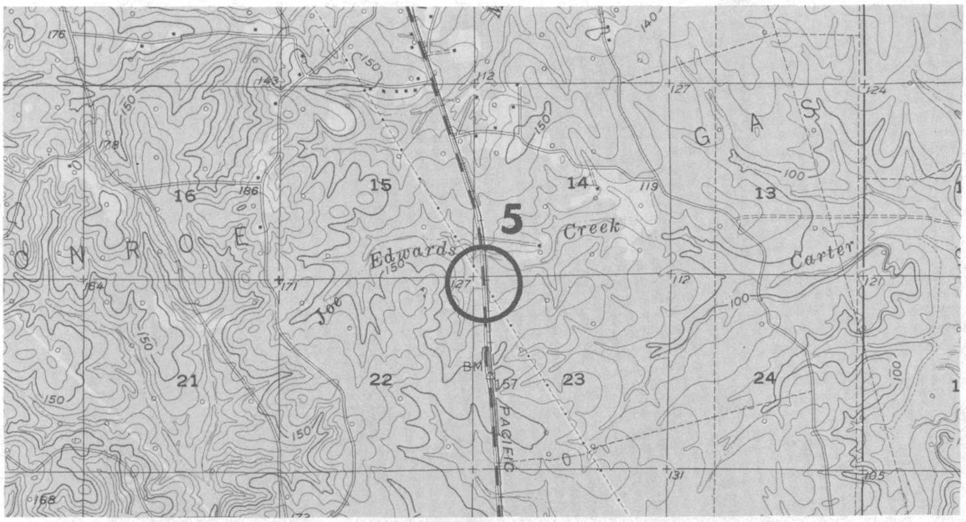
N 3 618 490 E 704 110 Z 14 Elev 152 M

Latitude ______ Long ______ Elev ______ M

Map Name Oak Cliff 7½ Photo # ______

Spheroid Clark 66

Figure 7.--Map data on control point 4, shown in figure 2.



Point # 5 Description Hwy.@ P.L. Xing

Area Louisiana, USA

_____ F

N 3 629 200 E 580 675 Z 15 Elev 38 M

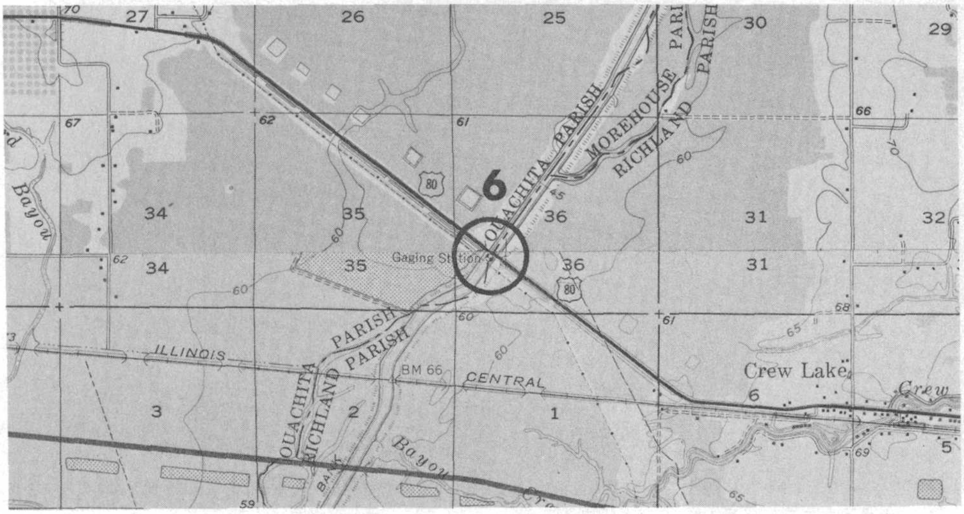
_____ F

Latitude _____ Long _____ Elev _____ M

Map Name Haile 15' Photo # _____

Spheroid Clark 66

Figure 8.--Map data on control point 5, shown in figure 3.



Point # 6 Description Center Bridge

Area Louisiana, USA

					______ F
N ______	E ______	Z ______	Elev	______	M
				64	F
Latitude N 32°30'00"	Long W 91°55'05"		Elev	______	M

Map Name Collinston 15 Photo # ______

Spheroid Clark 66

Figure 9.--Map data on control point 6, shown in figure 3.

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